3 Rotterdam: A City and a Mainport on the Edge of a Delta

Han Meyer, Anne Loes Nillesen & Wil Zonneveld

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This paper can be seen as the overall introduction in which the Rotterdam Rijnmond case study region and its spatial and flood risk challenge are introduced. It describes the strong historical relation between flood risk management interventions and the spatial development of the region. The region is protected against floods by an extensive system of (sea)barriers and dike-rings. Positioned on the edge of the Rhine-Meuse delta, the region developed as a port area and is part of the so-called Randstad area: the most densified area of the Netherlands.

Due to climate change, increasing sea levels and peak river discharges are expected in the future, resulting in an increased flood risk. In order to address this future flood risk challenge, the second Delta Committee was established - the first Delta Committee was established after the 1953 flood that flooded part of the Netherlands. This Delta Committee develops regional strategies for flood risk reduction for the long-term period, up to 2100. As part of the strategy development process, four conceptual regional flood risk reduction strategies are developed, which can be perceived as cornerstones of the playing field of possible flood risk reduction strategies for the region.

Those cornerstone strategies vary from the complete damming of the delta (thus lowering the extreme water levels behind the barrier) to opening up the delta and dealing with the expectedly high water levels by elevating the region's dike-rings. The different cornerstones offer different potentials and threats for the spatial development of the region. In addition, at a local scale, the different cornerstones impact the spatial quality of the dike zones and flood plains in different ways.

This strong relation between the flood risk management interventions and spatial composition and quality of the region supports the urgency of approaching the future flood risk reduction task in a comprehensive way.

Key aspects: urgency-integrated approach, future flood risk task, and spatial characteristics of the Rijnmond-Drechtsteden case study area, scale of flood risk management interventions.

ABSTRACT

Within Europe, Rotterdam is by far the largest port and supplier of fossil energy sources. City and port have a 'sandwich' position in the low lands between a sea with a rising level and rivers with increasing peak discharges. It is certainly no exaggeration to say that sustainability raises a matter of life or death for Rotterdam as a delta city. The question of whether Rotterdam is sustainable or not is related to the following issues: (1) water management (preventing hazards, the restoration of the estuary, salinisation); (2) urban renewal; (3) the spatial and climate footprint of the ever-growing port and; (4) energy transition. Currently, all these issues are dealt with largely independently of one another. For a genuinely sustainable future, links have to be made between strategies, projects, and actors.

§ 3.1 Introduction

The city of Rotterdam can ascribe its economic 'raison d'etre' and power, as well as its increasing vulnerability, to the same source: its position in the Rhine-Meuse delta, at the edge of the north-western European 'megalopolis'. Being the largest European port and supplier of fossil energy sources and, struggling with its 'sandwich' position in the low lands between a sea with a rising level and rivers with increasing peak discharges, 'sustainability' is a far from meaningless term in this city. We distinguish four main topics that can be regarded as questions of life or death for this city.

The first topic concerns how the city and the port can survive during changing conditions of sea, rivers, and rainfall. With a dense concentration of people, capital and economic activities (the Rotterdam region is responsible for 8% of the GDP of the Netherlands), the first question is how the risk of flooding can be reduced to a minimum. The central water problem in this delta region is the danger of flooding, but similarly, questions about salinisation, soil subsidence, and rainwater management need to be taken into account.

The second topic concerns the strategic position of the city as a European mainport in relation to energy transition. If the city aims to continue exploiting this strategic position, the port policy should consider how the port can anticipate the future transition of energy sources. Future scenarios concerning this energy transition should result in new visions and strategies concerning land use, accessibility, networks, supporting economies, etc. Moreover, being one of the most important contributors to CO2 emissions, the port is being forced to look for possibilities to substantially reduce these emissions.

Third, the development of a new flood risk management strategy, combined with a substantial transformation of the port, will result in new possibilities for the urbanisation of docklands and riverfronts. Altogether, we are talking about huge areas of hundreds of hectares that will be available for urbanisation in the future. This provides an opportunity for the city to develop an urban design policy, emphasising new spatial and functional qualities which might be important to the stimulation of specific social and economic processes.

The fourth topic explores the fact that, until recently, neither flood risk management nor the port economy was considered to be very good for nature and ecology. Land reclamations, the construction of many dikes and dams, and the expansion of the port industry resulted in the disappearance of wetlands and estuaries, a radical change in the ecosystem of the delta and a dramatic loss of bio-diversity. A new awareness of the importance of ecological sustainability, embodied in European rules and civic pressure groups, has forced the city and the port authorities to develop new strategies concerning flood risk management and port development, contributing to the repair of the natural deltaic system.

Certain issues that are important for Rotterdam and Rijnmond and could be considered as part of a wider interpretation of sustainability are not considered here. For example, the socio-economic problems in the greater Rotterdam area are greater than anywhere else in the Netherlands. The economic (industrial) history has left a legacy of problems: a relatively one-sided economy, high concentrations of social and economic deprivation, and a massive urban renewal problem. Since 2006, the Rotterdam South area has been one of the main targets of a national government programme to improve social and economic conditions in problematic urban areas (van den Brink 2007).

The city administration of Rotterdam is quite aware of the importance of the development of an effective policy concerning the aforementioned aspects of sustainability. Because of this, the Rotterdam Climate Initiative (RCI) programme was started in 2008. The aim of this programme is for the city to become a 'worldwide benchmark' for dealing with climate change and to make the city 'climate-proof' by 2025 [1]. Water and water management, as well as energy transition and the reduction of CO_2 emissions, play an important role in this programme. An important question that remains is whether we can really expect an innovative and comprehensive approach to be taken by the city administrators.

This paper starts with a general introduction to the origins of the delta city of Rotterdam and the wider area in which it is situated referred to as the Rijnmond region; we intermittently use these two names, in most cases referring to the wider Rotterdam area: the city and the dozen or so municipalities on either side of the Nieuwe Waterweg. Section 3 looks at the way in which the Rijnmond mainport system has evolved and the often non-critical—from a present-day perspective-political decisions that were made in order to achieve a continuous and almost endless expansion of Rotterdam harbour. We focus on the primary sustainability and climate change issues facing the Rijnmond delta city, independent from the water system. In Section 4, we look at the latest expansion of the Rotterdam port and how the Maasvlakte 2 project—the name given to the new port area—has become immersed in discourses about sustainability, delta nature, and climate change. In Section 5, we redirect our perspective towards the water-related problems that the Rotterdam delta faces. Section 6 focuses on the possibilities of new types of urban environments resulting from new strategies concerning flood management and port policy. In Section 7, we focus on the possibility of developing comprehensive strategies, based upon scenarios concerning flood management and port development. We round off with conclusions and discuss some of the future key sustainability and climate change issues related to delta and (main)port development.

§ 3.2 One Delta City with Two Faces

The spatial development of the city of Rotterdam has been strongly determined by its position at the edge of the southwest delta area of the Netherlands: this position defines its economic position and spatial structure and has influenced the social diversification of the city. This 'edge position' means that Rotterdam is settled on two different ground structures, separated by the Nieuwe Maas river.

North of this river, the ground structure is mainly peat, part of the 'peat continent' of central Holland (the area that covers the two western provinces with 'Holland' in their names), which stretches from the river Maas to the banks of the IJ, north of the historical core of Amsterdam. This peat area was the first area to be surrounded by dikes in the thirteenth century, and since then has been relatively safefor human settlement (Van de Ven 2004). This enclosure still plays an important role in the water management and flood control of Holland as 'Dike-ring 14', a part of the system of dike-rings that is the basis of water management and flood control in the Netherlands (Fig. 3.1). Dike-ring 14 surrounds the area with the highest safety standard and created the condition for a process of intensive urbanisation (De Vries & Van de Woude 1997), resulting in what we call the 'Randstad' today.

South of the river Nieuwe Maas, we find the actual delta, composed of a number of estuaries, islands, and peninsulas, with a ground structure that is mainly clay. Until the nineteenth century, the city of Rotterdam was built on the north bank of the river, in the peat area, and mainly safely behind the dike. Part of the city, the port area in particular, was built on raised areas outside the dikes. From the mid-nineteenth century, two important spatial developments took place.

First, the accessibility of the Port of Rotterdam was improved by digging the 'Nieuwe Waterweg', which started in 1863. The Port of Rotterdam struggled with increasing inaccessibility due to sedimentation processes in the main channels of the delta. This sedimentation was caused by the rivers as well as by the tidal currents of the sea. By digging a new channel from Rotterdam to the sea, parallel to the southern dike of Dike-ring 14, a new main discharge channel for the river was created. This channel resulted in a faster river currents and consequently in an increased discharge of sediments and cleaning of the river bed. The new channel combined two goals: it contributed to the control of the water levels of the principal rivers in the Netherlands, and it created a new deep-water access to the Port of Rotterdam. However, it also resulted in the sea becoming increasingly influential in the Rotterdam region itself, in terms of bigger tidal differences in the river water levels and a greater vulnerability to storm surges, as well as in terms of the increased salinisation of the whole region (Van de Ven, 2004).

FIGURE 3.1 Dike-rings in the western part of the Netherlands.

The second important spatial development concerns the extension of the city and port on the left banks of the river. During the nineteenth and twentieth centuries, the two parts of the city on both sides of the river banks developed in two different ways. The north bank, with the historical city, maintained its role as the city centre and developed some prosperous urban districts. The south bank is still part of the deltaic landscape and shows a more fragmented character; the former structure of the area as a conglomeration of small islands is still recognisable in the urban pattern of this part of the city (Palmboom 1987) (Figs. 3.2 and 3.3). The first generations of residents of this part of the city worked mostly in port-related industries (Bouman & Bouman 1952). For a large part, this was related to the fact that the left, southern riverbank became the main territory of port development of the nineteenth and twentieth centuries.

At the moment, the municipal territory of Rotterdam covers 314 km², with ca. 600,000 inhabitants. The metropolitan region has ca. 1.2 million inhabitants. The city territory includes a port area of 105 km² (Fig. 4), which is in the unembanked areas. Several urban districts, most of them built on former port areas, can also be found in unembanked areas.

§ 3.3 Conflicts about the Growing Territorial Footprint of Rotterdam Mainport

The open connection between the sea, the port, and its hinterland has been a crucial factor in the development of the Port of Rotterdam. It is generally accepted that the Rotterdam port owes its present position to its favourable location in northwest Europe in general and the excellent water connections to Germany in particular.

