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A STRATEGY FOR DUTCH RIVERS TO HANDLE CLIMATE CHANGE AND NEW SAFETY STANDARDS

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ABSTRACT:

Water management is crucial to the Netherlands. An advances system of levees, dams and dunes has been constructed over the past centuries to protect its citizens and its economy, making the Dutch Delta the best protected delta in the world. Programmes like Room for the River and regular maintenance programmes ensure that the current safety levels are maintained. However, to anticipate climate change and increased economic value behind the levees, it is necessary to consider whether the current safety levels standards are still adequate for the long term (2050 and beyond). This is done in the Delta Programme, a policy project to study new safety standards in combination with expected climate change (and hence, increased discharge and sea level rise) and the appropriated measures to reach to those standards.

In this paper, we will explain the process of getting to a balanced choice of measures, solving the combined problem of new standards and climate change. This is not a top-down process, nor bottom up. It is a process which is carried out in a close cooperation with various levels of government and stakeholders. The outcome of the process is a relatively well supported strategy which is however, not a blueprint for 2050, let alone 2100. It gives a direction in which a solution has to be sought, whereas the actual choice of measures (spatial measures, or dike reinforcement) is the subject of the next phase of the Delta Programme.

Key Words: Flood Management, Flood Risk, Climate Adaptation

1. INTRODUCTION

It is often said that the Netherlands, in the delta of the Rhine and Meuse river, is the best protected delta in the world, and this is most probably true. It is the result of centuries of river management, in the first centuries just by pragmatic actions, later on by more sophisticated strategies to prevent floodings as much as possible. This behaviour, however, has also resulted in a kind of lock in. After every flood event, or near flood event, the system of dikes and levees got repaired and improved. As a consequence, population and economy developed again and the values in the flood prone area increased rapidly. Because of that, the safety standards became more and more strict and this sequence was repeated after every flood event. Hence, already early in history it was clear that the Netherlands will always have a situation in which the rivers are constrained between dikes, and that floods should be prevented at practically all costs. Due to this management, the economy developed and the population grew. As economic growth and population growth are national issues, it is obvious that over the centuries, water management became the responsibility of the national government. The society relied on that same government to do that job the best possible way. Floods became almost unacceptable from economic point of view, and the awareness of the society, the fact that a flood could happen in the first place, faded.

In this locked-in situation, things are changing however. The Dutch rivers will remain constrained between dikes, but the water management as such is changing. Safeguarding against flooding is now not only a

task of the national government, but also of the regional and local authorities. River management has become an integral approach, where in earlier days, it was primairily an engineering-job. A hydraulic problem was solved by engineers, with little concern for other aspects. In the nineties, this gradually changed to a setting of multi-disciplinairy approach and finally to a fully integrated approach in which hydraulic, ecological, morphological and also governance aspects are equally well addressed in trying to find a safe solution.

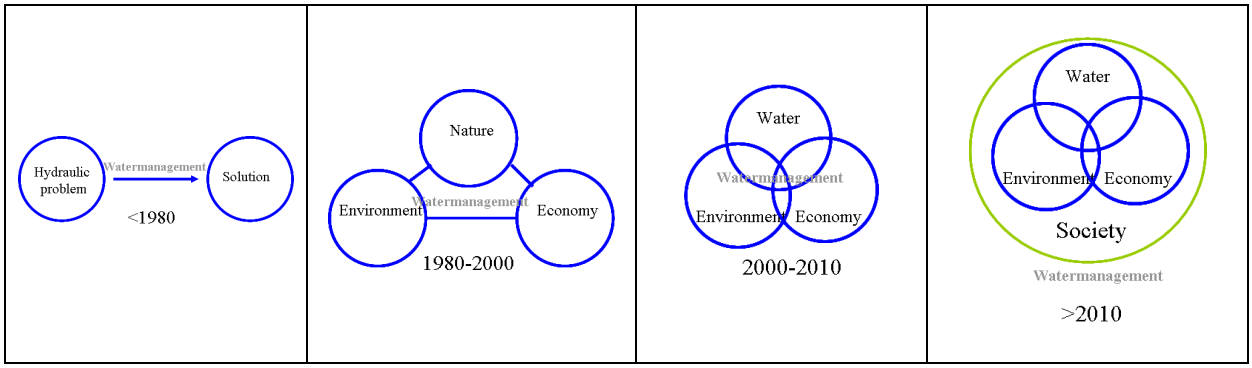

Figure 1: Different stages of water management and the (approximate) times when they were applied

