System analysis of sediments in the water system

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Sullied Sediments

Sediment Assessment and Clean Up Pilots in Inland Waterways in the North Sea Region

Many of the inland waterways in Europe are under threat due to the introduction of Watch List chemicals that are not currently regulated under the European Water Framework Directive. These chemicals enter our waterways as a result of our day-to-day activities and through industry, and many have been shown to be harmful to wildlife and the wider aquatic environment. Regardless of their source, these pollutants accumulate in the sediments in our rivers and canals over time.

Water regulators and managing authorities do not always know the levels, locations or impacts of these pollutants. Nor do they have the tools to assess sediments confidently and make informed environmental management decisions. To address these issues, the Sullied Sediment project partnership of scientific experts, regulators and water managers is developing and testing new tools that will enable stakeholders to better assess, treat and prevent contamination from these chemicals. This work is being carried out at selected sites in the Elbe, Humber and Scheldt river catchments.

The intention of the Sullied Sediments project is therefore to help regulators and water managers make better decisions with regard to the management, removal and disposal of sediments, thereby reducing economic costs to private and public sector organisations, and the impact of these pollutants on the environment.

The partnership is also working to reduce the extent of chemicals entering the water system by raising awareness about what we, as consumers, are releasing into the environment through the use of common drugs and household products. This includes the involvement of volunteers in a sediment sampling initiative across the North Sea Region, which will inform and empower them as water champions in their local communities.

The Sullied Sediments project has been co-funded by the European Regional Development Fund through the Interreg VB North Sea Region Programme with match funding from the 13 partners involved. The project partnership includes public, private, community and voluntary sector organisations based in the United Kingdom, Germany, Belgium and the Netherlands.

The project has been supported under the Interreg VB North Sea Region Programme's third priority, which is focused on a Sustainable North Sea Region, and is led by the University of Hull (UK).

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Abstract

Every year, a destination is sought for large quantities of dredged sediments. Many valorisation routes have been mapped out, but still too little sediment is finding its way to the market for beneficial use. VLAKWA, the Flanders Knowledge Center for Water, focusses on the environmental, policy and legal aspects concerning the reuse of dredged sediments. The aim of this co-creation project is to look for new solutions for sediment policy. To this end, an exploration has been set up from a systemic perspective. By identifying underlying mental models (in addition to events, patterns, etc.) , the deeper problems (with the associated opportunities) have been explored. This provided a widely broadened and enriched view of the factors that underlie a number of persistent mechanisms within this policy field and provides a broader view of possible causes. A non-exhaustive range of possible systemic levers have been listed throughout this report and may be explored further - preferably in a co-creative context.

The above challenge is a valorisation problem. The need for valorisation tracks, due to the large amount of dredged sediments, however, is a social choice: we are dredging to provide a sufficient draft for shipping, because of coastal protection, to ensure efficient water drainage, etc. Functions that in the light of climate change and in case of an unchanged approach will increase in importance.

In order to make, in the short term, the right choices for the long term, it is necessary to build up a shared understanding of the main underlying processes that contribute to these volume of sediments, the dynamics that play a role in the reuse and, if possible, how these dynamics are (or will be) influenced by climate change.

In order to increase this understanding, OVAM has set up an additional trajectory to get a clear picture of the complexity of the problem and to identify solution corridors. To this end, several co-creation sessions were organised at Flemish and European level, starting from the joint creation of a connection map. The full report of this trajectory is added as appendix.