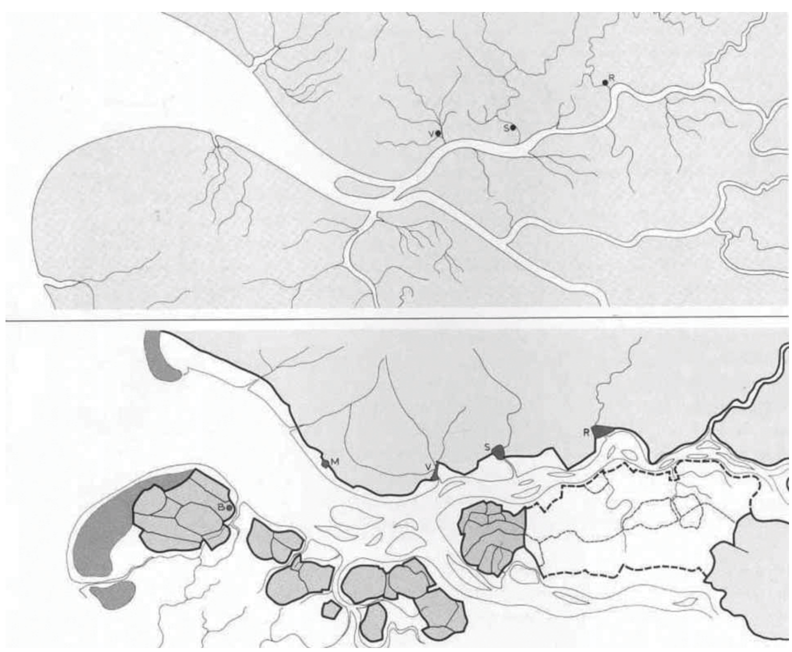

FIGURE 3.2 The Rotterdam region before 1100, dominated by rivers and creeks (top); and around 1400, with a dike along the north bank of the river and islands with dike-rings in the south (bottom) Source: Palmboom (1987).

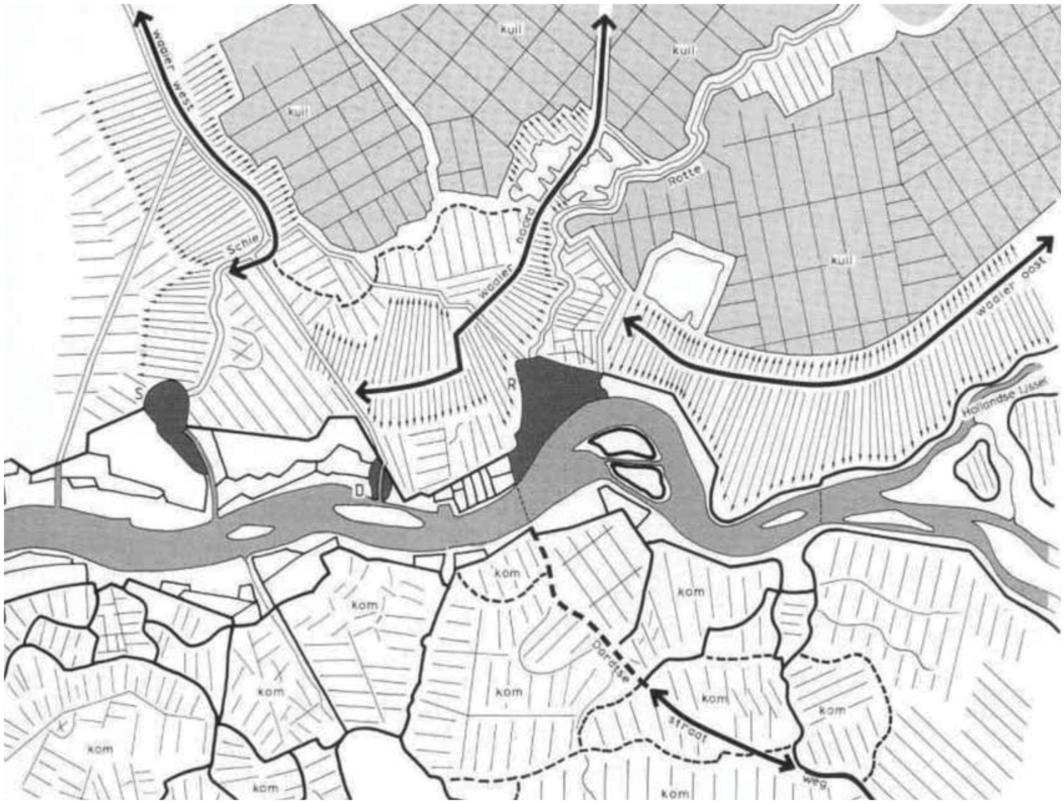

FIGURE 3.3 The spatial structure of Rotterdam: north of the river, it is defined by long lines of dikes and quays, and south of the river it is dominated by ring polders. Source: Palmboom (1987)

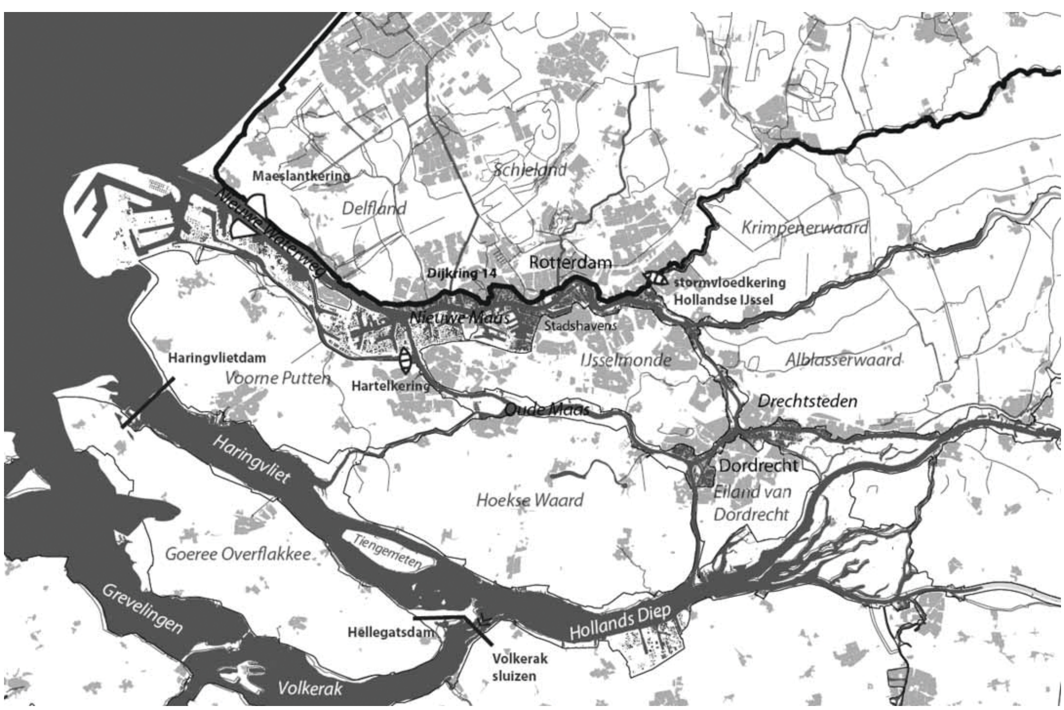

FIGURE 3.4 Rotterdam region ('Rijnmond') with unembanked and port areas.

§ 3.3.1 A Transportation Hub

Although no longer the largest seaport in the world—this position has been taken by Asian seaports—figures on the volume of flows at Rotterdam Mainport are still extremely impressive. The latest available figures for 2009 show that Rotterdam, in terms of transhipment, is more than twice the size of the second port of Europe, Antwerp: 387 million metric tonnes compared with 157.6 for Antwerp. Most of this volume, about 71%, goes into the harbour; 29% is transferred to other sea vessels (transhipment). When it comes to the number of containers, the differences with its main competitors are fewer. Rotterdam handles 9,743,000 TEUs (Twenty-Feet Equivalent Units) while the figure for Antwerp—the second European harbour in this respect as well—is 7,310,000 TEUs. Hamburg is close on the heels of Antwerp with 7,008,000 TEUs (Port of Rotterdam 2009). Although the market position of Rotterdam in the so-called Le Havre-Hamburg range—the range of harbours catering for the same hinterland—is gradually diminishing, the volume of goods and, consequently, the number of transportation units are enormous. In 2009, no fewer than 29,000 sea vessels entered the Rotterdam harbour areas to deliver or pick up goods and containers.

From the perspective of the ecological footprint of the harbour, it is interesting to look at other figures: what does the mainport position of the Rotterdam harbour area mean in terms of flows running through the metropolitan region: trains, lorries, and inland vessels? Although the number of inland vessels entering the mainport is rather impressive—about 110,000 in 2009 approximately—the modal split of the harbour results in a heavy environmental burden on the Rijnmond metropolitan region and the country as a whole. Although one should not overlook the fact that emissions from inland vessels are an important polluting factor, the overall majority of container transhipment does not take place via waterways but via roads. Of the 4132 million containers going to or coming from the hinterland, no less than 56% is transported via lorries, 33% via inland vessels, and only 11% via rail [2].

From the late 1960s onwards, the attention given to environmental issues increased and the development of the Rotterdam mainport attracted the attention of environmentalists who started to voice opposition. In the late 1980s, the debate entered a new period because of plans to build a dedicated freight railway line from Rotterdam to Germany as well as (again) a new, large-scale extension of the harbour area: the Maasvlakte 2. Both projects would have serious environmental repercussions. Environmentalists were joined by—at least some—economists claiming that more development space and improved accessibility were outdated strategies for strengthening a mainport. For instance, Boelens and Atzema (2006) claimed that instead of focusing on volumes of transported goods, a network-oriented strategy would make far more sense.

The concept of a mainport approach was born in Rotterdam as Van Duinen (2004, p. 64ff) explains. Two professors of Erasmus University of Rotterdam—Poeth and Van Dongen—published several reports in the early 1980s on port development. They highlighted the global trend to concentrate on specific activities in huge, centrally located ports, a trend resulting from worldwide shipping processes. For the sake of efficiency, shipping companies would direct their ever-bulkier vessels to a small number of ports: from 'multi-ports' to 'main ports'.

