Xplorelab

HOTSPOT ZUIDPLASPOLDER

Climate Adaptation in the Zuidplaspolder

FINAL REPORT

provincie ZUID HOLLAND

Contents

Foreword	**2**
Summary	**3**
1 Introduction	**4**
2 Effects of climate change	**9**
Context of climate change	9
Effects on the geomorphological layer (soil, drought and salinization)	11
Effects on the network layer (ecology and flood safety)	19
Effects on land use layer (rainwater flooding, increased temperature and design of conservation areas)	27
3 Designs	**33**
Anthology of Ideas	33
Pilot project Zuidplas Noord	36
Pilot project Rode Waterparel	38
Pilot project Nieuwerkerk Noord	40
Pilot project Moordrecht	41
Pilot project Gouweknoop	42
4 Evaluation	**43**
Anthology of Ideas	43
SCBA [Social Cost/Benefit Analysis] Five examples	46
Conclusions of the SCBA	51
Management and policy	52
Climate adaptation in practice	54
5 Conclusion: Climate proof?	**56**
Research questions: the effects, spatial planning and costs versus benefits	56
Climate proof?	58
Hotspot publications	**59**
References	**61**
Colophon	**63**

Foreword

The Dutch and water have always been intrinsically linked to one another. In all sorts of ways; small scale and large scale. As a child in Holland, you get swimming lessons at an early age; we are always guaranteed medals at the Olympic Games in a variety of swimming events; and Dutch engineers work all over the world providing solutions in the fight against water. Building at the lowest point in the Netherlands, in the Zuidplaspolder, is viewed as a challenge and not something that is impossible.

President of the Water Board Hans Oosters hands over the first copy of the Hotspot Compilation Bundle to Minister Cramer on 18th June 2008.

In the Netherlands you rarely get an opportunity to design new sustainable concepts and put them into practice on as large a scale as can now be done in the Zuidplaspolder (ZPP). Whether it is at all reasonable to build in this area has of course been critically considered. It is precisely this critical attitude that allows the Zuidplaspolder to function as a testing ground for the Netherlands. Showing what is possible in the field of climate resilient construction. The Zuidplaspolder is not the only low-lying area in the Netherlands; large parts of this country are to some extent vulnerable of flooding.

The Xplorelab approach in the Hotspot Zuidplaspolder project is a combination of research, implementation of ideas into inspiring examples and evaluation. This is all brought together in the Hotspot Compilation Bundle and summarized in this report. We have also tried to realize these ideas within existing plans for the Zuidplaspolder. This was endorsed once more on 18 June 2008 by myself on behalf of the Executive Board of the Province of Zuid-Holland, by the president of the local Waterboard, Hans Oosters and the Dutch Minister of environment and spatial planning, mrs. Cramer, among others. It is now time for the next step. Not only in the Zuidplaspolder, but also in the rest of the province of Zuid-Holland and in the rest of the Netherlands.

Asje van Dijk
Member of the Executive Board, for the Zuidplaspolder, Province of Zuid-Holland.

Summary

The Zuidplaspolder lies within the triangle formed by Rotterdam, Zoetermeer and Gouda and includes the lowest lying reclaimed land area in the Netherlands. The Zuidplaspolder has been designated to absorb the urban expansion demands of the Southern part of the Randstad, the prime Dutch West coast urban agglomeration. The following developments have been planned:

- the building of 7,000-30,000 homes, hundreds of hectares of commercial properties and greenhouses;
- improvements to the infrastructure
- development of extra natural reserves, green zones and green zonal links;
- space for water storage.

The Zuidplaspolder has to be developed in a sustainable way. Therefore future inhabitants and businesses should not have to suffer any negative effects from climate change. The Xplorelab of the province of Zuid-Holland has investigated which climate change impacts will effect the Zuidplas and what can be done to mitigate this. This report shows the effects and the adaptation possibilities. There are also preliminary assessments of the potential (social) costs and benefits.

Examples of measures are:
- no construction in lowest lying areas of polder
- aggregation of surfaces water management areas
- expansion of peak rainwater storage space
- assessment of safety margins for storm barriers
- construction in harmony with the geomorphological structures
- placing of compartmental dikes
- building waterproof houses
- connecting and strengthening natural conservation area
- seasonal storage of rain water for dry periods
- utilizing green areas and water as anti-“heat-stress” measures

Five climate resilient pilot projects have been designed, based on analyses of the effects of climate change. The total additional cost for four of them amounts to tens of millions of euros. The eventual cost to society is expected to become a benefit in the long run.

The Zuidplaspolder spatial plan appears to be climate resilient but it can still be improved. Despite the net positive result, implementation of these supplementary climate-related measures cannot be taken for granted. Merging long term interests into development plans demands close attention right up to implementation stage. Using a “workshop” like Xplorelab is a tried and true method for achieving this. Climate resilience is not a standard, but a way of working. Involving the right partners at an early stage and a creative attitude is crucial.

1 Introduction

The Zuidplaspolder includes the lowest lying land area in Europe. And precisely in this place, there are plans for intensive large scale urban development. Is this sensible and if so, how do you approach it especially now that the changing climate plays an increasingly prominent role. These societal issues already adressed the development plans for the Zuidplas for quite some time, and were the reason why the provincial Xplorelab has put these issues on the agenda. The final report below is the result of a quest for answers, under the title *Hotspot Zuidplaspolder*.

The climate on earth changes continuously. This is under the influence of a range of external and astronomic factors such as changes in the distance between the sun and the earth and the angle of the earth's axis. Man has also influenced the climate since the end of the 19th century. For years, policy measures to reduce the levels of greenhouse gases have been taken to stop climate change (mitigation). Because of the sluggishness of the climate system, this mitigation policy cannot prevent the climate changing within the coming years. We have to adapt as well.

This Hotspot Project has been implemented under the auspices of the national research programme Klimaat voor ruimte [Climate changes Spatial Planning]. Hotspot Projects have been established by this programme to translate the current climate expertise into practical application in urban and rural planning. The Hotspot Zuidplaspolder is one of these projects.

There has been intensive collaboration within this project with the project organisation Driehoek RZG-Zuidplas[1] [Triangle RZG-Zuidplas; RZG stands for Rotterdam-Zoetermeer-Gouda, three large cities bordering the reclaimed land of the Zuidplaspolder], which draws up the plans for the Zuidplaspolder. Other partners are the Water Board of Schieland en Krimpenerwaard, the VU University of Amsterdam, Delft University of Technology, Wageningen University and Research Centre and various market players. This final report is a summary of the previously published series of five pilot projects (see Chapter 3) and eight background studies (see Chapters 2 and 4).

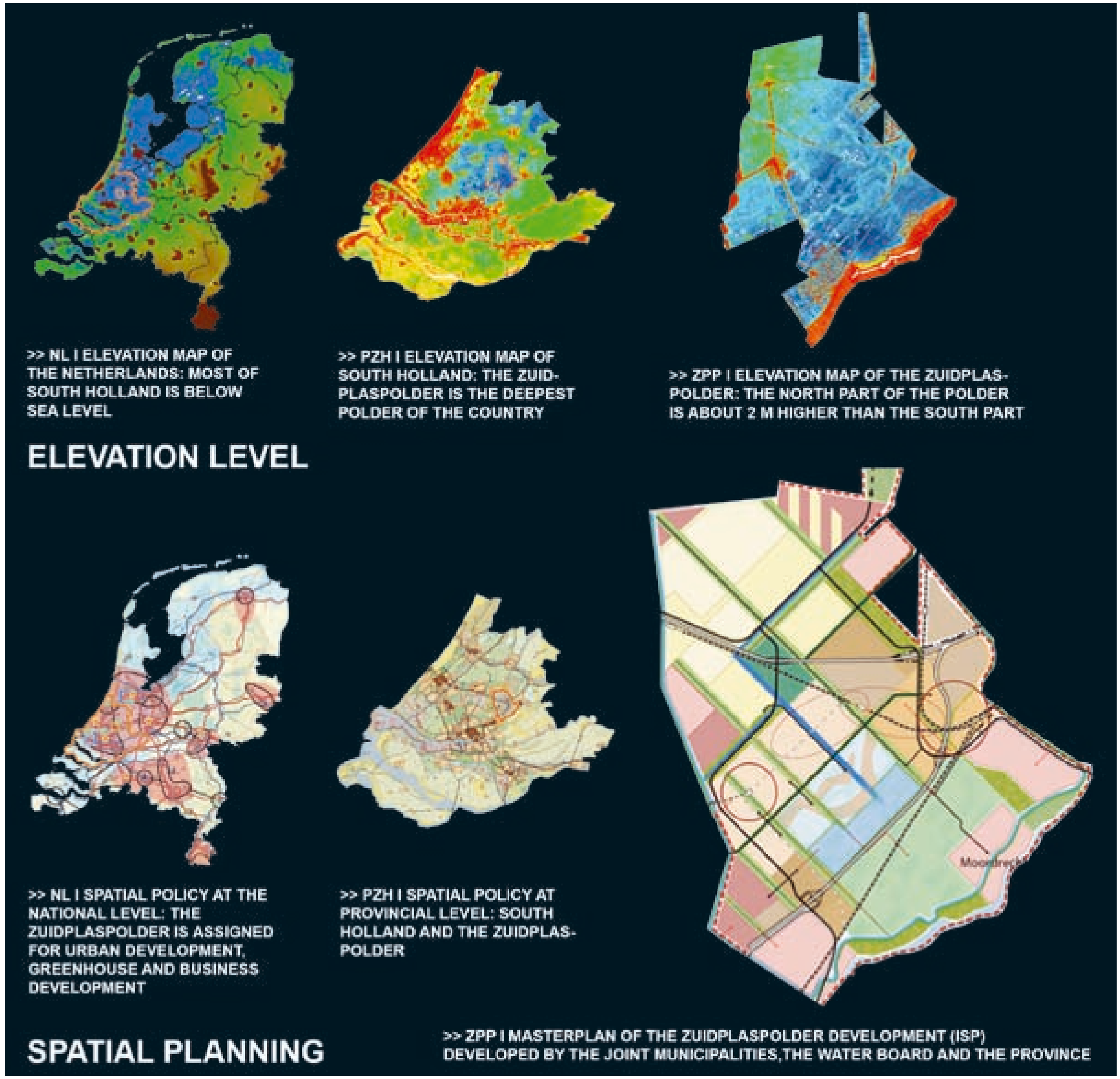


Figure 1: The location of the Zuidplaspolder in the Netherlands and the province of Zuid-Holland.

The top series shows the elevation level of the polder. The bottom series shows the planned developments at national and provincial level and the masterplan for the Zuidplaspolder; the Inter-municipal Structure Plan (ISP).

View of 'Bovenland' and the 'Restveen' area in the Zuid-plaspolder. There will be no urban development in this area.

Developmental Plan RGZ-Zuidplas

The Zuidplaspolder is situated in the south eastern corner of the triangle formed by Rotterdam, Zoetermeer and Gouda. It is one of the most low lying polders in the country and is situated near the river Hollandsche IJssel. In a policy document on land development, this area has been designated to cater for the developmental needs of the southern end of the Randstad (including greenhouse cultivation).

The Dutch national government has commissioned the province of Zuid-Holland to research the possibilities for new residential environments, recreation, space for water, commercial property development and greenhouses.

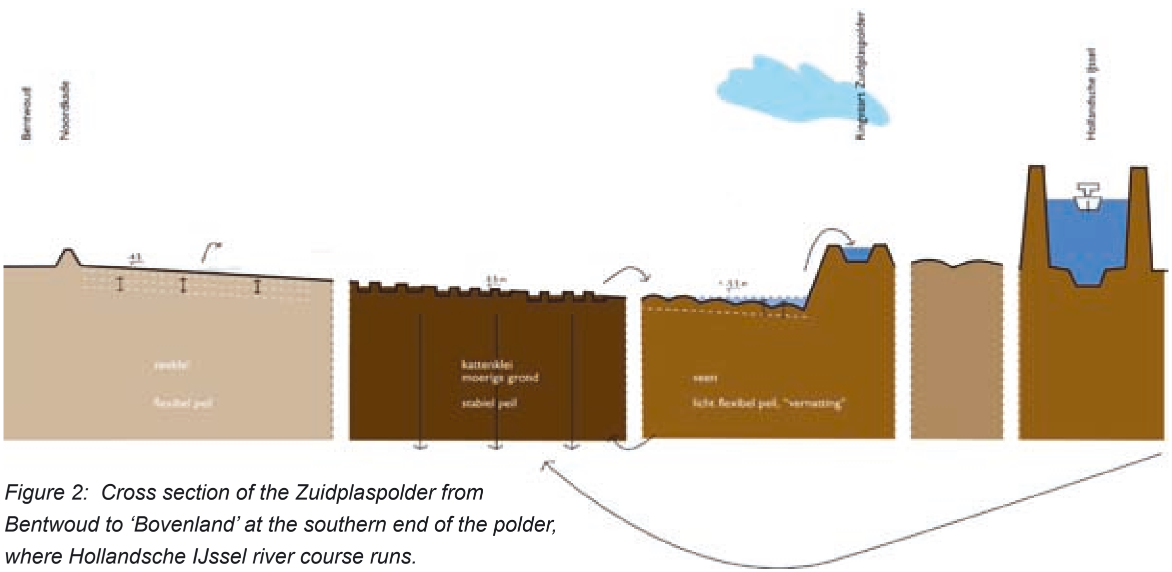


Figure 2: Cross section of the Zuidplaspolder from Bentwoud to 'Bovenland' at the southern end of the polder, where Hollandsche IJssel river course runs.

In 2004, the province of Zuid-Holland investigated the options for this large-scale development together with 10 local municipalities, regional co-operative ventures, interested parties and the Water Board. The results have been published in the Interregionale Structuur-visie [ISV] [Interregional Spatial Planning Vision] and worked out in the Intergemeentelijk Structuurplan [ISP], a revised provincial spatial plan for the area and a plan for an environmental assessment report.

These plans will be transformed into zoning plans during 2008. Within the Zuidplaspolder, the following developments in the period 2010-2020 have to be allocated:

The Hotspot project progresses through three different phases several times

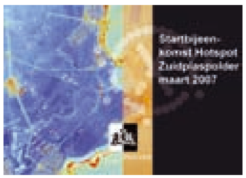
- The building of 15,000 homes (town expansion, exclusive residential areas, first phase of 7,000 homes);
- Development of 125 ha of business park
- Building of 200 hectares of new greenhouses and relocation of 80 hectares of existing greenhouses.
- Improvement to the infrastructure (roads, bicycle paths and public transport);
- Development of 500 hectares of extra natural reserves (around the A20 motorway);
- Green zones and green zone links;
- Space for water storage.

Project objectives

The polder has to be developed in line with sustainability objectives. Part of this is to ensure that future inhabitants and businesses will not be negatively affected by the effects of climate change. In view of the current discussion on the changing climate, the province of Zuid-Holland has taken the initiative to set up the Hotspot Zuidplaspolder Project together with the national research programme, Klimaat voor Ruimte [Climate changes Spatial Planning]. The steering committee responsible for the entire development of the Zuidplas supports this project. The president of the Water Board of Schieland and the Krimpenerwaard reports to the steering committee on behalf of the Hotspot Project.

Within the province, the project is being coordinated by Xplorelab, set up in 2007 as a laboratory for innovative work and learning.

The illustrations below refer to the initial steering report and the Interim report as source of the text printed opposite



Sources will be acknowledged in the same way for texts in all other 13 Hotspot publications

Xplorelab's objective is to stimulate integrated working methods by means of tailored research in both process and content. It is a forum where the different partners and people from various departments and management levels of the province of Zuid-Holland work together in an interdisciplinary and transdisciplinary way.

The project team members meet regularly at Xplorelab to work on implementing the project in a way that transcends individual areas of expertise. In this way, the demand for expertise is optimally matched to the pool of available expertise.
The project has answered three main questions:
1. What are the effects of climate change and how will they effect the Zuidplaspolder?
2. How can current spatial plan and zoning concepts anticipate the consequences of climate change?
3. Can the costs and the benefits of the proposed solutions be made socially accountable?

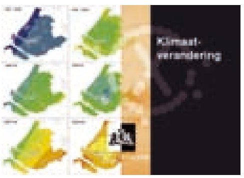
That is why Hotspot has been divided into three phases, which will be reflected in the format of this report. In phase 1, the long term effects of climate change are translated to the Zuid-Holland situation, specifically the Zuidplaspolder. Phase 2 proposes concept measures to make the Zuidplaspolder climate resilient. Examples of this are innovative building methods or clever measures to limit the effects of calamities.

The designs relate to different scales varying from the whole of Zuid-Holland or the Netherlands (infrastructure) to individual buildings or subdivisions (preparing the ground for development). In phase 3 the designs are submitted to a costs and benefits analysis based on social accountability. In this way the extra expense of sustainable solutions for climate change as well as the possible benefits to society are made clear. The proposed solutions have been included in existing spatial plans within the Zuidplaspolder. Where possible, the proposals are modified and extended. The basis for this has been the five pilot projects for climate resilient development.

Reading guide

This final report is designed around the principle of the three phases as used in the Hotspot Project. In Chapter 2, we describe the context of climate change and the models used, particularly the new insights and modifications that have occurred since the beginning of the planning of the Zuidplas around 2000. The effects of the fresh water shortage (including salinization), flooding as a result dike breaches, or too much rain, and rising temperatures will be discussed one by one. These themes will be split into three paragraphs, where a closer look will be taken into each level of the split layer approach (the geomorphological structure, the infra-structure and the land use layer). In Chapter 3 we present adaptive measures in (spatial) designs and technological innovations. We have condensed these designs into five pilot projects here described. In Chapter 4, we describe how these pilot projects have been assessed for their costs and benefits to society. We also touch on the interaction between the current planning process and the Hotspot results. In Chapter 5 we draw conclusions and make recommendations for a climate resilient form of development for the Zuidplaspolder.

2 Effects of climate change



Context of Climate Change
Earth's climate has always varied. The amount of greenhouse gases in the atmosphere is rising, mainly due to the combustion of fossil fuels. Because of this, the atmosphere's temperature is increasing, as well as the oceans' and the continents' temperature. This warming is accompanied by changes in the intensity and pattern of precipitation, snow and ice coverage and a rising sea level. Changes in wind patterns, storms, heat waves and droughts have been observed. The average temperature in the northern hemisphere was higher in the second half of the 20th century than the long term average over the last five hundred years.

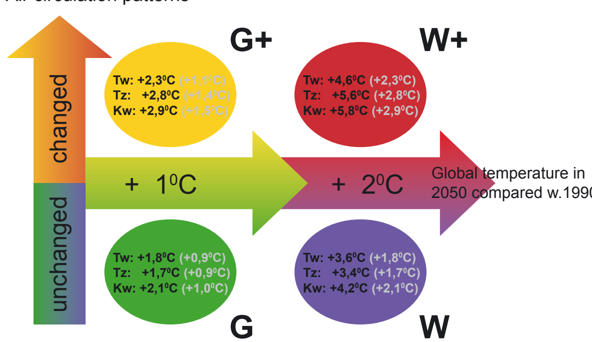


Figure 3:
The four KNMI'06 scenarios with the expected change of average temperature in the winter (Tw) and summer (Tz), and coldest winter day per year (Kw) for 2100 (and 2050 in grey)

It can't be predicted precisely how these observed changes will progress in the future. Because there are many uncertainties about future emissions and over the climate system itself, scientists use different future scenarios and computer models. These are used to try to predict the future climate within certain parameters. The intergovernmental Panel on Climate Change (IPPC) has indicated in its most recent report that the changes that have been observed are continuing. At the end of this century, the global temperature will have risen between 1.1 and 6.4°Celsius compared to the level in 1990 and sea levels will rise between 18 and 59 centimetres. These changes will continue through the ages even if the emission of greenhouse gases can be stabilized.