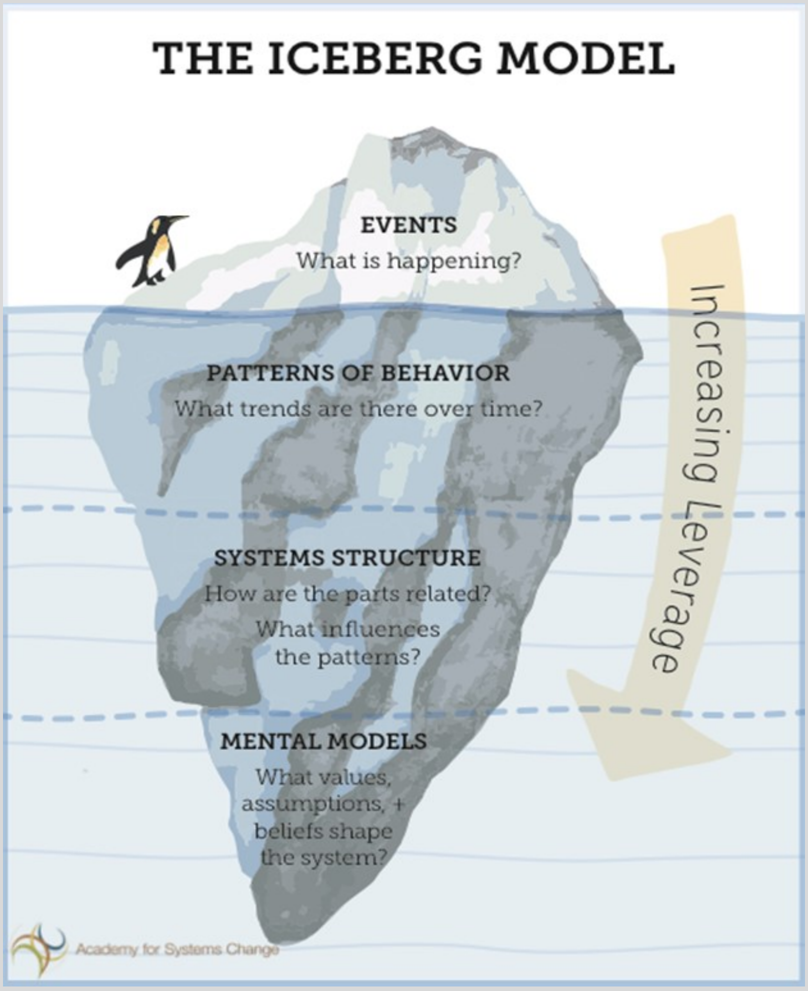
Introduction

For this assignment, the study “System exploration for the transition to a Robust water system (2018)” was further developed and the concepts of system thinking and system analysis were applied to reveal the underlying causes of water scarcity, water nuisance and water quality and the possible solutions.

A fundamental concept within system logic is that - regardless of the person / organization who makes decisions within the system - the same results / events will be achieved within the same system structure. The system structure is thus responsible for a substantial part of all events that occur. If we want to change the course of a system, we must therefore first focus on the system structures and underlying mental models / thinking patterns. A valuable model that can be used as a guideline to gain insight into this is the iceberg model, within which 4 clear levels can be distinguished (see box 1).

Integral system view: deeper than the tip of the iceberg

With an iceberg, only the tip is visible. Beneath the tip, there is a lot of mass that remains hidden. If we only react to the tip, the iceberg will keep coming. If you do not investigate the underlying structure / logic, you will stay busy with everyday events and never tackle anything structural. It is necessary to focus on the cause and not just on the symptoms. Systems thinking is thinking about the hidden part of the iceberg. It is sometimes better not to react directly to an event (drought, flood, fish mortality, etc.), but to wonder why it happened. Systems thinking is looking for the causes.



The analogy with the iceberg is nice here because it indicates that 90% of the causes of these events are below the waterline and are not directly visible to us.