The latest paradigm shift in the Netherlands took place in the years 2008. Around that time, a state commission was installed (see Deltacommissie 2008 for their final report) to investigate what actions in the Netherlands should be taken in the coming century, to maintain the safety in combination with economic development, nature and leisure possibilities. Climate change and economic scenarios were thought to be the drivers for adaptive strategies for the next 50 or even hundred years. This report was the starting point for the Delta programme, a national programme that looks at all water management issues, i.e., at rivers, the sea, the coast, safety as well as fresh water issues and spatial development issues. In this paper, we describe how the subprogramme Rivers of the Delta programme developed, and how the final result, the preferred strategy for the river area for the coming century, has come together. We will also point out the connection with the subprogramme Safety which deals with a revision of the safety standards and which has a very close relation with the strategy that is developed in the subprogramme Rivers.

The paper is organized as follows. In the next section, we touch upon some general principles of what we think proper river management is, at least in densely populated areas. In section 3, we describe how those principles have worked out for the Netherlands, one of the most densely populated countries in the world, and in the delta of two major rivers, Rhine and Meuse. We introduce the concept of the Delta Programme which aims at mitigating the consequences of climate change and increased safety standards. In section 4, we discuss the proposed solution for this problem. We conclude the paper by discussing some of the innovations that have come out of the Delta Programme and with a discussion and conclusion.

2. PRINCIPLES OF FLOOD MANAGEMENT IN A DENSELY POPULATED COUNTRY

Flood management in the Netherlands started already very early in history. The first inhabitants of the Netherlands experienced the benefits of the fertile soil, which was the result of continuous flooding by the rivers of that time. To protect the land from floods they constructed small levees which over the centuries were connected to each other to form a closed system of levees. In the 16th century, the larger part of the land was protected against floods by this closed system of levees. In essence, the system is still present to date. We refer to Ten Brinke (2007) and Van Heezik (2006) for excellent descriptions of the water history of the Netherlands.

For many centuries, the Netherlands already live in a technical setting in which rivers are 'tamed'. This is not to say that floods did not happen in the past. There is a long record of dike breaches at many locations along the river branches, with often substantial damage and loss of lives (see again Ten Brinke 2007). After every disaster, the system was repaired and reinforced. The alternative, moving away from the floodplains and let the river meander freely again was never considered for obvious economic reasons. This behaviour has resulted in a more and more technical setting for the river system in the Netherlands, not only for the dike system but also for other aspects of our rivers. The two bifurcation points in the eastern part of the Netherlands for example, were the Rhine bifurcates into three different branches (Schielen et al., 2007) are now provided with regulation works. In the late 18th century, the bifurcation points were already fixed by constructions, the regulation works have been added only recently. Furthermore, a closure dam which created the largest fresh water lake in Europe (and at the same time made a large inner sea vanish) was constructed in the early 20th century. After the 1953 flood that struck the south western part of the Netherlands in 1953 , a system of highly advanced sea dikes and closure dams (middle and late 20th century) was constructed to protect that part of the Netherlands. So although we often speak about the Dutch Rhine-Meuse delta, it is actually fair to say that our delta is not a classical one, i.e. a system of many, and continuously alternating channels, bringing the water from the river to the sea. Instead, the Rhine-Meuse delta is a system of 4 different rivers (3 Rhine branches and the river Meuse) which are protected by levees (or natural high grounds) from the point where they enter the Netherlands (and far upstream) up to the point where they discharge into sea. There is also a clearly defined navigation channel (the summer bed), and there are floodplains (the winterbed). Every suggestion that our rivers should be brought back to a natural situation in which they can freely meander is nonsense. We are living in a technical lock-in which originates from the middle ages. This lock in has contributed substantially to the well being of the Netherlands as such. The Dutch policy aims at maintaining and enhancing this system and studies how an optimal protection standard can be achieved. Within the limitation of keeping confined rivers, we can think about strategies and measures to improve our safety.