The effects of climate change will not be felt to the same degree all over the globe. In order to estimate the effect of worldwide climate change for the Netherlands, the KNMI [Dutch meteorological institute] has developed four scenarios: G, G+, W, W+ (KNMI '06 scenarios, see Figure 3). These scenarios have been classified according to two factors that are important for climate change in the Netherlands: the global rise in temperature (G = +2°Celsius and W = +4°Celsius in 2010 compared to 1990) and whether or not the air circulation patterns change in Western Europe (+ = with change). If the prevailing wind doesn't come from the sea but over land, the result will be a much drier climate in the Netherlands.

The scenarios indicate that the average temperature in the Netherlands in 2100 will rise compared to 1990; in the winter this can rise as much as 1.8 to 4.6^{O}Celsius and in the summer from 1.7 to 5.6^{O}Celsius. The average precipitation rises in all scenarios during the winter, but in the summer the average rainfall in the scenarios ranges from slightly more down to a whole lot less (the least in W+). In all scenarios and seasons extremes in precipitation increase (the most in W). Furthermore, the scenarios describe an absolute rise in sea level along the Dutch coast ranging from 35cm to 85cm in 2100 compared to 1990.
The changes in extreme wind speeds and frequency of storms appears slight compared with natural variation. On the basis of current knowledge, it is assumed that the four KNMI '06 scenarios are equally probable. To prepare for the future properly, all four scenarios should be taken into consideration.

Within the Netherlands, no differentiation in possible regional climate changes is made so far. There are, however, regional differences in the climatological parameters (such as temperature and precipitation). These regional patterns are important in establishing the effects of climate change. Within the framework of the project Klimaatatlas [Climate Atlas] run by the Zuid-Holland, Utrecht and Gelderland provinces, an answer is being formulated. The first results are included in the following paragraphs.

The spatial planning proces for the Zuidplaspolder predates the KNMI'06 scenarios. At the initial phase, the first largescale study into climate change, the WB21 scenarios (Water Management Commission for the 21st Century) in 2000 was used for the water related aspects. Of the three WB21-scenarios (low, middle and high) the designs are tested for the middle scenario for 2050. For this Hotspot study we have agreed to take the more recent and extreme KNMI scenarios dating from 2006 with a horizon reaching to 2100 as a starting point.

Split Layer Approach

In the spatial planning process of the Zuidplas, the split layer approach has been used from the starting point. In this approach the geomorphology layer, the infrastructure network layer, and the land use layer are central concepts.

Figure 4: The 'split layer' approach to the Nota Ruimte [White paper on Spatial Planning]

It appears that by using this methodology in the Zuidplaspolder, the designs have turned out to be intrinsically “climate resilient”. These layers are also pivotal for climate resilient design.
The following paragraphs in this final report are set out along the lines of the split layer approach.

Effects on the geomorphological layer
Drought and salinization

The most important effect of climate change on the sub-soil is drought and the accompanying fresh water shortages and salinization. It can have irreversible effects on the sub-soil structure and soil conditions and, therefore, on the ambitions for the development of the polder

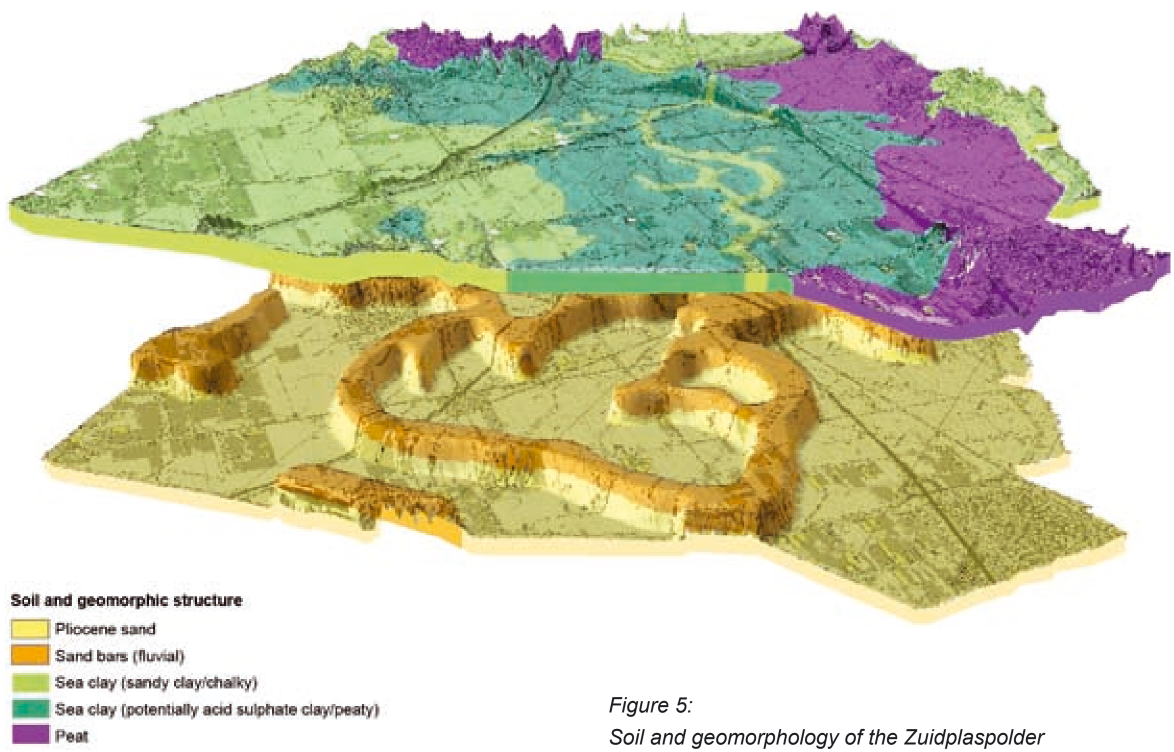


Figure 5:
Soil and geomorphology of the Zuidplaspolder

Soil

The geomorphology in the Zuidplaspolder has been formed by sedimentation from alternately river and sea deposits. The final change has been the removal of peat. This peat bog has been stripped to harvest the peat as fuel for heating and formed the Zuidplas [original lake]. When the lake was reclaimed, the Zuidplaspolder was formed. Since then, the surface soil of the polder consists of peat remnants and [acid] clay. Sandbars can be found a little deeper. Under them there is a permeable layer formed out of sand and gravel (the first aquifer). Because of the reclamation works, the deeper ground water has started to move and this wells up to the surface. The water pressure is strong and seepage can occur especially in places where the encapsulating clay layer is thin. This pressure restricts land use in the polder, all the more because the seepage water contains high levels of chlorides (almost everywhere). Because of the high pressure developed by the ground water, the soil surface can burst open. In the area of the Waterparel [water pearl] the quality of the water is excellent. Because of this, there are possibilities open for developing conservation areas.

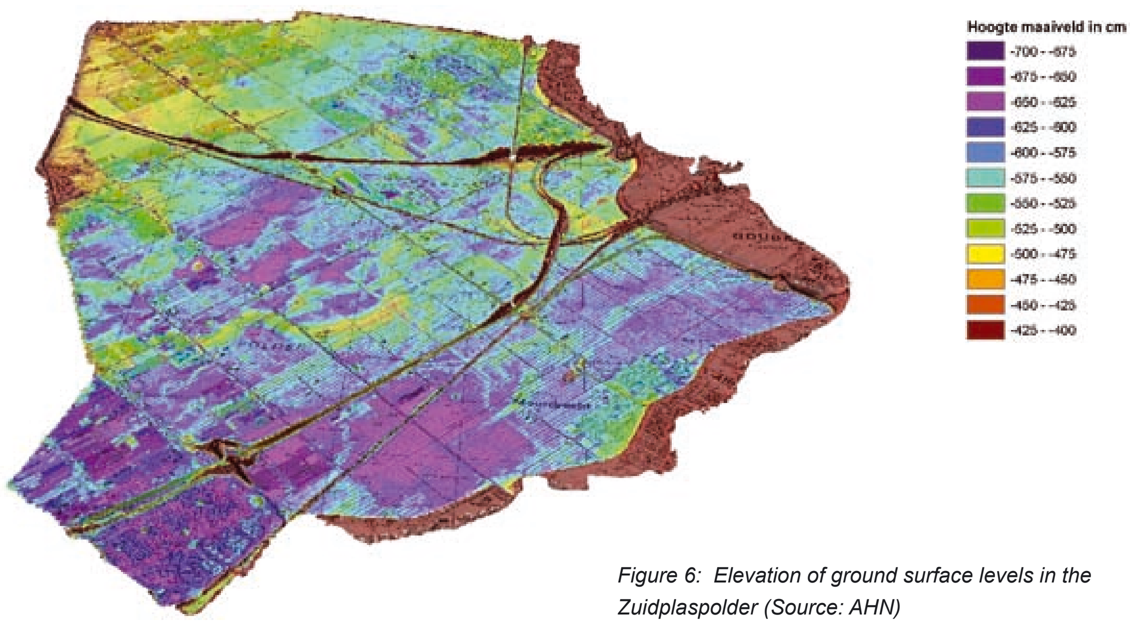


Figure 6: Elevation of ground surface levels in the Zuidplaspolder (Source: AHN)

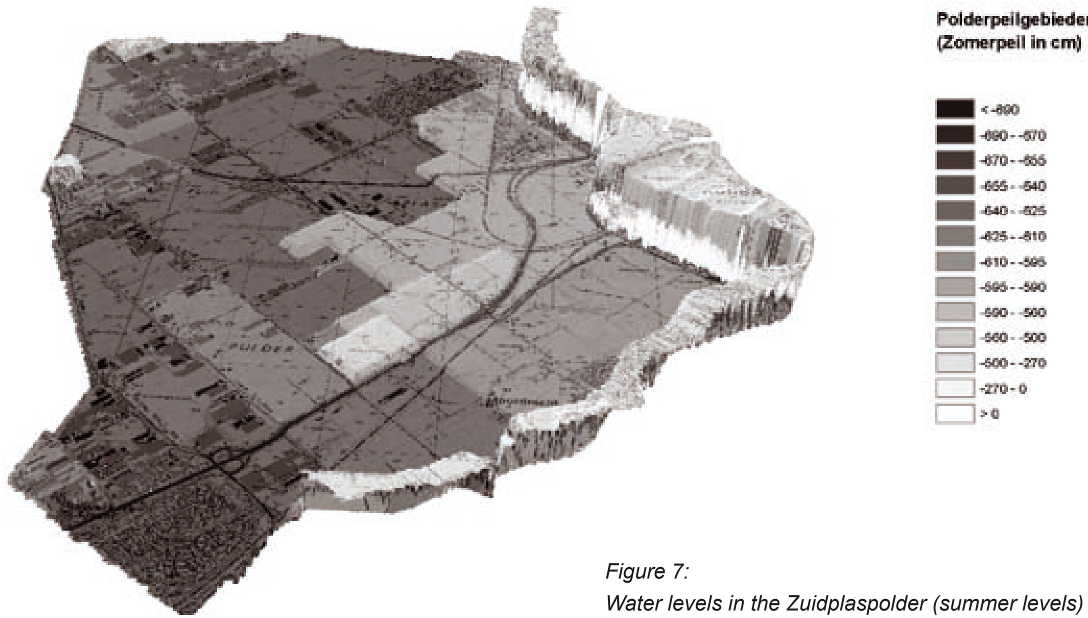


Figure 7:
Water levels in the Zuidplaspolder (summer levels)

Geomorphological Opportunity Map

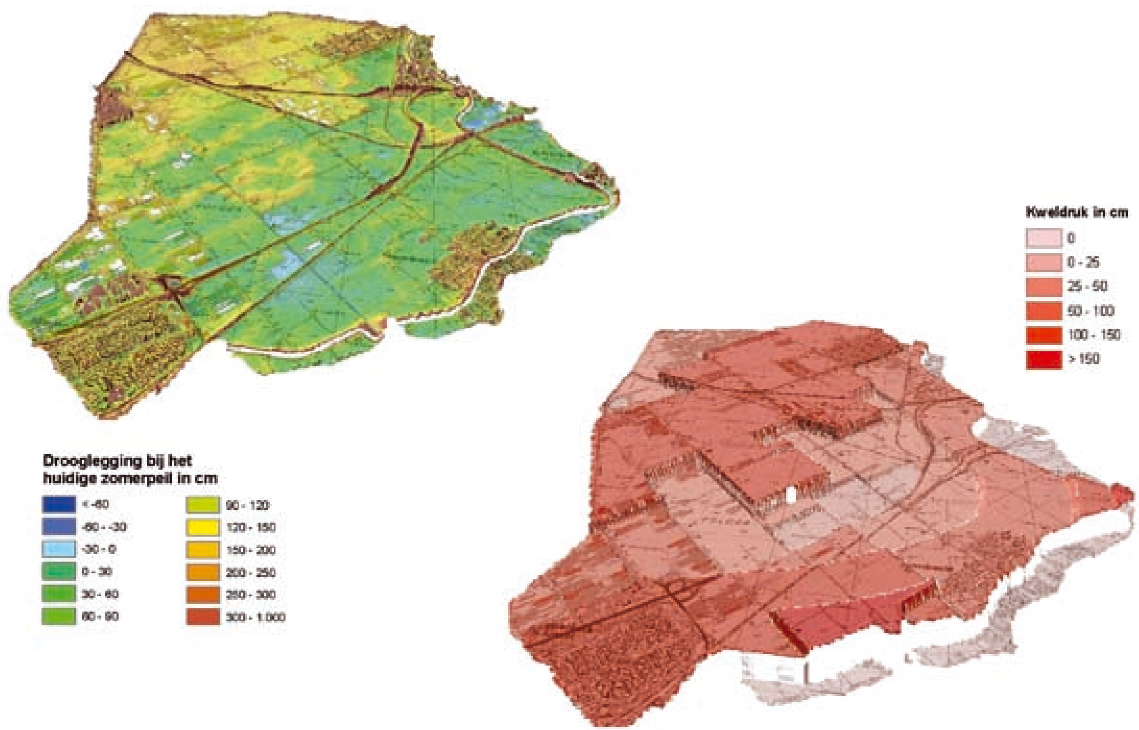
In developing the Zuidplaspolder spatial plans the special soil types have been carefully taken into account. For that reason, in the ISP the peaty and most low lying southern part has been designated for conservation and agriculture. Building development will take place where the geomorphological soil types are more suitable (for example, housing on the Kreekrug [the old river bed] and greenhouses in the northern clay area).

There are, however, a few land use development choices based on planological criteria (on the basis of the proximity of existing infrastructure and functions). These form a challenge due to the physical conditions (for example housing in Nieuwerkerk Noord). During construction work and the development of wet areas, the geomorphological structure has to be carefully taken into account.

Such as the risk of surface rupture or the formation of new shallow groundwater springs. That's why the geomorphological structure, water levels and seepage pressures, as well as land subsidence, geological values and methane gas in springs have been taken into account in the Geomorphological Opportunity Map that has been developed by Hotspot for the Zuidplaspolder. Research into the effects of climate change make it quite clear that the geomorphology is an important criterion, on the lower scale as well.

Figure 8:
Dry land areas (left); the difference between ground surface level and polder water level. The dry areas are larger as a result of private pumping initiatives, as in the blue area which would be under water if there was no extra drainage.

Upwards seepage pressure (right); the difference in polder water level and the head of water in the aquifer in the Zuidplaspolder.



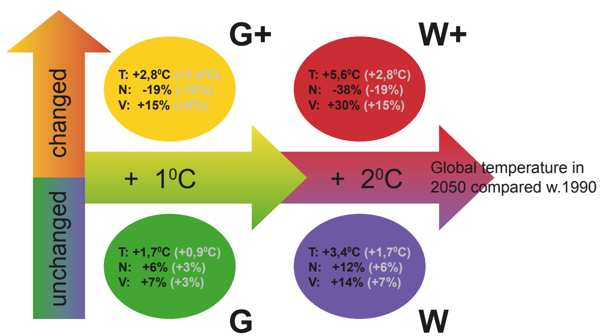
Drought
Climate change has consequences for water management in the Zuidplaspolder. An important effect is water shortage. Water shortage occurs when there isn't enough rainfall (drought), combined with an increased evaporation. The high evaporation is a result of higher temperatures and/or more sunlight.

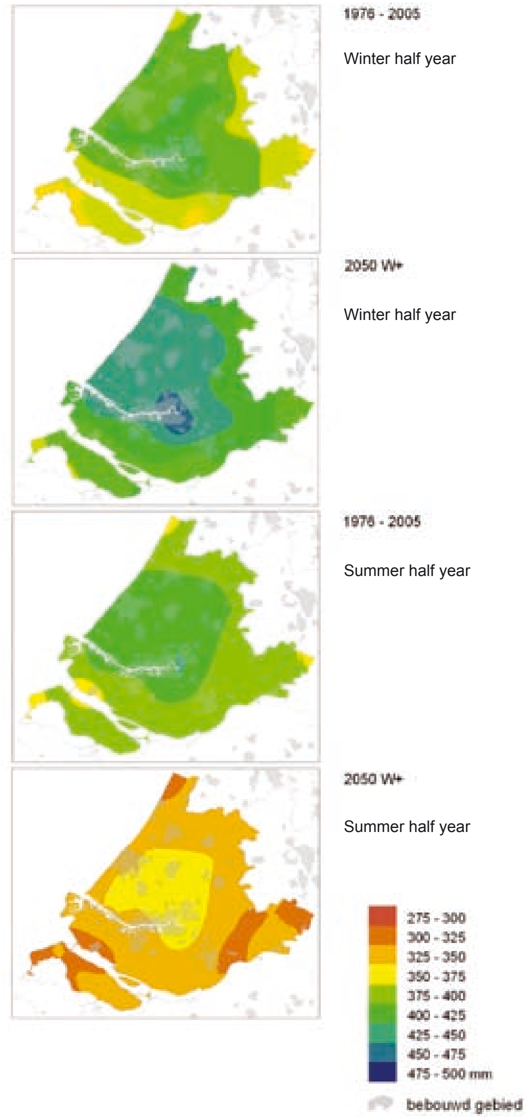
The KNMI'06 scenarios (see Figure below) indicate that the temperature will increase in the summer on average (from 1.7 to 5.6^{O}Celsius in 2100), while the average rainfall will drop dramatically (up to 30% in the W+ scenario) and evaporation will increase (up to 30%). In the WB21 middle scenario, only a 1% precipitation shortage in 2050 was assumed. The shortages are more frequent and last longer than was previously assumed. In the west of the Netherlands there is no question of a shortage of water quantities. There is plenty of water flowing in the rivers. The shortage is in water quality. The shallow groundwater springs and rivers turn out to be saline in more and more cases due to increasing sea water intrusion.

