Preparing for an uncertain future through option analysis

The case of the Roode Vaart

C.G. van Rhee

Infrastructure projects are subject to policy and exogenous uncertainties such as the impact of climate change. Being able to anticipate and manage uncertainties adds value: investment costs and risks can be reduced and/or benefits and opportunities increased. In order to manage these uncertainties and avoid over- and under-investment in deltas and water management, the Dutch Delta Commissioner has developed the Adaptive Delta Management approach (ADM). One of the characteristics of this approach is the active search for opportunities to link investment agendas and to take advantage of possible synergy benefits.

A case from the Southwestern Delta in the Netherlands illustrates the practical value of this method. In this area of the Netherlands, the ADM approach was first put into practice in the regional implementation strategy for the Grevelingen, Volkerak-Zoommeer, and freshwater supply. To secure allocation of sufficient freshwater for agriculture and water level management purposes now and in the future, there is a temporary opportunity to (pre)-invest in a water passage through the city of Zevenbergen. This has immediate value during cyanobacteria outbreaks in the Volkerak-Zoommeer when the water from the Volkerak-Zoommeer is not usable. But it also has a potential future value in case the Volkerak-Zoommeer becomes salty or if the demand for freshwater surges due to climate change and changes in land use.

This paper presents the case of the Roode Vaart – or the water passage through the city of Zevenbergen – and compares the alternatives and the values of these alternatives, concluding that pre-investment is a rational financial decision in spite of the policy and climate uncertainties. Due to the fact that this freshwater measure is still under adminis-

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trative debate, the statistics employed in this paper are indicative, and actual figures are omited to avoid interference with the policy process. The use of another set of alternatives and assumptions in the evaluation may lead to different conclusions.

Uncertainty and the financial implications of climate change require adaptive delta management

The anticipated climate change requires increased protection and additional measures to secure adequate freshwater supply for deltas in the Netherlands. This task is large because of a delta's natural properties, which amount to a number of both advantages and disadvantages. There is an increased vulnerability to sea-level rise and greater river water discharge in winter, and reduction in summer rainfall and land subsidence by groundwater withdrawal. At the same time, there is usually a high population density and greater prosperity in deltas, with excellent transport links to and from the hinterland and other parts of the world, and more fertile soil. As a consequence, much has been invested in deltas, and this makes their protection essential. Hence, there is a need for delta management.

To ensure the long-term goals in the areas of water safety and freshwater supply, the Dutch Delta Programme was set up. The infrastructure in the Netherlands has to be adapted, but how can this be done effectively? What decision or series of decisions are necessary? There is a need for a sober and flexible approach.

The uncertainties are huge: both the socio-economic developments and the pace of climate change are difficult to predict. We cannot make statements about the distant future with certainty. The further we look forward and the more uncertain our estimates of the costs and benefits are, the more problematic this becomes. We cannot afford to assume the worst possible climate scenarios. That would lead to draconian measures and extreme cost, which might well prove unjustified in the end. On the other hand, we cannot wait until things go wrong. In addition, (regional) executives have to deal with the often uncertain outcomes of decision-

making processes at national level or across regions and disciplines, all of which can have a large impact.

Therefore, we have to look ahead and to develop our environment in connection with changing spatial conditions, because adequate measures often have both a long lead-time as well as an interaction with socio-economic activities. This is not only about reducing drawbacks but just as much about seizing economic opportunities and synergy benefits. To meet these ambitions, flexibility is crucial. Hence, we add the term adaptive to our method: Adaptive Delta Management.