3. THE CURRENT APPROACH IN THE NETHERLANDS

For a long period of time, the flood defense strategy in the Netherlands was to react on flooding events, almost always by reinforcing dikes. The standard action was to repair and reinforce the dikes such that they could withstand that latest flood, and on top of that, add 1 meter to the height of the dikes to be at least safer than before. The methods to calculate flood levels (or design water levels to be precise) are now of course more sophisticated. Nowadays, the protection standards are based on statistical analysis of historical discharges, on extrapolation and extreme value distributions and on the outcome of advanced 2D-numerical calculations. The outcome is used to test the dikes and adapt where necessary, based on the latest scientific insights. Well into the twentieth century however, the measures to comply again with the standards, were mostly dike reinforcements. The society however, did not always approve those measures and over the years, resistance became stronger.

In the early 19-nineties, the first studies appeared which advocated a more integral setting of river restoration. Not only dike reinforcements should be considered, but also flood plain restoration. As synergy, a more natural river landscape would be the result, and nature and recreation would benefit from this. A good example of this strategy is the plan 'Living Rivers' (see Levende rivieren 1992), which was commissioned by the World Wildlife Foundation. The plan was adopted in 1992 by the Dutch government and it was tested for the hydraulic consequences. Results were promising, but at the time the urgency to implement this strategy was not present since no periods of high discharge had happened for a very long time. However, very soon after the WWF-report, two near floods (in December 1993 and in January 1995) occurred, and these events acted as a wake up call for river management in the Netherlands. These events were directly the cause of the increase of the design water levels for the Rhine branches, based on the already mentioned statistical analysis of historical discharges. The time series for the analysis was updated with the events of '93 and '95. The new design water levels were defined in 2001. It was in the spirit of that age to take spatial measures to mitigate the increased flood levels, rather then yet another round of dike reinforcements. This was partly because of the WWF-report and the resulting discussions. These two facts together (increased flood levels, and the preference for spatial measures) came together in the Room for the River programme (see Van Stokkom et al. (2005), De Vriend and Dijkman (2003))

and they reflect the paradigm shift that took place in the 19-nineties. In the Room for the River programme, which started in 2002 and has a total budget of 2.2 billion euros, about 39 different spatial measures have been identified that should be constructed before 2015. After completion, the safety levels will meet the legal standards again[1].

A second paradigm shift can be identified around 2008, so in a period that Room for the River was already under construction. In recent IPCC reports (see for instance the fifth assessment report, Stocker et al., 2013), indications of climate change became more and more eminent. This coincided with a periode in which the Netherlands started to rethink their safety strategy. The reason was that the height of our current safety levels dates back to the early sixties. Since then, both the economic value and the population behind the dikes had increased considerably. The first impression was that the safety levels should be increased with a factor 10. Combined with the predicted consequences of climate change (increased sea level rise and increased discharge on the rivers) these indications made us reconsider the state of the art of the Dutch water management. Rather than to wait for the next (perhaps catastrophic, but in any case devastating) flood event, it might be much better to anticipate on possible floods and to be prepared for those events. Preparation is then found in protection (i.e. more spatial measures, possibly in combination with dike reinforcement) but also in anticipating on floods, by taking measures in spatial planning and by improving the evacuation plans. This approach is called the multilayer safety approach. The idea is not to prevent a disaster ever from happening, but to be prepared as best as possible and to minimize the possible consequences in damage and in losses of lives in the unlikekely case a flood event does happen. This is, in short, the second paradigm shift that took place: from reaction to anticipation.

This approach was advocated by the second Delta Committee who delivered its final findings in 2008 (Deltacommissie, 2008). The name originated from the first Delta Committee which was installed after the large and devastating flood of 1953. Damage was enormous, and about 1835 people lost their lives. It is still an event that is stuck in the common memory of the Dutch people. The work of this first delta Committee lead to the famous Delta Works (among which the famous Eastern Scheldt closure dam) and in fact to the current safety standards. Although there was no direct threat and need of urgency in 2010, both the issue of revising the safety standards and mitigating the climate change problem was enough to establish a second Delta Committee. This committee advised to appoint a Delta Commissioner and to establish a Delta Programme to adress and solve these problems and hence, to make sure that the Netherlands remain a country in which people can work and recreate safely. The Delta Programme consists of 9 different sub programmes (details can be found in Van Alphen 2014) . There is a special programme on rivers, and a special programme on safety.