Figure 9 (below left): All data is valid for the summer 2100; T: average temperature, N: average precipitation aggregate, V: potential evaporation. The figures in grey relate to 2050. NB: The WB21 middle scenario (see p.10) assumed a +1% precipitation shortage for 2050

Figure 10 (right): Average precipitation per winter and summer half year (mm) in the current situation and in scenario W+ for 2050

Air circulation patterns





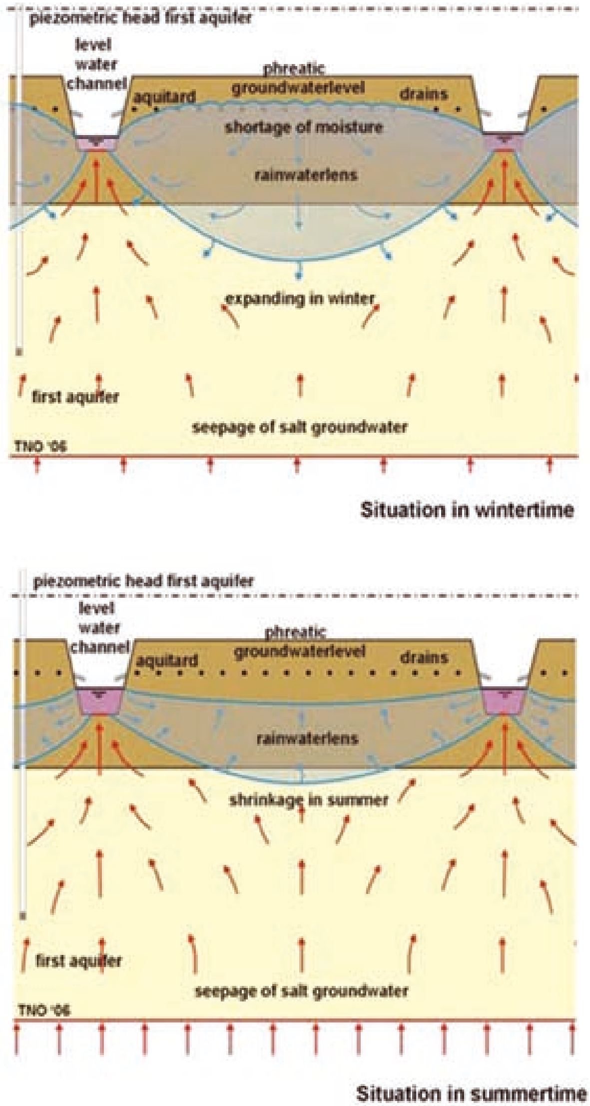


Figure 11: Fresh water lens in the summer and in the winter (Source: Oude Essink, 2008)

Internal salinization

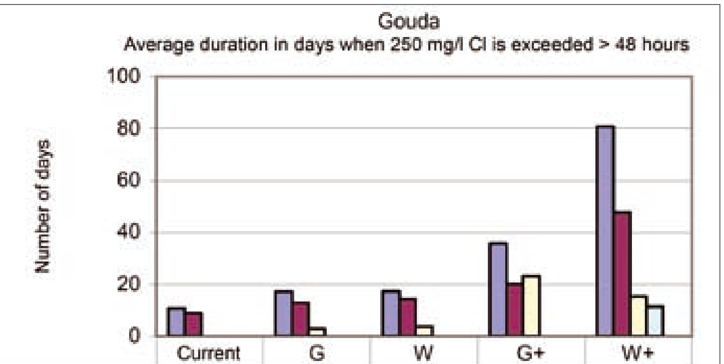
The water management system in the polder is influenced by seepage, rain and inlet surface water. The seepage comes from deep lying marine sediments. The pressure on the water in this formation is so high that the water finds its way to the surface. Seepage occurs particularly in places where the surface layer of impermeable clay is thin or interrupted by a sand bar.

The many groundwater springs in this area contribute to a large degree to the seepage water flow. Because of the marine origins of the subsoil, this spring/seepage water contains high concentrations of chloride (salt) but also high concentrations of iron, nitrogen and phosphate. The seepage finds its way into the water courses at the surface and negatively effects the local water quality. In this way the water doesn't comply with proposed quality standards. This form of salinization is called internal salinization.

Internal salinization doesn't form a big problem for agriculture at the present time. In the surface soil there is a layer of fresh water. Plant roots establish themselves in this freshwater layer. The brackish seepage is drained away via the water courses and doesn't easily reach the roots of the plants. In various climate scenarios, it is expected that summer rainfall will decrease. Because of the rising temperature, evaporation increases and the result is that the ground water decreases or even disappears altogether. In this way, the seepage can reach the plant root zone. Because of drought and salinization, there will be damage to crops, conservation areas, council planting and (roadside) trees.

An increase in seepage because of the rise in sea level is not really expected because the Zuidplas lies a good distance from the sea and the rivers that pass through Holland (Minnema et al., 2004). Internal salinization can be mitigated by raising the water level in the water courses. This has been recommended already for a large part of this area, but it doesn't completely solve the problem. To supplement water quantities during drought and to improve water quality, the Water Board lets in water from adjunctant water volumes like the Hollandsche IJssel. At the present time it isn't clear in what quantities. An improved insight into the water balance in the whole polder will clarify the view on possible solutions to salinization.

External salinization
The Zuidplaspolder is dependent on the river Hollandsche IJssel for its water supply. Because of the rise of salt intrusion into the Nieuwe Waterweg, the water in the Hollandsche IJssel is becoming brackish. The rise in salt intrusion is caused when the level of the river Lek drops (river water flow at Lobith is lower than 1200 m³/s). The flow of fresh water from the Lek is not able to keep the salt intrusion out of the mouth of the Hollandsche IJssel at flood tide. The Hollandsche IJssel doesn't have any upstream flow of its own.



	Current	G	W	G+	W+
Extremely saline	11	17	17	36	81
Saline	9	13	14	20	48
Average salinity	0	3	4	23	15
Brackish	0	0	0	0	11
Mildly brackish	0	0	0	0	0

Figure 12:
Average duration in days that 250 mg/l Cl is exceeded for longer than 48 hours at Gouda
(Source: Beijk, 2008)

On top of that, water with a high chloride content is sucked into the Hollandsche IJssel river due to water substraction for the different polders along its length, including the Zuidplaspolder. Figure 12 on the previous page shows the average duration of a chloride concentration exceeding 250 ml/l and lasting more than 48 hours as measured at the inlet point in Gouda. The most extreme situation is sketched in the W+ scenario. In the current situation, a "salt year" occurs once every 32 years. In the WB21 middle scenario, this is expected to happen once every 17 years in the future (2050). In the KNMI'06 scenarios, the frequency can rise even more.

Because salt intrusion occurs more often in the Hollandsche IJssel, the water that is needed to supplement the water shortage in the Zuidplaspolder doesn't meet the proposed quality standards anymore. There are National agreements about water distribution when there is a threatened shortage. These are set out in a "priority list". The national priority list indicates how the available water should be distributed. The foremost criterion is prevention of irreparable harm to dikes and natural reserves. Water quality is not particularly relevant for dike preservation. However, water quality is essential for conservation areas. When determining the designation for the area called the Waterparel, this has to be taken into account. The question is whether natural life in the Waterparel can cope with incidental high concentrations of salts, or whether it can cope better with temporary dry periods. One possible solution is long term rain water retention (restriction of inlet waters in dry periods, combined with decreased removal of seasonal storage) and lengthening the supply route (mixing brackish water with fresh water).

To combat external salinization, alternative water supplies can be sought, for example via the river Lek and through the Krimpenerwaard or via the river Gouwe (from the Markermeer via the Amsterdam-Rhine Canal).

The drought problem in the whole of west Holland – including the Zuidplaspolder – is becoming more widespread. Finding a solution at polder level isn't simple. The need to tackle the problem at a higher level is becoming more pressing.

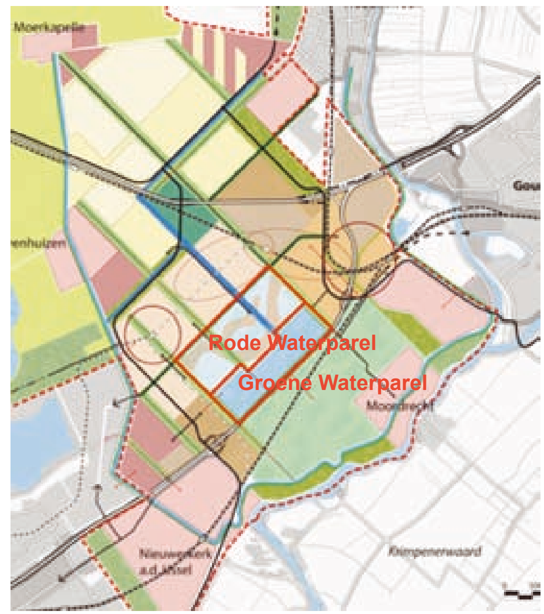


Figure 13: Location of the Groene and Rode Waterparel in the Zuidplaspolder

Effects on the network layer
Ecology and flood safety

Network layer
The high ambitions for conservation areas in the Zuidplas can become vulnerable as a result of climate change. By providing for a good ecological network (connecting the green areas with the main ecological structure) this vulnerability can be reduced.

Figure 14: Recommendations Map adaptation measures for conservation area from the background study Conservation, Drought and Soil Opportunities

Flood prevention and the related issue of evacuation is also highly related and influenced by the network of roads, dikes, sea, rivers and other water basins.

Ecological network
In the Zuidplaspolder there are four different conservation areas: the Waterparel, the Restveen area, all sorts of green structures in the form of woods, (including roadside trees and green belts) and fields. Climate change effects them all. The objective for these conservation areas is to make them so resilient that climate change, such as extended periods of drought, salinization and temperature change has little or no consequences for the conservation goals. As the temperature changes, the climate zones shift. Because of drought and increasing evaporation, it is the wet ecosystems that are most vulnerable.

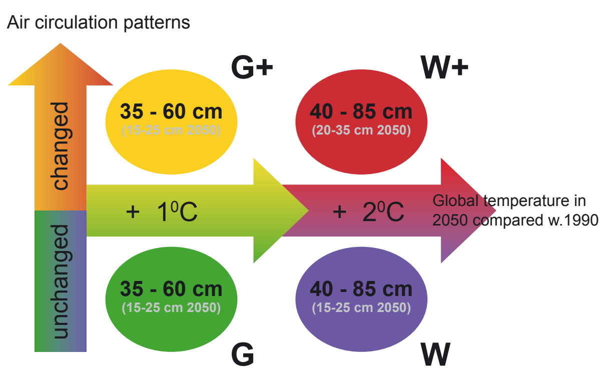
Of all adaptation strategies for conservation (Vos et al, 2007), the strategy of enhancement of the spatial interrelatedness between conservation areas specifically relates to the network layer. In general terms this means making large conservation areas that are properly linked to each other. Of the nine proposed adaptation measures (see Figure 14), four relate to strengthening the spatial interrelatedness (numbers 1,2,3 and 9). For instance, it is proposed that the orthogonal woodland elements should be even more continuous and connected more closely together.

Flood safety

The spatial structure such as (distance from) waterways, dikes, high-lying (rail) roads and developed areas within and outside of the Zuidplaspolder determine the degree of safety from flooding for this polder. The so called *risk approach* determines risk as the chance that a flood will occur in an area, multiplied by the consequences of the flood. A good spatial design can reduce the flood risk. This can be achieved by steering towards a lower chance of flooding (strengthening dikes, building barriers) as well as reducing the possible consequences if things go wrong (compartmentalizing, building waterproof structures and providing for effective evacuation routes).

Both the sea water level as well as the river discharge effect the waterlevel and water quality of the nearby Hollandsche IJssel river. The KNMI'06 scenarios indicate a variation in the degree to which the sea level will rise ranging from 35 to 85 cm in 2100. The increase in winter precipitation in the catchment areas of the Rhine and the Meuse rivers can increase the peak flow levels.

Figure 15: The four KNMI'06 scenarios with the expected absolute rise in seawater levels for 2100 (and 2050 in grey) NB The WB21 middle scenario (see p. 10) assumed a sea level rise of +20 cm for 2050, and +50 cm for 2100.



Not only that, they predict that more precipitation will fall in the form of rain instead of snow in the mountain areas. The Rhine will become a rain-fed river with higher peak flows in the winter and lower in summer.

The Hollandsche IJssel can be closed off at Krimpen aan de IJssel using a storm surge barrier comprising two sluice gates. This double storm surge barrier can keep out an excess of water, whereby the water level in the river can be controlled. With a higher sea level and increasing river flows, the storm surge barrier will have to be

The storm surge barrier at Krimpen a/d IJssel was constructed as part of the Delta Works in 1958 (Source: Deltacommissie)

closed more often. In 1997 the Maeslant barrier in the Nieuwe Waterweg was constructed to perform alongside the storm surge barrier at Krimpen aan de IJssel. With rising sea levels, this barrier will also need to be used more often. Although the risk of flooding in the polder isn't high, the consequences of a flood would be great and increase with the further development of the polder. Measures are needed to limit these consequences.

Flood simulations

Under the auspices of the project Veiligheid Nederland in Kaart [Registration of Safety in The Netherlands] and the Risk Map, the Province of Zuid-Holland has had flood simulations made. It transpired that the breaching of a dike along the Lek onto the Lopikerwaard can cause a chain reaction whereby a dike could be breached along the Hollandsche IJssel in the area between IJsselstein and Gouda (the channelled part of the river). In this way, flood waters could reach the Zuidplaspolder from the landward side. The water would reach the Zuidplaspolder after 10 days and in this time it would be possible to take measures to limit the damage. It is expected that the dike along the Hollandsche IJssel won't meet up with the 1:10,000 safety standard in the area between Gouda and IJsselstein. Formally this won't be confirmed until 2009 when the testing criteria become available.

24 hours after breach 36 hours after breach

Figure 16: Illustration of inundation simulation after a breach in the dike by the river Hollandsche IJssel by Moordrecht

Dike breaches near Rotterdam and flooding from the great rivers via the eastern side of dike ring 14 (Amsterdam-Rhine Canal) could also form an indirect threat for the Zuidplaspolder. From the point of view of safety for dike ring 14, which also includes the Zuidplaspolder, the primary barrier should be raised and strengthened near the canalized Hollandsche IJssel, as well as in other places. However, the negative effects for the neighbouring dike rings (so called *bath tub effect* in neighbouring dike ring 15 and 44) demand a wider study into possible solutions for reducing the vulnerability of the area as a whole (that means all three dike rings). This study will be made part of the Randstad Urgency Programme and taken up by the Province of Zuid-Holland, the Ministry for Transport and Water Management and the Province of Noord-Holland. The Water Boards in the area as well as the Utrecht province also participate. The effects of climate change will be considered at the same time.

Delft Hydraulics has done flood simulations for the Zuidplaspolder from the point of view of problems coming from the Hollandsche IJssel and the Gouwe river. The spatial designations of the Inter-municipal Structure Plan (ISP) and the Provincial Regional Plan have been partly based on these results. Conservation rather than urban development has been designated for the most vulnerable areas in the polder (the Restveen area in the relatively low-lying southern part near the Hollandsche IJssel). This choice fits within the split layer approach (no building on peat soils).

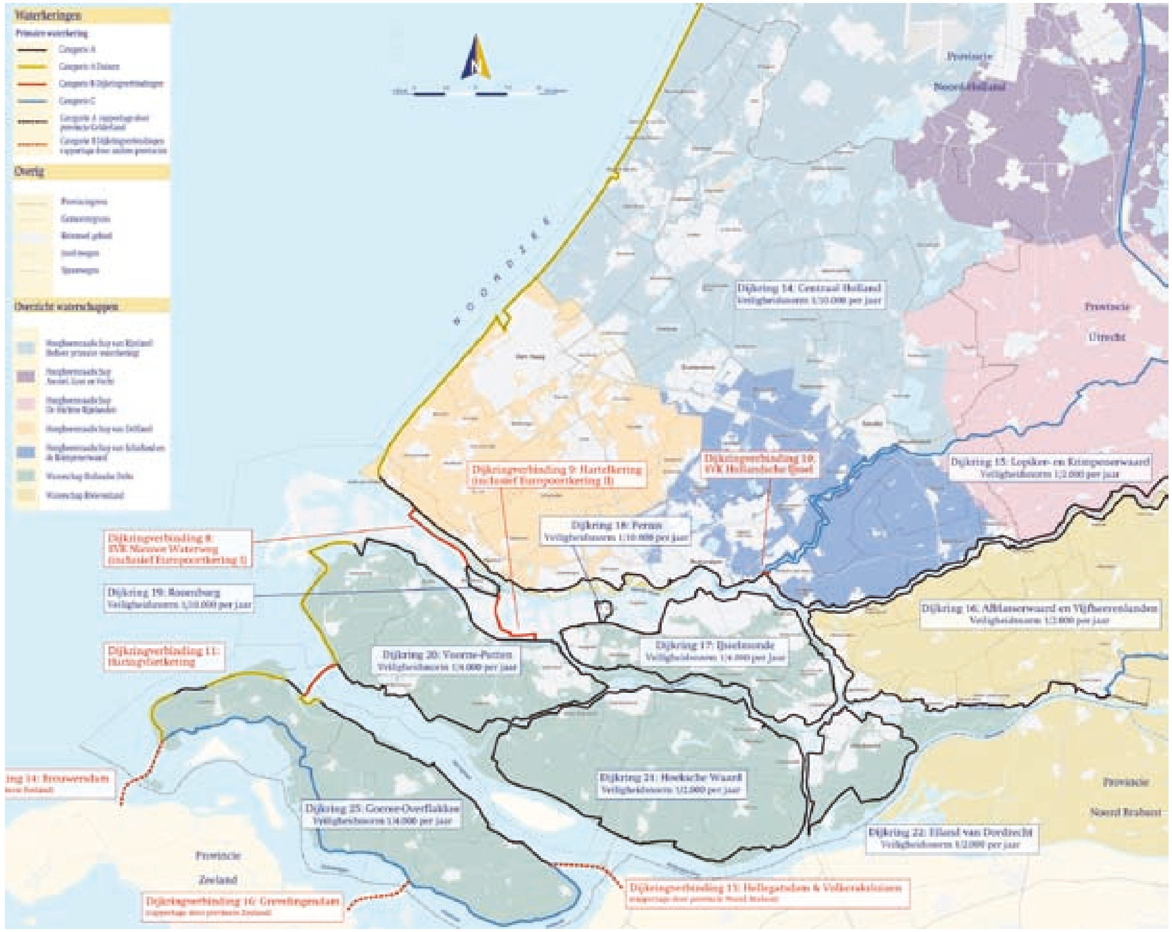


Figure 17: Dike rings and dike ring links in the west Netherlands

Compartmentalization

One way to reduce the negative effects of a dike breach in the Zuidplaspolder is by division of the polder. Compartmentalization is realised by building more (land)dikes or raising existing elements in the landscape. The objective of compartmentalization is to reduce damage and casualties. Compartmentalization is a known technique in the safety related world. In event of a disaster it means that not everything has to be written off, but just a part. Deltares has investigated just how much compartmentalization contributes to the reduction of negative consequences in event of flooding in the Zuidplaspolder. To this end, the consequences of different compartmentalization scenarios have been compared with the non-compartmentalized situation and the scenario whereby all the planned expansion housing development takes place on raised land.

In none of the situations does the Zuidplaspolder ever get completely flooded. Between the storm surge barrier at Krimpen aan de IJssel and the sluice at Gouda, the Hollandsche IJssel can carry a maximum of 13 million cubic meters of water. If the entire amount flows into the Zuidplaspolder, then the water level reaches about 5.3 metres under NAP. A small part of the peat meadow area will be flooded to the height of maximum 1.5 metres. Generally the water level will rise between 0 and 1 meter. As well as that, there is a large area near Moerkapelle (the north of the polder) that is so elevated it will never flood.

Constructing new compartmentalization dikes is very expensive, that is why Deltares recommends considering this option only when construction can be combined with existing planned developments. The most attractive options are constructing the new provincial road N219 around Nieuwerkerk Noord at 4.75 metres under NAP or even compartmentalizing the Hollandsche IJssel itself (so that the amount of threatening water volume can be reduced). This option should be combined with the construction of a new bridge over the river, for example by Moordrecht. The experts however do not recommend using the Rotterdam-Gouda railway dike or the A20 motorway as compartmentalization dikes. This would increase the damage in existing urban areas in Nieuwerkerk aan den IJssel and Moordrecht because it would raise floodwater levels. When making plans for raising entire housing developments, the potential flood levels have to determine the height. Geomorphology is a limiting factor. As is shown in the previous paragraph, parts of the Zuidplaspolder are prone to soil subsidence. If raising land levels is desired, then it is recommended to use materials with a low volume weight.

Evacuation

Even if all preventative measures are taken, there is still a risk of flooding. The Zuidplaspolder falls under the regional safety board *Midden Holland* (still in the planning stage). This board will be administratively and operationally responsible for dealing with the catastrophe and offers help should a flood occur in the Zuidplaspolder. The relevant municipalities, fire department, health authorities, police, water boards, Ministry of Defence and other partners will work together in this regional board. The chairman of the board Midden Holland will be the mayor of Leiden.