This approach adds the aspect of time as a variable to cost-benefit analysis. It no longer assumes investments being made at a fixed moment in time, but seeks to optimize the timing of investments or decisions based on coupling opportunities and actual developments as they unfold. Adaptive Delta Management aims to include uncertainties about future developments in decision-making in a transparent way. It focuses on the following points:

- Connection of short-term decisions with long-term challenges. Why? Because short-term savings can be realized or unnecessary future cost increases can be prevented with the relatively limited effort of coordinating initiatives. Example: making land reservations for future expansion.
- Working with decision sequences and adaptive pathways instead of end states. Why? Because it is not always cost-effective and necessary to implement short-term measures in favour of a long-term target situation. Example: the phased strategy to ensure water safety and freshwater supply in the cases of the IJsselmeer and Afsluitdijk. Postponing measures has the advantage of a better understanding of the actual developments before a decision is made, but the risk of being too late to move.
- Identifying and valuing flexibility in strategies and measures. Why? The ability to accelerate, delay or alter strategies or measures provides more opportunities for their implementation in line with actual developments, and prevents possible over- or under-investment. Example: regular sand nourishment instead of single dike reinforcement.
- Seeking opportunities to connect various investment agendas. Why? By linking agendas, synergies can be realized in terms of

social benefit and cost savings. Example: the water passage of the Roode Vaart, where an investment in future freshwater supply is brought forward and combined with the redesign of the city centre of Zevenbergen.

In Adaptive Delta Management we look for solutions that are both robust and flexible. A robust strategy is one that is useful across various plausible scenarios. A flexible solution simplifies switching to other strategies later on, should actual developments demand so, and makes it easy to speed up or slow down the pace of implementation.

Adaptive Delta Management leads to a compound adaptive strategy or a set of alternatives with intermediate adjustment options. By this we mean that the method results in a roadmap or series of possible decisions, of which perhaps only the first stands. Final choices on timing and execution can be adapted to the actual developments identified in water management and spatial planning, and to new insights and operationalization of innovative technologies.

The approach consists of several qualitative and quantitative analyses (table 1). In practice, comparing the valuation of the alternatives is considered the most difficult. This is because of the combination of multiple options and uncertainties. However, with option valuation it is possible. We will illustrate the approach with the case of the Roode Vaart.

Table 1: Combination of investment agendas is an important element of Adaptive Delta Management to reduce costs.

Linking of short-term decisions to long-term challenges	Pathways instead of end states	Identification and valuation of flexibility	Linking of investment agendas
• No regrets • Urgent opportunities • Anticipatory measures • Scenarios	• Tipping points • Time windows • Lock-ins and lock-outs	• Optimal order decision-making • Risks and indicators • Option valuation (real options analysis)	• Linking opportunities • Windows of opportunity • Synergy

One of the characteristics of the Adaptive Delta Management approach is the active search for opportunities to link new invest-

ments to proposed and possible plans, investments and initiatives by public and private parties. Linking the investment decisions for the water challenges to the investment agendas of others is a way to seize benefits for society and make better use of investments. Combination of measures realizes synergy or prevents cost duplication.

Examples include the combination of activities in a single period, which reduces both inconvencience and construction costs, and the merging of actions that join multiple features and solutions, such as an open connection between the basins of the Grevelingen and Volkerak-Zoommeer. This facilitates both a salty Volkerak-Zoommeer, improving water quality, and also provides a passage for temporary excess water storage in the Grevelingen, improving water safety.

