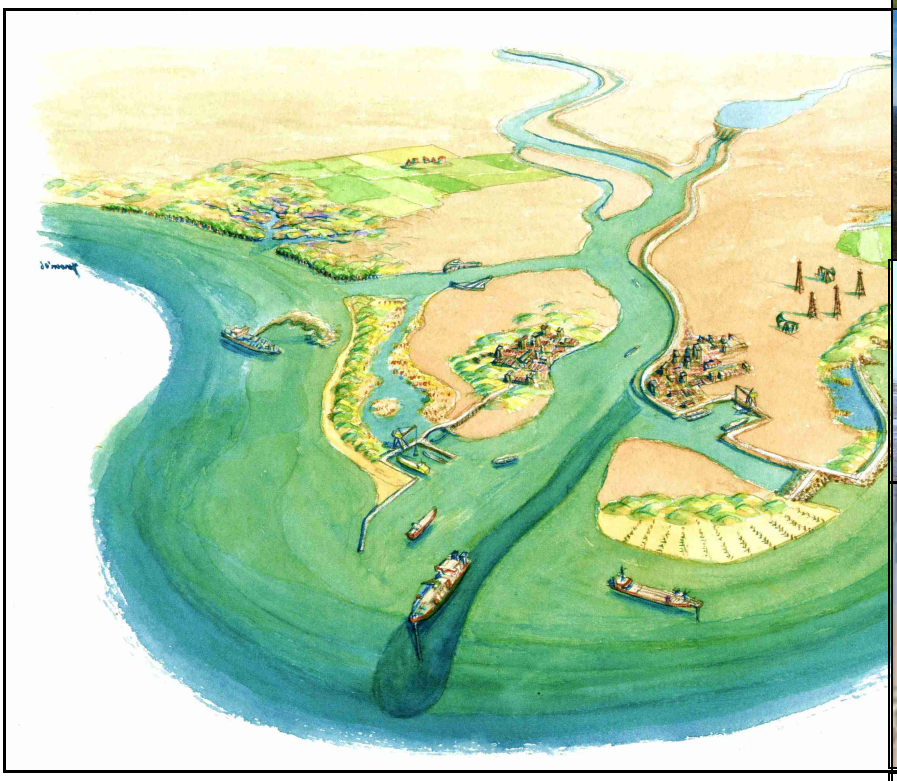
Working with Nature

to cope with flooding, droughts and sea level rise
caused by climate change



December 2007

Written by:

stroming

Commissioned by:

WWF

Content

Summary

Already today, we're witnessing the effects of climate change, including sea level rise, changes in precipitation, higher peak levels in rivers, longer periods of droughts and – of course – higher temperatures. We're also witnessing the secondary effects, such as changes in nesting and feeding habits of birds and changes in distribution patterns of certain groups of insects and plants.

When it comes to our response to these phenomena – and the International Panel on Climate Change IPCC reports that more change is under way - most of the attention is given to possibilities for prevention: improving energy efficiency, carbon sequestration, energy saving measures and development of energy from renewable resources. Necessary, but at best only half of what is needed. Because the effects of climate change are already felt and will still become stronger in future – even in the (unlikely) case that the obligations of the Kyoto protocol would be met to the full. That is not a defeatist attitude; it is a reality we will have to cope with.

In this report the focus is on water, one of the main avenues through which climate change will affect our daily lives: heavy rainshowers, longer periodes of droughts, increasing flood risks, increases in salt intrusion to mention just a few. Coping with these new realities can be seen as a problem but in this report we take the view that it presents us with a unique opportunity to develop a new routine: *Working with Nature*. Experience shows that in many cases it is possible to restore and harness natural processes in such a way that the resilience of areas against the effects of climate change increases and a form of natural safety is created. And more than that: *Working with Nature* also helps restore biodiversity, creates more space for leisure, can create better working and living conditions in both rural and urbanized areas and opens up new economic perspectives. It is not a panacea, but it certainly is a promising and realistic approach we cannot afford to ignore.

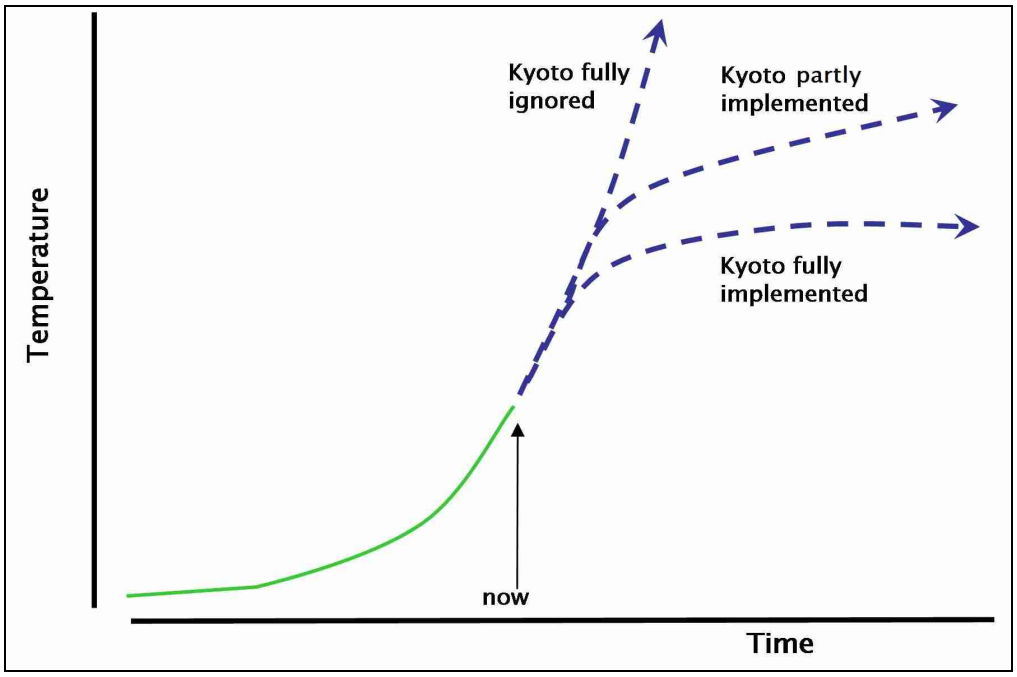
Working with Nature. *Mangroves and mussel banks (left and middle) and storm surge barriers (right), represent two different approaches towards coastal safety. "Working with Nature" implies that priority is given to restoring natural safety because this is cheaper, more sustainable and multifunctional (e.g. mangrove forests are rich in biodiversity, produce building materials and vast quantities of fish and shellfish). If restoring natural safety is not (sufficiently) possible, other strategies, including a more technical approach, need to be applied.*

1. Introduction

The world's climate is changing and will continue to change – at least for the next decades. Nature can be a powerful ally in combating the effects already presenting themselves and those which will follow in the near future. That is the main thrust of Working with Nature.

Climate change

The current debate on climate change could easily leave the impression that efficient light bulbs, energy from renewable sources, carbon sequestration – and some might add nuclear power – will provide the answer to climate change. They will not, simply because climate change is already underway and will continue for at least some decades. It is easy to see why.



Climate change is underway. *Countries with the highest (future) contribution to climate change, such as the US, China and India seem least inclined to take preventive action. The global effect of measures taken or planned by other countries, such as the EU, therefore will be limited. However, even if the Kyoto Protocol were fully implemented, global warming would continue before stabilizing on a new higher level. Even in this best possible scenario, a spatial strategy is needed to cope with the effects of climate change.*

Nature: victim or ally

What will climate change do to nature? That's an important question because many of us see nature as a friend – a vulnerable friend which should be protected against the influence man, including climate change. Of course we're also confronted with nature's strength: hurricanes, heavy rains or floods. In that case our judgment tends to tip the other end of the scales: we brand her as a powerful enemy, against which

man should protect itself. The outcome of this dichotomist attitude: protected species and nature reserves on the one hand, storm surge barriers, dikes and pumps on the other.

In our view nature neither is a vulnerable friend, nor an unpredictable enemy. We see her as the most powerful ally. This shift in mindset is not just an interesting philosophical exercise. It opens up new avenues to practical solutions for one of the most serious problems we're coping with today: climate change. And it's high time we start walking this road. Already now many countries, even in the rich Western world, even in moderate climatic zones, are unable to prevent themselves against climate-related problems like flooding, periodic shortages of drinking water, and coastal erosion. Where this is true for the affluent part of the world, it is certainly true for developing countries, in which climatic conditions often are more extreme and which often do not have the funds to implement even the simplest technical safety measures.

Working with Nature

This report illustrates how natural processes – nature itself – can be used to help us cope with climate change. The concept *Working with Nature* is based on the knowledge that natural dynamics have always allowed areas to adopt themselves to changing circumstances. An example can clarify this. A river not only carries water, it also carries sediments. When a river starts carrying more water, it also will carry more sediments, resulting in an increase in deposition of sediments on a river's shores. Under natural circumstance the river builds its own "dikes" and hence a dynamic balance between land and water is maintained. Of course this balance is not always to our liking: too much water, too little land – or the other way around. That is man started influencing river systems, with dikes, by cutting it's meanders and by deepening river beds.

The crux of *Working with Nature* is to rethink the current land-use and management of a given area and explore which of the landscaping natural processes can be revitalized. The purpose: to create a new situation which is resilient and robust enough to withstand the effects of climate change.

A spatial strategy

As a new, spatial strategy for dealing with the effects of climate change, *Working with Nature* complements the familiar package of energy saving measures, use of renewable sources and carbon sequestration. **It focuses on the question how nature can help us cope with the effects of climate change on our water systems – both in river basins and in coastal zones.** It shows how *Working with Nature* can help

- reduce the risk of **rivers flooding**. Without action, this risk will increase because climate change will lead to more and higher peaks in rivers discharge;
- reduce the risk of **flooding as a result of rain**. Heavy rainstorms will occur more frequently as a result of climate change;
- combat **droughts**. Climate change will lead to irregular precipitation patterns with longer periods without rain On top of that climate change will likely lead to higher evaporation;

- make coastal areas, especially delta's, more resilient against the combined effects of **sea level rise, increased wave action** and **higher river discharges**.