As a result of an Evacuation Assessment Study, it is recommended that a part of the Zuidplaspolder should not be evacuated (the part lying between the A20 and the Hollandsche IJssel dike including a part of Moordrecht). Theoretically there would be enough time, but because of time consuming decision making processes and the risks of using a weak dike for evacuation, this is not advisable. For the inhabitants of this area, it is recommended “to seek personal safety on the top floor of their house or on higher ground (otherwise known as vertical evacuation) or a crisis centre near their home, and be prepared to be self sufficient for a maximum of 72 hours”. The individual inhabitant has to have a plan of action to hand which is provided during risk communication. In the rest of the Zuidplaspolder, there are sufficient evacuation options and there is enough time to effect them.

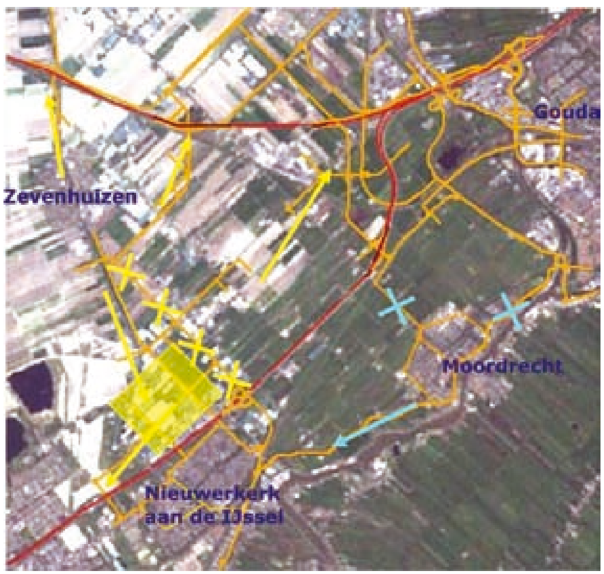


Figure 18: Hypothetical traffic flows during an evacuation simulation out of Moordrecht (Veenstra et al., 2008)

Evacuation options can be improved by taking them into account when developing the Zuidplaspolder. The evacuation options have been explored within the Hotspot Project in working sessions together with municipal workers and police dealing with law and order and public safety issues. These professionals can offer an important contribution to the design of an area. This could include small scale and relatively cheap measures such as poles placed alongside the roads, or risk communication by means of a “water week” at school or large and expensive measures such as raising road levels for evacuation purposes. Also the potential for quick recovery after a calamity is very important.

It is therefore recommended to involve order and safety partners early on in designing new developments at national as well as regional and local level.

By involving order and safety partners at the beginning, a lot of problems can be prevented when the time comes to deal with a catastrophe. At the provincial level, this has been stimulated by placing “safety” as a provincial interest in the Provincial Structural Spatial Plan.

This ensures when developing a new area, the authorities take account of the safety risks that the inhabitants of the area are subjected to. It is also possible that the tasks of the regional safety board expands in the future from just preparation and operation to prevention and pro-action. At the present time, the role of the safety partners in spatial planning has not (yet) been set down in policy and regulations.

Broader perspective on flood safety
The Zuidplaspolder is not an isolated case. There are development plans for many more low-lying polders in the western part of the Netherlands. Are the risks there smaller or bigger? What do the future inhabitants think of this? For this reason the relative flood risk has been investigated for 12 areas in the west of the Netherlands, including the Zuidplaspolder.
This has been done in cooperation with the Netherlands Institute for Spatial Research. The first stage was within a session with 15 flood risk experts. In this session it became apparent that the spatial structure within and outside of the polder was essential to establishing the risk and the consequences. Another conclusion was that a feeling of relative safety is determined by the degree to which there is a plan of action at hand, not only for individuals but for the whole community.

Areas outside the dikes were found to be unsafe in the first ranking (high risk of flooding). But because (the threat of) flooding can be ascertained very early on and will occur more frequently, everyone is prepared and chaos is averted. After a fact finding survey, a second ranking placed the areas outside of the dikes into new light, they were found to be safer than first thought. The Lopiker- and Krimpenerwaard still scored badly because of the low safety standard (1:2000) and the Haarlemmermeer scored well because of its considerable distance from the sea and the great rivers. Possible measures to improve the perception in “unsafe” polders is to make calamity plans and plans for dealing with catastrophes. Other ideas include improving insights into (external) changes of water management and river water levels in built-up areas and dry runs to practice for in the event of a disaster.

In the second stage, the composition of these 12 areas have been compared to one another. A large difference could be found in flood risk between the low-lying polders in the west Netherlands. The Prince Alexander polder and the western parts of the Lopiker- and Krimpenerwaard emerge from this analysis as being relatively vulnerable because of the extensive urban development. The areas outside the dikes in the Rhine delta area [Rijnmond] are scarcely vulnerable at all to flooding, due to their relatively high altitude. The highest flood risk rating with a level exceeding 5 meters of water in the polder, hardly occurs (only Watergraafsmeer, Koekoekspolder and the Alexanderpolder). The higher categories 2 and 3 (from 0.8 meters to 5 meters of water) occur in the Zuidplaspolder no more frequently than in other low-lying polders.

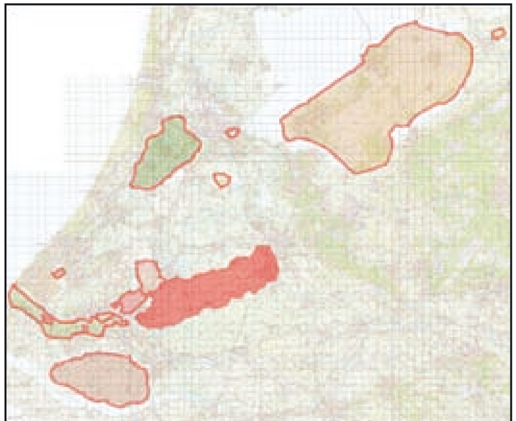
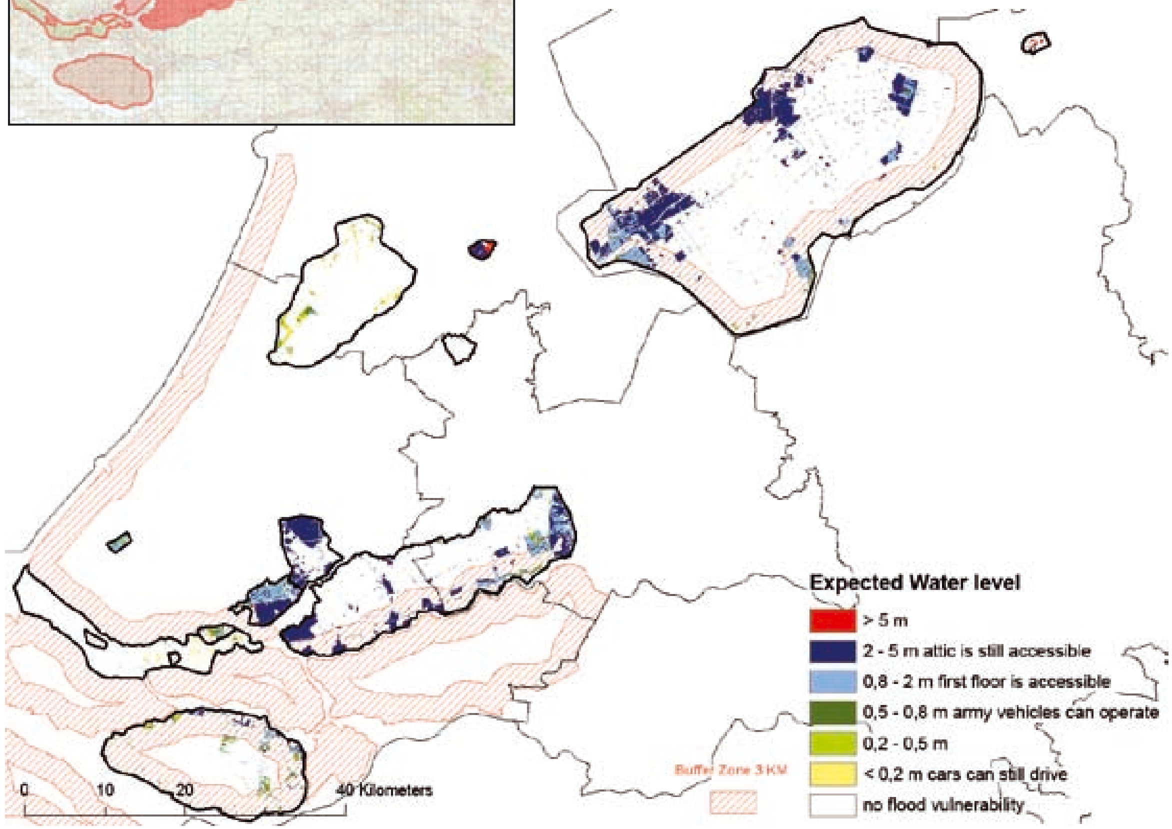


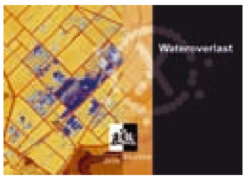
Figure 19: In the upper left hand corner, twelve areas that have been ranked on sensitive to flood risk by an expert team, in October 2007 (the Haarlemmermeer scores best). In the map below the actual vulnerability to flood risk, the economic damage, the casualties and the 3 km buffer zone around the primary dike system.



Effects on the land use layer

Rainwater flooding, increased temperature and design of conservation areas

When designing spatial plan (land use) on the lower scale, the climate effects of extreme rainfall and the rise in temperature are the climate change effects that play the main role.



Rainwater flooding

The KNMI'06 scenarios indicate that both the averages as well as the extremes in precipitation will rise. With inundation risk, it is the extremes that need to be looked at. In the winter the 10-day precipitation quotient which occurs every 10 years, will rise by 8 to 24% by 2100. In the summer, the daily rainfall occurring every 10 years will rise by 10 to 54%.

Flooding occurs after extreme rainfall whereby the land is submerged (inundation). The standards for rainwater flooding have been determined for the Netherlands by the National Administration Agreement for Water (NBW). This sets down the acceptable rate of flooding for the different land use functions (for example, grassland once every 10 years and urban developments once every 100 years). The NBW agreement also stipulates that the effects of climate change must be taken into account. In practice, the WB21 middle scenario is used to determine both the rainfall intensity as well as the 10-day winter precipitation level, which estimates an increase of 20% by 2100. Impact studies with this scenario form the basis of water management policy in the Zuidplaspolder as well. To reach the standards set out in the NBW by 2015, improvements are being brought about in the water system of the Zuidplaspolder (widening of water ways, extra wet areas).

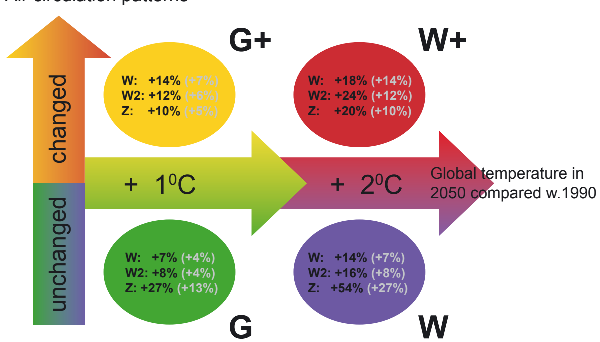
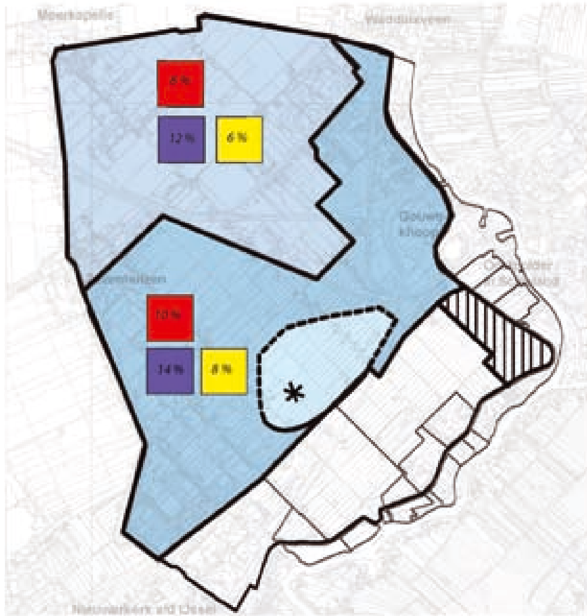


Figure 20: The four KNMI'06 scenarios with the expected flood levels in 2100 in the winter (W), the average precipitation amounts (W1), and the sum of 10 days' precipitation that is exceeded once every 10 years (W2). In the summer (Z): daily sum of precipitation that is exceeded once every 10 years. The values in grey relate to 2050.

NB The WB21 middle-scenario (see p.10) assumes a peak downpour in the summer of +10% for 2050 and +20% for 2100.

Figure 21: Percentages of mandatory open water when developing a hectare of greenhouses (yellow), commercial properties (blue) and residential areas (red) in the Zuidplaspolder. The Waterparel (*) area has still to be specified (Source: Grontmij Midwest, 2007)



	Green-house	Non permeable	Permeable surfacing	Open Water
Greenhouses	80%	-	14% / 12%	6% / 8%
Commercial properties		80%	8% / 6%	12% / 14%
Residential		50%	42% / 40%	8% / 10%

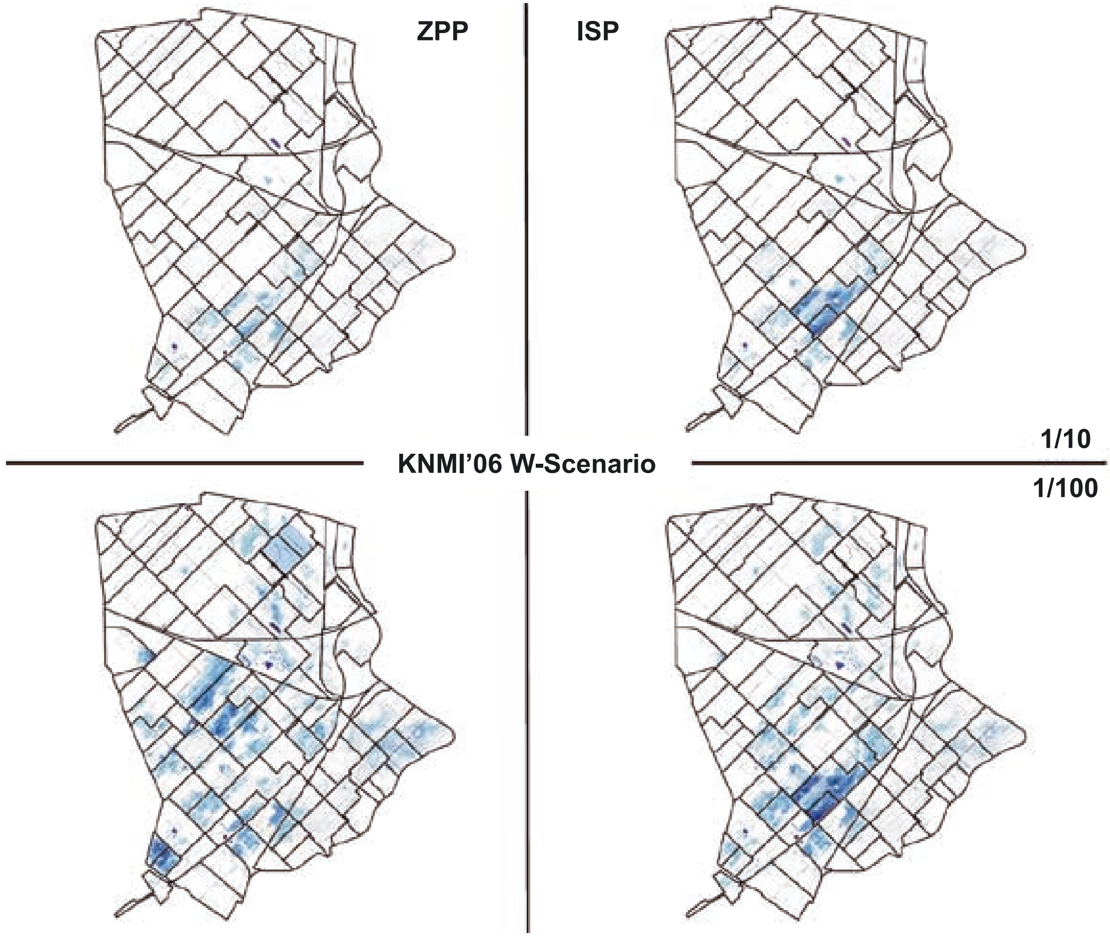
Table A: Percentages of greenhouse, non permeable and permeable areas and open water wherein 1 hectare of the development is set aside for various land use. The different figures for permeable and open water areas are a result of different demands for the northern (1st figure) and southern areas (2nd figure)

Rainwater flooding models

The VU University of Amsterdam has researched what the KNMI'06 scenarios would mean for water management in the Zuidplaspolder, on behalf of the Hotspot Project. This has been done by means of modelling calculations done in SOBEK. This is a hydraulic model whereby the water system is emulated and changes in precipitation and evaporation are calculated. The modifications that have been planned by the Water Board and the land use developments in the polder have been included in this model. Modelling the water system produces inundation maps. This type of map combines the height of the land surface with the possible rise of water level within an area. They are excellent guidelines for designers to make allowances for excess water in their plans for urban development. The calculations already show that the proposed modifications by the Water Board and the standards for constructing new open water areas will lead to improvements in water management compared to the current situation.

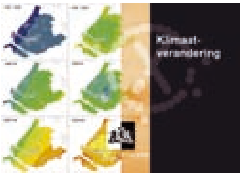
Climate change will cause a net rise in extreme (temporary) water levels. Using calculations from the scenarios, it is clear that once every 100 years, the average water level rise in the polder will be up to 10 centimetres higher in 2100. Three of the four scenarios (G, G+, W+) match the current points of departure. However, if the climate develops according to the W scenario, then extremely high water levels will be reached, and then current measures will not prove sufficient.

Figure 22: Differences between the existing situation in the Zuidplaspolder and the future situation (ISP configuration) for the 1/10 and 1/100 year water inundation levels as a result of rainwater, under the KNMI'06 W-scenario



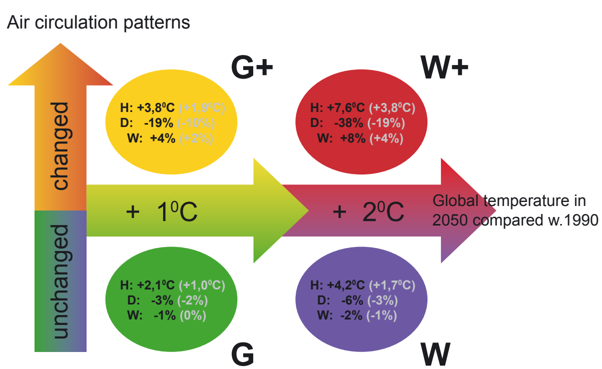
In some areas the average extra water level rises which occur once every 100 years will reach 60 centimetres. Extra measures will need to be taken over and above the ones that are currently planned.

Extra storage capacity and more flexibility in the plans are possible options so that new measures can be taken in the future.



Temperature

The first factor that shows climate change is the already occurring measurable change in temperature. The average annual temperature within the Netherlands has risen by almost 1°Celsius in the past century. The ten warmest years since 1901 occurred after 1989. In the KNMI'06 scenarios it is expected that in 2100 the average temperature in the winter will rise by 1.8 to 4.6°Celsius compared to 1990. This temperature rise is highest in the W+ scenario. The chance of enjoying natural ice skating has dropped because of this. In the coming century, in the winter, the wind will increase in the plus-scenarios with an increase of highest daily average windspeed of up to 8%. In the summer the change is even more dramatic. The extremes, such as the warmest summer day each year will increase by 7.6°Celsius in the W+ scenario by the year 2100, while the number of wet days (>1 mm rain) will drop in the summer by 38%. In 2050 the number of summery days will have doubled. The chances of a summer heat wave increase markedly.