With respect to water safety, the problem to solve in the Delta Programme is threefold. First of all, new insights in specific failure mechanisms of the dikes revealed that especially the mechanism piping is dominant in Dutch dikes. Piping is the phenomenon in which water flows under the dike and transports sand particles which form a canal under the dike (a ‘pipe’). If this mechanism is not stopped, the pipe can become so big that the dike looses integrity and fails. The result of these new insights in piping is that the failure probability of the dikes due to piping is much higher than previously thought. These problems can only be solved by reinforcing the dikes with additional berms such that the pipe cannot occur. Innovative solutions like geo-textile are now considered as alternative. This piping problem occurs almost along the entire river stretches, although the exact locations are difficult to determine and depend on the soil properties.

[1] The Netherlands are the only country that has the height of the safety levels explicitly in its legislation. The safety levels are linked to return times and hence to discharges, that are again linked to water levels. We call these the design water levels, or flood water levels. Every six years, the system of dikes is tested to see whether the legal standards are still met. If this is not the case, the law prescribes that measures must be taken to comply again with the standards.

The second problem has to do with predicted climate change. As a result, the design discharge increases, and the sea level rises. Increased water levels can be mitigated by looking for spatial measures in the river bed (for example flood plain excavation, dike relocation, side channels) which increase the discharge capacity of the river. Another possibility is to reinforce (in this case in height, in contrast to the piping problem) the dikes. Most probably, the optimal long term solution will be a combination of spatial measures and dikes. We come back to this in the next section.

The third and last problem is the new safety-standards that have been derived in the sub programme Safety of the Delta Programme. The new standards are based on an up-to-date cost benefit analysis and in general, result in standards which are 4 to 30 times stricter (sometimes even a factor 100 stricter at specific locations) (see Van der Most et al. 2014). Meeting the new safety standards can only be realized by making the dikes stronger (not higher), because due to the geographic situation outside the Netherlands, the discharge is limited to a critical number. Above that, large floods occur in Germany. This means that also the flood levels are limited. The situation for the river Meuse in Belgium is somewhat different, but also here, there is a limit to the increase in discharge.

Although not explicitly mentioned, it turns out that there is a fourth problem, and that is raising and maintaining awareness of flood risks and the need for flood management. Especially in situations where there is already a very high safety level, this is potentially a difficult task. Establishing the Delta Programme as such and getting media attention, contributes to keeping the awareness on a proper level.

The three problems have their own time scale. Climate change is on the scale of decades, and mitigation is expected before 2050 (and 2100 for the long term). The safety standards are derived for 2050 (because there are no economic scenarios beyond 2050) and problems due to piping are imminent.

4. SOLVING THE PROBLEM

From the start of the sub programme Rivers, in 2010, it has been clear that solutions to the treefold problem could not be issued top down by the national government. Informing the ‘region’, i.e. municipalities, water boards, provinces and non governmental organizations on a regular basis would not suffice. Instead, the region was actually made responsible for desiging a solution consisting of a set of measures (be it spatial measures or dike measures) and for finding enough support for this solution within the region. The Delta programme provided the ‘assignment’ i.e. the increase in flood levels due to climate change, and the increase in safety standards, as well as numerous tools which facilitated the region in finding a balanced set of measures. The starting point was always the situation of (around) 2015, when the large programmes of Room for the River and the Meuse Works (a large scale river restoration programme along the river Meuse) are completed.

Many regions have found a strategy which can be described as the best of two worlds: dike measures as well as spatial measures. In general, the leading principle is: spatial measure to mitigate climate change where possible, dike reinforcement where it is necessary. In the end, it is a powerful interplay between dike reinforcement and spatial measures. The strategy itself varies between the different Rhine branches and Meuse, which is partly because also the problem on the branches differs. Along the river Waal (the main river for transportation by ship), a backbone of rigorous spatial measures has been defined (dike relocations as well as large bypasses). Even a time schedule for these measures has been proposed, varying from concrete measure to be implemented before 2030 to measures which are considered between 2030 and 2050 up to suggestions for measures after 2050. Along the river IJssel, a thorough analysis resulted in a more concrete set of measures to be constructed before 2050, and an indicative set of measures after 2050. In this latter set, a large retention basin with a capacity of 40 million m3, located in the most upstream Dutch part of the river Rhine is proposed. This has also beneficial effects for the river Waal. The river Nederrijn solves most of the problems with dike reinforcement. This is due to the fact that there is only limited space available along the flood plains of the Nederrijn. Room for the River has already pushed the spatial possibilities along that stretch to the limits. Due to an agreement made in Room for the River, the excess-discharge above the current design discharge is not directed to the Nederrijn. The river Meuse, finally, very specifically solves a part of the water safety problems with dike

reinforcement, and a part with spatial measures. For the Meuse, it is relatively easy to realise the new safety-standards by implementing spatial measures.