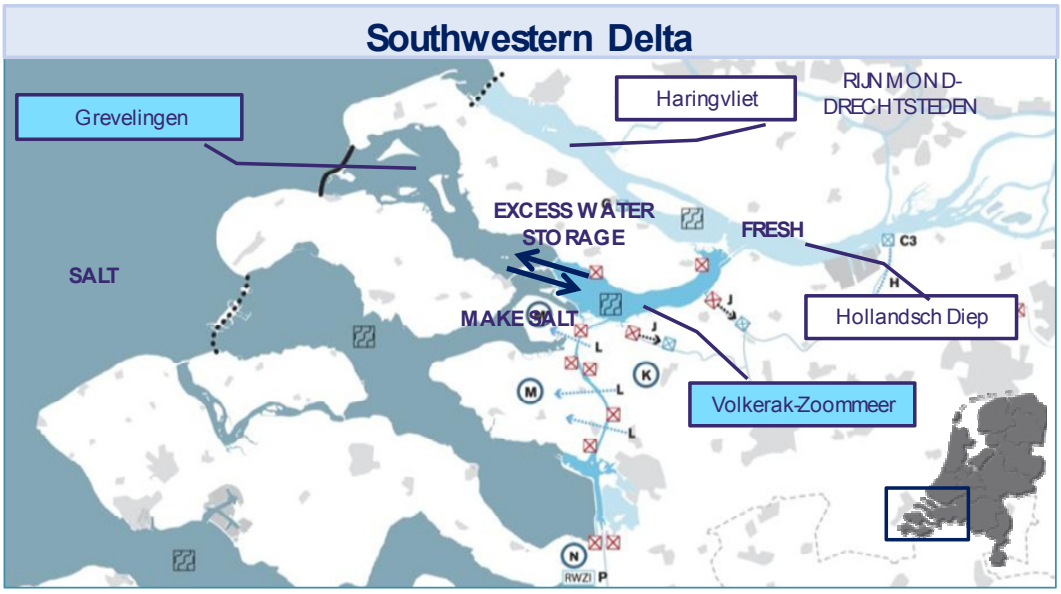

Figure 1: Overview of the Southwestern Delta (adapted from the implementation strategy for the Southwestern Delta, 2012).

It is necessary to weigh the cost of deviating from the original optimal timing, which was based on an autonomous choice, against the benefits of combining measures by advancing or delaying them. A new optimization can be derived from the required sequencing of actions, interdependencies, separate lead-times, and the costs and benefits of advance or delay. An illustrative example is the chosen solution for the Prins Hendrik Dike on Texel. Its traditional reinforcement would lead to adverse effects for housing

and agriculture. With an alternative, sandy solution, these disadvantages are avoided and measures meet regional objectives in the field of nature. This alternative effectuates a more natural Wadden system and makes contributions from the Wadden Fund possible. Similar examples can be found in the Southwestern Delta. We will elaborate on one of these opportunities: the Roode Vaart.

The Dutch Southwestern Delta: background and problem description

In the Southwestern Delta (figure 1), plans and projects from many domains come together. Commercial shipping is on the increase and requires an enhanced capacity of the Volkerak-sluices to reducing waiting times. The Krammer-sluices and their fresh-salt separation system are up for major repairs. The regional economy, nature and recreation require improvement of water quality in the Grevelingen and the Volkerak-Zoommeer. It is desirable for agriculture that freshwater supply in this area becomes more robust. The question is being examined as to whether excess water storage in the Grevelingen can postpone or downsize measures along the Haringvliet, Hollandsch Diep and in Rijnmond-Drechtsteden needed for long-term water safety.

The costs and benefits of all of these projects and their execution options are interdependent. Some choices exclude certain solutions and some choices affect costs and benefits. In order to find an overall solution for the whole area that is as efficient as possible, a comprehensive implementation strategy considering all options and scenarios is required. In this particular case: three main issues need to be decided upon:

1 For/against the reintroduction of tidal movement in the Grevelingen to improve water quality in this salty lake;
2 For/against temporary excess water storage in the Grevelingen to improve water safety in the area north of the Grevelingen;
3 For/against whether the Volkerak-Zoommeer should become salty to solve water quality issues. After the flood in 1953 and the construction of the Delta Works, the Volkerak-Zoommeer developed into a freshwater lake. However, the water quality of

this lake needs improvement, as it suffers from annual cyanobacteria outbreaks. This results in little water recreation and economic activity, especially in comparison with the Grevelingen. A salty lake could solve this problem.