Because of the shift in climate zones, the summer season will be warmer and longer. Tourism and recreation will probably increase. People will more likely want to be outside and more often. The demand for cooling will grow and the need for recreation facilities will increase. Places with shade (woods) and a watery environment provide cooling. Because of the heat, problems can occur with energy suppliers because there will be a shortage of surface water for cooling. This shortage will occur because of low river water levels combined with a high water temperature. This problem isn't specific to the Zuidplaspolder. Because of the increased temperatures, sea water will get warmer as well and summer thunderstorms will be more violent.

Health

Many studies have shown that there is a link between temperature and death rates. In extremely high temperatures, more people die. Heath hangs around in urban areas and it hardly cools off at night. This causes so-called heat islands. The quality of shallow surface water can also come under pressure, with negative consequences for public health. In planned urban areas for the Zuidplaspolder these things need to be taken into account.

Figure 23: The four KNMI'06 scenarios for summer 2100 with the expected warmest summer day per year (H), the number of wet days (> 0,1 mm) (D), and the highest daily average wind speed (W) per year in the winter. The figures in grey relate to 2050.

Designing green areas

It is important to determine the consequences of drought for all forms of nature in the Zuidplaspolder. Can this natural element cope with temporary drought or is it better off with a supply of nutrient rich, mildly brackish water?

The ecological quality of conservation areas in the Waterparel is very high at the moment. The highest ambitions are set down in the ISP for this area. The special quality of the Waterparel is due to three factors:

- the water in the water courses is mainly rainwater, saline seepage water doesn't occur here;
- the floor of the water courses is lined with acid clay and pyrite;
- the water courses are cleared regularly.

Figure 24: Conservation construction project in Waddinxveen; the dry bank contains acid sulphate clay soil and the water level is too low making the soil extremely acidic, and saline seepage water is present. The result; murky water and a bank with no vegetation.

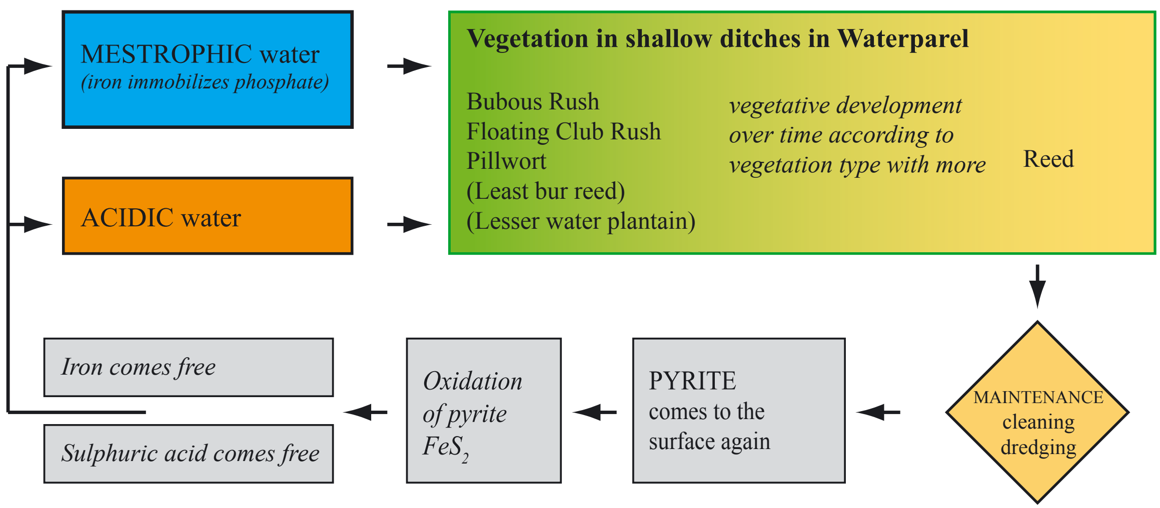


Figure 25: The 'pyrite-engine' in acid sulphate clay soil. With below right the 'ignition key' of the motor: maintenance.

The interplay of these three factors ensures that the ‘pyrite engine’ keeps going. In this way the Waterparel maintains itself; acidic ditch water, nutrient poor rainwater where unusual water plants, diatoms and macrofauna (small water animals) live.

The Waterparel is vulnerable to the supply of the wrong sort of water (nutrient rich) and vulnerable to the drying up of the acid clay whereby extreme acidification can occur. By carefully controlling the water circulation around the Waterparel, the right water can be guaranteed to get to the right place.

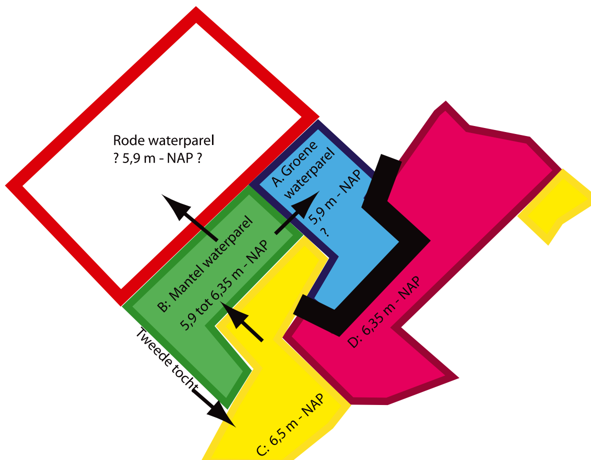


Figure 26: Profiles of sectors with their own system characteristics, crucial for achieving conservation ambitions. The given levels are proposed highest winter levels (Source: Broek et al., 2007)

The brackish polder water should preferably never reach the Waterparel. The clay layer should never be allowed to fall dry. In the pilot project Gouweknoop, a proposal has been drawn up which allows water to be stored which can then be used in dry periods for the Groene Waterparel. In this proposal rainwater is stored in and around the intensive urban development in the Gouweknoop (see Chapter 3 Design).

Not only that, it has been recommended to embed this natural reserve in a so-called “climate mantle” as an adaptation measure for the Waterparel. By linking development as well as the water system in the Groene Waterparel with that of the Rode Waterparel, a protective climate mantle can be created. This ensures that there will be crystal clear water in and around the housing area of the Rode Waterparel itself (see pilot project The Rode Waterparel). Environmental conditions are less critical for the other natural elements (woods and peat meadows). In the southern part of the Zuidplaspolder where farmers run cattle on peat soil, in times of drought the soil can become compact and shrink even more. The proposed raising of the ground water level is the answer to this problem. The quality of the woodlands will be boosted by better management of the soil conditions. Not only that, but expansion of the woodland areas has been proposed to strengthen the spatial cohesion (see Chapter 3 and the previous paragraph).

3 Designs

Key:
measures relating to climate themes rain floods, flooding, water shortages, salinization and heat stress

In this Chapter measures relating to the Anthology of Ideas and the five pilot projects will be revealed that could be important for further planning in the Zuidplaspolder to enhance its climate resilience. For these five pilot projects different ideas and measures have been brought together as inspiration for designs which function as a stepping stone to realisation of these ideas. The projects are examples of climate resilient construction and encompass different parts of the polder's development area. The projects have been a collaboration between diverse experts and market players, such as design bureaus opMAAT, +Architecture, TU Delft, TNO, Dura Vermeer and Deltares.

Anthology of Ideas

In the course of the Hotspot Project many climate resilient measures have been reviewed. In the end many measures were deemed impossible, unnecessary or already in practice in the Zuidplas. Because the Hotspot Project also had as its objective the expansion of knowledge, it was decided to produce a separate Anthology of Ideas. More then fifty adaptation measures for climate resilient design have been described in it. A complete summary can be found in the Chapter "Evaluation". Including these measures in the planning process doesn't cost much, in most cases, but they do offer extra climate resilience. This is especially true for measures that address a combination of climate effects. Three of these measures have been described below. Many of them reappear in the five pilot projects.

Adaptation measure no. 19: Increasing the spatial cohesion between natural reserves in the polder

Increasing the spatial cohesion is one of the most important adaptation strategies for natural flora and fauna. In this way, with remnant populations as a basis, nature (metapopulations of species) is better able to recover after a calamity. Examples of spatial adaptations are: the Boogpark, the Rode Waterparel and the Ringvaartpark. These interventions not only expand conservation areas for flora and fauna, but offer residents shelter, cooling and (water) recreation facilities.

no. 19 More cohesion through additional projects

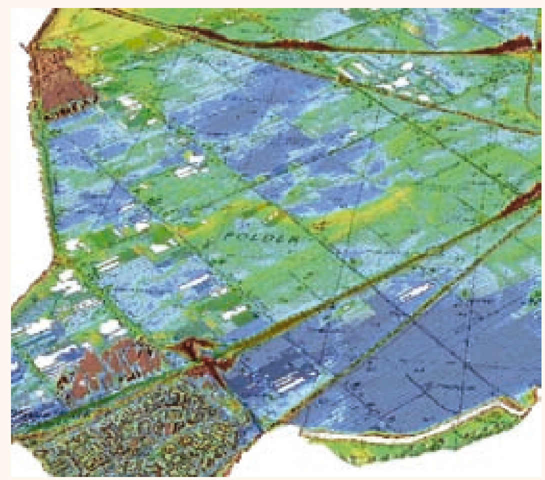
Adaptation measure no. 26: Water retention: making hard surfaces permeable

Water retention can prevent rainwater flooding in other places and can stave off water shortages in periods of drought. At the urban neighbourhood level, this can be realised with water courses, ponds and open water "plazas", or underground and in low-lying areas on the surface ("wadies"). Parking facilities and public green areas can be adapted to soften hard surfaces and make them permeable.
Water can be retained relatively easily within new housing projects in the Zuidplas. The possibilities are expanded further in the pilot projects Zuidplas Noord and Nieuwerkerk Noord.

no. 26 Pilot project Zuidplas Noord: Artist's impression of the Bredeweg

Adaptation measure no. 33: Raising the ground water level to prevent soil instability

Peat soils shrink when the peat comes into contact with oxygen (vegetative material decomposes). A low ground water level speeds up the subsidence of peat soils. If the ground water level is high then the subsidence rate drops. By raising the ground water level the soil is kept moist which prevents shrinkage as much as possible. Supplementary benefits include preventing surface cracks, settling and gas forming, and counteracting seepage pressure. By reducing seepage pressure, there is less salinization, which improves the water quality in the water courses. Application in the Zuidplaspolder: stabilization and raising the ground water level has already been realised in the Restveen area. It will be implemented in the two Waterparels.



no. 33 Zuidplaspolder after raising water level until the seepage pressure in all areas is lowered

A few Anthology measures have been deemed necessary, mostly related to the scale of the Zuidplaspolder itself, or higher scales:
- Raising the safety norms and reliability of the storm surge barriers (no. 1)
- Strengthening dikes outside the Zuidplaspolder (no. 3)

Other examples of “necessary” adaptation measures play at the lower scale:
- Protection of vulnerable functions and essential components (no. 22)
- Water discharge: (accelerated) discharge of excess water (no. 28)
- Taking the geomorphology into account in spatial planning (no. 35)
- Allow only shallow water courses, excavation restrictions and isolation of springs (no. 37)

For details see the Anthology of Ideas.

Figure 27:
‘Drainage: (accelerated) drainage of water, no. 28’ (already proposed)

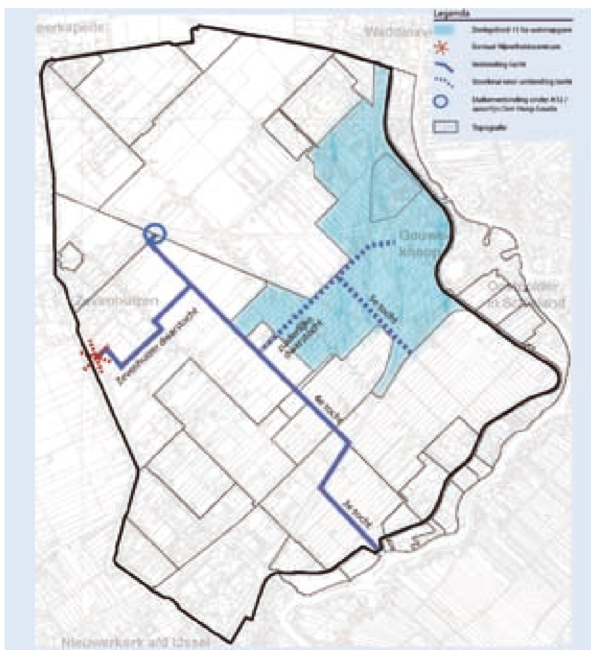
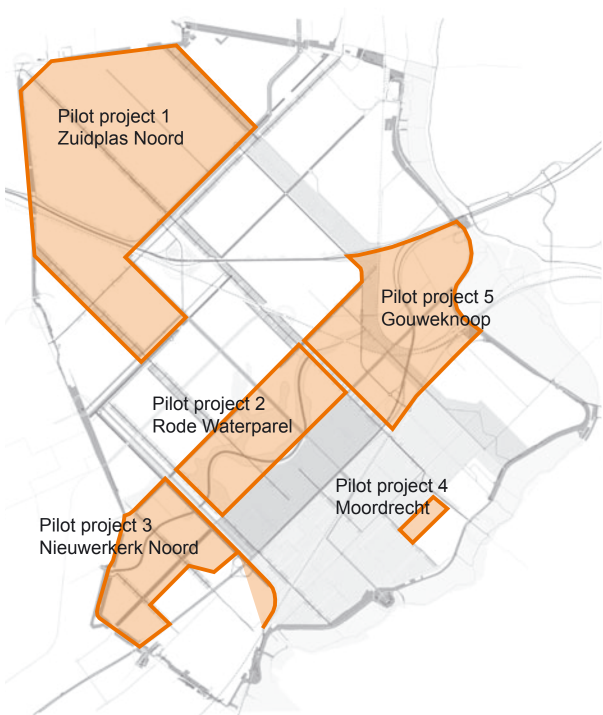


Figure 28:
‘Excavation restrictions and isolating springs, no. 37’

Figure 29: Overview giving the locations of the five pilot projects in the Zuidplaspolder



Pilot project Zuidplas Noord (A Climate Resilient North Zuidplaspolder, opMAAT, Xplorelab, 2008)

In the current plans for developing the Zuidplaspolder, certain percentages of the surface have to be reserved for open water in the areas that are to be developed. Calculations based on planned hard/dry areas and extra open water in the polder indicate that these percentages will be achieved almost everywhere.

However, under the KNMI'06-W scenario extra measures will need to be taken to avoid potential damage.

Bureau opMAAT has investigated the possibility of safely absorbing and storing a large amount of rainfall in a design study. The design has been drawn up and calculated to cope with a downpour which could occur less than once in every one hundred years (120mm in 24 hours, a cloudburst that is even more extreme than the T=100 downpour in the KNMI'06 scenario). The extra water storage capacity prevents flooding. This costs space but prevents damage and delivers more spatial quality and ecological value.

Design

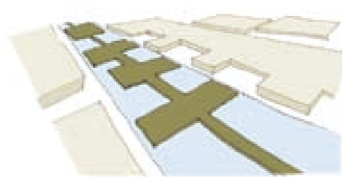
This concept for a residential environment in North Zuidplas, caters for 800 houses, to be built in small clusters on mounds in a ribbon development. The mounds offer different subdivision possibilities. Between the mounds, terraced spillways have been created. In this way large amounts of rainfall can be absorbed. These terraces can be used for diverse functions.

The lowest level can be given a reed land type character with open water areas that have restricted access and it has conservation development and ecology as its main function. (Figure 31). Extensive recreational functions are possible (fishing and boating). The houses are situated at same (high) level as the access road.

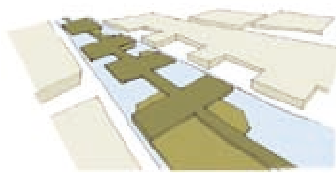
The middle level has more functions, such as a mini football field/playground or use as secondary route for slow traffic. These grounds can be allocated as gardens with an inundation risk. EVA-Lanxmeer in Culemborg and other municipalities in the Netherlands have practical experience in the allocation of land to private individuals. This land is sold for a low price because there are conditions placed on its usage (no fences, sheds and such like). Houses built next to this type of wetland or flooding areas have an added value. The added value is determined by the natural water side experience and the guaranteed unhindered views. The periodically flooded areas are communally owned by the inhabitants.

Figure 30: The planning map shows the building possibilities on mounds in the planning area (ribbons)

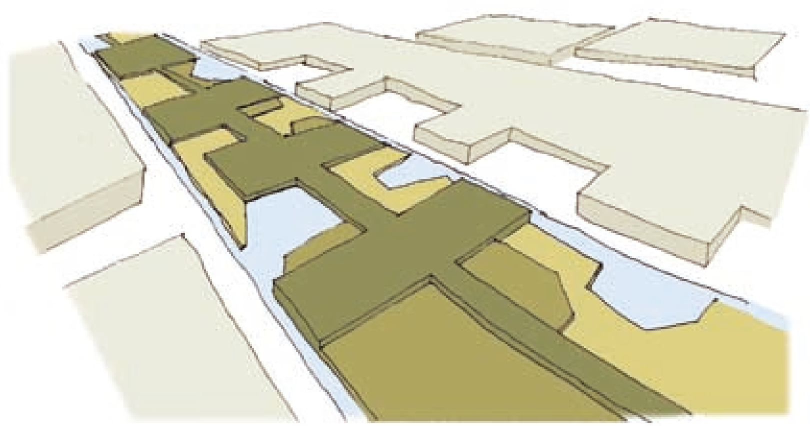
Figure 31:
Artist's Impression of the different ground surface levels



Situation when the water level rise is more than 0,5 m (recurr. > 100 yrs)



Situation when the water levels rise up to 0,5 m (recurrence 25 years)



Situation without an increase in water level

Pilot project Rode Waterparel (Crystal Clear Water Dwellings, Dura Vermeer, Xplorelab 2008)

This design by Dura Vermeer offers a high quality residential environment for 1300 houses in the Rode Waterparel area. Water plays a prominent role. The ground water level is raised to -5.9 metres NAP, whereby the contours of the original creek bed stand out and the water quality is equal to the high quality found in the Groene Waterparel. During periods of rainfall, parts of the area are submerged. Because of climate change this can happen more frequently, and it is precisely this factor that is exploited to create a high quality residential environment. Three types of houses have been developed, each based on the local geomorphology and technological possibilities.

- Low density living on the Creek bed;
- Aquatic living at the edge of the area;
- Crystal Clear Water Dwellings in between.