This signal was rapidly picked up by the Rotterdam Port Authority but, in doing so, part of the story was overlooked. Instead of just concentrating on the qualities of the ports itself, Poeth and Van Dongen emphasised the crucial importance of looking at entire international transport chains: advanced logistical systems, hinterland connections, inland terminals, automation, etc. (Van Duinen 2004, pp. 65 – 66). According to Van Duinen, this was a bridge too far. Rotterdam port authority stayed within its span of control: a (main)port is a physical entity that needs excellent external connections via all relevant modes. The institutional position of an organisation and its internal doctrine and (spatial) planning concepts determine how the world looks (see, for instance, Throgmorton 1992).

At first, public opposition was small. An obvious explanation is that, at that stage, the mainport concept was just an idea on paper. The full effect only became visible later when the mainport concept was used to substantiate plans to build Maasvlakte 2, the Betuwe freight route to Germany, and also Schiphol's fifth runway. All these projects have been heavily contested with judicial fights in the highest courts in the Netherlands. Environmental concerns including the effects on the landscape—which were of particular importance in relation to the Betuwe line—were at the top of the opponents' agenda.

Ultimately, all three projects have gone ahead, although two of them are still under public and political discussion. Schiphol is the object of ongoing rows about noise pollution (on the whole, only NGOs and the GreenLeft party emphasise the negative effects of air transport on CO2 emissions). A prinicpal issue of the Betuwe route was the dramatic increase in the estimated costs. This eventually led to an official parliamentary investigation, which included public hearings. Moreover, the line—which started to operate in 2007—is still not properly connected to the German railway system. The original plans foresaw a connection in 2003. The present indication from Germany is that this is not likely to happen before 2020.

It was several years after the birth of the mainport concept that the Port of Rotterdam developed a strategy focused on wider transport 'chains' rather than just focusing on the port area itself. The port authorities started negotiations with inland ports in the region and the hinterland with the aim of better controlling the quality of hinterland connections, which were of vital importance for the position of the port itself. This resulted in the port of Dordrecht being managed by the Port of Rotterdam from July 2011 onwards, with further plans of it becoming a shareholder—together with Antwerp—in the port of Duisburg (Germany), the largest inland port in Europe. These latter plans have, however, been heavily opposed by the Port of Hamburg [3]. In addition, negotiations concerning collaboration and coordination with the ports of Amsterdam and Antwerp have recently started. What will come out of such negotiations is highly uncertain: these three ports have always competed with each other. Moreover, the port authorities of Amsterdam and Antwerp are still municipal services, while the Port of Rotterdam is privatised, its shares owned by Rotterdam municipality and the national government. In the case of Antwerp and Amsterdam, perceptions of territorial interest and the competition of municipal councils might still tip the balance.

§ 3.3.2 Maasvlakte 2: Sustainability Conflicts

During the 1970s, it became clear that due to the changing port economy and transport technology the inner-city port areas would be abandoned. The port concentrated its activity in the large-scale post-war port areas of Botlek, Europoort, and Maasvlakte (Meyer, 1999). As a result, large sections of the inner-city harbour areas became available for urban transformation. The second half of the 1980s turned out to be a period of economic recovery; growth figures for the Rotterdam port were rising, resulting in a new plan for the port: the 2010 Port Plan. The plan was officially adopted by the municipal council late in 1993, although there was some opposition due to environmental concerns. The main proposal therein was to create a new major port immediately west of the latest Maasvlakte 1 extension.

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The role of environmental groups became powerful when the realisation grew that the future development of the Port of Rotterdam not only fell under Dutch law, but also under European law: the

1992 EU Habitat Directive. In 2000, this directive had still not been properly transposed into Dutch law as required under the EU treaties. But that does not change the working of an EU directive: in the absence of a (proper) transposition, a European directive takes effect directly. This strengthened the position of environmentalists opposing the plan to build the new port area.

Eventually, a compromise was reached between the various actors and arenas. Of particular importance was an agreement between the municipality of Rotterdam and three large environmental groups laid down in a memorandum of understanding in 2000 called 'Vision and Courage'. In this document, both parties agreed that the objectives to further develop the Rotterdam mainport were equally important to the improvement of liveability in the Rijnmond areas. A second Maasvlakte could be realised and compensated by various measures. Moreover, several projects to develop new nature and outdoor recreation areas up to a total of 750 hectares had to be realised (this would eventually lead to four projects in Rotterdam). Within the existing port area, the available space would be more intensively used, and measures would be taken to improve the environmental impact of industrial and harbour-related activities. Easterly port areas that were no longer needed would acquire new urban functions. At the time of writing, work has already started; their progress can be followed through a webcam [4].

§ 3.4 The Ecological Footprint of Rotterdam Mainport and its Possible Future

§ 3.4.1 The RCI

The debate about Maasvlakte 2 and the making and future use of Maasvlakte over time have become increasingly framed within the perspective of climate change. As Rotterdam is a major transport hub as well as a (very) highly concentrated area for industry and, in particular, the petrochemical industry, environmental policies are becoming increasingly intertwined with climate change mitigation policies and energy transition strategies. In both these areas, 'Rotterdam'—that is, a coalition of various stakeholders—is striving to become a world leader and a benchmark for many other port and delta cities.

The major vehicle for this ambition is the RCI (Rotterdam Climate Initiative), in which energy transition and the reduction of CO2 emissions play an important role in the aim to make the city 'climate proof' by 2025. The RCI is a cooperative body with four members: Rotterdam municipality, Port of Rotterdam, DCMR Environmental Protection Agency Rijnmond, and Deltalinqs. The latter is a regional NGO which— according to its website— "[.. .]represents the common interests of all the logistical and industrial companies in the Rotterdam port and industrial area. The organization is considered to be the focal point and spokesman for more than 600 registered companies and associations."[5]

Almost always publicly represented by its ambassador, former prime minister and UN's High Commissioner for Refugees Ruud Lubbers, the RCI has a very simple slogan: 100% climate-proof.

It seeks to create "[.. .] a movement in which government, organizations, companies, knowledge institutes, and citizens collaborate to achieve a fifty per cent reduction in CO2 emissions, adapt to climate change, and promote the economy in the Rotterdam region." [6]

The RCI CO2 reduction targets are ambitious when compared with those set by others. The region of Rotterdam for instance—a statutory cooperative body in which the municipality of Rotterdam participates — is seeking a reduction of 40%. The province of South Holland is following general EU policy targets: a reduction of 20% (OBR, 2010, p. 97). This figure also stands for the present centre-right national government, which explicitly does not strive to move beyond the ambitions of the EU. What is more interesting is the way in which the government would like to reduce CO2 emissions, namely through large-scale carbon capture and storage (CCS), and nuclear energy. The latter is unprecedented when compared with a number of previous government coalitions: the present government explicitly sees nuclear energy as a climate friendly technology.

CCS is a primary component of the RCI strategy. CCS has become urgent because there are plans to build two new coal-fired power plants in the port area. However, the CCS strategy of the RCI received a major blow in November 2010. A major project to store CO2 in a depleted gas-field under the city of Barendrecht has officially been abandoned after heavy protests by the local community, who were afraid of certain risks such as leaks from the installations or from deep underneath the soil. The North Sea is now fully in the picture. Plans to store CO2 in the continental shelf are already being carried out. As is the case with offshore wind farms, potential opponents are literally over the horizon.

§ 3.4.2 To Maintain Mainport Status in an Age of Energy Transition

We can say that port areas at present are indeed hubs in the global and continental flows of energy. In this respect, no other European port has the same status as Rotterdam. To maintain this position within the perspective of energy transition is part of the survival strategy of the Port of Rotterdam and other major stakeholders involved in the port area.

Being an energy hub is currently almost exclusively related to fossil fuels: oil, coal, and—in the near future—liquefied natural gas (LNG). The throughput of oil at the port is quite stable at the moment, at around 100 million metric tons annually. About half of this is transported through pipelines to Vlissingen in the southwest of the country, as well as to Antwerp and Germany. The other half is processed in the port area itself; together with Singapore and Houston, Rotterdam belongs to the top three global petrochemical clusters. Throughput of coal has steadily risen over the years and now stands at about 25 million metric tons. Transported by belt (in the Rotterdam port itself), barge, and rail, about 20% is used in steel mills, the remainder going to power plants, mainly in Germany[7] A main goal is that a third energy flow will be added to the two traditional fuel sources, oil and coal: LNG. This is part of a wider, national strategy to diversify the importation of natural gas to improve the security of the supply. But Rotterdam is also striving to play a major role in the European transhipment of LNG, as well as building an industrial cluster around LNG in the port area itself.

At present, the port is also developing a strategy to become a hub in the transhipment and use of biofuels and biomass. With this in mind, the so-called Rotterdam Biomass Commodities Network (RBCN) has been set up as an offshoot of RCI, and is formed by a large number of companies.[8] As biofuels have come under heavy attack by environmentalists and NGOs—driven by the cutting down of (rain)forests and pushing aside food production—RBCN supports the certification of biofuels mainly through the Dutch NTA8080 standard.[9] As with other fuels, biofuels are supposed to play a role in energy production within the port area itself (there are plans to build several energy plants), as well as becoming the core of industrial clusters. This is called co-siting by the Port of Rotterdam Authority; new facilities link up directly with adjacent tank terminals and factories.

What the effects could be of the future energy transition—the general heading for the period during which, according to many, fossil fuels will be gradually phased out—for Rotterdam is the object of discussion and scenario building. At the time of writing—early Spring 2011—the port authority is preparing its new 10-year vision, its horizon 2030. The full effects of energy transition, according to many, will be felt later. At present, the harbour is still developing in a mainstream fashion, as has been outlined above. For years to come, fossil fuels will continue to be fundamental to the harbour, their negative effects being overcome by CCS. Although the overall objective is to maintain the position of being an energy hub on the continent, during and after a possible period of energy transition, one can only speculate on whether this will indeed be the case. There are many unknown factors and quantities. Bio fuels form an entirely different sort of commodity compared with oil and coal; in particular, the concentration of production and transport of these traditional fuels are totally different when compared with biofuels. Rotterdam's position as one of the world's top three petrochemical clusters is largely due to its location: in the centre of a mega-region, connected to a major mass-transport axis (the Rhine), and accessible for the largest vessels on the planet. If the future pattern of biofuel and (sustainable) energy production is to become much less concentrated, which seems to be becoming the case, transport patterns could change radically. More spatial inertia could stem from the spatial pattern of chemical complexes. If the Rotterdam petrochemical complex is to gradually turn into a biochemical complex, the sheer scale of investment needed would lead to some form of stability in the transport chains of biofuels and the biological replacements of (crude) oil and their (semi-) manufactured product.