There is in the region a wide support for this 'preferred strategy', as it is called, at least on the administrative level. It has been negotiated in the past 5 years. A clear and reproducible route has been followed to come to this strategy: after exploring the possibilities in defining 'possible strategies' (2010-2012), the result of 2013 was a limited set of 'likely strategies', and 2014 has been used to finalise the preferred strategy. It goes without saying that not everybody has been consulted yet and not everybody agrees with this strategy. In the final stage of the Delta programme, some elements of the strategy were picked up by newspapers and television and caused some turbulence in the municipalities. It has to be stressed however, that the preferred strategy is not a blueprint of static and clear defined measures. Even the measures for the mid-long term (after 2030) can still change or can be replaced by other solutions. The preferred solution offers a clear *direction* to the approach of water safety, and explores combinations of solutions to water safety with other functions in the river area.

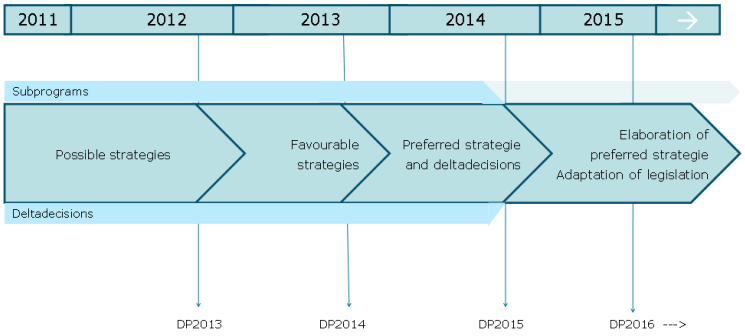

Figure 1: schematic representation of the Delta programme. DP2013 (and further) refers to the progress reports that are issued every year.

4.1 Costs

As said before, the problem that needs to be solved is at least threefold: bringing the system up to date, implementing new safety standards and adaptation to climatic changes. To bring the system up to date, most dikes have to be adapted and must be equipped with large berms to prevent piping from happening. Calculations show that these might be up to a few hundred meters wide. This is not only from societal point of view a measure with substantial impact, it is also a very costly measure. Costs are estimated to be of the order of 2.5-4.5 million euro per kilometer, so altogether in the order of billions of euro's. The bandwidth comes from the fact that one can choose to construct the berm on the river side of the dike, or on the land side of the dike. On the river side is cheaper. On the other hand, innovative solutions (application of geo-textile instead of berms) can reduce these costs enormously. Spatial measures to mitigate climate effects are also costly. Experiences from Room for the River learn that a typical flood plain measure costs somewhere between 10 million euros for a small measure (for instance a small side channel in a floodplain) up to 350 million euros for a large measure (a large dike relocation with a side channel and adaptations to improve the spatial quality). Regular dike reinforcement (as additional measure in case the spatial measures are not sufficient, or in order to comply with the new safety standards) cost in the order of 3.5-6 million euros per kilometer (this is then including repairing the piping problem). There is of course the possibility of synergy: making the system up to date, solving the climate problem and the problem of new safety standards in one step can lead to savings of more than 40 percent. Most savings come from the fact that the road and the infrastructure on the dike only have to be removed and reinstalled again a single time.

5. INNOVATIONS

The Delta programme as such has brought numerous innovative aspects in (delta) river management. One of the most obvious innovations is perhaps on the meta-level: instead of taking action *after* a (near) disaster, and hence, *responding to* an event, the delta programme takes into account various scenarios for the future in order to be prepared *before* anything happens and thus *anticipates* future events. To our knowledge, this has not been done before anywhere in the world. There are also important innovations, both in the governance of the Delta Programme and in the technical approach. In the scope of this paper, we want to mention two of them.

5.1 Joint Fact Finding

Joint fact finding (Karl et al. 2007, McCreary et al. 2001) in the delta programme is used to bring together all available knowledge on a certain (sensitive) subject. This gathered knowledge is then discussed in expert groups and shared with policy makers and administrators. Conclusions and recommendations as a result of this process can count on general support, have authority and thus minimise the chance of a battle of opinion.