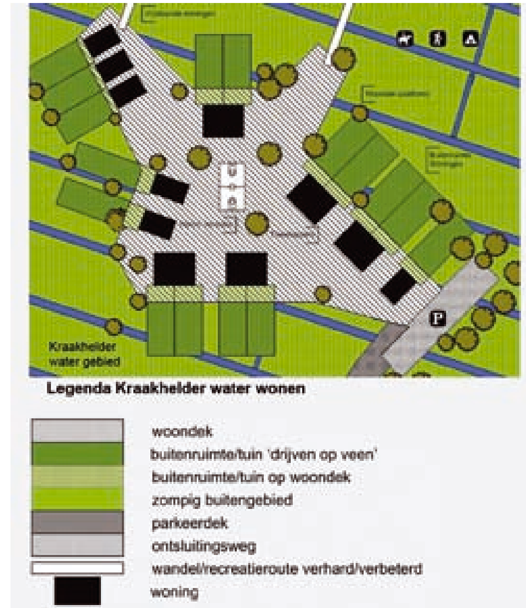


Figure 32: Prototype of Crystal Clear Water Dwellings

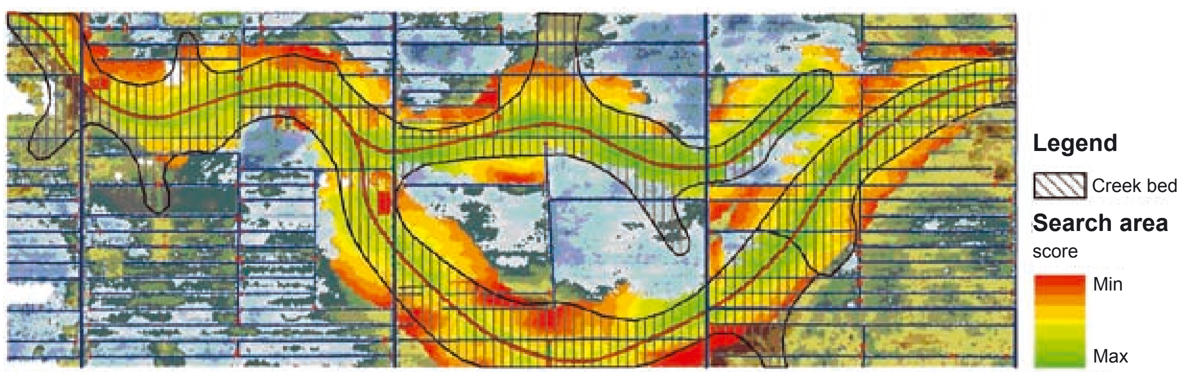


Figure 33: Search area traditional foundation methods around the Creek bed in the Rode Waterparel

The last type is characterised by enclosed residential clusters and situated in a rural wetlands setting.

The access roads and the residential clusters with homes and (parts of) back gardens remain dry in case of flooding because they are built on mounds. In order to prepare the area for construction Dura Vermeer has proposed diverse alternative methods such as EPS construction.

The surrounding conservation area with fluctuating water levels will be allocated as well, but will be communally managed and have restricted use. The pilot project Crystal Clear Water Dwellings and the background study Conservation, Drought and Soil Opportunities has had a direct input into the recently completed Masterplan Rode Waterparel by BVR (Janssen, 2008).

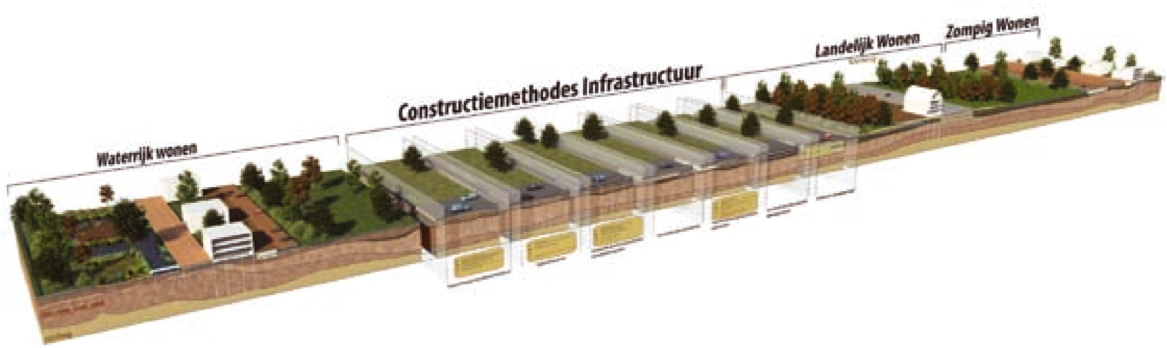


Figure 34: Cross-section with the three characteristic sectors and the technical possibilities

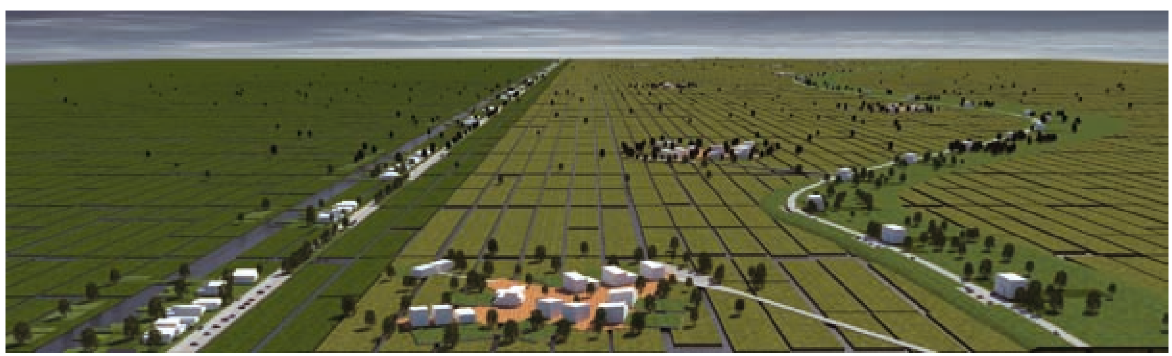


Figure 35: Landscape with rural residential areas, housing built near water, and Crystal Clear Water Dwellings in the Rode Waterparel

Pilot project Nieuwerkerk Noord,
(Climate resilient design in North Nieuwerkerk, TNO, Xplorelab 2008)

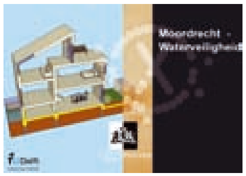
TNO Built Environment and Geosciences has investigated alternatives for climate resilient development in North Nieuwerkerk. This is the largest residential housing location to be realised in the Zuidplaspolder until 2020. The area is in the lowest lying part of the polder, comprising characteristic peat meadowlands. The current land use is mainly greenhouses. The 1800 planned houses will be situated close to the Hollandsche IJssel and built on unstable peat soil.

During the design process a number of principles were upheld which relate to the above mentioned special characteristics of the area.

The objective was to make the area climate and calamity proof, assuming that the risk of flooding was the one described in the most extreme KNMI'06 scenario. Two methods of preparing the ground for construction were investigated: raising the ground level with sediment or another similar non heavy material, and the compartmentalizing method. Both are an alternative for the traditional way of raising the ground surface level with sand.

Using sediment or non heavy material is more sustainable than the traditional method of raising the ground level. This is to avoid further soil subsidence because the peat soil is so unstable. By sediment we mean using light material like peat which will come available from other works in the area surrounding the Zuidplaspolder. With compartmentalization you don't need to raise the ground level at all. The housing area in Nieuwerkerk Noord is protected from flooding by a raised new provincial road (N219), should a dike along the Hollandsche IJssel be breached. Within the new development area the original water course network can be retained.

Figure 36: Overall picture of the compartmentalization method, incorporating the raised N219 and including the existing watercourse structure



Pilot project Moordrecht,
(The 1.3 Metre Plan, TU Delft, Xplorelab 2008)

From the results of the flood simulations (Deltares 2008) it is clear that should a dike be breached along the Hollandsche IJssel, the flood waters will reach a maximum of 1.3 metres. The chance that something like that will happen is very small. It still makes sense to think about solutions for house building in this low lying area, bearing in mind the “remaining risk”. The basic principle behind the design study for Moordrecht is to make a plan in which a 1.3 metre flood doesn’t pose a problem. This so-called 1.3 metre plan is applied to the approximately 250 homes on the northwestern side of Moordrecht. The buildings themselves have been the focus of attention. The basic principle is a safe and dry design even when flood levels reach 1.3 metres. Nine prototypes of waterproof houses have been drawn up and placed in a basic subdivision. A number of them will not be built on mounds. In these cases, the homes will be fitted with waterproof outside walls, garden walls and/or windows. These homes will be showcase models for domestic and international markets.

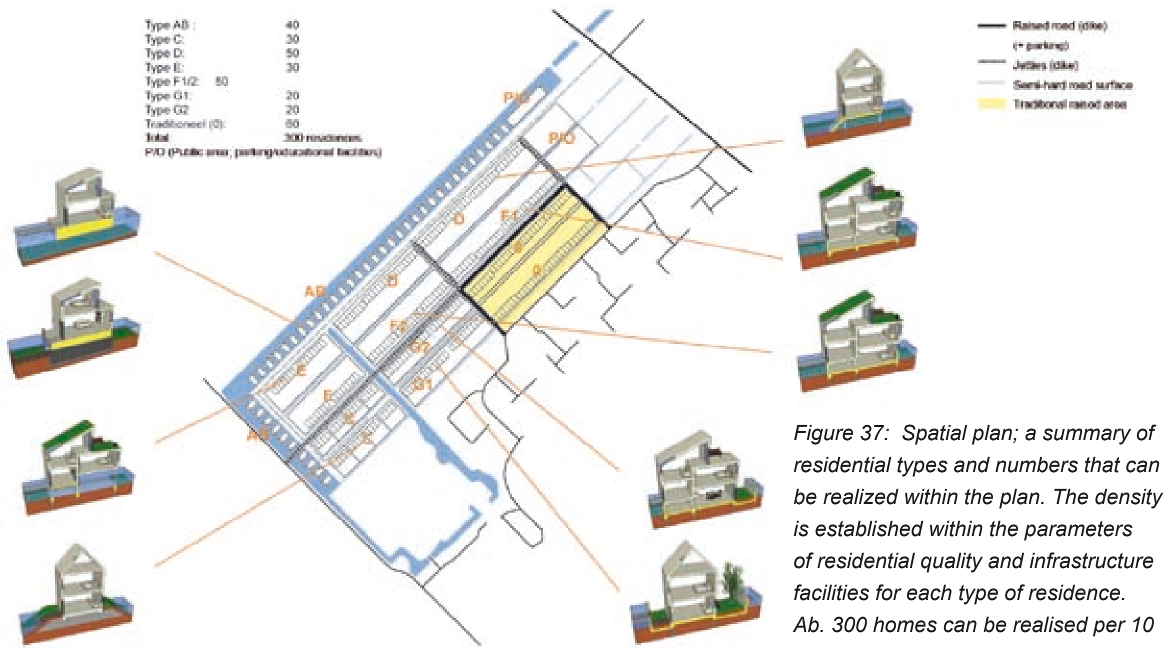


Figure 37: Spatial plan; a summary of residential types and numbers that can be realized within the plan. The density is established within the parameters of residential quality and infrastructure facilities for each type of residence. Ab. 300 homes can be realised per 10 hectares.

Pilot project Gouweknoop
(Climate Engine, Xplorelab 2008)

The 'Climate Engine' is the collective term for climate measures in the Gouweknoop on three levels. De Climate Engine deals with three climate related themes in these three levels: climate resilient conservation, drought and heat stress. The Gouweknoop has been chosen as a pilot area because it will house the most urban development in the polder once the ISP plans have been carried out. It is precisely there that the most heat stress will take place. Because of the planned large scale transformation, this area also lends itself for experiments with seasonal water storage and green space as a measure to promote cooling.

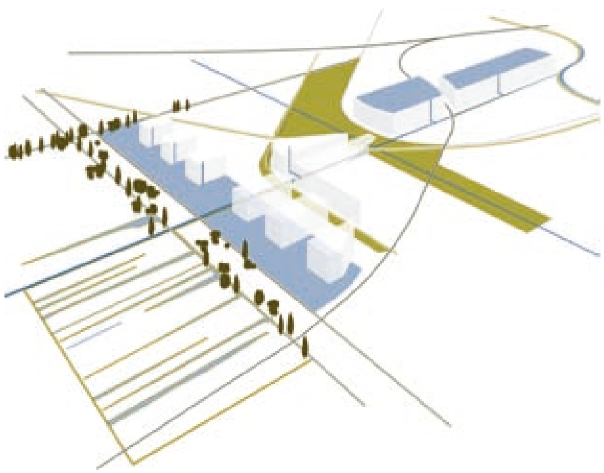


Figure 38: Birds eye view of the "Climate Engine Gouweknoop" with blue-green cross, water reservoir and water storage

The three levels of the Gouweknoop Climate Engine can be each viewed and implemented separately. But by designing them together, they enhance each other so that the "climate engine" will keep running. From the low to the higher scale levels and in the short and long term.

Level 1 Adaptation measures for natural conservation areas.
The 'blue-green cross' made up of the Boogpark and the Nieuwerkerker Dwarstocht is a part of the adaptation strategy for natural reserves in the Zuidplaspolder. It is the link between the different natural conservation areas in the polder and outside of the polder.

Level 2 Measures to prevent drought in the Waterparel
The Gouweknoop will be fitted with large scale seasonal water storage as a facility for the nearby situated conservation area, the Groene Waterparel, for times of water shortage and drought. The storage is to be used when there is insufficient river water available of good enough quality that can be let into the Zuidplaspolder.

Level 3 Rainwater in buildings: storage and cooling
The Climate Engine Gouweknoop as water cooling system during heat waves and in times of heat stress in the urban and hard-surfaced environment. The stored water can be used for green areas and in this way contributes to the cooling in the Gouweknoop.

4 Evaluation

Anthology of Ideas

Each measure that has been included in the Anthology of Ideas has been assessed for its applicability to the Zuidplaspolder. The relevance to the theme of climate has also been assessed for each measure. Of the 52 measures, research has shown that five were inapplicable to the polder, including the idea of building a super dike (the existing dike should be considered as a sort of super dike). In the case of twenty-nine of the 52 measures, they have been found to be quite feasible; including them into existing plans doesn't cost much and they offer extra climate resilience ("easy picking fruit" or "no regret"). Exactly how this works is set out in the descriptions of the aforementioned five pilot projects.

Table B1 (see next page for explanation):

Number	Flood safety	Rain floods	Water shortage	Salinization	Heat stress	Adaptation measures Hotspot Zuidplaspolder	Necessity	No Regret	Tempting	Example (pilot)	Not applicable	To be specified	Already applied
2	1					Compartmentalization of large water feeds (rivers)			1				1
4	1					Dike strengthening around the Zuidplaspolder (super or delta dike)					1		1
7	1	1	1	1	1	Zoning programme, land use and function changes				1			1
9	1					Emergency overflow area for the Hollandsche IJssel					1		1
13		1				Retention: buffer locations (extra green)				1		1	1
25	1	1				Evacuation mounds						1	1
29		1	1		1	Raising consciousness of flood risk		1		1			1
33			1	1		Raising water levels to prevent soil instability		1					1
38					1	(Water)recreation potential: council gardens /shelterbelts in urban area			1	1			1
28		1				Drainage: (accelerated) drainage of water	1						1
1	1					Tighten safety requirements and reliability of storm surge barrier	1						
3	1					Strengthening dikes outside the Zuidplaspolder	1	1					
22	1	1				Protect vulnerable facilities and vital components	1						
35			1	1		Take geomorphology and soil into account in development designs	1			1			
37				1		Shallow water courses, excavation restrictions and isolating springs	1						

Number	Flood safety	Rain floods	Water shortage	Salinization	Heat stress	Adaptation measures Hotspot Zuidplaspolder	Necessity	No Regret	Tempting	Example (pilot)	Not applicable	To be specified	Already applied
8	1	1				Drain off water into rural areas		1					
12	1					Integrating evacuation options in spatial development plans (HPS)		1		1			
14		1				Storage: more open water / inundation areas (on lower lying land area)		1		1			
16			1	1		Alternative fresh water sources / alternative distribution of fresh water		1	1	1			
18			1	1		Intelligent watermanagement (pumping stops)		1					
19					1	Increasing the spatial cohesion between natural reserves		1		1			
20	1					Compartmentalization (dikes): strategy of value protection		1		1			
21	1	1				Raising surface level of development areas / lowering water levels		1		1	1		
23	1	1			1	Protection of road and water infrastructure		1					
24	1	1				Raising road levels for evacuation purposes		1					
26		1	1	1		Water retention: making hard surfaces permeable		1		1			
27		1	1	1		Water storage: in bufferzones or in open water areas (storage ponds)		1		1			
36				1		Routing the watersupply in dry periods and functional adjustments		1	1				
39					1	Attention to cooling by positioning urban areas / orientation parcelling		1					
40					1	Passive underground heath (and cold) storage		1					
41					1	Embedding natural reserves in climate mantles of multifunctional zones		1					
11	1	1				Raising the ground surface level of the polder			1	1			
10	1	1				Overflow area in case of pumping stops			1				
17			1	1		Use of clean water and water-purification marshes			1				
30			1	1		Sustainable watermanagement: closed watercirculation in subareas				1			
32			1	1		Retention and purification: helofytenfilter / water-purification marsh				1			
15		1				Drainage: increase of pump capacity						1	
31			1	1		Sustainable watermanagement: principle of water-current systems						1	
34			1	1		Application of under water drainage						1	
42					1	Increase natural ecosystem resilience by adapting maintenance						1	
5	1					Compartmentalization: ‘double wall strategy’					1		
6	1					Compartmentalization: strategy of partitioning					1		

Table B2: Already applied (brown) and essential measures (dark-green) applicable to the Zuidplaspolder. The numbers in the first column refer to the measures of the Anthology of Ideas. The light grey cells refer to measures interfering on the ‘polder level’, the grey cells refer to measures interfering on a smaller scale; the district area.

Number	Flood safety	Rain floods	Water shortage	Salinization	Heat stress	Adaptation measures Hotspot Zuidplaspolder	Necessity	No Regret	Tempting	Example (pilot)	Not applicable	To be specified	Already applied
43	1	1				Raised (elevated) building		1	1	1			
44	1	1				Building with flexibility		1		1			
45	1	1				Dryproof building		1		1			
46	1	1				Wetproof building		1		1			
47	1	1				Evacuation measures		1		1			
48		1	1	1	1	Retention: roofs with vegetation and vertical water buffers		1	1	1			
49		1	1	1		Retention: disconnecting rainwater drainage / permeation into the soil		1					
50		1	1	1	1	(Water)recreation potential, public development gardens / shelter belts		1					
51			1	1		Rainwater installations: filtering of water at user level		1					
52					1	Insulated, heat resistant buildings (ensembles)		1		1			
Tot.	23	24	17	18	12		6	29	9	23	5	6	10

Table B3 (result of measures on the scale level of 'building' and totals per theme and type).

Nine measures can be regarded as tempting propositions; very attractive, but not urgent. They can be carried out at a later date. These encompass all scale levels and all climate themes. Ten measures have been applied already. The existing geomorphology plays a role (differences in height the ZPP). They have been purposefully included into the ISP (such as zoning based on the split layer approach) or they lie outside the polder itself (construction of the storm surge barrier at Krimpen aan de IJssel). Six necessary measures have been identified. The action that has to be taken is partly independent of the Zuidplaspolder (such as strengthening dike ring 14). The measures at the higher scale level deal mainly with flood risk. Heat stress and flooding itself are themes that relate to the lower scale level.

The measures that were deemed unsuitable, related mainly to the higher scale level and were found to coincide with the particular soil types (risk of settling and land subsidence) and/or the excessive cost of side effects (compartmentalization). Further research is required into the effects of drought, salinization and heat stress (nature). These issues are complicated and need to be solved at national level. The rainwater flooding theme is mainly a question of tailoring that can be done at the lowest scale level.

Concluding, it can be stated that the issue of climate change has been properly included into the plans in the Zuidplaspolder. Inspite of this, there are still many more opportunities to be exploited. The Anthology of Ideas could yet prove relevant for the Zuidplaspolder and other planning developments.

SCBA Five Pilot projects

Motivation

Can the five pilot projects be recommended in light of the costs and benefits to society? In other words: are the additional adaptation measures justified from a societal costs and benefit perspective? To answer this question, a Social Costs and Benefits Analysis (SCBA) has been performed.