§ 3.5 Sustainability of the Delta City

Besides energy transition and the reduction of CO2 emissions, water and water management play an important and multi-faceted role in the RCI programme. This means that policies concerning sustainability necessarily need to consider the different aspects of water in the city. These are:

- groundwater control and soil subsidence;
- rainstorm management;
- rises in sea level;
- increasing river discharges;
- environmental quality and bio-diversity;
- salinisation.

§ 3.5.1 Groundwater Control and Soil Subsidence

Like many other delta cities, Rotterdam is dealing with a difficult dilemma concerning groundwater control. Originally the peat areas were very wet and unsuitable for human living and building. Draining these areas had already started in the twelfth century and continued over the following centuries, supported by improving technology. A result of draining peat, however, is that the dried peat starts to oxidise, thereby resulting in shrinkage. As a consequence, the ground level subsides by about 1 m each century, resulting in ground levels varying from 1 to 6 m below average sea level (referred to as Normaal Amsterdams Peil (NAP)). This subsidence means that the consequences of flooding as a result of a broken dike would be disastrous. Considering a storm surge with a sea level of 4 m above NAP, the result of dikes being broken would be that the water level in the flooded city would be 5 – 10 m above ground level.

Stopping the process of soil subsidence is crucial in order to make the city less vulnerable to flooding. It means that the groundwater level needs to be maintained at as high a level as possible, which conflicts (especially in the older parts of the city) with the interests of people who own houses with basements that are vulnerable to high groundwater.

§ 3.5.2 Rainstorm Management

Because of climate change, northwest Europe is confronted with an increasing frequency of heavy rainstorms, delivering much more water in a short time than was usual in the past. During the last 100 years, the average rainfall has been 790 mm per year, but this is increasing rapidly. It is estimated that the increase will be 20%, while the intensity of rainstorms is also increasing (Gemeente Rotterdam et al., 2007).

During the nineteenth and twentieth centuries, many of the original canals in the city of Rotterdam were filled in. They not only lost their function as transport routes, but new drainage technology focused on the construction of underground draining systems. As a result, the amount of surface water decreased from its original level of 16% to less than 6% of the built-up area. Because of this decrease, sewage systems are frequently over-loaded during periods of heavy rainfall. Pumping stations are not able to pump the water from the sewage system into open water (river or sea) fast enough, resulting in flooded streets and an overspill of sewage water in what is left of the canal and open water system in the city.

Rather than increasing the capacity of the sewage systems and pumping stations, the focus of water management in Rotterdam (and other Dutch cities) has shifted to increasing the storage capacity for water in the city. This means making new surface water areas as well as the creation of public spaces that can play a role in the temporary storage of water. This policy is linked to a more sustainable groundwater management: an increased amount of surface water supports a higher groundwater level (Gemeente Rotterdam et al., 2007).

§ 3.5.3 Rising Sea Levels and Increasing River Discharges

Rising sea levels and increasing river discharges are two different things. However, the combined effect creates new problems for the city. Rising sea levels are nothing new, and this has already been taking place for thousands of years. During the twentieth century, the sea level rose by ca. 17 cm. The 'speed' of the rise in sea level, however, is expected to increase due to climate change. The various calculations and estimations of, for instance, the Intergovernmental Panel on Climate Change do not give any certainty about the exact situation in the future. The second Delta Committee installed by national government—the first Delta Committee was installed after the disastrous 1953 flood that killed about 2000 people—assumes a considerable increase in sea level over the coming decades. The Delta Committee bases its advice on the scenario of a maximum 130 cm rise in sea level by the end of this century (Delta Commissie 2008). Apart from the question of whether this scenario is realistic, it is generally assumed that a structural rise in the sea level will take place.

At present, the dike system runs right across the urban fabric of Rotterdam. The unembanked areas, directly adjacent to the river, were raised to a level of 3.20 – 4.00 m above NAP over the course of the nineteenth and twentieth centuries. These levels were supposed to be sufficient to avoid regular flooding, but they are likely to become increasingly vulnerable to flooding in the future. To prevent flooding, a storm barrier in the mouth of Nieuwe Maas has been built: the Maeslant Storm Surge Barrier.[10], which closes when the sea level is expected to rise by more than 3 m above NAP. Without this barrier, a large proportion of the areas outside the dikes would be flooded by several centimetres of water during serious storm surges.

With the expected rise in sea levels, it is anticipated that the Maeslant barrier will have to close more frequently in the future, thereby creating substantial problems for the port. The barrier is currently closed at a frequency of approximately once every 10 years which is regarded as acceptable for the continuity of the port economy. However, a substantial increase in the frequency of closing, as well as uncertainty about when the barrier will be closed, combine to produce an unacceptable decrease in the reliability of the open entrance. We will come back to this later.

Increasing river discharges have been a reality since the mid-1990s, when the river area in the Netherlands was confronted several times with either serious floods or near-floods. According to the Delta Committee, river discharges could increase by 150% over the coming decades. The extreme river discharges of the Rhine, which enter the Netherlands at the eastern border, currently deliver 12,000 m^3 per second, but are expected to increase to 18,000 m^3 per second in the future (Delta Commissie 2008). For the Rotterdam region, this means that the flood hazards come from two directions: from the sea and from the rivers. A worst-case scenario would be a coincidence of an extreme storm surge and extreme river discharges.

In the Delta Committee's report, the Rotterdam region is defined as a special case, which makes extraordinary solutions necessary. In 2010, a high-level Delta Commissioner was appointed by the government, alongside the establishment of a special programme committee for the Rotterdam region. Supported by several research initiatives,[11]this committee investigates different scenarios and options to increase safety, varying from raising the existing dikes to closing the whole region by a system of locks or storm surge barriers and directing the river water to the delta south of Rotterdam.

Technically, all these different options are possible; the big question concerns the effects of each type of solution on the port economy, the city structure, and the environment. An important issue concerning city structure is that the dike system runs right across the urban fabric of Rotterdam. As already mentioned, the unembanked areas were raised to a level of 3.20 – 4.00 m above NAP over the course of the nineteenth and twentieth centuries. The ground levels behind the dikes are much lower, due to subsidence resulting from continuous drainage, as explained above. Therefore, a now-typical situation has occurred in which the area 'outside the dike' is much higher than the area inside the dike. In between, the dike itself has an average height of 5.5 m and is experienced as a barrier between the floodplain areas and the areas behind the dikes.

§ 3.5.4 Environmental Quality and Bio-diversity

Since the 1980s, interest in the environmental value of estuaries has increased substantially, in particular because of their function in the complex ecosystems of connecting the seas, oceans, and rivers (see, for instance, Saeijs, 2006). Several (Dutch) environmental groups, large NGOs (World Wildlife Fund, 2008), landscape architects (Sijmons, 2002; Sijmons & Venema, 1998), scientists (Tjallingii, 1996), as well as governmental institutions, are paying increasing attention to the environmental effects of large-scale hydraulic works in the southwest of the country; damming the estuaries resulted in dramatic changes to their bio-diversity and produced a concentration of pollutants, river sediments, and toxins from agriculture (see, for instance, Adriaanse & Blauw, 2007). The title of the report of Delta Committee, 'Working Together with Water', is a recognition of the attention paid to environmental issues in official flood-control politics. It has resulted in a serious reconsideration of the future position of the Delta Works, the series of dams and storm surge barriers in the delta in the southwest of the country. NGOs like the Word Wildlife Fund put a lot of energy into their pleas to maintain or restore the openness of the large estuaries worldwide. They have chosen the Dutch delta as an important test case and developed a plan for this delta, showing a complete reopening of all the estuaries (WWF, 2008).

For the Rotterdam region, this means that the combination of flood defence, port installations, and environmental issues has been placed high on the political agenda here also. The clearest example so far is (as described in Section 3) the layout of a series of new natural areas in the Rotterdam region to compensate for the loss of natural environment resulting from the construction the new Maasvlakte 2. The construction of this new area of land reclaimed from the sea will change the environmental system of the coast; the new natural areas are supposed to compensate for this loss to a greater extent than required by the EU Habitat Directive (see below). However, this solution can be regarded as a rather artificial and incidental approach; for future challenges, a more comprehensive approach will be expected.

§ 3.5.5 Salinisation

The changing climate results not only in more rainfall and intensified rainstorms, but also in longer periods of drought. Combined with rising sea levels, this phenomenon leads to a shortage of fresh water and the increasing influence of salt water in the peat and clay areas of Holland. This process has a damaging effect on agriculture in the Rotterdam region. Due to the Delta Works, the estuaries Haringvliet and Brielse Meer have been transformed into large suppliers of fresh water. This guaranteed fresh water supply on a large scale (a unique condition for a sea port) was a main motivation for the establishment of the petrochemical industries in Rotterdam in the 1960s, resulting in the second largest petrochemical complex in the world. Today, the port's industrial complex uses more than 36 million m^3 of fresh water each year (Stuurgroep Zuidwestelijke Delta, 2009).

A supply of fresh water is also essential for agriculture. The clay polders south of Rotterdam have become one of the most productive agricultural areas in Europe (Ruimtelijk Planbureau, 2005) and the 'Westland' area just northwest of Rotterdam has been developed into the most intensive complex of greenhouses in Europe. This agricultural and horticultural area is also dependent on the availability of fresh water on a large scale and is connected, via a pipeline, to the Brielsemeer.

§ 3.6 Promises and Problems of New Urban Waterfronts

The recent increase in interest in the effects of climate change on water management and flood defence, and the increased attention to competitiveness and identity, have created perspectives and opportunities for a new interweaving of hydraulic engineering targets and concerning urban and economic regeneration targets.