- The first level is above the waterline and are the events we can see. If we focus on these events, we can only take reactive measures aimed at short-term remediation:
  - The damage suffered by agriculture because of a long-term drought is compensated from the disaster fund;
  - An operator in the port that is confronted with large volumes of dredging sediments sets up new sites to dump the sediments;
  - …
- The second level is just below the 'waterline' and these are the patterns or trends. At this level, insight is gained into how certain events evolve over time. These insights allow you to act more proactively, or to detect underlying explanations for certain events. Some important observed patterns are:
  - The drought is increasing year after year, so farmers / province governments, etc. will invest in buffers / basins to deal with prolonged periods of drought;
  - Year after year, a port is confronted with important quantities of dredged sediments and invests in a structural solution to process and store these dredged materials;
  - New forms of contamination are emerging (especially in the medical field) that are currently escaping from the existing and ingrained control structures;
  - …
- From the third level, we begin to gain insight into the system structures and look for the relationships between different patterns, which already allows us to start working on the design (e.g. by weakening reinforcing patterns). Some important observed structures are:
  - Decrease of the organic matter content in the soil results in a reduced water retention capacity and an increased erosion to watercourses. This erosion, in turn, further reduces the organic matter content (example of strengthening pattern - reinforcing loop). Initiatives that aim to increase the organic matter content in the soil (for example by assigning a financial value to it) can break through this reinforcing loop;
  - Certain types of (historical) pollution are only activated and thus acutely problematic when they are taken out of the water and come in contact with the air;
  - …
- The fourth level are the mental models. These are beliefs, apparent evidence, thought patterns that underlie how the system is structured and ensure that the situation remains as it is. Focusing the mental models as well as finding out from which (historical) environmental context these have arisen and questioning whether these mental models are still relevant in the current resp. future context is an important lever to achieve system changes. Some important observed mental models are:
  - Added value in the future is not included in short-term considerations, and therefore remains 'out of the picture'. As far as the dumping of contaminated sediments at the current landfills is concerned, there may still be room for about 10 years. Afterwards, space needs to be looked for again, which is not evident in permits and the limited space (costs for dumping will increase). In addition, nature compensation is often required for such activities. In this way, twice as much space may be taken up. Space for a mono-functional purpose of landfill and space for a mono-functional purpose of nature;
  - Solutions are very strongly framed within considerations of pure economic utility and bilateral transactions between parties. If costs and benefits cannot be balanced in an agreement between two parties, a solution is not considered feasible or realistic. As a result, other added values, or value models at the level of possible networks between different actors may not be considered. But also,

damage is sometimes resolved through compensation, without that compensation being linked to the root cause of the damage. Expanding water-related activity, which increases the intensity of dredging activity, compensated by providing elsewhere nature reserves, does not change the link between water-related activity and its impact on the watercourse system. Only in the tables the account of compensation is correct. At system level, the imbalance may be exacerbated;

- Another archetypal mental model within systems thinking is the " tragedy of the commons ', in which common goods (such as a river) are intensively and unlimitedly used by several actors separately, until at some point it can no longer be used by anyone. A classic example is when, due to increasing competition and demand, a lake is emptied more quickly than the fish can reproduce, so that ultimately no one can fish, and no one gets more fish.

Methods

This co-creative transition process was aimed at developing a shared understanding of the system structures and underlying mental models to arrive at sustainable intervention strategies at the dredging and clearance level. To this end, various co-creation sessions were organized on Flemish and European level, in which people with different and additional perspectives on the problem in question, with fresh ideas and an open mind were brought to the table. The focus on having different perspectives around the table is essential as we do not make decisions based on reality, but on our perception of reality. By looking at a challenge from different angles, the quality of our perception is improved and so is the quality of our decision / intervention strategies

The table below gives an overview of the different co-creation sessions and expertise that contributed:

Date	Target audience	Location	Number of participants	Expertise
18/03/2019	Flemish	Mechelen (Baarbeekhoeve)	20	Policy (water, waste, materials, earthmoving), knowledge institutions (reuse, ecosystem services), agriculture, construction, technology, remediation, dredging
20/05/2019	European	Antwerpen (Port of Antwerp)	35	Policy (water, waste, materials, earthmoving, mobility and public works, port authority), knowledge institutions (reuse, ecosystem services, nature-based solutions), energy, agriculture, construction sector, technology, remediation, dredging, legislation
11/06/2019	Flemish	Antwerpen (Amoras)	21	Policy (water, waste, materials, earth moving), knowledge institutions (reuse, ecosystem services), agriculture, construction, technology, sludge treatment, waste treatment and soil remediation and water treatment, mining
23/10/2019	European	Bremen Ports, Germany	27	SEDNET – WG Circular Economy