Joint fact finding has been applied to a specific problem of the discharge distribution of the river Rhine in the eastern part of the Netherlands. There are two bifurcation points right after each other at which the river splits into three branches. From safety point of view, this ratio needs to be (almost) fixed at high discharges because the height of the dikes downstream the bifurcation points depend on that. This is so important that the specific ratio at design conditions has been prescribed in policy documents. Changing this discharge distribution, and directing more discharge towards a branch that has more capacity may lead to a cheaper or more robust solution for the problem defined in section 4. On the other hand, this is a major (system) intervention which requires massive technological and constructional efforts and which effects all the downstream branches with respect to the problem that have eventually has to be solved. Joint fact finding has led in this case to the conclusion that in 2017 the situation around the bifurcation points is judged again with the knowledge and boundary conditions of that time. This may then lead to a decision to change the discharge ratio after 2050.

5.2 Governance

The Delta programme emphasizes that cooperation between the national government, provinces, water boards en local authorities creates substantial synergy and leads to solutions which are supported by many of the stakeholders (see Teisman and Van den Aarsen 2014). This cooperation is particularly important because the physical borders of the water bodies (rivers, local streams, lakes) in general do not coincide with the governmental borders. There is a system-dependency in river management (action at one location influences water levels at many other locations) and that calls for proper governance. The sub programme Rivers of the Delta programme has therefore chosen for an approach per region (geographically roughly based on the different branches of the river) with commitment of government agencies on different levels. The programme aimed at commitment of societal organizations, joined in a ngo-group. To a certain extent synergy with respect to other (economic) functions was included. At this moment individual citizens are not explicitly involved, but they will be in a later stage.

This approach fits well in a general trend, experienced in large programmes, that there is a shift from government approach to governance approach in which different levels of government interact. An important aspect is that the interdependent interference of acting on different levels creates more value than isolated actions on the individual levels. This also contributes to the aspect of selforganisation, which has taken place in the region approach.

6. DISCUSSION AND CONCLUSION

Proper flood management is a matter of national importance in the Netherlands. With 25% of the area of the country below sea level, and with almost 2/3 of the country flood prone, the consequences of flooding are beyond imagination. Not only is 70 % of the GDP earned in the protected area, also the lives of 6 million inhabitants are at stake. That is why the current safety standards are already the highest ones in the world. Yet, maintaining the defense system as such will in the long term not suffice. Maintenance is necessary, of course, for it reveals weak spots at levees which can then be repaired in regular maintenance programmes. But every 25 years or so, the safety approach itself should also be reviewed in order to bring it up to date and in accordance with new knowledge and with the new situation with respect to protected value. Then there is also the issue of climate change which causes flood water levels to rise due to higher design discharges. The challenge is to come up with a strategy that solves these combined problems in a cost effective way, with widespread (societal and administrative) approval. This is exactly what has been done in the period between 2010 and 2014 in the Dutch Delta programme. In a period of almost 5 years, in a well defined and reproducible way a preferred strategy has been put together. This strategy consists of a balanced mix of dike reinforcements and spatial measures. It is not a blueprint but forms a strategic compass for the coming decennia. Up to 2050, the measures that need to be carried out in order to solve the problem are relatively clear. This is not a fixed set, however but they should be viewed as possible measures that solve the problem, but alternative measures at more or less the same location with the same effects can also do the job. Exactly what measures are going to be implemented is something that is going to be determined in the coming years (before 2018). After 2050, the strategy acts as a guideline for the next 5 decades, but the set of measures can again change due to the circumstances (economic, demographic and climatologically) of that time. This is the principle of adaptive delta management.

The process of the Delta Programme revealed new innovative methods, such as applications of joint fact finding and innovations in governance. The process of the delta programme itself is also innovative. It is the first time in history that a country determines its water management on anticipation rather than reaction. The process is neither top down, nor bottom up. It is a process in which the region is taken along from the beginning in the problem formulation right to the end of deciding on the supported solutions.

The approach of the delta programme had another advantage which was not intentionally but turned out to be very positive. Through the delta programme, the issue of proper water management stayed on the policy agenda in the last 5 years, without having even a slightly high discharge in that period. Normally in such a situation, awareness might have dropped dramatically and planning measures needed for water management might have resulted in opposition from the general public because of a (misplaced) feeling of lack of urgency. Now, at least awareness has stayed on the agenda, and in the unfortunately event of a (near) disaster in the next five years or so, a well balances strategy is at hand to be carried out. In this way, the Netherlands keep their position as a guiding country in flood management issues and they continue to export new knowledge in water management.

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