As a result of its historical development, the city of Rotterdam is split by the river into two very different sides: Rotterdam Centre and Rotterdam South. Both sides are different in the sense of spatial structures, economic activities, and social and cultural structures. Currently, the two parts of the city have different safety standards concerning flooding. The northern dike-ring 14 area (Fig. 3.1) is given the highest safety standard, with a chance of flooding once in 10,000 years. Rotterdam South is part of a dike-ring with a greater chance of flooding: once in 4000 years.

With the departure of port-related industries during the 1980s and 1990s, Rotterdam South became one of the most problematic urban areas of the Netherlands, characterised by high rates of unemployment, poverty, low degrees of education, racial tensions, etc. Since the 1980s, the city administration has tried to change the one-sided economical focus on the port to a more diverse urban economy. Approximately 15,000 residential units, mixed with offices and amenities, have been built on approximately 250 hectares of former port areas, like, for instance, in the Kop van Zuid area on the left bank of the river. All of these developments took place in unembanked areas.

During the planning and construction of the first generation of transformation projects, the city of Rotterdam agreed upon a provisional rule with the provincial and national authorities: the entrances and floors of new houses in unembanked areas should be raised to a level of 4 m above NAP. This rule was regarded as sufficient, considering the new 'Maeslant' Storm Surge Barrier that was constructed close to the mouth of the Nieuwe Waterweg during the 1990s, which is intended to close whenever the sea level rises more than 3 m above NAP, as explained in the previous section. However, the growing danger of high water levels because of increasing peak discharges of the rivers that feed the delta, as also described in the Section 5, has forced the city to develop new strategies.

The need for a comprehensive strategy is becoming increasingly more important, as a huge unembanked port area will shortly become available for urban (re)development: the so-called city ports area that covers 1000 hectares. The city ports provide great potential in terms of new urban districts in attractive environments and creating more spatial coherence between the two parts of the city on both river banks (Meyer 1999); at the same time, they are part of the most flood-prone areas in the urban territory. One of the main aims of Rotterdam's urban policy will be solving this paradox.

§ 3.6.1 Perspectives for Solutions

In general, there are three basic principles that can be used to protect the unembanked areas against flood damage (De Hoog & Nillesen, 2010). The first is to dam the water off by creating dikes, barriers, or dams that keep the water out. This can happen on a regional scale (see next section), but also on a local scale, at the site of a building. This method, however, creates a similar barrier between the built-up areas and the water, as is nowadays found to be problematic in Rotterdam's city centre. There are new options for designing dikes in such a way that they become part of the waterfront, by integrating urban space, nature, and built functions within the body of the dike (Stalenberg, 2010).

A second option for making the unembanked area flood-proof would be to elevate either the whole area or the building grounds. This method is one of the oldest water defence mechanisms used in the Netherlands. Farmers from the northern provinces built their houses on artificial mounds called 'terpen', to protect themselves from floods. Elevation is also used frequently in the Rotterdam harbours when creating harbour sites, such as, for instance, the Maasvlakte. This is the same principle that is successfully used in Hamburg's Hafencity, an old harbour in Germany that is being transformed into a flood- proof residential and business area. In the former port area, a partial elevation has been created. Next to the elevation, buildings are placed on flood-proof plinths that simultaneously serve as parking garages. In case of high water levels in the river Elbe, the garages are locked and the lower parts of the streets, the original quays, are flooded. A secondary network of pedestrian evacuation roads connects the buildings with the elevated main street. In the Hafencity project, the construction of a dike around the building site was considered but was also rejected as the relationship with the water would have been compromised and a large upfront investment in water safety would have been needed. By flood-proofing each building block separately, the investment in flood protection grew in line with the pace of development, reducing the economic risk in case of stagnating development. The public space is brought close to the water and designed with multiple layers the optimise the experience of the fluctuation and natural force of the water.

The third principle is to make buildings flood-proof by, for instance, placing them on poles, using floating or amphibious houses or by making the interior of houses water-proof. The latter options are still at an experimental stage and in urban developments, these are often considered as small-scale solutions rather than as extensive urban flood strategies. Floating houses and functions are very popular with designers, even though they occupy water instead of land. Therefore, the amount of floating functions the water can hold without losing its openness—an invaluable quality offered by the river to the city of Rotterdam— should be studied carefully.

Since the Rotterdam city ports aim to be an experimental site for water-proof innovations, a wide range of flood-proof measures for buildings and public spaces could be applied within the area, creating new urban typologies that deal with the water in ways that are distinct from existing practices. One of the essential questions will be how to create highly functioning connections between the harbour areas being transformed and the rest of the city. Apart from the existing industrial transportation network, the sites are poorly connected to their surroundings and the city centre. Socially and economically poor neighbourhoods, combined with a large amount of infrastructure, form a barrier that creates a separation, especially between the southern harbour sites and the city centre. Transportation over the water is now intended to better connect the transformation areas.

§ 3.7 Flood Protection: Crux of a Comprehensive Strategy

The Delta Programme proposes four flood risk strategies that define the corners of a 'playing field' of possible safety solutions for the Rijnmond region. Many different aspects of sustainable development in Rotterdam (port development, safety against flooding, possibilities for new forms of urbanisation in the former dockland and waterfront areas, and care for the environmental quality of the delta) are strongly interlinked with the choice for a regional flood defence strategy.

The four strategies are based on the principle that a storm surge barrier reduces the amount of inland dike reinforcements, by closing the front entrance to the sea and thus protecting the region against high water threats. The same basic principle led to the construction of the existing Maeslant Storm Surge Barrier that currently protects the Rijnmond region against high water levels in the case of a storm surge.

The first water safety strategy is based on a 'business as usual' approach, protecting the Rijnmond region with the existing, closable Maeslant barrier at the sea-bound side of the region (Fig. 3.5). Barriers which can be closed carry with them a chance of failure, however, meaning that the dikes behind the barriers have to be strong enough to protect against rising water levels in the case of barrier failure, or in the case of high river discharges (which are expected to become more extreme and increase from 12,000 to 18,000 m³ per second at peak discharge) occurring simultaneously with a storm surge. Due to rising sea levels, this might (as mentioned in Section 5) in the future result in more frequent closure of the barrier. In an extreme scenario put forward by the Delta Committee (Delta Commissie 2008), the sea water level might have risen 1.30 m by 2100. The barrier would then have to close up to 30 times a year—unacceptable for the Rotterdam port authority, since the accessibility, and with that the reliability, of the port depend on the open connection with the sea. Besides that, the chance of the Maeslant barrier failing to close is estimated to be one in every 100 closures. More frequent closing of the barrier would lead to a greater risk of failure in the future. Therefore, the Delta Programme (Deltaprogramma Rijnmond Drechtsteden, 2010) proposes that the barrier, when the time comes for it to be replaced, should be upgraded to a barrier with an improved chance of failure of 1 in every 1000 closures. It is also proposed that the barrier should not be closed more frequently than once a year, even if this results in closing the barrier at a higher water level than the currently prescribed +3 m NAP. With some of the unembanked areas starting at a height of 3.2 m above NAP, this means that additional measures would be needed to protect these areas against flooding.

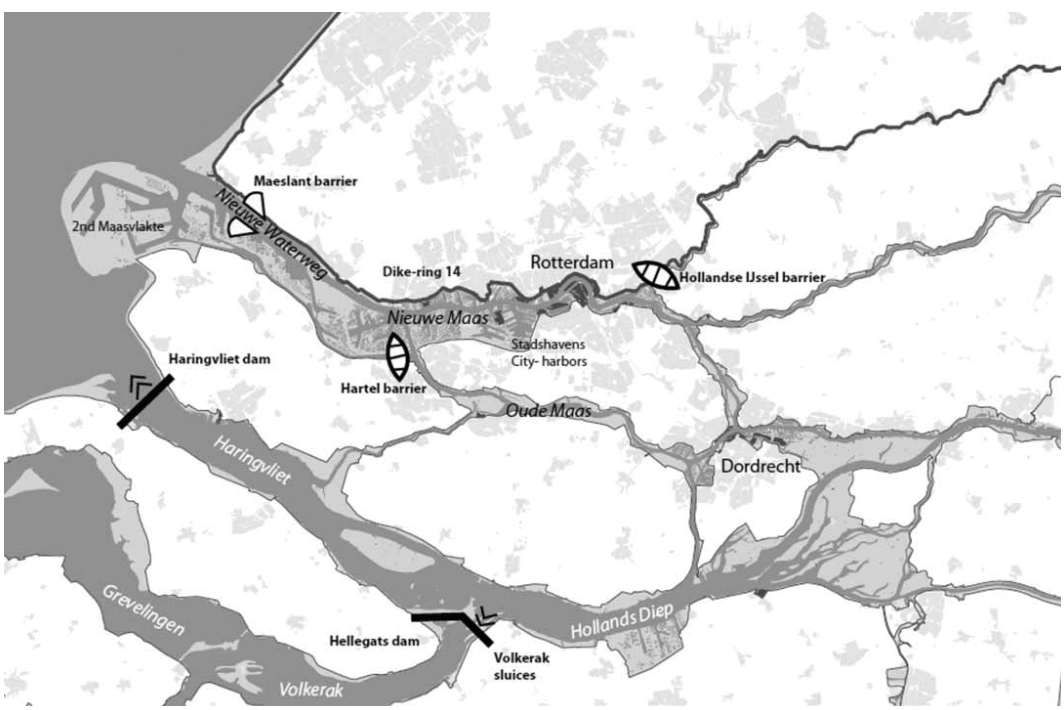

FIGURE 3.5 Rijnmond open/closable interventions at the seaside, with storm surge barriers in the sea gates.

The second water safety strategy comes in response to the extra flood risk caused by simultaneous storm surge and peak river discharges by placing additional closable barriers on the river side of the region (Fig. 3.6). In the case of peak discharges, the barriers could then be closed, and the water redirected towards the Haringvliet, which directs it towards the sea. An extra advantage of the placement of barriers is the possibility to use them to improve the infrastructural network of the region. However, the small-scale 'business as usual' interventions between the barriers that are related to this strategy hardly create a catalyst for new urban transformations of a scale that could redefine the relationship between the northern and southern parts of Rotterdam.