Table 1: Overview of the different co-creation sessions during this process and the expertise that contributed

During the different co-creation sessions, various exercises were set up to let the participants get in touch with:

- The different levels of the iceberg model (see Appendix 1 – Iceberg model);
- Drawing up connections to focus on the system structure (see appendix 2 - Minister of Sludge);
- Mental models (see Appendix 3 - Illegal dumping);
- Further refining these analyses and identifying high-impact relationships (see appendix 4 - Enrich, validate, and deepen the link analyses);
- Making the transition from diagnosis to action (See Appendix 5 - Turn the stream);
- Finding new alliances (See Appendix 6 - Unusual suspects);
- Defining priority actions from a long-term perspective (see Appendix 7 - E- article).

The resulting insights were then structured in the report attached as appendix. The system structures and mental models are briefly presented in Chapter 3 and Chapter 4. The starting points for interventions are listed in Chapter 5. A start with prioritization, conclusions and follow-up steps are described in Chapter 6 and Chapter 7 respectively.

Results - System structures

During this trajectory, three connection analyses that were made and validated, are briefly described in the causal loop diagrams (CLD) below:

- Sedimentation relationship analysis (risk of flooding & non-navigability);
- Contamination relationship analysis (delay in clean-up);
- Treatment relationship analysis (disposal/landfilling vs. cleaning of sediments).

Sedimentation relationship analysis (risk of flooding & non-navigability);

Increasing sedimentation increases the risk of flooding and the navigability of waterways (1). To remedy this, dredging works are carried out (2-3). However, carrying out dredging works at a specific location results in a reduction of the flow velocity, as the flow profile of the waterway increases at the location of the dredging works, (4) as a result of which the capacity of the water to transport sediment decreases (5), causing sedimentation to occur again (6) and the waterway clogs up again.

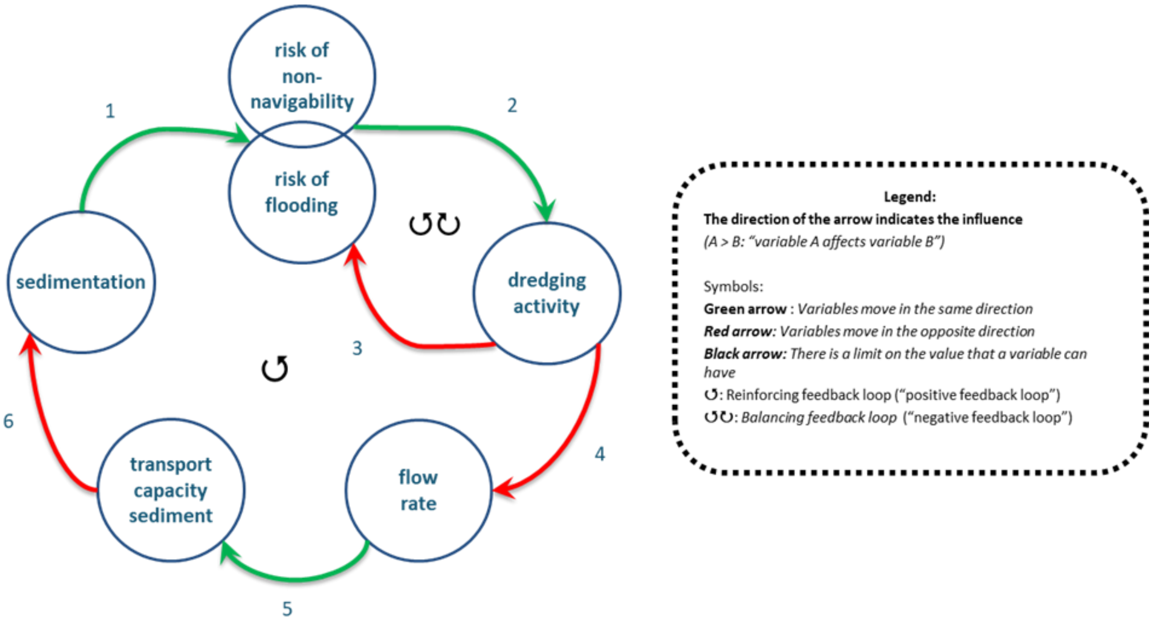


Figure 1 System analysis - sedimentation (CLD 1)

Contamination relationship analysis (delay in clean-up)

The contamination of the waterbed leads to higher dredging costs. Given that there are only a limited budget available, certain dredging activities are temporarily postponed. This mainly concerns small waterways and unnavigable waterways. This increases the risk that the pollution will spread over a larger area. Further dispersal of pollution will further increase costs (2), which means that certain dredging activities will be postponed even further over time (3).