An SCBA systematically expresses every aspect of a plan for a community in monetary terms. Along with this, a comparison is made with a zero-alternative (doing nothing). When estimating the direct financial costs and benefits of these adaptation measures, it was apparent that there are many variables. The accurateness of the estimates used differs greatly. For some entries (particularly expenses) the estimates can be fairly accurate. Especially for costs and benefits for which there are no market prices available, it proved difficult to make good estimations. For estimating the benefits of extra wetlands and conservation areas in the area for the SCBA, Hotspot Zuidplaspolder commissioned the VU University of Amsterdam to survey the inhabitants of the region to assess their willingness to pay for these added values (Brander, 2008). They also took stock of which determinants for costs and benefits in conservation, water and soil are relevant and known (Ruigrok, 2007).

The zero-alternative and the project alternative

The study only looked at the extra adaptation measures that had been recommended to increase the climate resilience of the Zuidplaspolder. ‘Extra’, in this case, means over and above the measures that have been recommended in the Inter-municipal Structure Plan. The zero-alternative is thus the ISP and the adaptation measures as drawn up within the pilot projects have been compared with it.

The pilot projects are:

1. Anticipating rainwater flooding in north Zuidplas;
2. Crystal Clear Water Dwellings in the Rode Waterparel;
3. Climate resilient design for north Nieuwerkerk;
4. Modified construction in the urban expansion of Moordrecht
5. A climate resilient conservation infrastructure / “Climate engine” Gouweknoop

Pilot project 1 Anticipating rainwater flooding in Zuidplas Noord

A design has been made in this pilot project which couples climate adaptation with a desire for a high quality residential environment in which water and nature are important elements. In this design, areas water storage have recreational and esthetic values. This means that a smaller area is available for housing development, but the area enjoys improved quality for the residential environment. The costs and benefits estimate reveals that it isn’t economically efficient to create this space for water. It is more cost-effective to reserve space for water storage in the greenhouse area. The added value of extra water in the residential area in terms of improved living conditions and recreational benefits has been determined by a survey. These benefits have been estimated to be about €14 million. However the costs of creating a residential environment with sufficient water storage

capacity have been estimated to be €35 million.
The extra water is, of course, primarily meant to prevent flooding in the event of extreme rainfall. Assuming the most extreme climate scenario for rainfall (W), a cloudburst which occurs once over 100 years can cause considerable damage (estimated at €3 million). But the net present value (using a discount rate of 2.5% over a period of 100 years) turns out to be €1.2 million. One has to conclude, on the basis of the cost/benefit analysis that the costs don't offset the benefits. The costs are estimated to be €35 million offset against some €15 million in benefits (€14 million the added value of the watery environment plus the €1.2 million flood damage prevention).

Although the plan is not likely to be economically efficient, it is attractive and offers a tempting perspective for the northern area of the Zuidplaspolder: an area coexisting with water which is proof against the most extreme rainfall. The relatively high construction costs are a result of comparing the plan with a zero-variant whereby the extra space for water doesn't have to be constructed at all. If the government makes the water task compulsory, the project could well turn out to be economically viable.

Pilot project 2 Crystal Clear Water Dwellings in the Rode Waterparel

Within the Rode Waterparel area, the most important climate factors are related to water quantity (rainwater-floods, droughts) and ecology. Raising the water level in the polder reduces the storage capacity for water within the Rode Waterparel.

Because the area is marshy, eventual small scale inundation is no problem. As long as the inundation levels do not exceed the thresholds of houses or the height of primary access roads, then no problems are expected. On the other hand a "no regrets" strategy offers the possibility to implement sustainable measures. This would mean, as a basic principle, that the area should be protected from damage to maintain its current ecological and landscape qualities.
Using this as starting point, the following principles have been highlighted:

- Apply construction methods that don't effect the soil structure (for example, weight balanced construction methods)
- Separate homes, residential environments and infrastructure clearly from the surrounding landscape
- Aim for flexibility (adaptability)

Using alternative construction techniques incurs extra costs compared with traditional road building. Applying EPS (polystyrene) for example, costs about 25% more on average than conventional techniques. Therefore, an important question is: what will produce enough in a development proposal to compensate for this? Is it always a question of financial compensation, or
is it also one of social and climate accountability for businesses. This depends on the chosen development perspective for the relevant area. From the chosen "no-regret" development strategy for the Rode Waterparel, a certain choice has to be made for housing and the technology to be used for the infrastructure.

Figure 39: Building a road on EPS (polystyrene)

That means the additional costs for roading built on EPS will be 25% higher, but the abovementioned objectives within the development perspective of climate change and sustainability will be achieved. Because there has been no design made from this perspective, it was not possible to perform a cost benefit calculation.

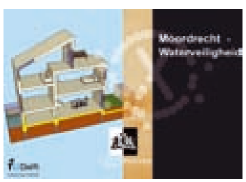
Pilot project 3 Climate resilient design for Nieuwerkerk Noord

The soil in the area for the planned expansion of Nieuwerkerk is subject to land subsidence. As a result large volumes of sand will be needed to prepare the land for construction. By choosing to raise parts of the area with lighter materials than sand (like sediment), costs can be significantly reduced. By taking the land subsidence into account, TNO has calculated the volume of sand that would be required to raise the ground level in the area. The cost of raising the land and preparing the ground for construction has been estimated at €38 million. Raising the land level with sediment is much more cost effective, but on the other hand using sediment has a negative image and it is not always possible to apply this technique. But bearing in mind its price/quality effectiveness, it can certainly be viewed as an attractive alternative.

The so-called compartmentalization variant whereby only the level of the N219 will be raised also results in a significant reduction in costs for preparing the ground for construction. The costs of this variant are estimated at €11 million. In other words a saving of €27 million compared with the variant in which all the land in the area will be raised. Not only that, but this variant offers the greatest spatial quality. The urban development will include lots of surface water areas and will be realised while still maintaining the threshold level of existing buildings and preserving the current soil conditions. This added value has been calculated to be €10 million – on the basis of research done by the VU University of Amsterdam (Brander, 2008), although this is offset against the estimated costs of reserving and developing extra open surface water areas (€10 million). The flood damage reduction in each variant is the same (the flood risk is reduced locally by raising the ground level with sand, as well as sediment, and that counts for the construction of a compartmentalization dike as well).

This flood damage avoidance is in absolute terms quite extensive and estimated to be €78 million. But when the damage is converted to a net present value (that means that the expected damage is discounted over a 100 year period at the rate of 2,5%) then a negligible figure remains (€0,3 million). This is because there is a minimal risk that a flood will happen (estimated by Deltares as in the order of 1:10,000 years), but also because the discounting means that costs and benefits that lie further in the future, don't weigh much in the cost-benefit analysis.

In short, this plan has a positive cost-benefit result. In terms of direct cost savings for preparing the ground for construction, this variant is some €27 million cheaper than the zero-alternative. Creating new open water features costs money, but also delivers a similar benefit in terms of quality of life. The damage that is avoided due to flood prevention is neglible.



Pilot project 4 Climate proof construction in the urban expansion of Moordrecht

A quick overview of the costs of preparing the ground for construction fosters the assumption that there are cost savings to be made by not raising all the land in the expansion area. But building jetties, raised infrastructure and nonstandard ground preparation techniques will increase the costs. The Delft University of Technology has made a tentative estimate of the additional costs. These are estimated to be some €20 million. The possible damage as a result of flooding via the Hollandsche IJssel has been off set against the additional costs of the plan. This is estimated to be €12 million. Because of the small chance of flooding, the expected frequency of flooding is also very small. As well as that, discounting means that the damage in the future counts for much less.

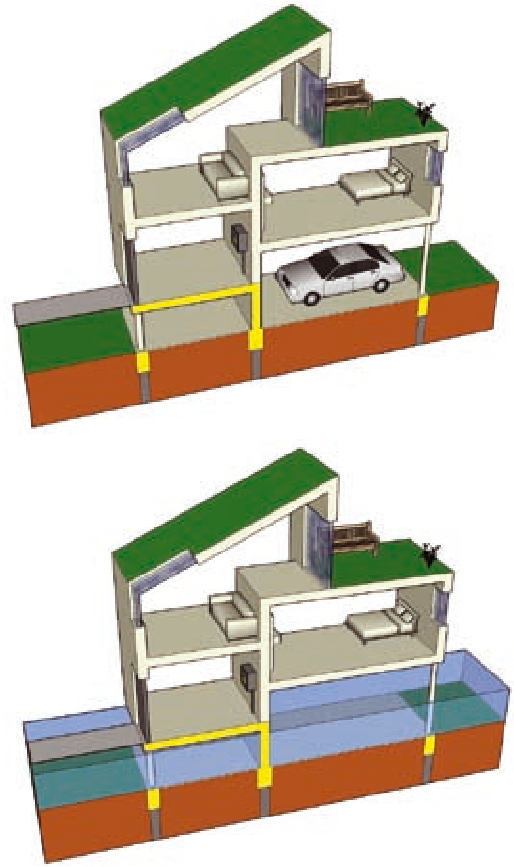


Figure 40: Climate resilient design: wetproof split level

In the end, they are of negligible importance in the SCBA. Because the additional costs of the plan are higher than the potentially avoided flood damage, then the plan should not be recommended from the point of view of cost-benefit considerations.
Determining whether this climate resilient design is financially viable is dependent on a variety of factors. The urban expansion borders on an area with a lot of open water and natural reserves (Restveen and the Groene Waterparel area) and this can enhance the value of the homes in the 1,3 meter plan. In the end a property developer will have to decide whether this sort of project can be developed profitably. Apart from the direct costs there are a number of benefits that are difficult to quantify. The plan can serve as an international example of a construction design that incorporates water proof solutions.

Pilot project 5 A Climate Resilient Natural Infrastructure/ Climate Engine Gouweknoop

The background study Conservation, Drought and Soil Opportunities, has indicated what adaptations are necessary to allow the Zuidplaspolder fauna and flora cope with climate change and this has been applied onto concrete advice for its development and management. This advice is summarized in Figure 14.

The costs of taking over, developing and managing the extra natural reserves have been estimated by experts from the Zuid-Holland provincial administration. The total cost amounts to €9.4 million. The management costs are capitalized in this calculation. To calculate the benefits to society of this conservation area, a survey has been used that has been developed for the Zuidplaspolder (Brander, 2008). From this survey it became apparent that the inhabitants of the Zuidplaspolder were willing to pay €17,000 per hectare per year for public access to natural reserves.

Figure 41: Conservation and green infrastructure in the Gouweknoop

The total extra conservation area amounts to 93 hectares. In this way, this area can be said to represent an annual benefit of €1.6 million.

Putting the costs and benefits alongside one another over time (discount rate of 2.5% over 100 years), produces a net present value of €50 million. The project has a positive outcome from this perspective. The relatively high level of willingness of households to pay for accessible conservation areas is remarkable, but can possibly be explained by the lack of recreational natural areas in the southern part of the Randstad. This lack of green area is possibly being redressed already with the development of large conservation areas such as Bentwoud and Rottewig. Finally, it should be stated that the people who carry the costs in this example are not the same as those who enjoy the benefits. That is why investment is still needed for construction, development and management of this area. The benefits evaluation just indicates that this type of investment is socially desirable and appears to be accountable.

Conclusion SCBA

While carrying out the SCBA, a large number of factors turned out to be uncertain or unknown and that is why the results should be considered indicative. A reasonable estimate can be made for some items (namely costs), but the indirect goods and services for which no market prices exists are difficult to assess. In order to be able to include such benefits in the SCBA a survey was carried out amongst the inhabitants of the region to assess their willingness to pay for these non-tangible assets. The relevant figures for estimating costs and benefits in the area of conservation, water and soil have been considered. These have been included in the SCBA. The most important results have been summarized in the table below. The figures give an indication of the order of magnitude. In spite of many uncertainties, the figures have been included because they give an indication of the necessary investments and whether these investments can be justified from a social perspective.

The table presents the net present values of all costs and benefits (with a discount rate of 2.5% over 100 years).

Adaptation measure	**Net present value of costs and benefits (in millions € using a discount rate of 2.5% over a period of 100 years)**
Zuidplas Noord (opMAAT) Water storage in the residential ribbons	-20
Nieuwerkerk Noord (TNO) Compartmentalization option	28
Moordrecht (TU Delft) 1.30 metre plan	-20
Climate resilient green infrastructure	50

Table C: Significant results from the SCBA

The total package of additional climate measures requires an extra investment over and above the current plan as set out in the ISP. This is for the measures in Nieuwerkerk Noord according to the compartmentalization principle, Zuidplas Noord via the opMAAT principle, Moordrecht 1.3 metre plan, the green infrastructure and the climate resilient Rode Waterparel.
The rough SCBA indicates that these extra measures earn their own way in the end and eventually provide a profit of €38 million. The positive net present value is mainly caused by the community benefits to be derived from extra green and the savings made in the preparation of the ground for construction in Nieuwerkerk Noord.

The pilot projects appear to be economically desirable on the basis of this quick scan, but only if they are linked to one another (via balancing off costs and benefits by setting the costs of one measure off against the benefits of another). Although there is an apparent positive result, initial investments will have to made. These investments will have to be made at the beginning. The benefits will be realised in the future (via increased quality of lifestyle) but some benefits are in fact savings (because preparing the ground for construction and raising the ground level costs less.

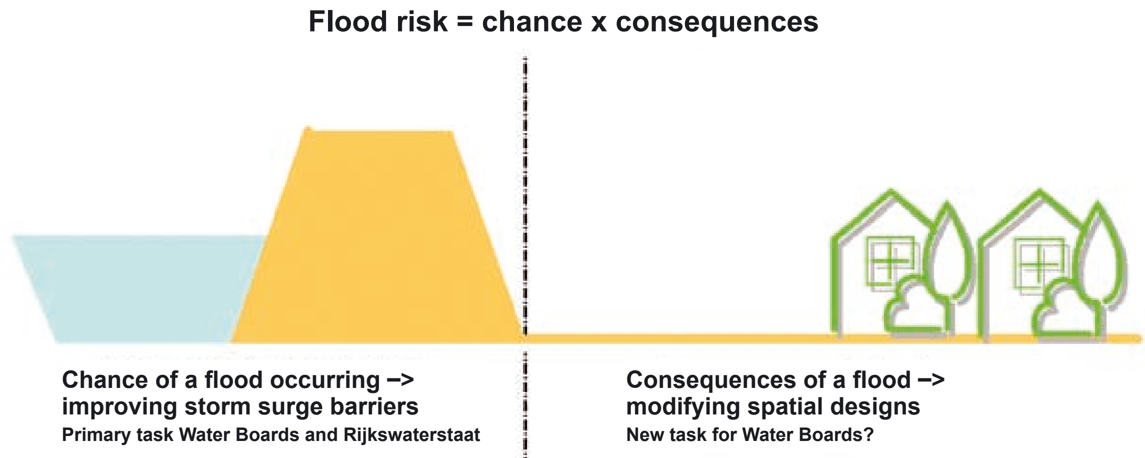
It is striking that avoiding damage as a result of flood risk has hardly any influence on the final balance. In other words, the argument to increase investment to reduce the flood risk is not not supported by a cost-benefit analysis. The measures' costs outweigh the benefits of mitigating damage by a long way.
This does raise questions as to the usefulness of a social cost-benefit analysis with projects that are explicitly directed at climate adaptation in the very long term (>50-100 years). The methodology of the SCBA effectively causes the costs and benefits to fade away over time.

Management and policy

Climate change is fraught with uncertainties. The exact consequences are difficult to predict and that is why it is a difficult task to arrive at consensus about it and make policies. The scientific discussion has shifted for this reason to the political domain. The demand for integral spatial solutions grows because of this. Collaboration between scientists and governmental authorities in different sectors has provided integral solutions for achieving climate resilient spatial development. No simple task as long as no one really knows what we have to make ourselves resilient to and there are, therefore, no good guidelines about what "climate resilience" actually entails.

In the case of the Zuidplaspolder, many different responsibilities are interwoven. The national government is responsible for the main infrastructure and protection against flooding in general. The province in turn supervises the integral coherence of spatial planning in the Zuidplaspolder. At the same time it has an independent executive and developmental task, whereby it has to take account of national and local interests. The Water Board has, on the one hand, a clear role as water manager, at the same time it has a background role as an advisory body in the spatial planning process in the province,

Figure 42: Schematic outline of an altered task description for governmental authorities in flood risk management



whereby it also executes national policy with regard to flood risk management.

Water management in the Netherlands now has to deal with huge uncertainties about water levels, rising sea levels, precipitation patterns and river flows. In this way the spatial plans are also confronted with these uncertainties. While in the past the water managers put their energies into reducing the risk of flooding, these days, they have to spend more energy on reducing the consequences arising from inundation. This novel attention to the consequences confirms the necessity for water managers to provide adequate advice in spatial planning. The situation in the Zuidplaspolder is one of the first integral projects where the water managers take an active place at the spatial planning table.

In the Zuidplaspolder the Water Board has participated fully in the design process from the very beginning. In this way there has been an adequate response to the split layer approach to land use planning. The participation in the Hotspot Project, where climate scenarios are tested, show that this approach offers the best starting position for realising a robust (water) plan in which climate change can be best dealt with. At the level of flood risk mitigation the importance of the advisory role of the water manager has increased.
At this point in time, the role of water and flood risk partners has not yet been formally anchored in spatial planning regulations. A possible solution is to set down the involvement of water and flood risk parties via the appraisal framework “climate and spatial planning”.

This appraisal framework is in the process of being set up by the Ministries of Spatial Planning and the Environment together with the Ministry of Transport and Water Management. In the appraisal framework, criteria have been set whereby climate resilient decisions can be taken. In this way risks formed by climate, water and safety can be considered in an integral way during the development of spatial plans, by the national government as well as provinces and municipalities. The appraisal takes place on the basis of advice from water and safety partners who have a more concrete idea of the criteria that their advice must conform to as a result of the framework.

Although this appraisal framework offers more concrete guidelines to the parties involved, the integral communication is still dependent on the attitude of these partners. Not only must things change on paper, but also "in their heads". Interested parties should sit together more often and at an earlier stage around the table realising that that they can augment each other's knowledge with perspectives from their own field of expertise. In the Zuidplaspolder this proved to be a successful approach within the collaboration in the Hotspot Project.

Climate adaptation in practice

The Hotspot Project can be viewed as a shadow project alongside the actual planning process in the Zuidplaspolder. That planning process is being carried out by the project organisation, Driehoek RZG Zuidplas and has been running since 2004. In this project organisation, the Zuid-Holland provincial government works intensively together with the municipalities of Gouda, Waddinxveen, Nieuwerkerk aan den IJssel, Moordrecht, Zevenhuizen-Moerkapelle, Rotterdam, the Water Boards of Schieland and the Krimpenerwaard and the Rotterdam Regional Authority. These parties together form the steering committee which is responsible for the planning process.

The Hotspot Project, however, ran in the period 2007-2008 as part of Xplorelab, thus enjoying a certain degree of independence. The link between Hotspot and the project organisation has been effected by seconding the project leader for planning into the core team of Hotspot. The president of the Water Board has been installed as reporter from Hotspot to the steering committee. In this way the flow of information was optimal, at the bureaucratic as well as the management level. This has clearly stimulated the adequate implementation of Xplorelab's ideas in the planning process. As a general rule it can be said that the Hotspot Project has greatly increased insights into the possible effects of climate change and has thereby greatly increased the climate resilience of the plans in the Zuidplas. The function of the pilot projects in the Zuidplas' further designs deserves more detailed explanation. Because the pilot study "Crystal Clear Water Dwellings" was carried out at the same time as the designation plans for the for the Rode Waterparel, interim results were exchanged with the designers of the Masterplan for this area. In this way the material basis for the development of the Rode Waterparel has been reinforced. Not only that, but the findings from this pilot study can still be used in the research into the most desirable manner of preparing the ground for construction in Nieuwerkerk Noord. In this pilot study, different strategies for raising (or not raising) the ground level have been investigated. In a further study with the Nieuwerkerk aan den IJssel municipality, three methods of ground preparation for this low lying peaty area are being subjected to a more detailed comparative technical investigation. The traditional raising of the ground level with several meters of sand, is being considered along with the option of using sediment. The third variant is not or hardly raising the ground level and allowing large areas of open water combined with a protective high lying road segment of the N219.