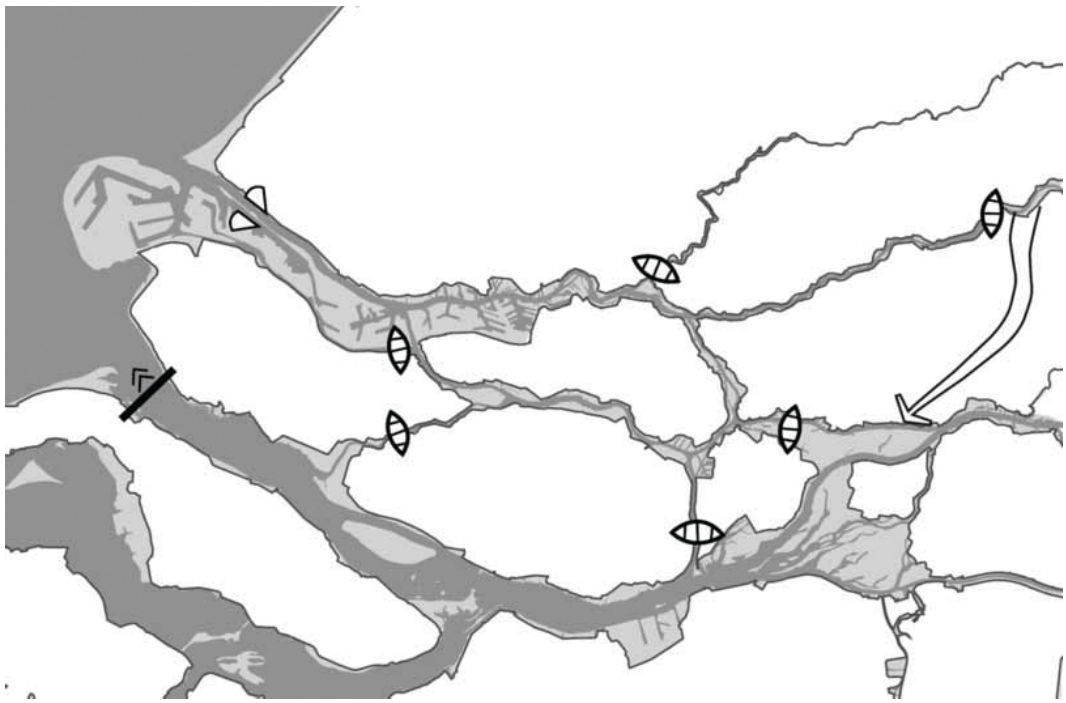

FIGURE 3.6 Rijnmond open/closable interventions at the seaside and riversides—with storm surge barriers in all waterways to the urban territory.

The third strategy, 'closed Rijnmond', provides a solution to the problem of the chance of failure related to the closable barriers by damming off part of the Rijnmond region— leading to a similar situation to that of Amsterdam (Fig. 3.7). The new barrier would disturb the natural, open connection of the river to the sea. The Port of Rotterdam would lose its big competitive advantage: open access to both the North Sea and its European hinterland. Ships would have to pass locks to access the port or use hinterland connections. However, between the barriers a controlled water level would create many possibilities for urban redevelopment and would allow for the transformation of the central riverside part of the city, which now divides the city into two parts. Because of the controlled water level, the dikes that form a barrier between the city and the river could be partly removed or lowered in order to strengthen the connection between the city and the water. By gaining a more recreational and urban function, water could become part of the city itself and connect the two halves of the city. The closed system makes it possible to connect the river Maas with the canals and creeks within the dike-rings, creating possibilities for transportation over water as well as ecological connections. In this scenario, the river has the potential to develop into a central spine. Depending on the development of the port and the need for growth or shrinking of the city, new urban environments could be created that include mixed urban areas, port-related functions, or green recreation or nature areas.

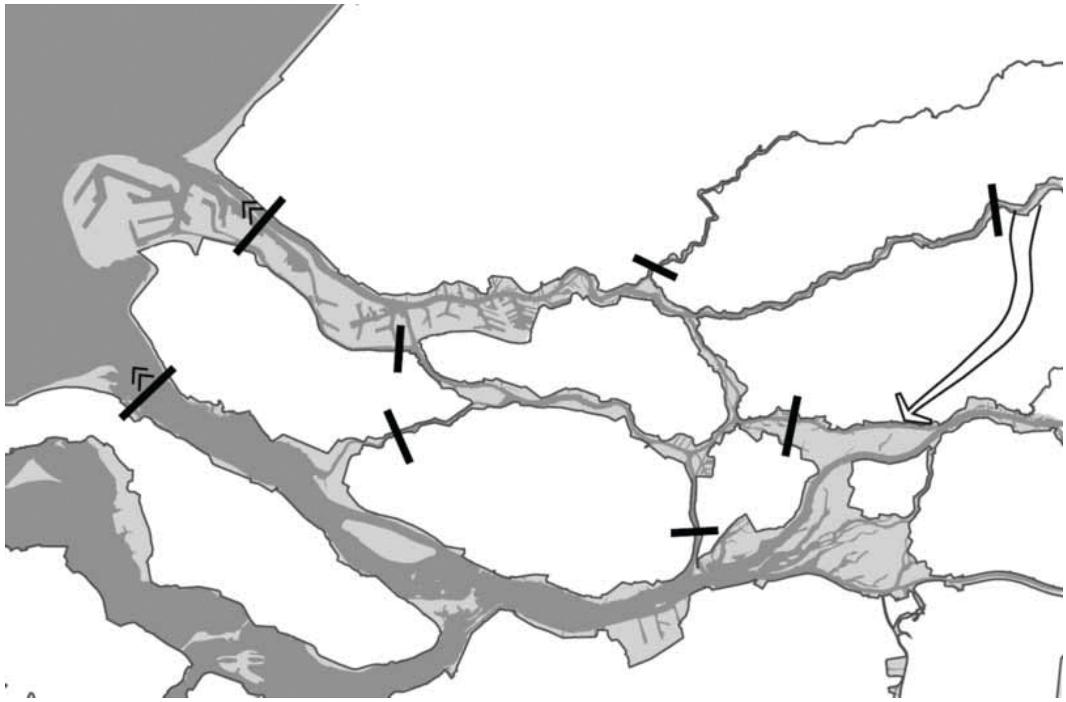

FIGURE 3.7 Closed Rijnmond, with locks and dams in all waterways to the urban territory.

The fourth safety strategy is referred to as open Rijnmond. In this strategy, all storm surge barriers including the Grevelingendam would be removed, creating an open relationship between the rivers and the sea (Fig. 3.8). The natural tide, sedimentation processes, and the fresh and salt gradient of the water would be re-established, resulting in a more natural estuarine delta area. For the shipping traffic, this open connection guarantees accessibility to the port and the hinterland. The unembanked areas would come under tidal influence and flood on a more regular basis. Any areas containing buildings, polluted grounds or industries vulnerable to floods would have to be protected by additional small- scale dikes or barriers. The regeneration projects within the unembanked area can be designed as flood-proof areas, strengthening the relationship between the river and the city. To reach the safety levels prescribed for the dike-rings, most dikes would have to be reinforced in a radical way. New forms of delta dikes could be used to strengthen the dike while at the same time making the dike itself become part of the urban waterfront. From this perspective, the open Rijnmond strategy offers opportunities that are comparable to those of the closed Rijnmond strategy—to give the river a more central and binding position within the city of Rotterdam.

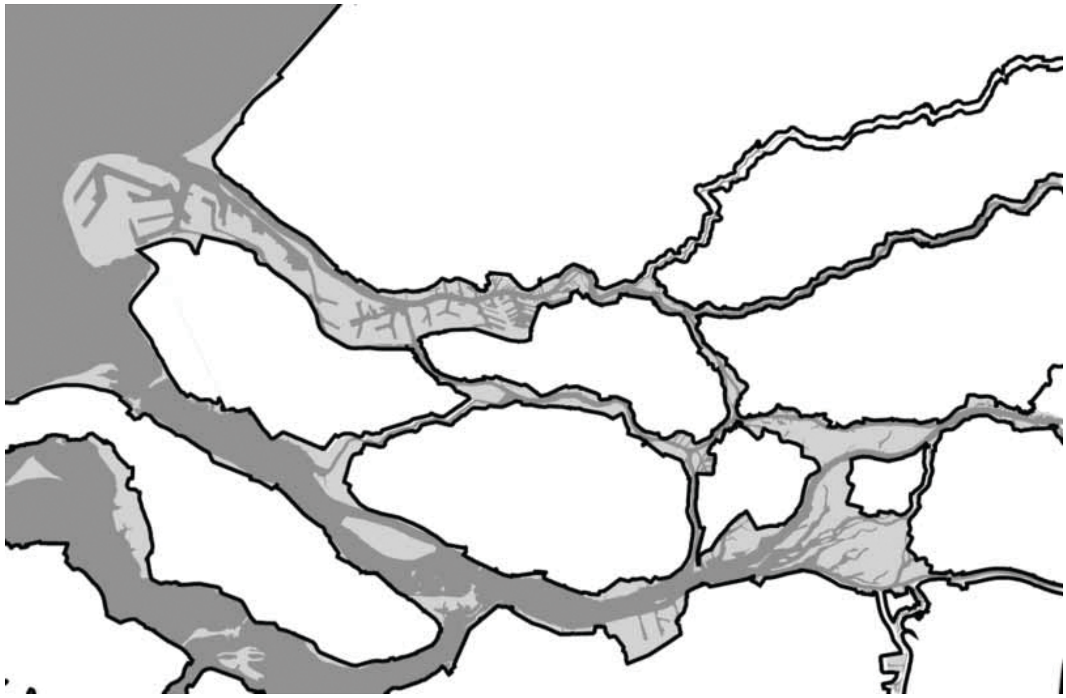

FIGURE 3.8 Open Rijnmond, with enforced and heightened dikes.

The range of possible water safety strategies defined by these four 'corner positions' creates possibilities to compare them and distinguish their characteristics, effects, and opportunities. The four options ('corner positions') result in different conditions for water levels in the unembanked areas, as shown in Fig. 3.9, and thus propose different conditions and possibilities for the urban environment.