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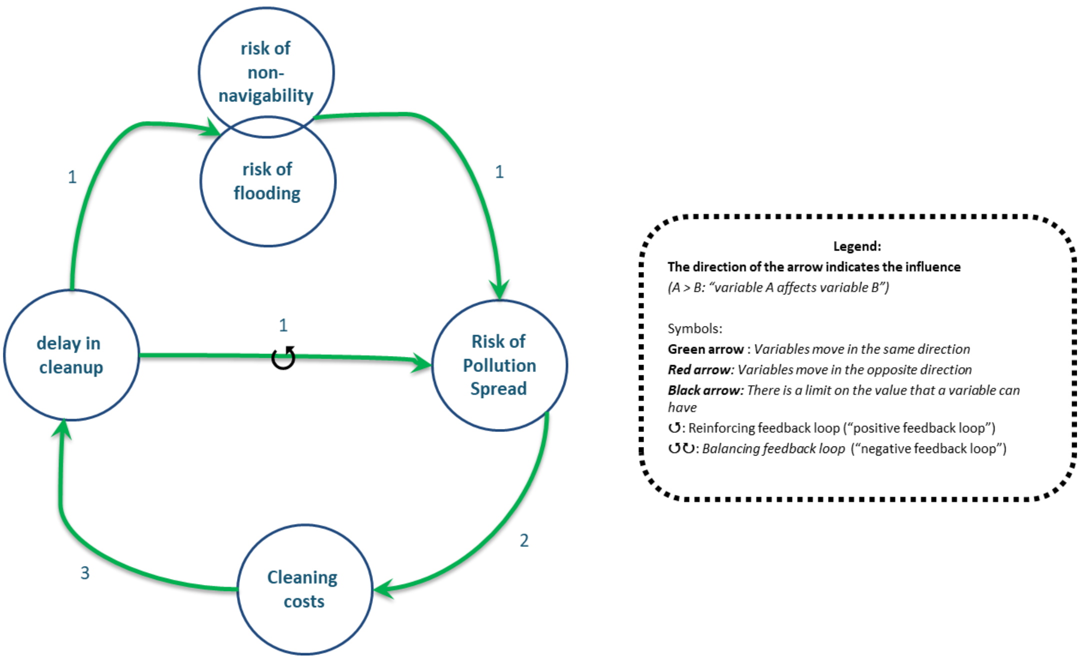

Figur2 System analysis - Contamination (CLD 2)

Treatment relationship analysis (Disposal vs. Cleaning)

Every year, a solution must be found for a significant volume of contaminated sludge. As a back-up solution (safety net), the choice is made to dump it (the more the sediment is disposed of (1), the less contaminated sediment remains in the waterway (2)). However, for the transport of the sediment to the landfill sites and the storage of the contaminated sludge, capital is withdrawn from the track to clean these sediments (the more sediment that is cleaned (3), the less contaminated sludge is left in the waterway(4)). The greater the possibilities of giving a second life to the stored or cleaned volumes, the lower the storage or cleaning costs. The potential for valorisation, however, depends on different factors:

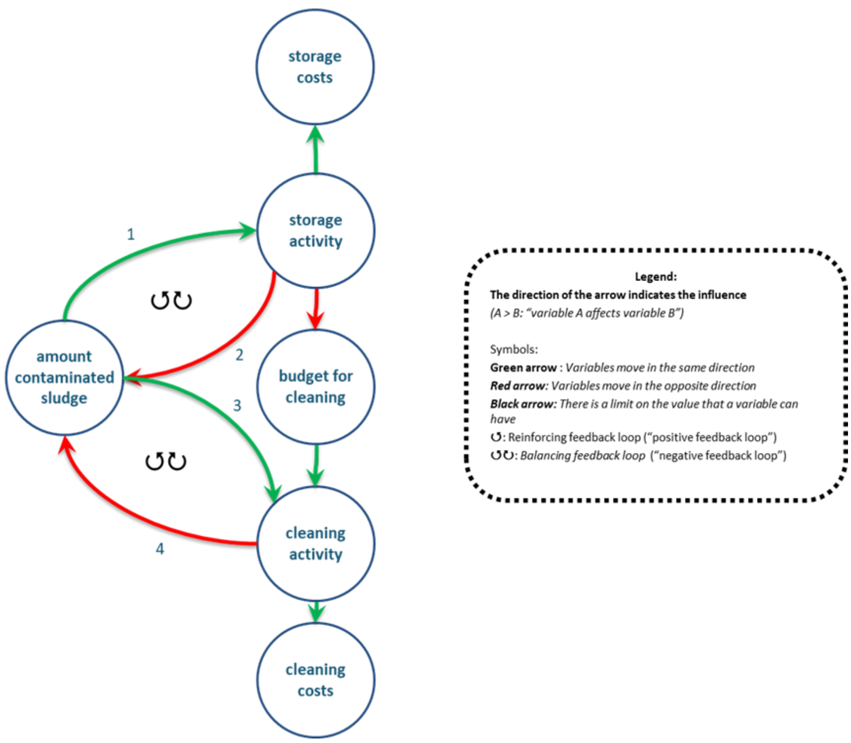

Figure 3: System analysis – disposal vs cleaning (CLD 3)

A variable that has a specific impact on landfill costs is space. Space is required for the storage of dredging and clearing sludge. But that space is limited, so that the cost of landfilling will only increase (to a level where it becomes interesting to clean the sludge immediately). In addition, there is a decreasing acceptance towards landfilling, because of which obtaining permits for the expansion of the landfill capacity is not obvious (this is already an incentive to reconsider whether certain fractions can be valorised. If volumes are reduced, one can dump longer within the licensed landfill capacity).

Identifying mental models

The above-mentioned system structures are driven by certain mental models (beliefs, apparent evidence, thought patterns). Usually they are part of a broader worldview, within which the mental models acquire a certain coherence. The following mental models could be identified throughout the discussions in the thinking sessions.

- <u>We need economic growth for our prosperity (CLD 1)</u>
  The general mental model is that we need economic growth for prosperity and that nature is at the service of human activity (cutting of natural environment e.g. of new docks, straightening, widening watercourses for increased shipping, etc.).
- <u>No incentive to tackle problems if no one can be blamed, without a guilty party the responsibility automatically lies to the government (CLD 2)</u>
  If the debt cannot be allocated to an existing / specific actor, and the problem has no immediate unambiguous consequences for a particular social actor, then there is usually no incentive to solve the problem. (e.g. remediation or clearance is postponed).
- <u>Tackling problems is put in front until all knowledge is available (CLD 2 & 3)</u>
  Delay behaviour is not only the result of not being able to identify the guilty party, but also from the fact that we want to have all knowledge available before acting. An approach that is generally known as evidence-based policy (or evidence policy): only if one perfectly knows the effects of a particular policy measure or policy approach, one will make responsible decisions.
- <u>Need for ownership to generate added value</u>
  If there is no ownership, there is little incentive to generate added value. As a private owner, with real estate you have a value of bare ownership and a value for usufruct (read = utility value). Remediation of a land will increase the value of the bare property. When remediating a waterbed (in public ownership), the utility value will increase, but the bare ownership will not be valorised. In that respect, the government is well placed to take ownership, but it is faced with a short-cycle political system that often makes long-term 'ownership' difficult.
- <u>Inability to advance added values from the future to the present (CLD 2)</u>
  It is difficult dealing with delays We don't find it easy to draw added value from the future into the present. The inability to deal with delays is also manifests itself at the type of measures we take. If it is decided to act, preference is given to measures in which we can see the results immediately - these are often also measures at the end of the chain.
- <u>Downscaling to tackle major challenges</u>
  By dividing large problems into small problems that can be tackled quickly, our natural need for quick feedback and results is met. This may have led to the creation of silos with a division of disciplines and powers, among other things.
- <u>Postpone interventions until an emergency occurs</u>
  There is a mental model that we first need a disaster / catastrophic / impactful event to take steps towards our dream image. But do citizens really want a disaster to happen first?
- <u>A linear thinking</u>
  We are convinced that by remediating the sediments at the end of the chain, we safeguard all possible social functions that sediment fulfils (I. Security - e.g. attenuation of tidal amplitude, ii. avoiding erosion in the river which could cause damage to infrastructure, ecology: distribution of nutrients, nurseries for fish,