After a prolonged drought, heavy downpours can result in rivers of mud to flood streets and houses.

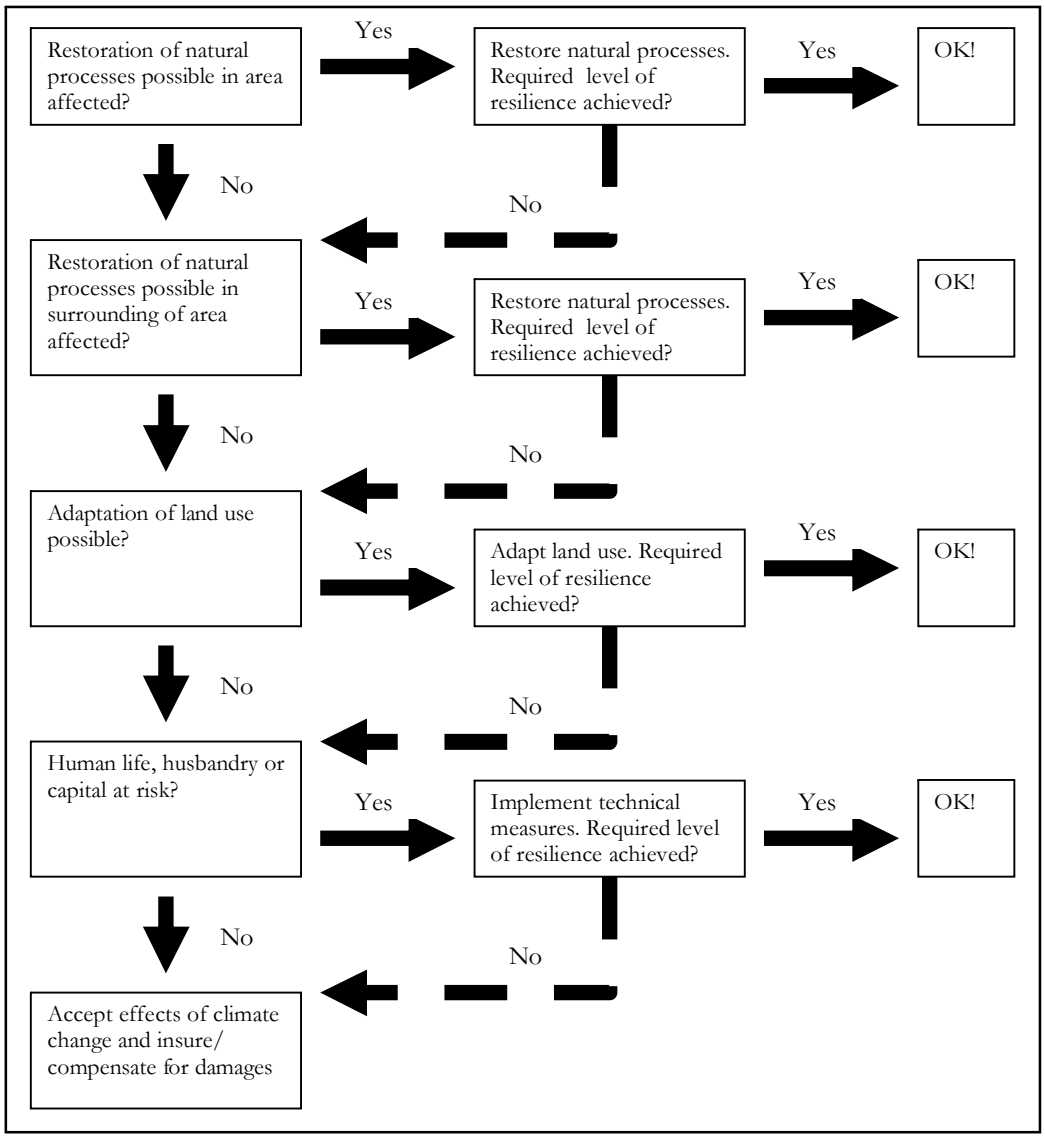
Prevention is better than cure?
Working with Nature is aimed at decreasing the *effects of climate change*. Naturally also *climate change itself* should be prevented as much as possible, e.g. through energy saving measures and increased use of energy from renewable sources. However: some of the effects of climate change are already underway and cannot be undone. As a strategy *Working with Nature*, is complementary to energy saving measures. Although the latter is crucial to prevent a further increase of the problems, this report focuses on the much less known second part of the "treatment": creating spaces which can help absorb at least part of the changes already witnessed.

Decision model: natural safety first

Working with Nature cannot be applied in every situation. However, in our view it is the preferred strategy because it creates sustainable solutions and a wide array of "side benefits" (see chapter 3). Therefore we propose the following decision model:

1. is it possible to restore ecological and geomorphological processes in such a way that an area regains its capacity to cope with the effects of climate change? If so, this – or option 2 – is the preferred choice;
2. if 1 is impossible to restore processes in the area itself: is it possible to do this in areas in the wider surrounding? In other words: can *working with nature* in area B help in coping with the effects of climate change in area A?
3. if 1 and 2 are impossible or only partly possible: is it possible to adapt land-use in such a way that the (remaining) effects of climate change can be dealt with. For instance, if flooding of part of a (planned) residential area cannot be fully prevented, is it than possible to (re)build houses in a manner or on a location which is compatible with (partial) flooding of an area?
4. if 1 and 2 are (partly) impossible: is it possible to take (additional) technical measures to reduce risks
5. if 1 and 2 are (partly) impossible: is it possible to take no action but accept risks and compensate for damages caused by the effects of climate change (e.g. through and insurance).

The choice between strategy 3 and 4 will largely depend on current use of the area concerned. Strategy 4 for instance, cannot be applied in situations where human life is at risk.



Decision model Working with Nature

New chances, new partners

Working with Nature is not a defensive strategy. It takes the view that climate change provides us with an unique opportunity because it forces usto rethink our relationship with water, nature and "space" in general and therefore provides a powerful stimulus to restore biodiversity, create more space for recreation, look for alternatives to economically weak forms of land-use, create better working and living conditions in and around cities, purify freshwater and so on. Climate change as an opportunity!

Traveling a new road also means meeting new fellow-travelers and opening up ones mind for new ideas, new questions and new opinions. That is essential, because *Working with Nature* is not the same as working *for* nature. It is also different from working *against* nature. Conservationists and developers really need to team up: without it *Working with Nature* won't work.

2. Effects of climate change for water

Worldwide climate change will influence our water system. And it will do so from Hilltop to Ocean: H_2O.

Glaciers melting

It isn't new but since Al Gore's *Inconvenient Truth* we can no longer ignore it: worldwide glaciers – as well as Arctic ice masses – are melting. Fast.

> Most of Earth's 160,000 glaciers have been slowly shrinking and thinning for more than a century as the climate warms up from both natural causes and human activity. But scientists say the melt rate has accelerated dramatically since the mid-1990s, which was the hottest decade in a thousand years, according to data from ancient ice cores and tree rings. A glacier in the Peruvian Andes, Qori Kalis, is losing as much ice in one week as it used to surrender in a year
>
> *From: website National Geographic, 2001*

Every now and then the question is raised to what extent climate change is man-induced. The fact is that this isn't even relevant for the case we are making. Whether or not man-induced: glaciers are disappearing and all of us will have to deal with the consequences. The most important among them relate to our water supply. Glacier-fed rivers, one of the most reliable suppliers and distributors of freshwater, will increasingly become rain-fed rivers. These often fall dry in periods and in places when and where water is most dearly needed: during droughts, in arid zones.

Melting of glaciers will impact on the way we provide ourselves with drinking water, it will change the possibilities for irrigation and agriculture and it will decrease possibilities for hydropower. It will be felt from hilltop to ocean. Stopping the process is impossible: it is underway and will continue even if emissions of CO_2 and other greenhouse gases will be reduced to levels agreed in the Kyoto protocol or future UN climate conferences. So, we'll have to deal with it.

Flooding and droughts

Since glaciers will no longer be the origin of many of our rivers, rain will become the main source of river water. Water supply therefore becomes much more erratic. As a rule of thumb peak discharges in glacier fed rivers are 20 times higher than the lowest discharge. In rain-fed rivers it is 100 times higher, so the difference between high and low water levels is much more extreme. This effect will be strengthened because rainfall will become more irregular: periods with heavy precipitation will become more common, as well as periods without any rain.

This creates a new challenge for river managers around the globe. In most countries river management is geared towards getting rid of (excess) water as soon and as safely as possible – for a variety of reasons. In the past the demand for water was much lower than it is now and addition floods, with houses destroyed and the loss of

human life, appear to have a much heavier impact in the world's political an news arena's than droughts. This coincided well with another function of the river: transport. In order to shorten the distances to be traveled, many rivers were straightened and deepened – the byproduct of this being an increase in discharge capacity of the river.

Given the ever rising demands for freshwater and the foreseen decrease – or at least irregularity – on the supply side, a new strategy is needed. The challenge is to even out extremes (floods vs. droughts) and create a more constant flow of water, despite the fact that the source will be more irregular than it is now

Deltas drowning

Delta's are particularly sensitive to climate change, because they experience changes in water regime in 3 different ways. First of all, also in our delta's changes in river hydrology will cause more floods and draughts. However, these effects are strengthened by the influence of rising sea levels. During periods of high river discharges a higher sea level will mean that it is more "difficult" for a river to discharge its water into the sea. The result: more flooding than otherwise would be the case. The second consequence is that during draughts the effects of limited freshwater supply will be felt stronger because the rising sea level, especially in regions with tidal action, will increase salt intrusion. Thirdly, delta's will be attacked by higher waves as a result of the predicted increase of storms, both in frequency and force.