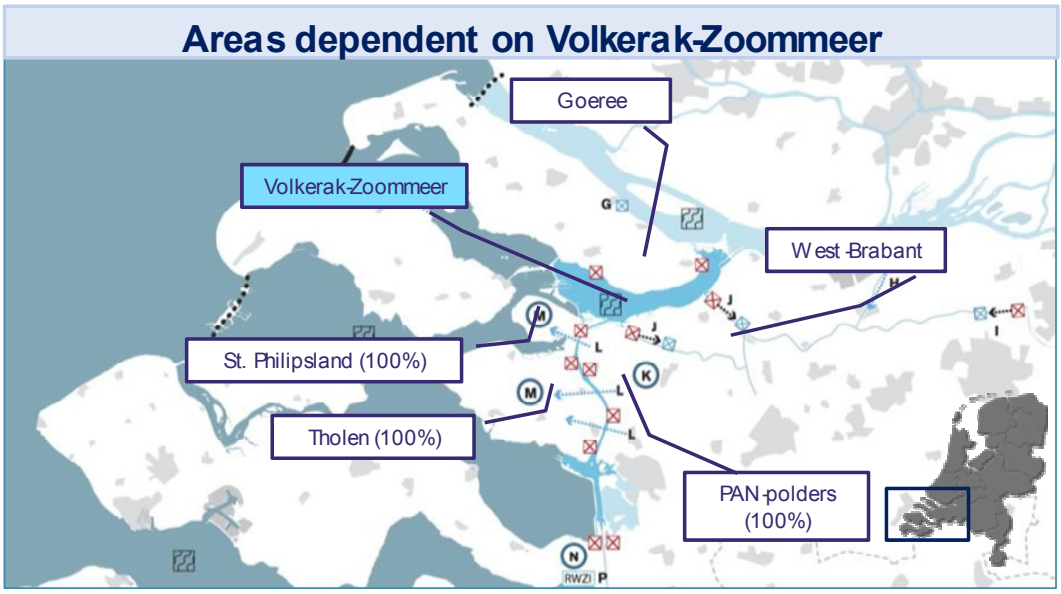

Figure 2: Overview of areas dependent on Volkerak-Zoommeer for freshwater supply.

Issue 3 is relevant for our case of the Roode Vaart. A future salty Volkerak-Zoommeer would require additional supply of freshwater, since its water is currently being used for irrigation (sprinkling), water level management and flushing. Adjacent areas even depend fully on the lakewater, as can be seen in figure 2. Hence, in the future an alternative supply of freshwater is a prerequisite should the Volkerak-Zoommeer become salty. But this is not a matter of certainty. This decision requires expensive measures to make the lake salty, for combating salt intrusion and for an alternative freshwater supply, and the consequences of climate change and changes in land use are not clear. The balance between demand and supply of freshwater may change.

But even now, the freshwater situation is problematic. During summer, its intake is sometimes prohibited due to the development of cyanobacteria in the Volkerak-Zoommeer. These bacteria produce a smelly slush and secrete toxins that make people and animals sick. The areas around the lake that are 100% dependent on the supply from the Volkerak-Zoommeer experience dimin-

ished crop growth and production yields, due to the lack of freshwater. There is also damage due to inadequate water level management at such times. In these conditions, a second freshwater 'tap' would be beneficial.

Even at present there is an advantage to the autonomous start of freshwater measures such as the passage of the Roode Vaart through the city of Zevenbergen (figure 3) if benefits outweigh costs. *So how can be determined whether measures are cost-effective under these uncertain conditions?*