In addition, the future of the port will be seriously influenced by the type of flood-protection strategy. However, the interests of the port are not unambiguous. Considered from the perspective of the importance of accessibility of the port area, the option of an 'open Rijnmond' seems to be the best one. However, considering the importance of the availability of fresh water supply to the process industry, the closed option delivers the best conditions. And considering the long-term perspectives, with a possible transformation from petrochemical industry to other types of production and storage of energy, the question is whether the port will need the total amount of the present-day 10,500 hectares of port area in the future. The answer to this question will be important in the context of making a decision regarding the location of a new storm surge barrier or lock system.

Finally, the environmental quality of the rivers in and around the Rotterdam region will be dependent on the final solution concerning flood protection. An open system will mean that the estuaries will be repaired as transition zones between salt and fresh water; a closed system will mean that also the river Nieuwe Maas will be transformed into a fresh water body. Recently, the World Wildlife Fund (WWF, 2010) presented its report 'Met Open Armen' ('With Open Arms'), as a plea for an abolishment of the dams in the southwest delta and for the repair of estuarine wetland systems in the river mouths. The WWF states that the repair of an open system will contribute to a new balance of nature, safety, and economy, but does not say what the safety consequences would be in this concept: the heightening of many kilometres of dikes in the region.

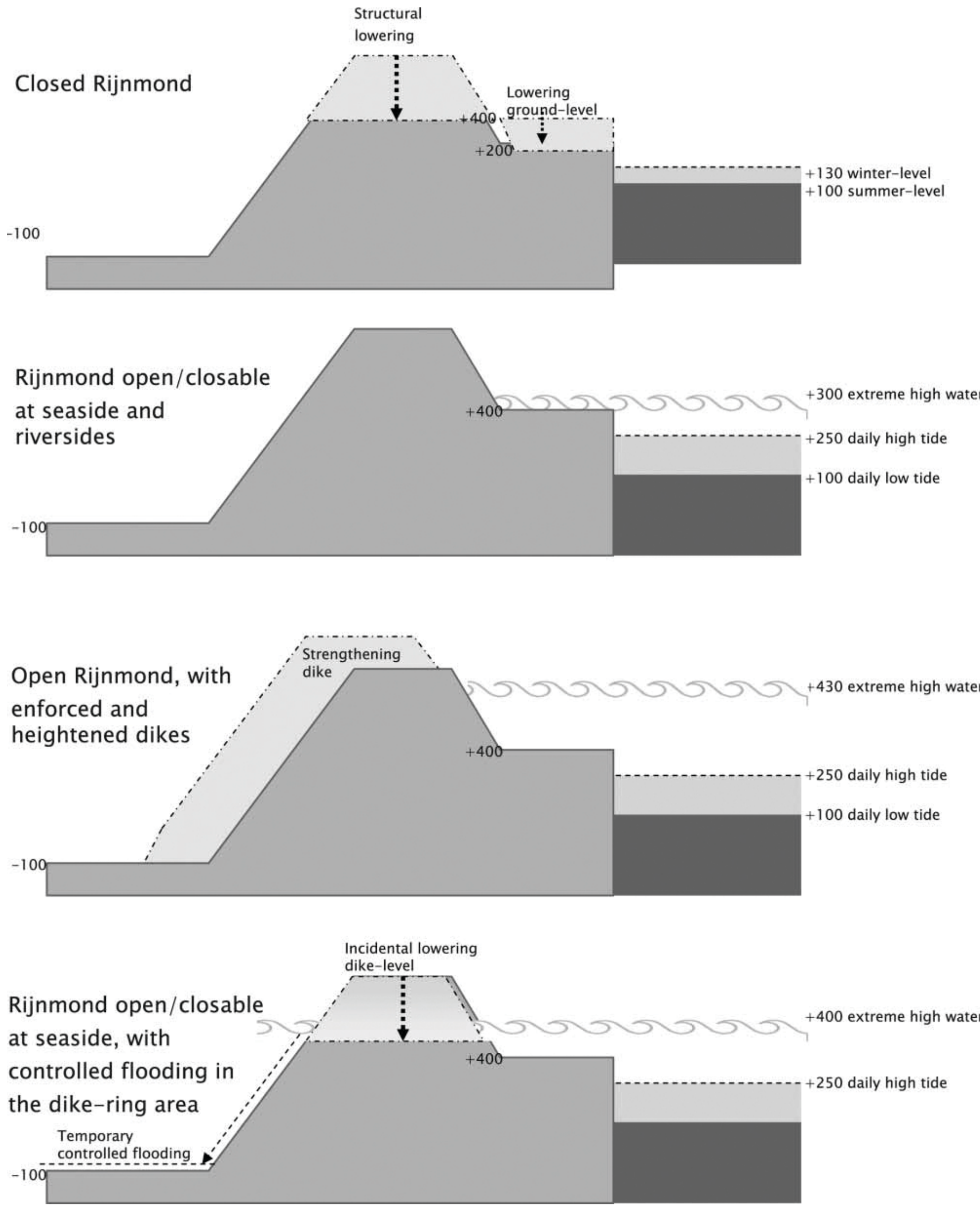

FIGURE 3.9 Dike sections showing the effects of the different regional water management options for the local situations of unembanked areas and dikes.

§ 3.8 Conclusion and Discussion

The Rotterdam region plays a central role in two main issues concerning sustainability in the Netherlands: water management and energy transition. These two issues are directly linked to each other because of the central role of the port as a global energy hub and as a central element in any new water management strategy. Furthermore, the decisions concerning these issues directly influence other sustainability issues, such as the environmental quality of the delta waters and the chance to provide the city of Rotterdam with new attractive urban waterfronts which might play a role in the strategy to attract innovative industries and medium- and high-income groups.

The future of Rotterdam mainport is intrinsically connected to changes in the Dutch delta system and therefore to one of the main effects of climate change: the rise in the sea level. The first major step on the road to the present status of Rotterdam as a global mainport—the realisation of the Nieuwe Waterweg in the nineteenth century—created an open port, accessible directly from the sea without the necessity of passing a lock barrier, an advantage in comparison to other ports in the Hamburg—Le Havre range. It remains to be seen whether this system can be maintained long term. Worst-case scenarios will make it necessary to surround the Rotterdam region with a system of locks or storm surge barriers, but also in the case of a system of storm surge barriers, these barriers will have to close so often that the shipping connection to the hinterland will become unreliable, and will result in 'unacceptable' financial damage to the shipping sector.

The paper shows that altogether, 'water' refers several different issues, which touch and overlap with each other. Moreover, many of these issues touch spatial, economic, social, and environmental questions in the city and harbour area. The question remains as to how a planning approach and policy can be developed which considers the linkages between the different issues of water and the linkages of water with spatial, economic, and social issues as a possibility to develop comprehensive plans.

In summary, to answer the question of whether Rotterdam really is a global benchmark in terms of water and port management: perhaps, yes, in the sense of ambitions and intentions; in the sense of real practice, there is still a long way to go.

On the positive side, it is clear that many initiatives are underway at this moment in time, several of which have been discussed in this paper. The main challenge though is to link the various individual initiatives, strategies, studies, and projects, and the actors and coalitions behind them. There is, for instance, the process which should lead to a new strategy for the port (Port Vision 2030) and which—among other things—will deal with an issue totally new to the port authority: climate change. It does not yet seem to be the case that thinking about the future of the port has been linked to the issue of a long-term hazard-proof system of flood control. The question of how water management could be linked to urban renewal and the revitalisation of Rotterdam South is yet another example of how linkages can be made between issues, but which is still in its infancy.

At first sight, this seems to be a call for comprehensive planning. This is not what we mean. Comprehensive planning presumes—among other things—the presence of decisive actors. These actors are simply not there, have never been there, and nor will they ever be. What we would like to see is the making of linkages. One way of achieving this is to give a key role to the water system because this system is so closely linked to the way the city and the port is developing, and could, or even should, develop in the future. One example of this close relationship, as we have already highlighted above: the dependence of the petrochemical complex of Rotterdam—as one of the largest in the world—on a reliable and large supply of fresh water.

A water system is a territorial network in itself and based on these characteristics networks can be developed at the level of strategies, programmes, projects, and actors. A serious handicap for such a network approach is the extremely complex system of government in the Rotterdam region and the south wing of the Randstad at large. What is needed is what Bob Jessop calls 'metagovernance'. But it is very difficult to see which actor(s) could take the lead to create some kind of metagovernance capacity. Some kind of administrative restructuring appears to be an obvious strategy. There is doubt in the literature (see, for instance, Salet, 2006) about whether this would be the right way forward, especially in the case of the Randstad and its sub-regions, such as the north (centred around Amsterdam) and the south wing (centred around Rotterdam and The Hague): the territorial organisation of government will never perfectly match territorial relationships. Moreover, every new design of this organisation is likely to become outdated in the future thanks to processes of spatial rescaling. Nevertheless, one could, or should, ask at what point a certain territorial arrangement becomes unworkable. This seems to be the case in the Rotterdam region. Starting a discussion on the territorial structure of government in the Netherlands is like opening Pandora's box, as has been proven by decades of such discussion. At present there is, yet again, talk of rearranging the governmental structure of the Randstad. A genuine political pandemonium is the result: provinces, municipalities, and their umbrella organisations take different positions, as has always been the case. However, some administrative reorganisation seems necessary: the use-by date of the present organisation has long since passed.

Notes

1 www.rotterdamclimateinitiative.nl (accessed February 2011).
2 Of the 5.9 million containers transported via the Rotterdam harbour nearly 30% is called sea – sea trans- port (Port of Rotterdam, 2009).
3 http://www.rnw.nl/english/bulletin/germans-reject-dutch-purchase-port-duisburg-share (accessed February 2011).
4 http://www.maasvlakte2.com/nl/index/ (accessed February 2011).
5 http://www.deltalinqs.nl/index.php?option=com_content&task=view&id=54&Itemid=4 (accessed 8 February 2011).
6 http://www.rotterdamclimateinitiative.nl/en/about_rotterdam_climate_initiative/rotterdam_climate_initiative/mission_ambition (accessed 7 February 2011).
7 All figures collected from the website of the Port of Rotterdam.
8 Biomass is a wider concept than biofuels. Biomass is of particular importance for the Netherlands: according to some (for instance, Hetsen & Hidding, 1991), the large-scale, very intensive cattle breeding which forms a major pillar in the Dutch agri-business industry owes its existence mainly to cheap and reliable imports of biofood through the Rotterdam port.
9 NTA is the Dutch acronym for Dutch Technical Agreement (see http://www.sustainable-biomass.org; accessed February 2011).
10 See http://www.keringhuis.nl/engels/home_noflash.html (accessed February 2011).
11 Especially the programme 'Knowledge for Climate', supported by NWO, the Dutch research council (see http://knowledgeforclimate.climateresearchnetherlands.nl; accessed October 2010).