Precisely the places where these three climate effects come together have for millennia been favorites for human occupation. Not surprisingly: the sea guarantees a constant supply of protein as well as (trade) connections to far-away countries, the river is a perfect connection to the hinterland and a source of fresh water, and the flat fertile soils are excellent for settlements and agriculture. Until today most of the world's metropolis and industrial complexes are found in delta's.

What goes for the glaciers is also true for sea level rise: it is underway. We may be able to slow down the pace and extent of it, but it will continue during the coming decades.

Effects of climate change on water

It is clear that climate change will impact differently on different parts of the water system. A rough summary:

Hilltop

- glaciers disappear and with them a reliable source of freshwater. This will be felt all along the river;
- production of artificial snow for skiing – to compensate for the reduction of natural snow – puts additional stress on water resources at high altitudes.

Middle section

- higher flood risks as a result of more and heavier rain showers;
- increased droughts, as a result of longer periods without rain;
- lower ground water tables and more droughts caused by increased evaporation;
- increased pollution of freshwater, especially during summer, becausea given amount of pollutants will be present in a smaller amount of water (concentration);
- increased growth of polluting algae because of higher water temperatures.

Ocean

- sea level rise as a result of warmer (=expanding) water;
- sea level rise as a result of melting ice on the landmasses of Greenland an Antarctica;
- increased coastal erosion due to the combined effect of a higher sea level and an increase in storms;
- salt intrusion due to the combined effect of a higher sealevel and longer periods with limited freshwater in rivers

Not boxing but judo

Naturally plants, animals and people will respond to these changes. This will causea wide array of secondary effects. Whereas nature will "go with the flow", people tend to defend themselves against upcoming change. *Working with Nature* takes a different approach: it is not about fighting against the forces of nature but rather about using them to our advantage. It not about boxing, it is about judo.

3. Soft engineering for increased resilience

Towards a dynamic approach

The natural equilibrium: most of us are familiar with the term, most of us like nature and most of us also like balance. So, what is the problem? Why not leave things to nature and have her deal with climate change? Basically: because we are settlers. We invest in a certain spot by building a house, plowing a field or setting up an industrial plant – *and don't want to see that investment destroyed*. The higher the investment, and the more people depend on it, the more we want the place to stay as it is. Precisely this collides with nature, because nature's equilibriums are dynamic. Certainly modern societies have difficulties coping with this.

Flexibility. *As individuals we use modern technology to move faster than any animal on the globe. As a society we mainly use it to live as sedentary as an oak. Climate change requires us to become more sedentary as individuals and more flexible as a society.*

However, we cannot continue the static life we've frozen ourselves into, despite modern technology. Climate change will thaw things up, not just decades from now but fairly quickly. This will force us to become more adaptable and develop forms of land-use planning and –development in which forces of nature are not blocked out but allowed in. This new approach is also necessary to help combat pessimistic or even fatalistic attitudes towards climate change – a challenge in itself!

There is a lot to gain if we succeed in forging new partnerships with nature. Immaterial gains like increased quality of life, longer-term security and increased biodiversity. But also financial gains: fewer damages to be paid and a new business to be developed with world-wide market potential: "soft engineering."

Soft engineering

An important vector through which climate change will enter our daily lives is "water". That is cause for concern but fortunately river and marine systems are dynamic by nature and in fact "know" how to deal with change. **Soft engineering makes use of this knowledge and allows and assists nature to apply it. Soft engineering therefore is not just "doing nothing": it is the conscious use of**

natural and geomorphological processes for human needs. If necessary this can be supplemented with technical measures or other strategies In short: nature first.

There are several natural phenomena to be tapped in soft engineering First of all nature is a supplier of **building materials.** These can be mineral, like sand, clay, gravel or rock, but also organic (peat). Nature also provides us with the **transport mechanisms**: wind, water and ice. Thirdly nature in a sense also provides us with a variety of **management tools.** Large herbivores can inhibit forest development and heavy winds or ice can even remove larger tracts of existing forest Since forests decrease the stream velocity of a river and also dampen wave action, large herbivores, storms, and frost can have an important effect on water levels in rivers. An additional advantage of *Working with Nature* is that it provides a flexible solution: of a natural "climate buffer" has the potential to keep pace with the speed with which the effects of climate change present themselves.

Sleeping beauty

The first thing needed in soft engineering is knowledge of the "landscaping" natural and geomorphological processes such as erosion, sedimentation, groundwater and river flows, tidal action, coastal currents and wave action In some areas these are still active but often they have been immobilized with dikes, dams, concrete and mortar. In these cases they are like sleeping beauties, waiting to be awakened by the kiss of a prince. That brings us to the second requirement: a prince to administer the all-important kiss. There are several that can do the trick.

The farmer

Hill-farming often is small scale and therefore has a difficult time surviving in the highly competitive, global market. Among the worst spots, from a farmer's point of view, are depressions which are difficult to drain. So, at a given moment a farmer may decide to stop draining a spot like this in order to cut his losses. That farmer kisses awake the natural process of marshland formation. These swamps will act as a sponge, soaking up water in times of plenty and gradually releasing it in drier periods. A water (or climate) buffer will evolve, contributing to the prevention of both flooding and desiccation downstream. If he would be aware of this, the farmer could even tap this as a source of income: after all his action decreases the need for expensive flood prevention schemes downstream.

The brick-maker

In many parts of the world, people built dikes to protect their lands and homes against flooding by rivers. Because of this also sediments carried by the river are no longer spread out over large areas but concentrate in the narrow areas between the dikes. Here a thick layer of clay builds up, filling up side channels in the winter bed, decreasing the stream-capacity of the river and thereby undermining the very river safety the dikes were meant to provide. Fortunately the clay deposited can be used to make bricks and therefore has economic value. If clay-mining takes place in such a way that the side channels are restored, the brick-maker restores the natural discharge capacity of the river, thus decreasing the need to use tax-payers money for construction of higher and stronger dikes

The harbour developer
Even ports designed a few decades ago, can no longer accommodate the gigantic vessels cruising oceans today. Many ports therefore are developing themselves in a seaward direction, where deeper water and plenty of space are available. However, a new area of land protruding in the sea influences the direction of the coastal currents which, combined with wave action, bring a constant supply of sand to the shore. If coastal currents are pushed seaward, this natural coastal defense mechanism is lost. Depending on the situation, a well thought-out shape of the new land-surface or a limited number of well-placed dams, can keep the coastal current alongside the shore, thus preventing the need for concrete coastal defense structures. In addition: when the larger vessels can be accommodated offshore, harbour basins more inland as well as the river's mouth, can be more shallow. As a result river sediment which would otherwise be trapped in deep river channel and basins will reach the coast and help maintain a safe coastal zone.

The city development
City developers often try to concentrate their projects on as small an area as possible – not only because prices for land may be high but also because generally building is seen as a threat to the environment. However, when the construction of a new residential area or business park is coupled, both in design and financially, with the conservation or restoration of a larger surrounding area, urban development no longer is a threat for landscape quality but an incredibly strong partner, creating "climate buffers" which can absorb excess water, provide water during droughts, provide space for leisure in natural habitats, contribute to biodiversity and as such improve the overall the quality of life of the city's inhabitants.

Limitations

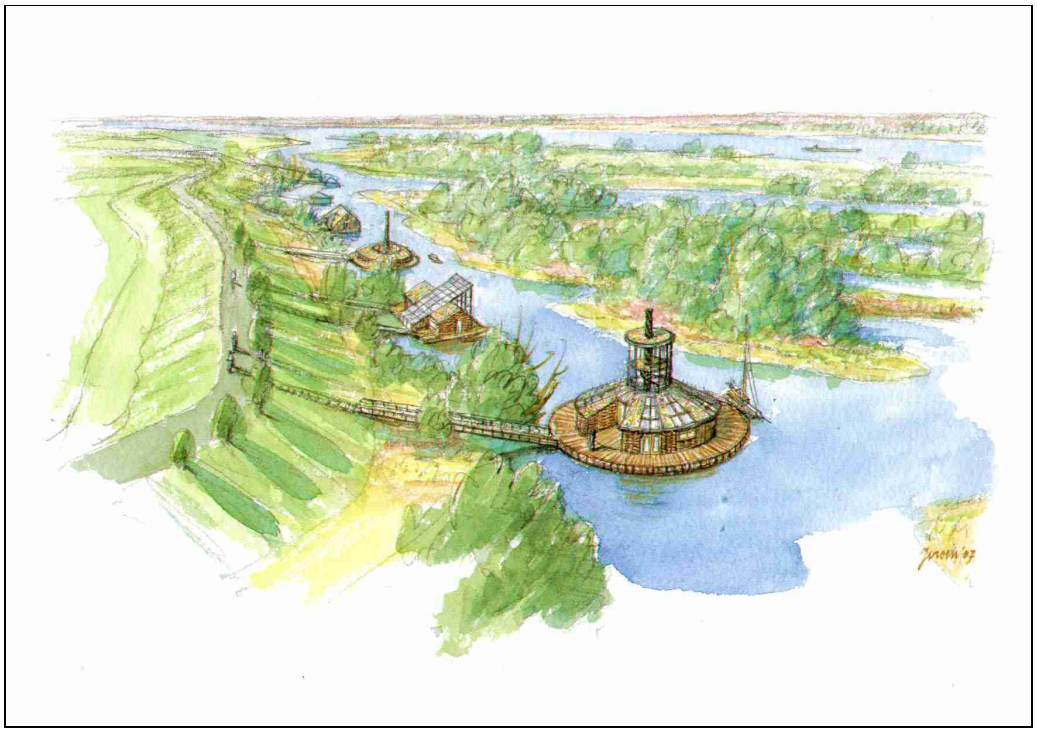
Working with Nature is about recognizing and (re)valuing natural and geomorphological processes and finding partners who will benefit from harnessing or restoring them. As a consequence there are two specific limitations to the approach:

- the **geomorphological genius of the place**. *Working with Nature* is only possible in areas where the natural and geomorphological processes are still present or can be revived to a meaningful level. For instance: allowing a more natural flooding regime of a river can help decrease flood risks. However, if the sediment balance of the river is irreversibly disturbed this may not be possible because the river may continue to deposit or remove sand, gravel or clay at critical places;
- the **social genius of the place**. *Working with Nature* is about creating a new, dynamic equilibrium between water and land, between salt and freshwater, etc. Land-use – or autonomous changes in land-use – in a certain area should allow for this. *Working with Nature* is only possible in places where societies are still able (physically and/or financially) to partly adapt their way of life to new, more natural circumstances. For example: where agricultural land gradually becomes saline as a result of sea level rise, owners may well be interested in selling their property for the development of a new dune system for coastal defense. It would be useless to propose this for a highly industrialized coastal section.