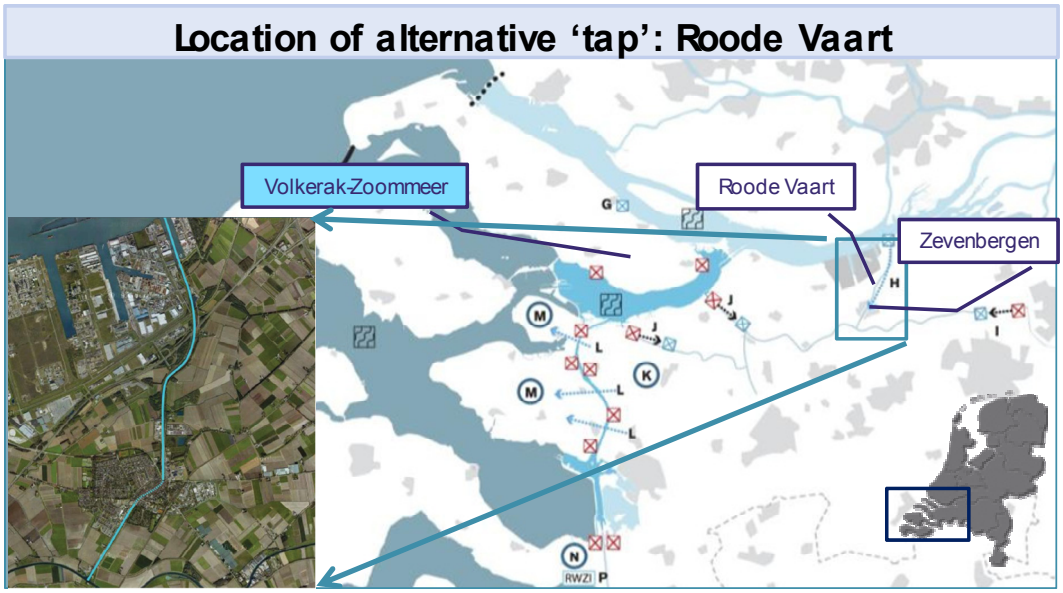

Figure 3: Alternative freshwater tap: the Roode Vaart.

Valuation of the opportunity

Because of policy, climate and social-economic uncertainties it is not easy to determine whether investment in a passage through Zevenbergen is a no regrets option or a sound opportunity that should be pursued. Before expanding on this evaluation, first we explain the opportunity at hand.

Redevelopment Master Plan for the city centre of Zevenbergen

The city centre of Zevenbergen will soon be redeveloped. Two alternatives for the redevelopment are being put to the vote: a 'green' one and a 'blue' one. The green one consists of the development of a park-like promenade. The blue alternative includes the restoration of the Roode Vaart and the old quay walls. This waterway was filled up in the seventies. This alternative has the option to carry freshwater from the Hollandsch Diep to the Mark-Vliet-Dintel river system, possibly in two or more capacity steps: first 3.5 m^3, later 10 m^3 or 12.5 m^3. Through this river system, freshwater can be distributed further into the western parts of the province of Brabant and via some additional measures to Tholen and St. Philipsland in the province of Zeeland. In this way, an alternative supply can be achieved for the areas that are now fully dependent on the Volkerak-Zoommeer for freshwater.

Basic construction costs of the green or the blue alternative are the same. In order to avoid double counting, construction costs of the water passage itself is excluded from the comparison. They are accounted for within the cost-benefit analysis of the option to make an initial investment in freshwater supply in combination with the redevelopment.

Both the blue and the green alternatives deliver comparable benefits. The attractiveness of the area will be enhanced, resulting in a value increase of the surrounding homes and buildings and an expected growth in retail sales. There are no indications that these effects will differ between the alternatives. The blue variant may cause an increase of leisure spending if moorings for recreational boating are built. Since it is uncertain whether they will actually be constructed and at what cost, this benefit is not taken into account. On the other hand, the passage of recreational vessels could deliver additional benefits. But this opportunity comes at high cost and its implementation is currently considered unlikely.

An initiative called Waterpoort aims to connect cities by water in the region around the Volkerak-Zoommeer. Five municipalities around the lake, the three responsible provinces and several other institutions and stakeholders have signed a Cooperation Agree-

ment. The blue variant for the centre of Zevenbergen fits well within this framework.

Cost and benefits of the option

As discussed before, the passage of the Roode Vaart is required should the Volkerak-Zoommeer become salty. If it remains a freshwater lake, there are benefits whenever cyanobacteria prevent the use of water for agriculture. However, is an initial investment cost-effective? It is not yet certain whether pre-investment is worthwhile: a salty Volkerak-Zoommeer requires a higher freshwater capacity than the initial investment can provide, and phased construction is usually more expensive than a single investment. A fresh Volkerak-Zoommeer does not require additional water supply immediately. The current financial means do not allow for 'nice to haves'. Only if combining the investment agendas of the national and regional government pays off for all parties involved under all scenarios, the option is likely to be exercised. The option should be a real no-regrets option. To qualify as a no-regrets option, a measure should:

- contribute to solving existing water quality problems;
- have a positive benefit to cost ratio, which is likely to be positive or neutral in all possible scenario, i.e. for both a fresh and a salt Volkerak-Zoommeer and under changing demand and supply conditions.