biodiversity, etc.),…
Other mental models that have been identified include that waste - regardless of the cleaning steps undertaken - continues to be perceived as waste, that the location of a port cannot be changed, that the price of a good is determined by the market logic of supply and demand, that the SPECS that are set by the industry to determine which type of raw materials they need are sacred, that the responsibility for a clean waterway / sediment lies with the government (there is a low social responsibility), in order to remain competitive as a port, the requirements of the shipping companies must be met.

Based on the above insights (e.g. at the level of the system structures and the underlying mental models) it is then examined how the system can be influenced in a positive way. This exercise uses the system levers as drawn up by Donella Meadows, which can be used as a starting point for this exercise:

- Events and patterns (variables, quantities, delays, etc.);
- System structure (introduce balancing loops, slow down reinforcing loops, change system rules) – see the causal loop diagrams higher up in the report;
- Mental models.

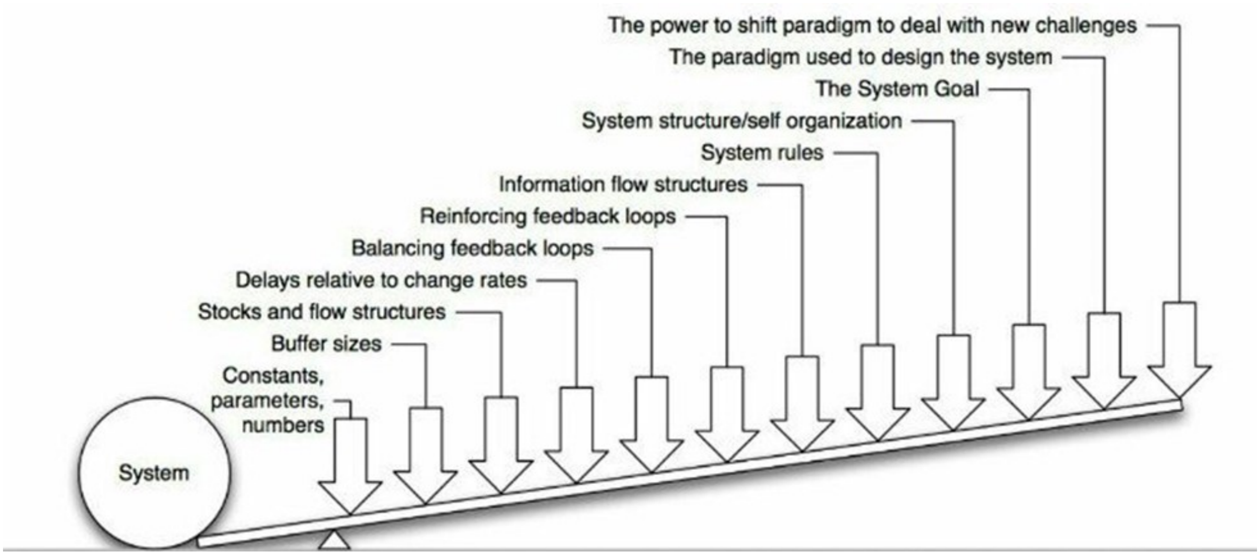

Figure 2: System levers as drawn up by Donella Meadows

Discussion

The discussions during the different sessions led to a further insights at the level of the system structures and the underlying mental models. Further discussions examined how the system can be influenced in a positive way.