So, soft engineering cannot be applied everywhere andwhere it can, a combination with technical measures may still be necessary to provide required levels of flood protection, coastal safety, drinking water and so on.

Multifunctional benefits, multifunctional partnership

The above shows that *Working with Nature*, just like technical solutions, has its limitations. But where it can be applied,it creates a wide array of benefits. The examples above show that storing water at the sourcemay provide an alternative income to farmers and may contribute to flood prevention as well as droughts downstream. It will also certainly increase biodiversity and if the areas restored are large enough they may be interesting for tourism. So, whereas technical solutions often are monofunctional, a systems based approach without exception generates multifunctional benefits. This is important in itself but alsoprovides the basis for broad, often innovative partnerships in which people responsible for flood protection team up with conservation organizations and businesses.



Floating houses allow people the unique experience of living in the floodplain of a big river. The pole in the centre not only allows the house to move up and down but also allows thowner to turn it around to follow the sun or simply to change the view. The square building can be used for living but also as a greenhouse for smallscale food production. Large scale food production– either in greenhouse or out in the open– takes place behind the dike (left on the picture).

Cost efficient

Working with Nature is always cheaper than working against nature– that is easy to see. Currents bringing sand to the shore and the resulting natural coastalprotection are cheaper than concrete structures with their high building and maintenance cost. In addition the application of technical structures, like dikes and pumps, introduces

the possibility of risk management, for instance safety up till peak flood levels occurring only once every 1000 years. If such high safety levels are achieved, this often attracts investments as if there were no risk at all. If reality hits and an (near)disaster occurs, the increased economic value of the area will spur the demand for even higher safety levels and hence: stronger dikes, bigger pumps. This works for a few rounds but it is clear that this strategy cannot be continued in the long run. In addition it is extremely costly.

Working with Nature requires space. That would be a major disadvantage if "climate buffers" would be monofunctional. Fortunately they are not: there is plenty of opportunity for other types of use, even for settlements – in this case on an artifical mound. The revenue earned by the building project could help pay for the purchase and management of the land needed for the climate buffer.

Working with Nature is different: inherently cheap, both in the implementation phase and in the long run, sustainable and the cost involved will generate a wide array of benefits. In summary: it is extremely efficient.

Of course also the benefits provided by *Working with Nature* come at a price. Firstly the strategy needs space. Whereas a technical approach often creates a linear defense (a dike, a storm surge barrier etc.) a systems based approach often results in a zonal defense (a second row of dunes, a marsh to absorb water etc.). Providing space can be expensive, financially but also mentally. Certainly people in the developed world are used to adapt the environment to the working and living conditions the want *Working with Nature* requires the opposite: the willingness to – at least in places – adapt our way of life to natural circumstances.

Overall approach

In the following chapters we will travel from hilltop to ocean to illustrate how *Working with Nature* can be applied in various parts of the river system: at the source, midstream and where it reaches the sea. The overall approach aims at improving possibilities to:

- hold water at the source
- store water midstream
- discharge water downstream and grow with the sea.

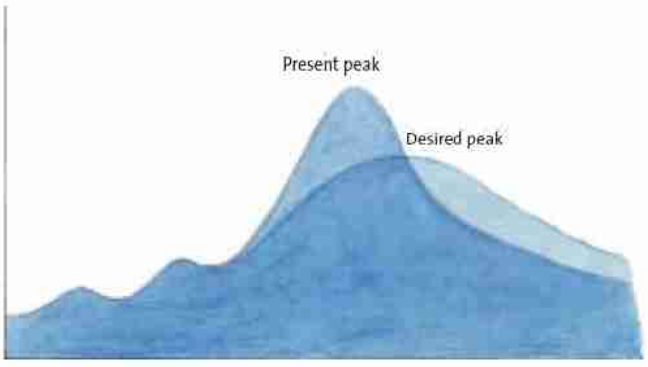
Living on an island with a "natural coastline", e.g. without a coastal defense structure. Buildings which can be moved around or are built on poles open up this enormously attractive perspective.. During times of plenty water is stored in the lake around the island. This will help cover the demand for water – also in the surrounding of the lake – in times of drought and if natural processes in the water and along the shores are allowed to do their work the crystal clear water is highly attractive for flora, fauna and people.

4. Holding water at the source

Retaining water at higher altitudes levels off flood peaks and at the same time ensures that rivers still carry water during dry periods. Measures to be taken include redevelopment of woodlands, filling up drainage systems and restoration of river beds. Highly cost-effective and even a source of income.

The loss of the enormous reserves of *solid* water stored in glaciers will need to be compensated by the creation of reservoirs for *liquid* water. Only then at least part of our rivers will have a future as reliable sources of freshwater.

Of course man-made reservoirs and storage tanks could do the trick but these would need to be gigantic and therefore extremely expensive to build and maintain. Also this would be a mono-functional solution: it would only provide us with drinking water but not provide us with a living ecosystem with its fish, trees, effects on groundwater levels and many other green and blue services. In addition the management of such reservoirs would take someone to decide who gets water, when and how much. When such important issues are dependent on human decision making, a possible source of conflict is created. Natural reservoirs therefore are the obvious choice: relatively unsusceptible to human interference and conflicts, multifunctional and relatively cheap to make – a possible source of income even!



Holding water at the source will level off peak discharge thus decreasing the flood risks. The water which otherwise would have contributed to the build-up of the peak, is released to the river at a later moment in time, thus decreasing the number of days during which irrigation or navigation is impossible due to low water levels.

High mountains

Working with Nature cannot remedy the problem of melting glaciers in the high mountains. The effects resulting from the changes at these very high altitudes can only be mitigated in the lower parts. The first chance lies in the middle mountains where natural sponges and the ecological functioning of little brooks can be restored.

Restoring natural sponges

Over centuries the growing human population has been mirrored by a constant increase in the surface of agricultural land. Tractors, drainage techniques and fertilizers even allowed farming high up in the hills, in marshy areas, in areas with poor soil conditions or places which otherwise are difficult to farm.

But things have changed: food production has become so efficient and the worldwide market has made farming so competitive, that less-favorable agricultural lands are abandoned[1]. In Europe alone up to 70 million hectares of farmland may be taken out of production between 2005 and 2035[2] and in the US land in farms has declined every year since reaching its peak at 1.206 billion acres in 1954 In other words: land to (re)create natural sponges is available, both physically and socially. There is growing interest among landowners to offer lands for water storage. This has various reasons:

- farmers are not pushed from (part of) their lands by water managers but by the fierce competition on the global agricultural market. This non-competitive relationship between water managers and farmers provides a good basis for cooperation;
- storing water on a piece of marginal land opens up the possibility for "water farming": a new form of land-use in which the land-owner receives a premium for him providing "blue services" (per hectare, per cubic metre stored or both);
- the surface of the different sponges combined determines how much water can be retained. The size and location of the individual sponges is largely unimportant (see figure 4). This means that space can be found in partnerships, on a voluntary basis. Only where landowners are interested, sponges will evolve and this will not decrease the overall effectiveness.

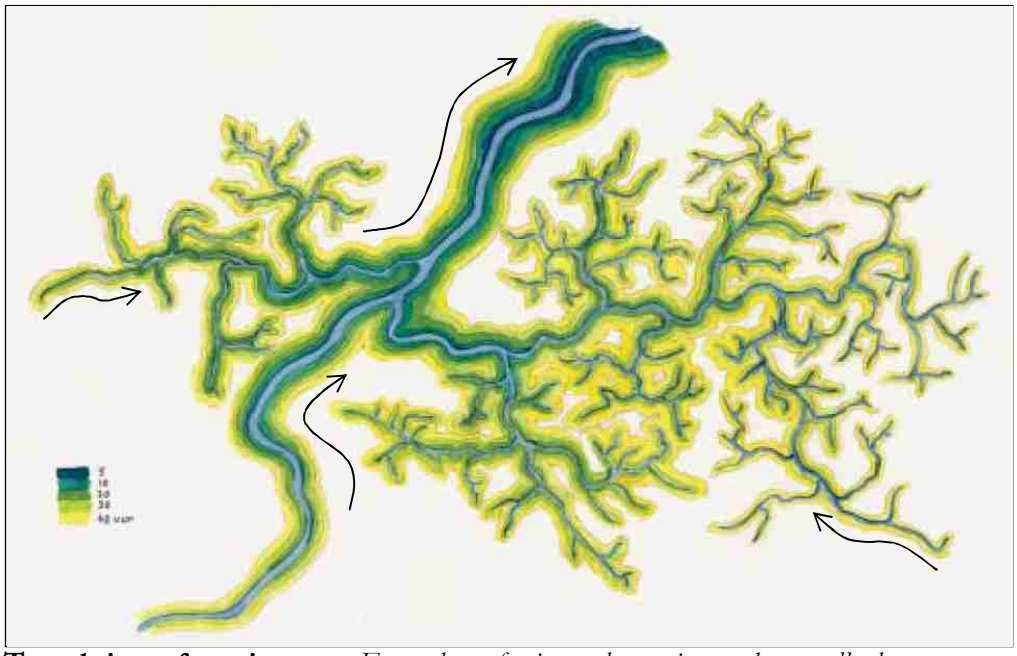
Benefits

The creation of natural sponges has several benefits:

- Mitigation of flood peaks, resulting in less flooding and/or a decrease in the need for flood control measures downstream
- Gradual release of water during dry periods, contributing to a more secure water supply in the whole river basin, for drinking water or irrigation
- Decrease of number of days during which navigation is not possible due to low water levels in the river
- Natural purification of the water stored
- Restoration of biodiversity which, if close to the source, can spread out over the entire river basis
- Depending on size and location: new possibilities for recreation
- Depending on size and location: new areas for housing in a green environment

1 The demand for bio fuel may influence this but as yet the impact is limited and there is growing debate on the issue. Research (ref) shows that one hectare of nature is more effective in reducing carbon levels than that same hectare being used for production of bio fuel.