To evaluate whether this option is cost-effective, we first explore the required measures and corresponding costs and benefits for all plausible scenarios. These scenarios differ in: (a) whether the Volkerak-Zoommeer becomes salty or stays fresh; (b) the demand and supply for water, depending on climate change and social-economic developments; and (c) the development of new alternatives to the Roode Vaart for freshwater supply. Since this case is used to illustrate option analysis, we will focus on the impact of a freshwater or salty Volkerak-Zoommeer.

During the first years the Volkerak-Zoommeer will stay fresh, because making it salty would require costly and time-consuming

changes to the infrastructure and several measures to mitigate any adverse effects. In this period the pre-investment (for 3.5 m^3/s) can be made, consisting of a pumping station that sends the water from the Hollandsch Diep through the Roode Vaart, the reconstructed canal through the centre of Zevenbergen and some pumping stations, culverts and water inlets to lead the water to the PAN-polders (1a and 3 in figure 4). This water supply can already be used during cyanobacteria outbreaks to prevent crop damage in Brabant.

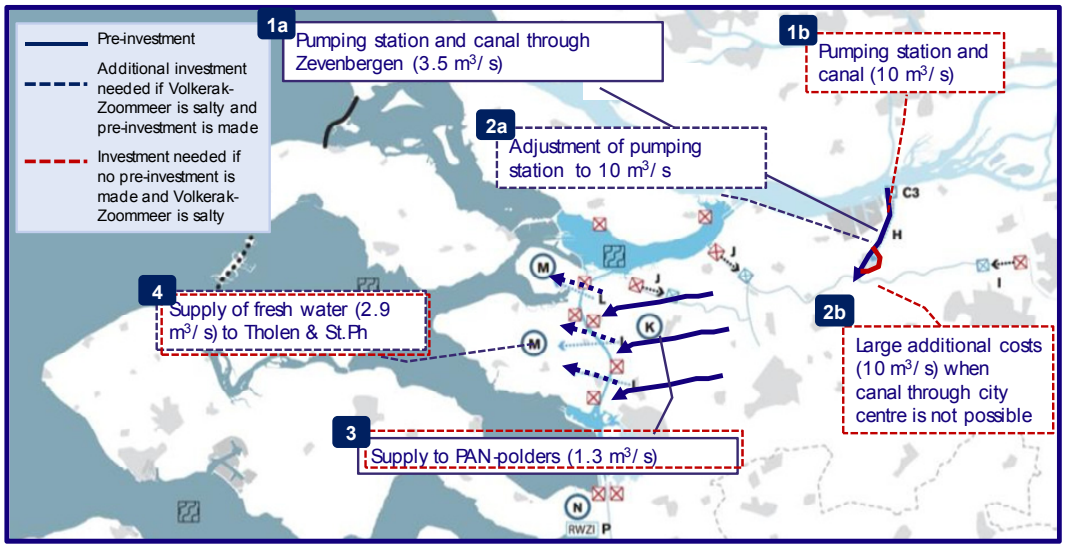

Figure 4: Overview of measures included in the Roode Vaart option.

Should the Volkerak-Zoommeer become salty, the canal's capacity can be increased (2a in figure 4) and the water supply can be extended into Zeeland (4 in figure 4). This phased construction of the pumping station near the Hollandsch Diep is slightly more expensive than immediate construction for maximum capacity.

In the case that this option is not used and the Volkerak-Zoommeer becomes salty, a passage through Zevenbergen would no longer be possible. It is not probable that the city centre will be reconstructed a second time. A detour must be made in the green alternative as well as in the blue one without the initial investment. Such a canal around Zevenbergen is more expensive (2b in figure 4) because greenhouses and other industrial activity need to be expropriated. As for the required pumping station, this can be constructed all at once, saving cost. Extension of the water supply to

the PAN polders and to Tholen and St. Philipsland requires the same costs as when an initial investment is made.