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Intermezzo 3: Historical Development in the Rijnmond Region

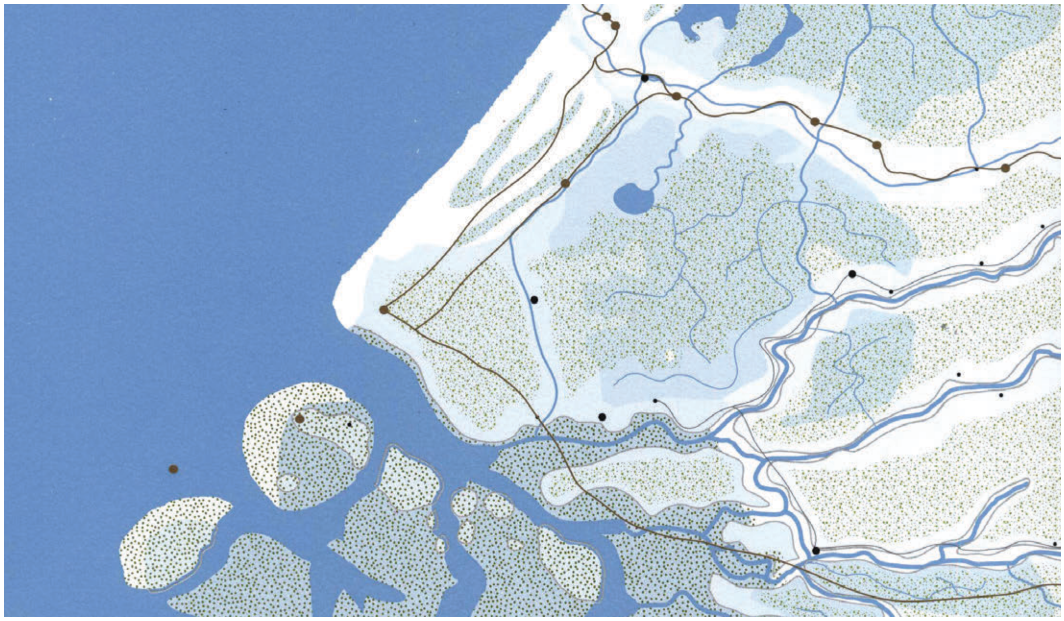

FIGURE 3.10 Map of the Rijnmond region in 1200AD. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

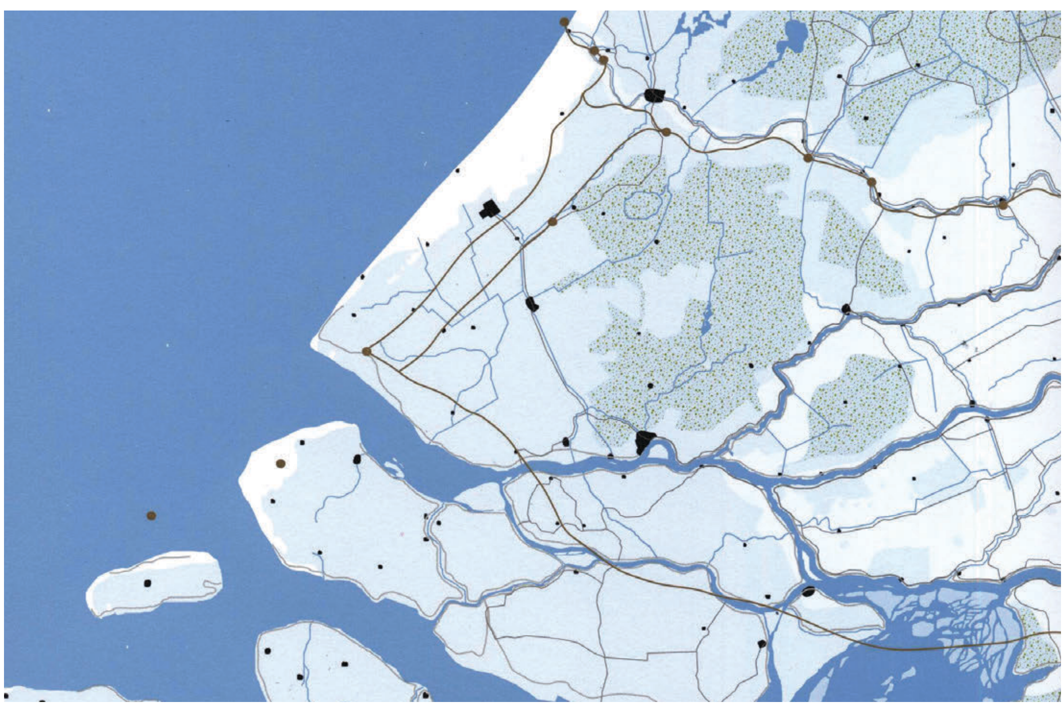

FIGURE 3.11 Map of the Rijnmond region in 1650AD. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

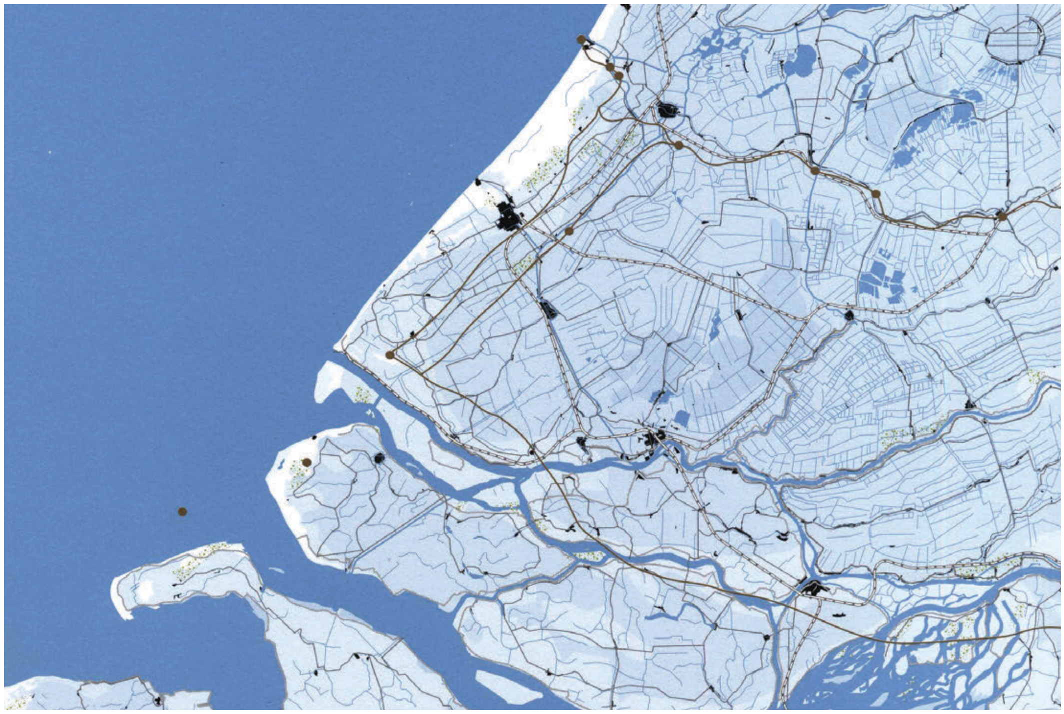

FIGURE 3.12 Map of the Rijnmond region in 1900. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)

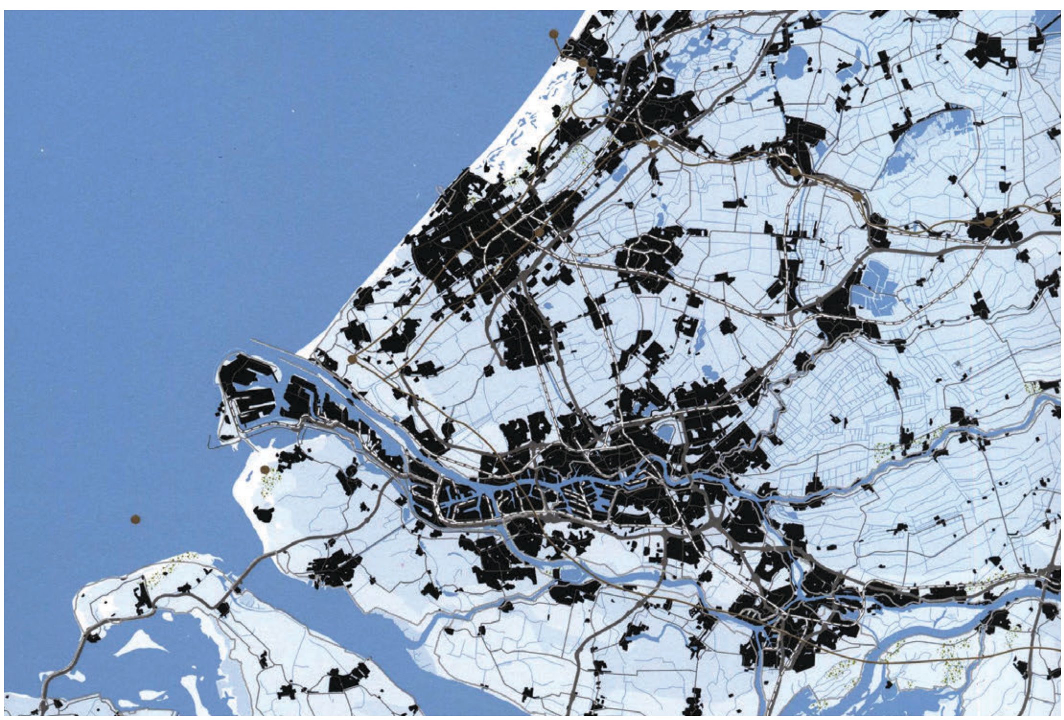

FIGURE 3.13 Map of the Rijnmond region in 2000. Source: Limes atlas (Colenbrander, MUST 2005, 010 Publishers)