2 Land-use scenarios for Europe: qualitative and quantitative analysis on European scale European Environment Agency, Technical Report No. 9/2007.

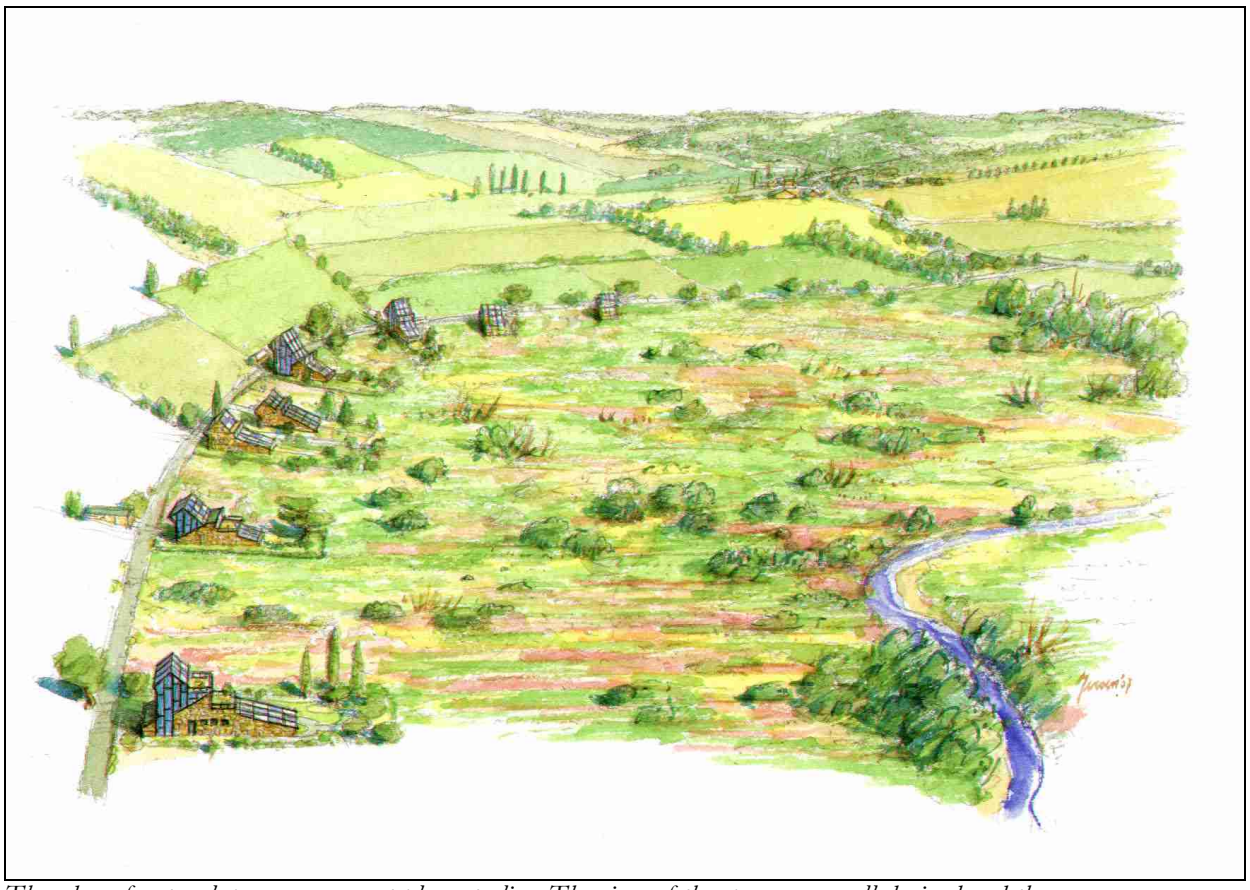


Travel times for rainwater. *Every drop of rain reaches a river and eventually the sea. Therefore every area in a river basin can store water and release it to the river at a later stage. However: in order to also contribute to the leveling off of peak discharges, sponges have to be located in areas which discharge their rainwater relatively soon – but not immediately – into the river. This schematic map shows zones with different traveling times for rainwater (the time between a raindrop falling and the moment it reaches a river branch). Zones with traveling times of 5 or 10 hours hardly contribute to a peak discharge: they cover a limited surface (= catch a limited quantity of rainfall) and water from these areas is already carried away by the river before the peak starts building up. Creation of sponges in areas with traveling times between 20-40 hours can effectively top off peak discharges: these are large areas, discharging enormous quantities of rainwater into the river at the critical moment (peak build up time). Rain falling in the white parts (traveling times more than 40 hours) will travel so long that it will not contribute to peaks building up. However, storage in these areas can be used to ensure water supplies in times without rain. (N.B. traveling times of water differ between regions).*

How it's done

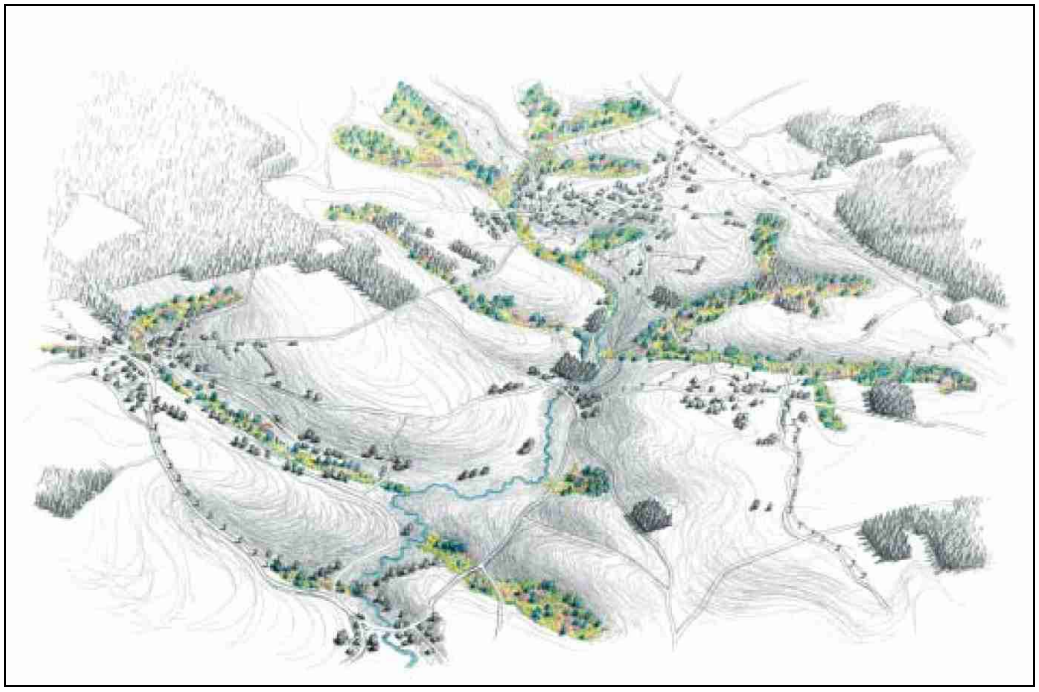
There are different ways to restore natural sponges Let's follow a raindrop and see where and how we can slow it down on its journey towards the sea.

The first possibility is to postpone the moment a raindrop permeates the soil. The short vegetation (heathlands, grasslands) between the barren, rocky landscape of the high mountains and the tree-line only offers limited possibilities for this. This is different below the tree line. Here forests break the force of heavy rainstorms and also the package of decaying leaves distributes the water and retards the speed with which it penetrates the soil. Deciduous forests are more effective in this than coniferous forests because a layer of fatty "needles" is more permeable than a layer of composting leaves. So, **protection and natural regeneration of forests** is a first possibility to facilitate a more gradual downstream of water over the course of a year.