Comparing the different costs, we may conclude that, in the case of a fresh Volkerak-Zoommeer, making an initial investment causes higher expenses, but in the case of a salty Volkerak-Zoommeer exercising this option is cost-effective. A detour would be much more expensive than the difference in costs between a phased or single construction of the pumping station. In this example, the annual agricultural benefits of the supply to West-Brabant and to the PAN-polders are considered to compensate for the initial investment cost (1+3). So even if the Volkerak-Zoommeer remains fresh, exercising the option has a positive return.

Decision roadmap

Basically, there are three issues:

1 The blue or green alternatives which are to be decided upon at municipal level;
2 A pre-investment in the Roode Vaart to be decided upon by the province and regional water boards. This decision is needed within the next five years, but is only possible if the blue alternative is selected. For the green alternative this option does not exist;
3 Whether the Volkerak-Zoommeer becomes salty or stays fresh. This decision is related to two other primary decisions in the Southwestern Delta that have a national impact through the Delta Programme. A decision is not expected before 2015 and needed by 2027 at the latest.

The third issue is outside the scope of the regional decision-makers in Brabant, and will not be decided upon shortly, as it is connected to other Delta decisions. But the first decision is urgent. We can decide upon the first two, even without knowing what will be the result of decision three. How is this analysis done?

The three alternatives (see figure 5) are:

A The green alternative (without a pre-investment option);
B The blue alternative with the option exercised;

C The blue alternative without exercising the pre-investment option.

First we examine the mid-term future with a freshwater Volkerak-Zoommeer. In this case there are no differences between the alternatives resulting from the decision to keep the Volkerak-Zoommeer fresh. In case of alternative A (no option) or alternative C (not exercising the option) there are no costs and benefits in the short term either, because there is no pre-investment. The costs and benefits of the blue and green redevelopment alternatives are roughly the same, possibly with a slight advantage for reconstructing the canal because this would align with the Waterpoort ambitions. Hence, it is required to assess whether the benefits of the pre-investment outweigh its costs. As a matter of fact the net present value of the investment is positive. Within a few years, the avoided damages to crop productivity and water level management are higher than the investment costs. Consequently selecting the blue alternative with the option of the water passage has the highest return.

However, what will happen when the Volkerak-Zoommeer turns salty? In the case of no pre-investment (alternatives A and C) the costs and benefits are identical in the short and medium/long term. The most urgent decision about the redevelopment of the city centre slightly favours one of the blue alternatives, or C in the case that only A and C are compared.

Then alternative C is compared with alternative B. The pre-investment option has a higher return because of the expensive expropriation and detour that it prevents.