The pilot study, “The 1.3 Metre Plan”, offers inspiration to actually develop these examples in different low lying locations.
These could be realised in Moordrecht, as well as Nieuwerkerk Noord and perhaps in the Rode Waterparel and/or the Gouweknoop. In terms of spatial planning, the rainwater flood risk study for the northern part of the Zuidplaspolder goes much further than the solution that is set down in the Intercouncil Structure Plan (ISP) for the Noordelijke Dwarstocht. This idea will be reassessed in the further development of the area north of the Zesde Tochtweg (after 2020). The pilot study on fresh water facilities for both Waterparels in the Gouweknoop has lead to a discussion about the dry variant in the climate scenarios and the actual need for fresh water. Is an incidental supply of slightly brackish water such bad thing in the polder? Or does the Randstad need a lot of fresh water from other places? This pilot study has ensured that ways of coping with periods of drought has been clearly placed on the agenda.

As well as this, the general desire to realise sufficient water storage capacity has been made concrete in the Water Board’s zoning plan advice. This will be included in the zoning plan for the whole of the Zuidplas, which will be finalised by the Councils during 2009. Proposals have been taken up in the Quality Manual to construct green zones alongside water ways. this can also be realised in the prospective urban developments whereby the green zone also functions as an emergency overflow. In this way the long term flexibility can be guaranteed without asking for extra space.

Guaranteeing the desired sustainability and spatial quality is one of the tasks of the Zuidplas Regional Development Organisation (ROZ) which is currently being set up. The idea is to establish an independently functioning quality control team, which will also monitor Hotspot’s results. The project Zuidplaspolder is also one of the projects in the Randstad Urgent programme, and thus enjoys national guarantees and support.

5 Conclusion: Climate proof?

Research Questions

The Hotspot research done by Xplorelab has focussed on identifying the specific consequences of climate change for the Zuidplaspolder and has derived measures from this, translated into five pilot projects to promote a climate resilient polder for the long term. The research has answered three main questions:

1. What are the **effects** of climate change? How do they relate to the Zuidplaspolder?
2. How can preparation for the consequences of climate change be included in the **spatial planning** process?
3. Can the suggested solutions be made accountable in a social **costs/benefits** evaluation?

These questions will be answered one by one:

The effects

Fresh water shortage and salinization
The effects of climate change on the geomorphology means there will be longer periods of drought with a quality water shortage (salinization) as a result.
To predict the effects on the Zuidplaspolder more accurately, more insight into the (ground) water system and the water balance in the Zuidplaspolder is required. The water balance offers insights into the quantities of water that is let into and pumped out of the polder, the quantity of precipitation and evaporation and the quantity of seepage water. With this information, the water quality can be further improved, especially in the area of the Waterparel, and the possible effects of climate change can be neutralised.

Special attention should be paid to the role of salinization in relation to the water quality and ambitions for conservation. There are still many unknown factors in the role that seepage water plays, the consequences of water level adjustments in the polder and excavation works. Water level and the altitude of soil (above and under the water) have a minimum limit in the Zuidplaspolder and this has to be respected.
The internal salinization has to be accepted as given. External salinization is a problem in the whole of Zuid-Holland and is not unique to the Zuidplaspolder. In the case of external salinization, a management choice has to be made about how to deal with it.

Safety
Climate change doesn’t form an increased threat to the safety of the polder in terms of flooding. The storm surge barriers (at Krimpen aan de IJssel and the Maeslant barrier) regulate the water level in the Hollandsche IJssel. These barriers need to be used more often which increases the demands made on them. Thanks to the barrier, the rise in seawater levels and higher river flows will not have a direct effect on water levels in the Hollandsche IJssel.

The chance of flooding hardly increases as a result of climate change, but the invested capital and, thus the ultimate risk, does rise. That is why measures have been proposed that restrict the risk (compartmentalization, waterproof construction, building on mounds).

Flooding and temperature
Extreme rainfall can lead to problems with draining water in some parts of the area. In the KNMI'06 W-scenario peak downpours increase markedly. Additional measures need to be included in existing plans such as creating extra water buffers over and above the current prescribed percentage of open water in the lowest lying parts. At neighbourhood level, permeation via wadies and public green areas, and vegetation roofs on buildings are recommended. The extra open water gives relief when the temperature rises.

Spatial planning

The plans for the Zuidplaspolder are climate resilient. Many measures have already been applied, such as not building in the lowest lying parts of the polder. The amount of open surface water has been increased and the water ways have been widened whereby torrential rain over a short period can be coped with and drained away. The areas where the water level is maintained at the same height have been increased so that the water system is less vulnerable.

Water levels will be raised in a large area to reduce seepage. Not only that but in the areas where urban functions (living, working and glass) are planned, the percentages of open water are determined to ensure that the storage capacity in the area is not diminished. For flood safety purposes, the threshold levels have been determined, whereby no flood damage will occur.

In spite of this, the climate themes water shortage and rainwater flooding as set down in one or more of the KNMI'06 scenarios reveal that the abovementioned measures will not be enough. Under the theme of safety, the rise in monetary value of the damage as a result of flooding means that action has to be taken.

In the five pilot studies, encompassing only parts of the Zuidplas, ideas have been developed at conceptual level. These pilot projects each offer a varying degree of additional solutions for possible climate change, whereby the designers have dared to deviate from traditional approaches. Examples of this include using the revamped N219 as a compartmentalization dike and creating seasonal water storage in the Gouweknoop. In the coming years the Zuidplaspolder faces the challenge of taking up additional measures in their planning.

Costs versus benefits

Not only that, but financial considerations show that the pilot projects can also be socially viable. In any event, the investment necessary to mitigate possible damage as a result of flooding doesn't weigh up against the damage itself. Other considerations play a role here.

Climate proof?

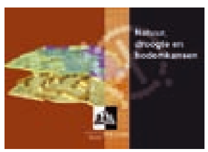
The measures that have been developed at conceptual level and the pilot projects are being checked out for their applicability in concrete situations within the developments in the different parts of this area. This has been stimulated by the collaboration between the various disciplines since the beginning of the planning process and their innovative attitude. The water and flood safety partners should be given a role from the outset.

The researched effects of climate change provide a reason for taking diverse measures seriously. In this context, an attractive perspective arises, which is given shape in five pilot projects. The principle is to increase sustainability and spatial quality using measures for adapting to climate change. An opportunity is there for the taking to develop the Zuidplaspolder as a testing ground for sustainable and climate resilient construction, so as to serve as an example for the whole of the Netherlands and for other delta areas in the world. By capitalizing on this opportunity, the Zuidplaspolder can arm itself against future changes. A challenge for us all.

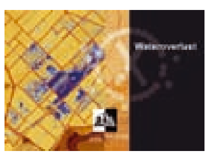
Hotspot publications

Background studies Hotspot Zuidplaspolder

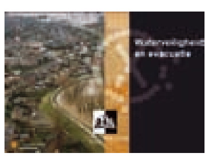
Moel, H. de, E. de Haan & M. van Steekelenburg, 2008 **Achtergrondstudie 1. Klimaatverandering.** IVM-VU, Xplorelab. Provincie Zuid-Holland, 2008.



Mes. R, L. Smeets & D. van der Eijk, 2008 **Achtergrondstudie 2. Natuur, Droogte en Bodemkansen.** Xplorelab. Provincie Zuid-Holland, 2008.

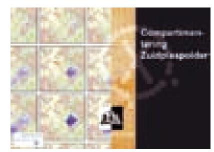


Moel, H. de, 2008 **Achtergrondstudie 3. Wateroverlast**. IVM-VU, Xplorelab. Provincie Zuid-Holland, 2008.



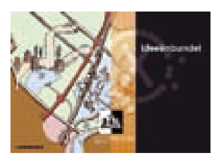
Koppers, M & C. Schneider, 2008 **Achtergrondstudie 4. Waterveiligheid en Evacuatie.** Universiteit Utrecht, Xplorelab. Provincie Zuid-Holland, 2008.

Bergh, D. van den & M. van Steekelenburg, 2008. **Achtergrondstudie 5. Breder perspectief op waterveiligheid.** Xplorelab. Provincie Zuid-Holland 2008.



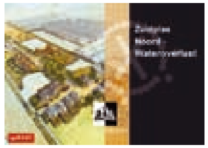
Hoes, O. & E. van Leeuwen, 2008 **Achtergrondstudie 6. Compartimentering Zuidplaspolder.** Deltares, Beelen & Schuurmans, Xplorelab. Provincie Zuid-Holland, 2008.

Goosen, H, K. de Bruin & B. Leurs 2008. **Achtergrondstudie 7. MKBA.** WUR, Xplorelab. Provincie Zuid-Holland, 2008.

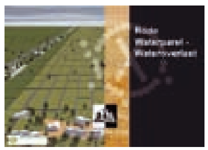


Mes, R., M. van Steekelenburg & M. Peen, 2008. **Achtergrondstudie 8. Ideeënbundel.** Xplorelab. Provincie Zuid-Holland 2008.

Pilot projects Hotspot Zuidplaspolder

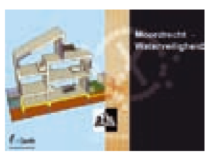


Pötz, H. & P. Bleuzé, 2008 **Voorbeeldproject 1. Zuidplas Noord**. Een klimaatbestendige Zuidplas Noord. opMAAT, Xplorelab. Prov. Zuid-Holland, 2008.



Boer, S. de, M. van Eijsden et al. 2008 **Voorbeeldproject 2. Rode waterparel.** Bouwen met kraakhelder water. Dura Vermeer, Xplorelab. Prov. Zuid-Holland, 2008.

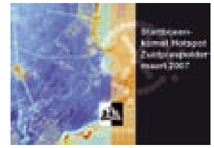
Brouwer, M., E. Rietveld, J. van Brussel & T. Reijs, 2008 **Voorbeeldproject 3. Nieuwerkerk Noord**. Klimaatbestendig ontwerpen Nieuwerkerk Noord. TNO, Xplorelab. Provincie Zuid-Holland, 2008.



Dobbelsteen, A. van den, A.K. Lassen & M. Fremouw, 2008 **Voorbeeldproject 4. Moordrecht.** Het 1,3 meterplan. TU Delft, Xplorelab. Provincie Zuid-Holland, 2008.

Mes, R., M. Peen & M. van Steekelenburg, 2008 **Voorbeeldproject 5. Gouweknoop**. Klimaatmotor Gouweknoop. +Architecture, Xplorelab. Provin. Zuid-Holland, 2008.

Previous Hotspot Zuidplaspolder publications



Groot, M. de, 2007
Startbijeenkomst 23-03-2007 Hotspot Zuidplaspolder. Plan van aanpak. Xplorelab. Provincie Zuid-Holland, 2007.

Groot, M. de, M. van Steekelenburg et al., 2007
Tussenrapportage november 2007. Xplorelab. Provincie Zuid-Holland, 2007.

Cardenas, S., C. de Koning, N. Stukje, 2007
EnvironMENTAL Design, Xplorelab. Provincie Zuid-Holland

Groot, M. de, 2007a
Japanese Dutch Design Workhop, Xplorelab. Provincie Zuid-Holland

Keizer, G. & J. van der Meer, 2007
Klimaatbestendig bouwen in de Zuidplaspolder. Kan compartimenteren het tij nog keren? Afstudeerscriptie Hogeschool Van Hall Larenstein WUR; Provincie Zuid-Holland, Xplorelab. Met cd-rom.

Schneider, C., 2008
Water in de Ruimtelijke Ordening. Het beleidsproces op overstromingsrisico van rijk tot Zuidplaspolder. Bachelor thesis, Universiteit Utrecht; Provincie Zuid-Holland, Xplorelab.

References

Actueel Hoogtebestand Nederland AHN
www.ahn.nl

Beijk, V., 2008
Klimaatverandering en verzilting. Modelstudie naar de effecten van de KNMI '06 klimaatscenario's op de verzilting van het hoofdwatersysteem in het noordelijk deltabekken. Rijkswaterstaat, Dienst Zuid-Holland, mei 2008.

Brander, L., 2008
Valuation of landscape characteristics in the Zuidplaspolder. Instituut voor Milieuvraagstukken, Vrije Universiteit. Oktober 2008.

Broek, A.J.M. van, L. Brouwer en K.-H. Grootjans, 2007
Globale systeemanalsyse Restveen en Groene Waterparel. Bodem, grond- en oppervlaktewater en vegetatie. Haskoning Nederland b.v. RO, december 2007.

Brouwer, R., S. Hess en V. Lindeloof, 2007
De baten van wonen aan water: een internet keuze experiment. IVM-VU, E07-15. Vrije Universiteit, Amsterdam.

Commissie Waterbeheer 21e eeuw, 2000
Waterbeleid voor de 21e eeuw; Geef water de ruimte en de aandacht die het verdient, The Hague, Commissie waterbeheer 21e eeuw (Commissie Tielrooij), p. 1-50.

Grontmij MidWest, 2007
Bestemmingsplanadvies Zuidplaspolder, Grontmij Nederland bv.

Janssen, B., B. Bomas, C. Kwantes, P. van Empel, 2008
Waterparel, Masterplan Rode Waterparel. BVR, van Bergen Kolpa Architecten, Alterra.

KNMI, 2006
Klimaat in de 21e eeuw - vier scenario's voor Nederland, de Bilt, KNMI.
www.knmi.nl/klimaatscenarios/knmi06/samenvatting/KNMI_NL_LR.pdf.

Minnema, B., Kuijper, B. & Oude Essink, G.H.P., 2004
Bepaling van de toekomstige verzilting van het grondwater in Zuid-Holland. NITG 04-189-B, 86 p., Utrecht, TNO Bouw en Ondergrond

Oude Essink, G. E. van Baaren, M. van Vliet, 2008
Verkennende studie klimaatverandering en verzilting grondwater in Zuid-Holland. Deltares, Utrecht, projectnummer 092.81111.

Projectbureau Driehoek RZG, 2006
Intergemeentelijk Structuurplan ISP Zuidplas

Projectbureau Driehoek RZG, 2008
Handboek Kwaliteit Zuidplaspolder

Provincie Zuid-Holland 2008
Waterplan Zuid-Holland 2010-2015, ontwerp.
Provincie Zuid-Holland, Den Haag.

Ruijgrok, E. 2007
Baten van klimaatadaptatie Zuidplaspolder. Overzicht van relevante kentallen ten behoeve van de maat-schappelijke kosten baten analyse. Witteveen en Bos, gv863-1-1/ruie/1.

Veenstra, N., R. Mom, W. de Vries en J. Knoops, 2008
Evacuatiecalculator Zuidplaspolder. Infram, Marknesse, projectnummer 08i029, 16-5-2008. Samengevat in Bijlage 3 Evacuatiecalculator van Achtergrondstudie Waterveiligheid en Evacuatie. XploreLab, 2008.

Vos, C., P. Opdam, G. Nabuurs, R. Bugter & M. Epe, 2007
Klimaatverandering en ruimtelijke adaptatie natuur: wat we (niet) weten. Routeplanner. Klimaat voor Ruimte, Leven met water, Habiforum, en CURNET. ISBN / EAN 978-90-5192-037-6. November 2007.

Colophon

Editorial board
Marco van Steekelenburg (editor in chief), Hasse Goosen, Ron Mes, Mathilde Peen, Frank van Pelt en Lucy Smeets

Publication
The Final report *Climate adaptation in the Zuidplaspolder* is a publication of Xplorelab, Province of Zuid-Holland: Marco van Steekelenburg (project coordinator), Hasse Goosen en Monique de Groot.

Den Haag, 2008
ISBN/EAN: 978-90-8815-607-4
KvR: 011/2008

Special thanks to the authors of the background studies;

The province of Zuid-Holland, Xplorelab
Bas Leurs, Dick van den Bergh, Deidre Jakobs-Coolen, Dirk van der Eijk, Erik de Haan, Frank van Pelt, Hasse Goosen, Linda Frinking, Lucy Smeets, Marco van Steekelenburg, Marlies Koppers, Monique de Groot, Niki Muileboom, Paul van Eijk, Ron Mes

+Architecture
Mathilde Peen

Deltares
Olivier Hoes

Dura Vermeer
Steven de Boer, Marjolijn van Eijsden and others

Water Board of Schieland en de Krimpenerwaard
Hans Oosters, Hilde Westera, Jan Oostdam, Jelmer Biesma

Institute for Environmental Studies, VU University of Amsterdam
Luke Brander, Hans de Moel

Nelen & Schuurmans
Edgar van Leeuwen

opMAAT
Hiltrud Pötz, Pierre Bleuzé

TNO Built Environment and Geosciences
Elmer Rietveld, Judith van Brussel, Michiel Brouwer, Theo Reijs

Delft University of Technology
Andy van den Dobbelsteen, Ann Karina Lassen, Michiel Fremouw, Thorsten Schuetze, Kristel Aalbers

University of Utrecht
Caroline Schneider

Wageningen UR
Karianne de Bruin

With thanks to the other colleagues and partners:

Alterra Wageningen UR
Evelien Steingröver, Sabine van Rooij

Consept
Ellen Verkoelen

Deltares
Elgard van Leeuwen, Frans Klijn, Frans van de Ven, Govert Verhoeven, Rob Nieuwenhuis

Dienst Landelijk Gebied
Harm Janssen

Dura Vermeer
Berry Gersonius, Chris Zevenbergen, Elton Boogaard, Gert van Werven, Henk Slappendel, Joell Thepen, Johan van der Pol, Joost Kuijs, Marc de Ruiter, Mariska Mörs, Mark Plaisier, Najib Puyan, William Verbeek

Gouda City Council
Jaap van Bezooyen

Nieuwerkerk aan den IJssel municipality
Chris Schrieks, René van der Linden

Unitech van Hall Larenstein WUR
Gerben Keizer, Joost van der Meer

Water Board of Schieland en de Krimpenerwaard
Hans Oosters, Hilde Westera, Jan Oostdam, Jelmer Biesma

Institute for Environmental Studies, VU University of Amsterdam
Jeroen Aerts

Climate changes Spatial Planning
Florrie de Pater, Marit Heinen, Pier Vellinga

KNMI [Dutch meteorological Institute]
Janette Bessembinder

Province of Zuid-Holland
Adri Jansen, Bart Gosen, Ben Fisser, Chris van Eijnsbergen, Hélène Fobler, Helmut Thoele, Jaap Sneep, Mark Bel, Pieter Jan Hofman, Pieter Hordijk, Renco Mulder, Walter de Vries, Willem de Klijn, Willemien Croes

Universiy of Utrecht
Friedel Filius

and many more

Initial design
Haagsblauw
Jeroen Leupen

Layout design
+Architecture
Mathilde Peen

Printing
Koninklijke De Swart

Hotspot Zuidplaspolder

The lowest lying land area in Europe is situated in the Zuidplaspolder. It is precisely in this area that extensive development is planned. Is this a reasonable idea, and if so, in what way to do this? Especially now that the changing climate is becoming such a prominent issue.These questions adressed the development plans for the Zuidplas and formed the motivation behind the decision of provincial Zuid-Holland's Xplorelab to set up the Zuidplaspolder Hotspot project. *Climate Adaptation in the Zuidplaspolder* is the project's final report.

The project has been commissioned by the national research programme Climate changes Spatial Planning. The project's objective is to increase the climate resilience of the plans for the Zuidplaspolder. Xplorelab used the method: analysis, design and evaluation. The analysis revealed that it wasn't the low land level but drought that would be the biggest issue in the future. Five pilot projects have emerged from this analysis. The evaluation offered the insight that carrying out these designs could have great advantages for society.

Aside from this final report, 8 background studies and 5 pilot projects for climate resilient design have been published.
For more information: *www.xplorelab.nl*

climate changes spatial planning

ISBN 978-90-8815-607-4