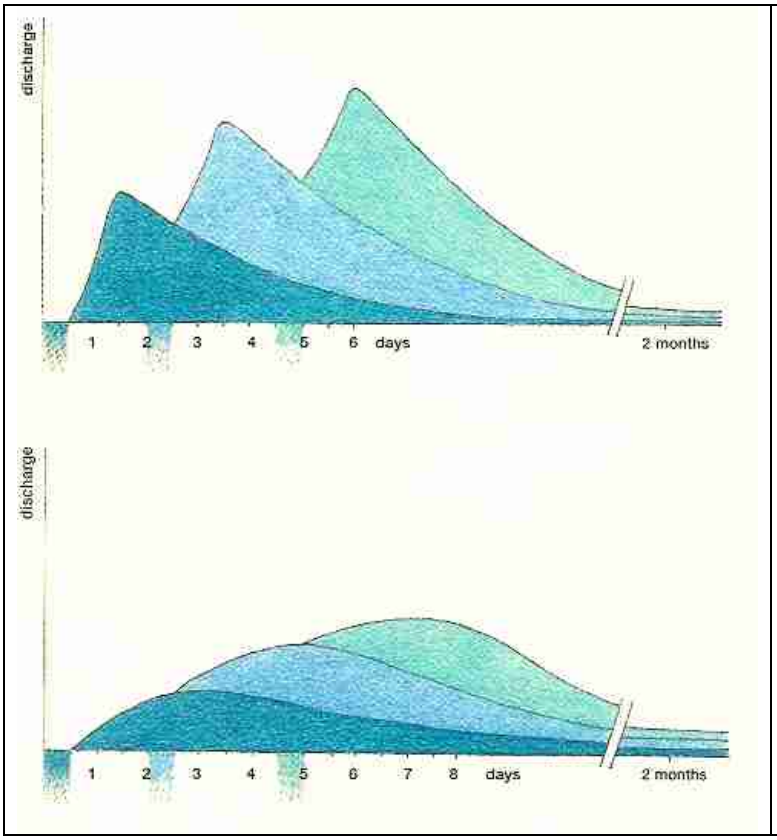
The edges of natural sponges are great places to live. The rims of the sponge are well drained and the natural landscape provide an excellent view and– if disclosed with board walks– opportunities for leisure.

At a given moment a raindrop will penetrate the soil and continue its vertical journey until it hits an impermeable (rock) layer. Once it does,its will continue traveling downhill over the rock surface. Under natural circumstances this underground journey will continue until the lowest part of the slope has been reached and the water surfaces in an upwelling zone. However, where these underground currents are intersected by forestry drains or forest roads, little streams develop through which the water is quickly carried away to the river. Such shortcuts can be removed by **filling up old drainage canals** and **preventing the construction of new forest roads**.



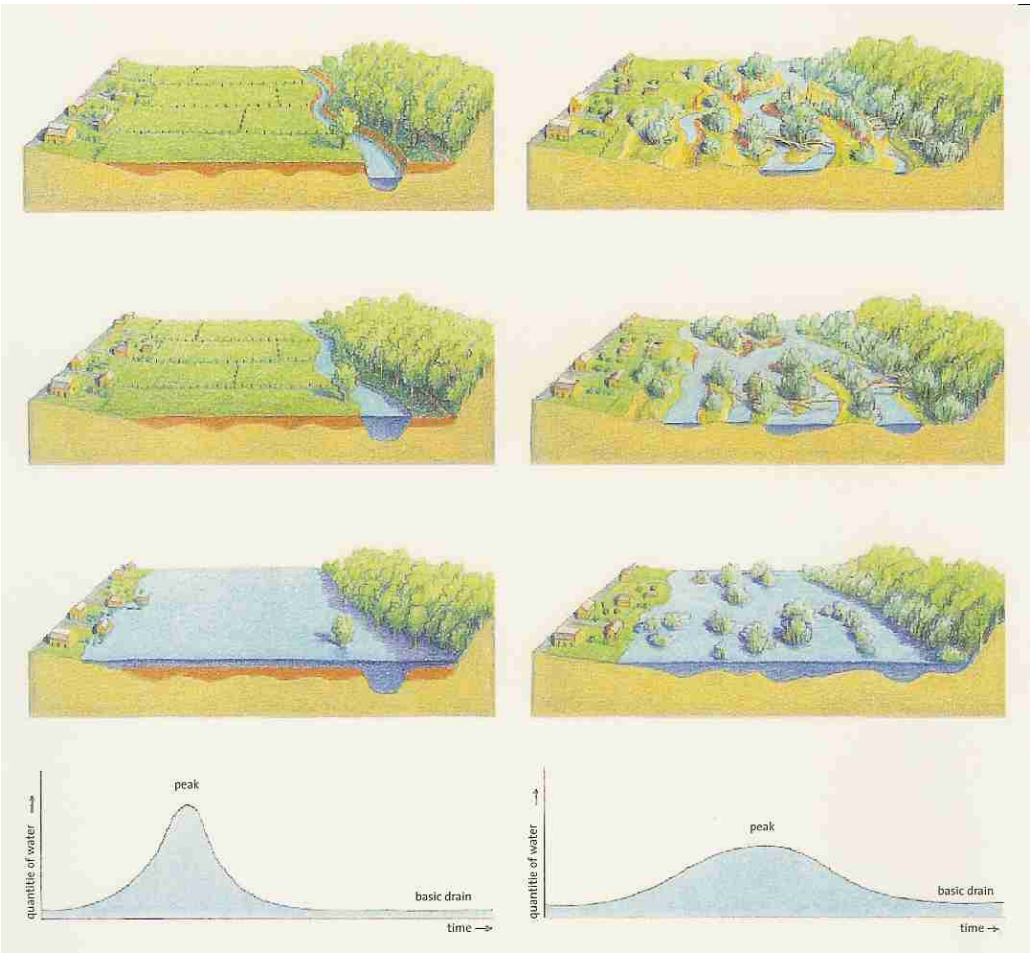
Sponges. *Marshes at the upstream end of small brooks are among the best locations for water storage. It is here where water from the entire surrounding region is collected, e.g. in upwelling zones. As a result one hectare of (restored) marshland in such places, can store water originating from a much wider region.*

When at the end of is underground journeya raindrop surfaces in upwelling zones at the edges of the valley, it will slowly creep through the marshy areas which under natural circumstances cover the higher parts of the valley floor.Naturally, such marshes also receive rain directly falling from the sky.However, in many cases these marshes have been drained for agriculture and once the water reaches a drainage canal it is quickly carried away. **Restoration of these marshes** by filling up these drainage canals will effectively help store water. As a result marshlands and eventually peaty areas will develop, thus further increasing the storage capacity of the area.



Accumulation of discharge peaks as a result of three periods of rainfall within four days. Above: when marshes are drained they quickly release water. This generates a high discharge peak in the stream fed by the marshes and extremely low water levels afterwards. Below: natural marshes hold water and in this way the flow of water is more evenly spread over time.

At the lower part of the valley marshes, eventually little streams emerge. At this point the resistance met by the water is lower than in the soil or marshes but it will still move at a moderate pace because these little brooks are shallow and obstacles like natural vegetation, fallen trees, beaver dams etc. impede the steam velocity. In addition these brooks have natural "emergency breaks" which start to operate when water levels rise. In that case the water spreads out over larges surfaces and the enormous increase of the river bed combined with the breaking effect of vegetation and height differences, prevents a sudden increase in stream velocity. The principle is illustrated in figure 5. Unfortunately in many places these natural breaks have been removed through canalization and removal of forests and other natural vegetation from the shores. **By restoring the natural characteristics of the brooks**, the upstream storage capacity of river systems can be greatly improved.



Natural vs. canalized brooks. *Under natural circumstances (right) rising water levels gradually fill up numerous sided channels and the pace of the water is slowed down by vegetation, beaver dams, dead trees which tumble into the river bed and other natural "emergency breaks" The result: lower peak levels and a more steady supply of freshwater downstream. In many cases brooks have been canalized and natural vegetation removed, causing more extremes in the flow of water. Climate change will exacerbate this situation but restoration of the natural qualities of the brooks can remedy this: allowing for natural flooding of areas upstream at an early stage, will help prevent high peak levels downstream.*

5. Storing water midstream

Flooding and droughts are two sides of the same coin. Both indicate that the natural characteristics of a river have been disturbed. In many cases restoration is possible, through restoration of side channels and wetland areas. In this way "climate buffers" can be build in the mid-section of a river system.

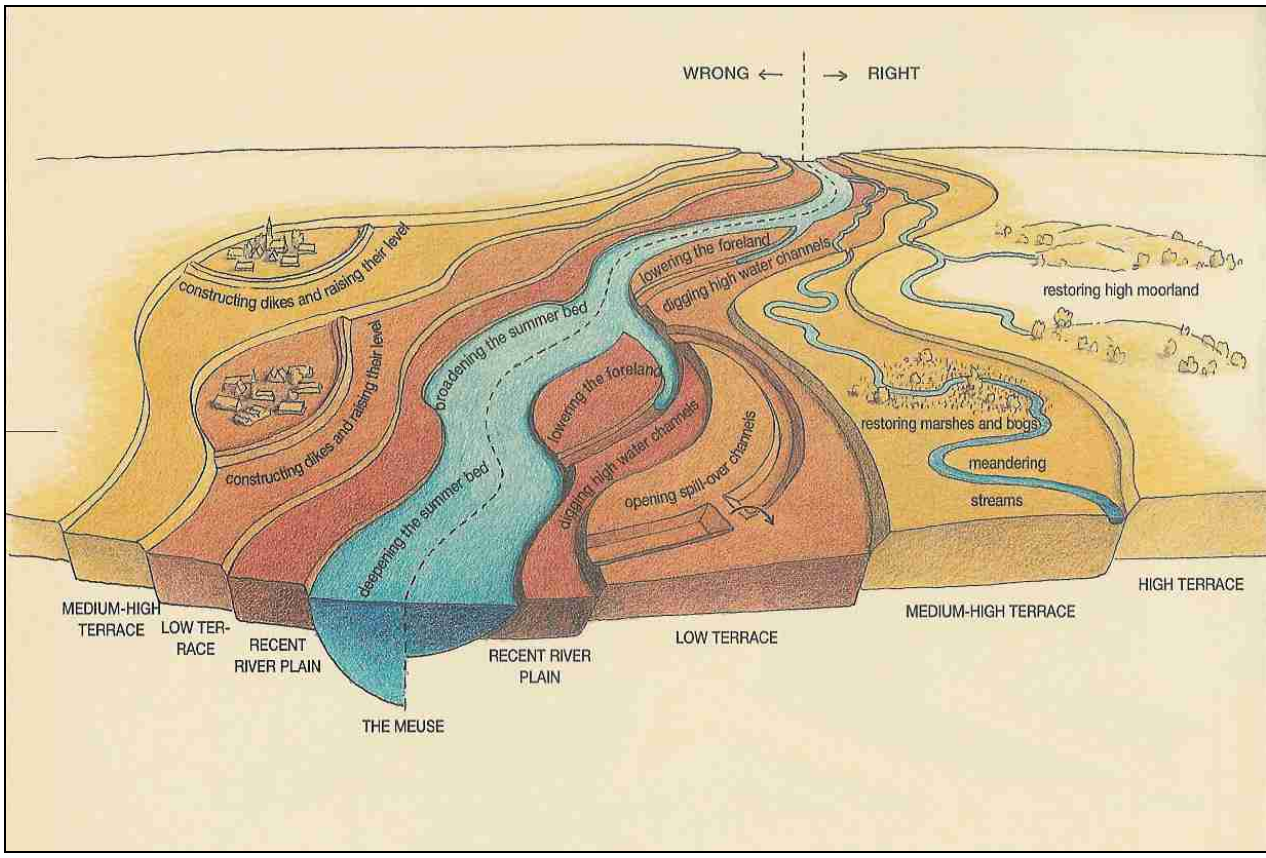
When little brooks and streams leave the middle-mountains and jointly build bigger rivers, *Working with Nature* requires another set of measures. Where such rivers flow through an almost flat landscapes, a plain, the approach differs from situations where a river flows through a natural valley.