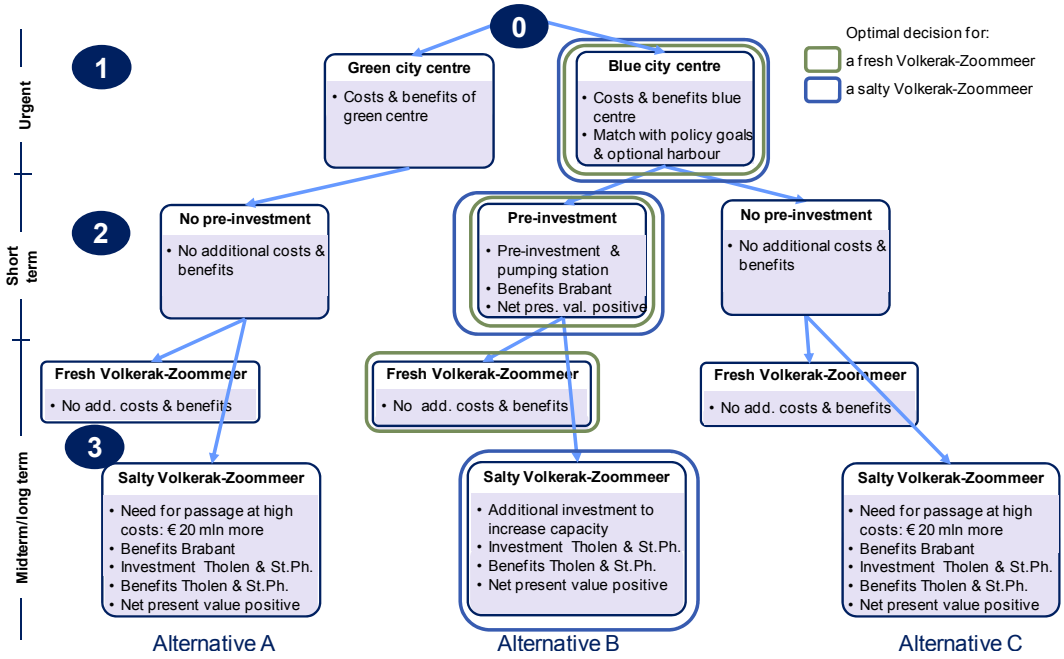

Figure 5: Overview of decisions, scenarios and alternatives.

Even if a salty Volkerak-Zoommeer is a matter of certainty, pre-investment is cost-effective. Weighed against the one-off construction, the additional costs of a phased decision are small given the annual costs it prevents. Hence, this investment will break even before a salty Volkerak-Zoommeer can be implemented.

Conclusion: pre-investment is a no-regret measure

For a lasting, fresh Volkerak-Zoommeer

For a lasting, fresh Volkerak-Zoommeer there are no clear differences between the three alternatives in the medium and long term if we ignore changes in supply and demand for water. However, there is a difference between alternatives B and A/C in the short term. This depends on the benefits of the pre-investment. Do the benefits of the investment outweigh the costs during the period of temporary water shortages? In this case they do. Recuperation of the investment is done within a few years.

For the city of Zevenbergen, there is no clear distinction between the returns of the blue and green versions of the Master Plan. Since construction costs for these alternatives are equal, the

choice is financially neutral but the choice for the blue variant is in line with the Co-operation Agreement Waterpoort.

For a salty Volkerak-Zoommeer

The measures constructed in alternative B are for the most part equally useful for a salty Volkerak-Zoommeer. Additional costs for the capacity extension are relatively limited. Since the Volkerak-Zoommeer will not become salty within a few years, the annual agricultural benefits are sufficient to recover this investment before then. Starting with a throughput of 3.5 m^3/s is a wise choice as well for a Volkerak-Zoommeer becoming salty.

The construction of the Roode Vaart through the centre of Zevenbergen (blue version) prevents the need for a future canal around Zevenbergen. The total costs for a route around Zevenbergen are much higher than the additional cost of increasing pumping capacity, in particular if the greenhouse area should develop further. Another advantage of the blue variant is that the capacity adjustment of the Roode Vaart needed for a salty Volkerak-Zoommeer will have a shorter duration than the construction of a new route including land acquisition.

If the Volkerak-Zoommeer becomes salty, there is a need for an alternative freshwater supply to Tholen-St. Philipsland. The costs of creating a freshwater supply from West Brabant are lower than the increase in agricultural income. This applies equally to a flow capacity at the level of current demand, and to an upgraded one. Moreover, there would be additional advantage of ensuring continuous availability of freshwater.

Combination of scenarios

Based on the information used, it can be stated that the blue variant of the Master Plan can be considered as a set of no-regret measures. This also applies to the initial investment in the water passage.

The choice of this alternative is positive in both scenarios, fresh and salty. Taking into account long-term changes in demand or supply also support this conclusion. The investment has a positive return within a few years. Should freshwater demand reduce, this would only impact the need for a future capacity extension. If demand decreases, capacity will not be increased. If there is a growing need, the initial investment becomes part of the end state and has a positive return, both for a salty and fresh Volkerak-Zoommeer. For a freshwater lake, pre-investment will actually bring greater benefits. Crop damage during cyanobacteria outbreaks will be better avoided, giving initial investment a higher return.

Therefore, in spite of the many policy and climate uncertainties it has been possible to determine a rational financial decision. Systematic option analysis as promulgated in the Adaptive Delta Management method prepares for an uncertain future and limits the chances of over- or under-investment. It gives us a roadmap with a decision sequence that provides benefits and allows us to seize the opportunities offered by linking ambitions and investment agendas.