Rivers in valleys

In most cases dikes are absent in cases where rivers run through a valley. For centuries the natural slopes of the valley provide ample space for people to settle relatively close to the water without the risk of their houses and goods flooding.

However, with populations growing and technical possibilities increasing, also the lower parts of the valleys gradually were occupied, especially in the richer countries of the world. As a result, even in such situations unsafe or at least unsustainable situations have been developed, which will increasingly be put to the test by climate change.

Like in other cases, the first response to higher flood risks and longer periods of draughts is often to put in a new round of technical measures. But here too, a new approach is possible. The philosophy is the same as elsewhere: create a new, more natural, more sustainable relationship with water and adapt human use to this new, dynamic equilibrium.



Soft engineering. *A bird's eye view of a terraced river valley, showing different approaches to respond to water-related effects of climate change. Left technical measures which temporarily create protection against flooding but also limit the discharge capacity of the river. Right examples of "soft engineering" to anticipate the increase in extremes (droughts and floods) caused by climate change.*

Rivers in plains

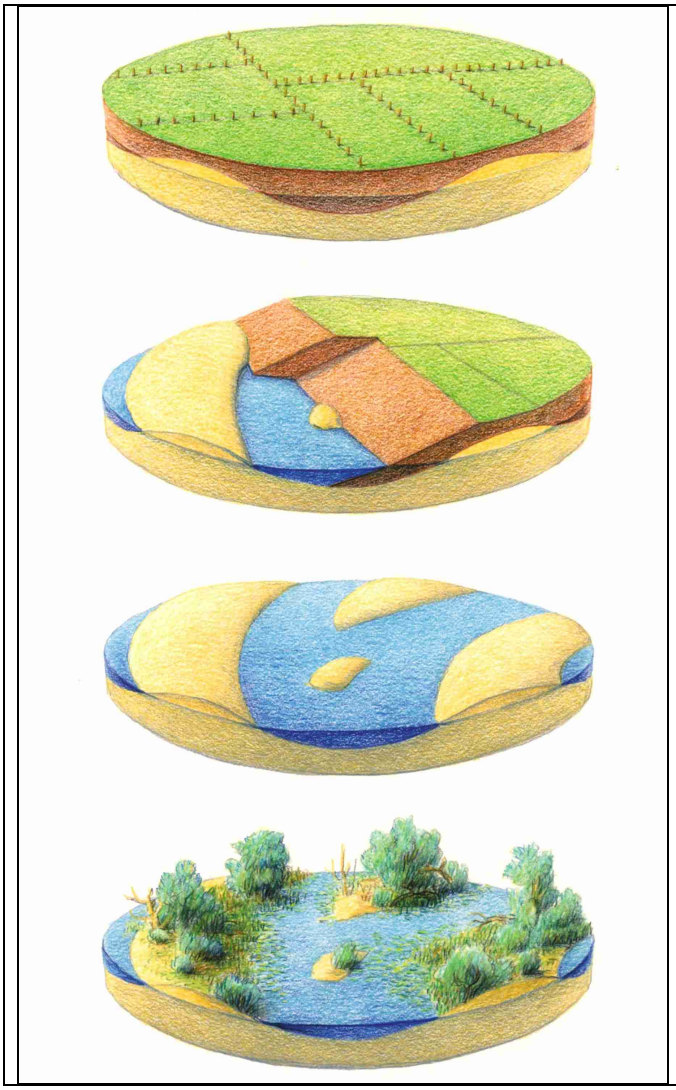
In an almost flat landscape, most rivers are regulated by the construction of dikes to prevent the hinterland from flooding. However, not only the water is kept from spreading over the plains, also the sediments carried by the river remain concentrated in the narrow stretch of land between the dikes. As a result the side channels which characterize a natural river system may quickly fill up, thus limiting the discharge capacity of the river and hence threatening the very safety the dikes were meant to provide. The first response to this phenomenon often is to heighten and reinforce the dike, but there is growing awareness that this is a non-sustainable approach.

Navigation and irrigation. *In times of plenty dikes along a river guide water quickly to the sea. As a consequence the river runs dry during periods with limited rainfall. This limits the number of days river water can be used for irrigation and increases the number of days during which navigation is impossible. Climate change will reinforce they economic damage caused by this and therefore provides an extra stimulus to restore a more natural, moderate hydrological regime.*

To river management authorities, sediments clogging up parts of the river bed are a nuisance. However, to the brick maker it is a valuable resource clay. In many countries extraction of clay is seen as a menace to the quality of the landscape. Therefore it is concentrated as much as possible and can only work under the condition that, once the project is completed, clay miners erase their tracks and leave a recultivated agricultural landscape.

However, superficial and subtle mining of clay, sand and gravel can be an excellent tool to restore old side channels of the river. This has many advantages:

- the restored side channels increase the discharge capacity of the river when it carries a lot of water and help lower peak levels
- when water levels in the river drop, the side channels stop flowing and slowly release water afterward – either directly to the river or by supplementing ground water levels;
- the side channels function as a natural breeding ground and refuge for riverine plants and animals, which in many cases find no place to grow, feed or breed in the main (canalized) stream of the river;
- the natural qualities of the landscape developing provide excellent opportunities for leisure and provide new economic opportunities.



Clay mining can be an excellent tool for restoring the ecological an geomorphological functioning of rivers. In many places river forelands are used by agriculture but only are of marginal quality because of the regular flooding (top). The ceramic industry can be used to peel off the layers of clay which over the years has been deposited on the sandy subsoil, thus bringing old side channels to the surface (middle). This creates an excellent basis for the development of riverine forests, increases both the discharge and retention capacity of rivers and attracts new (economic) tourism related activities.
Experience shows that this transformation of the landscape can be carried out by "the market" without tax payers money being needed.

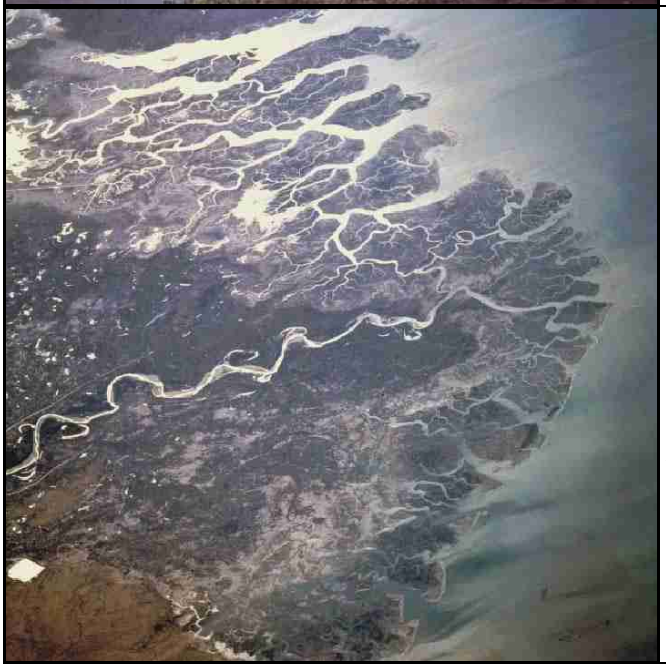
New rivers (above and below).If existing rivers cannotprovide enough space for water, nature and people, the development of new riverscreates additional opportunities. After the initial, large scale technical human intervention – the digging out of the river bed– natural processes can take over. The development of new riversrequires an integrated approach, both in design and in terms of finance. The aim should be thatthe new river becomes the ecological, economic andsocial backbone of the area is flows through.

6. Coast: growing with the sea

Coastal areas have a natural resilience against changes in sea level and river discharge. Their capacity to "grow with the sea" can be harnessed to anticipate the spatial consequences of climate change.

Where a river approaches the sea, an estuary develops or– when plenty of sediment is available - a delta. In both cases the river mouth will be confronted with climate change but in estuaries the effects will only be felt within the area covered by the estuary itself and have relatively limited consequences.

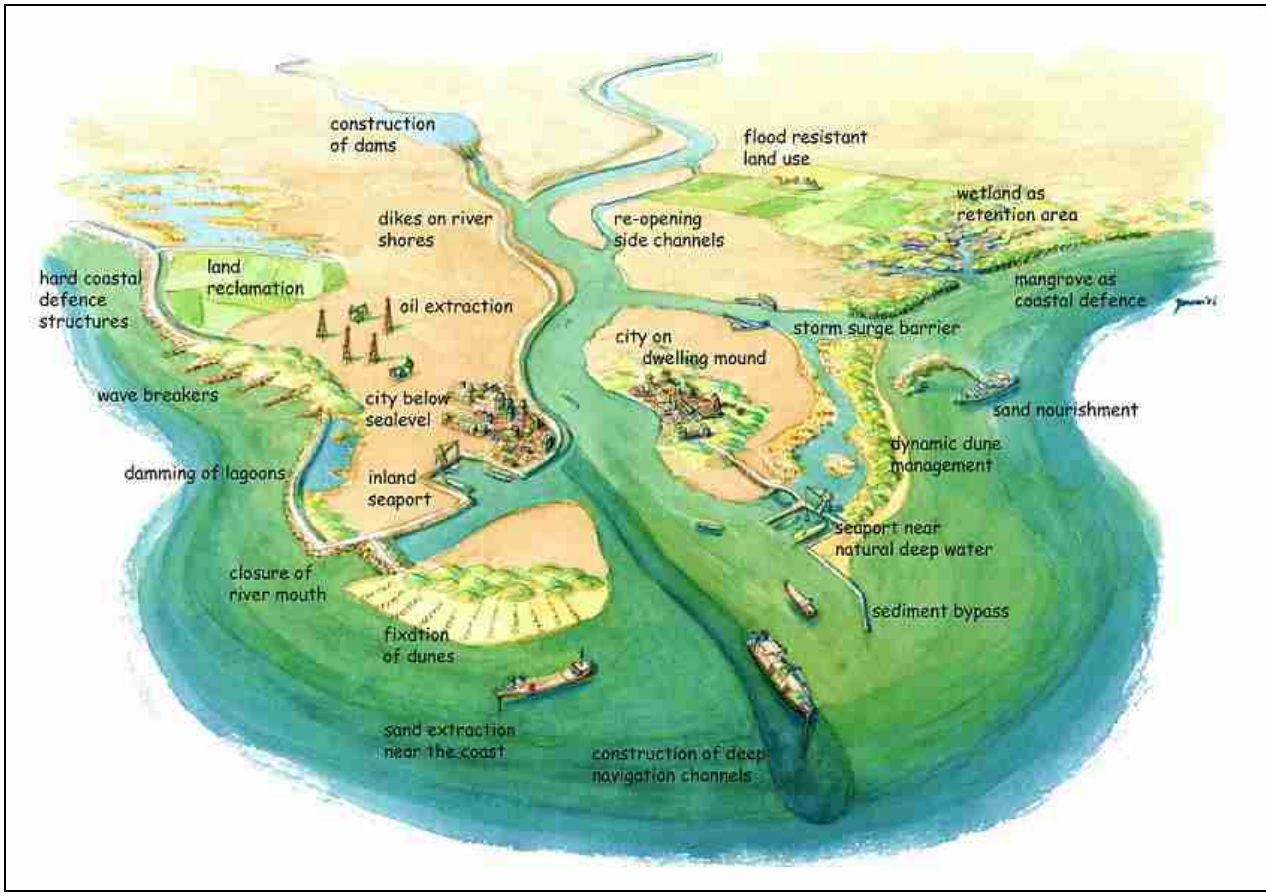
Estuary. *In areas with steep coastlines, the contact zone between river, sea and land is limited in size. Climate change will certainly affect such areas but the effects will stay limited to a relatively small area.*



Delta. *The Indus will be affected by climate change from its glacier fed source in the Himalayas to its mouth in the Indian Sea. The combined effects of this will be felt all over the vast delta plain.*

In delta's the effects will felt much stronger because the vast delta plain, which may have taken centuries to develop, is prone to large scale flooding.Under natural circumstances, where enough sediment is available, delta's "grow with the sea" and therefore are well adapted to changesin sea level and river discharges. As a result, climate change in itself is not necessarily a threat to delta's.

However, over the past centuries human interventions have in many places paralyzed the system's inherent natural resilience to climate change. These may be interventions in the delta itself (e.g. dikes preventing the influx of sediments building up the area) buts also interventions elsewhere in the watershed (e.g. afforestation decreasing sediment loads) or in the sea (e.g. offshore harbour development affecting long-shore difts). In this way the very areas which under natural conditions are most resistant against the effects of climate change, are now among the most vulnerable. *Working with Nature* can help reverse this situation. The various possibilities are summarized in the birds-eye view below.



Working with Nature in delta's. *The left-hand side of this bird's eye view illustrates the various ways in which delta's are usedby man. The interventions are all leading the area away from sustainability and resilience against climate change. The right hand side shows examples of the alternative approach, in which natural processes are used to help the area cope with the effects of climate change.*

Building with sand

Where industrial plants or urban centres are situated close to the coast it will be difficult to just "abandon site" and allow the seato take hold of the area– although in the long run this might be the best option. In those cases coastal erosion caused by rising sea levels and increased wave action can be slowed down by pumping sand from deeper sections of the sea to the coast. This sand should not be deposited directly on the seashore, but rather be released close to the coast. In this way wave action, tidal action, long-shore drifts and wind will all contribute to the most efficient distribution and recycling of this building material all along the coast.

Removing sea walls and coastal defense works

Where coast lines are weak or where there are enclosed sea inlets coastal protection often is provide by rubble, sea walls or other coastal defense systems. Strangely enough, breaking through these defense structures could actually offer a solution for sea level rise.

Breaking down the defense, as a defence. *Coastal erosion weakened the connection between the Hondsbossche sea wall (Netherlands) and the adjacent dunes. What once was an effective defense, nowis a weak spot. A gap in the sea wall would cause part of the land behind it to flood with the tides. The silt caught up in the vegetationensures that the land gradually increases in height, thus keeping pace with rising sea levels.*

Living in a delta. Floating houses or houses on poles allow people to live with the fluctuating water levels in a delta. Although usually known as a "traditional" type of settlement, especially in tropical countries, this way of building is also very suitable for high tech societies in moderate climates, where this form of building would link water and living in a positive and innovative way.

Dune management

Closed dune lines protect coastal lowlands against flooding from the seaward side. Dune restoration, dune relocation and allowing for natural dune dynamics and wash-overs, all help in the conservation or restoration of this dynamic coastal defense zone. Wind driven transport of sand to the inner part of the dune system ensures that the coastal defense zone recedes when sea levels rise. Allowing washovers during storm-surges, will have similar effects. In many cases such a "strategic retreat" is possible or changes in land-use behind the dunes may make in possible in the longer run.

Vegetation management

Salt marshes, mangroves and other coastal vegetations all reduce the energy impact of waves. When such vegetations are allowed (or maintained) in front of dikes, the effectively protect damage of the outer dike foot. In addition coastal vegetations create a low-energy environment, ehancing sedimentation of suspended material and preventing erosion of sediments already accumulated. Management geared towards the conservation or restoration of coastal vegetation is therefore an effective example of *Working with Nature*. This strategy can also be applied in the inland areas of a delta,

where the development of riverine forests and riparian zones not only breaks waves and enhances the build up of the land, but also increases the retention capacity for river water. In addition the high productivity of such areas can satisfy part of the need for energy, building materials and food of the inhabitants of the delta area.

Separating navigation and sediment routes

Traditionally, many ports are situated in delta areas. The deep channels allowing vessels to travel to and from the harbor, cause sediments to creep into the port's basin and necessitates frequent dredging. Those same sediments under natural circumstance would help maintain the delta front and in this way would contribute to the natural safety of the area. Inother words: deep navigation channels draw sediments to the "wrong" place. Possibilities to separate the deep navigation channels from the route taken by sediments need to be explored.

Managed retreat

In tide dominated areas the dimensions of the channels through which water flows in and out, is determined by the size of the area behind them that is allowed to flood (tidal storage). If that flooded area is reclaimed, the natural response of the system is for the channels to silt up. In this way, numerous villages and towns in delta's (would) have lost their natural connection to the sea.In order to prevent the close off, inhabitants of these settlements started dredging the canals. "Depoldering" the reclaimed areas would not only take away the necessity for dredging, but would also allow the depoldered area to gradually silt up in pace with the (rising) sea level.

Natural retention areas

Due to reclamation and construction of dikes, the flooding regime characteristic for a natural delta, in many places is a phenomenon of the past. By removing the dikes in sparsely populated areas and allowing the controlled flooding of these areas, sufficient storage space will be created thus helping prevent the breakage of dikes protecting the more densely populated areas. In addition the flooded areas will increase in height – and thus become safer – as a result of the sediments deposited.

Reopening distributaries

Coastal defense projects in many cases lead to the closeoff of distributaries and sea-inlets. Where this has happened, the delta's inland water and sediment management is thrown off balance. Symptoms not only include eutrophication and algae blooms but also river sediments no longer reach the coast. This reduces the amount of building material available in the long-shore drift: the natural maintenance mechanic of our coast. The natural system can only be restored by opening the distributaries on the seaward side or use storm surge barriers instead of closed dams.

7. Potential partners

Working with Nature potentially has a wide array of benefits. This opens up the possibility for innovative partnerships which together can develop.

Working with Nature is working in partnerhips

The spatial approach illustrated in this report requires different groups to work together. Where applied the strategy usually generates a broad spectrum of benefits but in each case different combination of interests will be served. Therefore building partnerships, just like *Working with Nature*, requires a tailor-made approach.

The most effective partnerships are formed if the people working together are not only driven by a joint motivation to contribute to sustainable solutions but also – equally important – by well understood self-interest. A non-exhaustive list includes possible partners includes:

- Farmers
- Foresters
- Land-owners
- Fisherman (professional or recreational)
- River managers
- Navigation organizations
- City developers
- Harbour authorities
- Industries in need for cooling water
- Energy sector (because many oil- and gas reserves are located under delta's)
- Drinking water companies
- Conservation organizations (national and international)
- Social/health organizations (e.g. Red Cross, Oxfam)
- Recreation and tourism businesses
- Construction companies/project developers
- National governments
- International institutions (e.g. EC, VN)