Constants, parameters, numbers (such as subsidies, taxes, standards)

These are measures with which you typically try to adjust the speed of the inflow and outflow from a system to ensure that the system is ultimately in the preferred state (e.g. no contaminated sediment in the waterway / no storage of dredging and clearing spoil). Metaphorically, it is about turning on the tap and closing the drain tighter or looser to have or keep a desired amount of water in the bath. The focus is on the water in the bath, not where the draining water is going, nor where the water for the bath should come from.

If you remove the above taken measures, the negative consequences will simply reoccur. It will therefore in any case be necessary to start activating levers 'sideways' in the system to achieve a longer-term impact. For example, we can think of the following suggestions that were mentioned by the co- creators:

Creating buffers

You can often stabilise a system by increasing the capacity of a buffer. However, large buffers cost a lot of money in construction and maintenance. That is why it is important to always look at deeper drivers, which control the necessity and often also the costs of buffers. However, if the sediments were not contaminated, they could simply be returned to the field and used by the farmer.

Improving physical structures

The way in which (in/out) flows and buffers are physically organised can have a major impact on the functioning of the system. The challenge with this lever is (1) that it usually takes a long time before the physical structure is adjusted (is it still up to date upon delivery?), and (2) it is very expensive and often has a long depreciation period, causing you lose flexibility. It is therefore worthwhile to first identify which approaches are the least infrastructure-dependent for achieving your system’s objective. Avoiding pollution at source probably requires

The duration of delays

If you try to adjust a system to your target but you only receive delayed information about the impact of your actions, you will under- or over- achieve your objective. The same applies if you receive timely information but there are significant delays in the response (e.g. the required planning and construction time / adapting the legislation based on new insights into contamination). It therefore requires a different set of links in information flows and often also different knowledge or statistical insight.

Enhance negative or balancing feedback loops

Each negative feedback loop has a target, a monitoring tool to detect and signal deviations from the target, and a reaction mechanism. A classic example is the thermostat, which has the objective of keeping the ambient temperature at a certain value.

These loops are often limited by a certain limit in one of the variables. As an example, here, the available space can be taken for the dumping of dredged material. Because space is finite (physically or policy-wise), a feedback mechanism arises: if more is deposited than the available space decreases and the storage cost increases, so that less will be deposited (search for other routes).

Weaken positive feedback loop

A negative feedback loop is self-correcting, while a positive feedback loop is self-reinforcing. Positive feedback loops are sources of growth, explosion, erosion, and system collapse. -Positive feedback loops include:

Increased dredging activity at a certain location → leads to more sedimentation at that location → leading to more dredging activity at that location;

Delayed remediation → leads to an increased risk of spreading contamination → leading to higher costs (less can be done with the available budget) → leading to delayed remediation.

Improving the structure of information flows

Providing information can be an important lever and much cheaper than adjusting the physical structure. An important precondition is that it is delivered in the right place and preferably in a compelling form (information must encourage people to take the right action).

Change of system rules (e.g. laws, penalties, social agreements)

The rules of the system determine the room for manoeuvre, the limits, the degrees of freedom:

Self-organisation = System repairs itself

The most amazing thing that systems can do is to completely change themselves by creating entirely new structures and behaviour. In biological systems, that power is called evolution. In the human economy, we call it technical progress or social revolution. In system lingo, it's called self-organisation. Self-organisation is the result of a supply of a raw material for innovation, from which a large variety of patterns can emerge as well as a test mechanism to evaluate the new patterns.

Any system that sweeps away the incentive for innovation is doomed to fail in the long run. Therefore, it is extremely important to pay attention, among other things, to the preservation of biodiversity. Allowing species to become extinct is a systemic crime, just as arbitrary eliminating all copies of certain scientific journals, or certain scientists, would also be. A few examples:

Adjusting system objectives

Most negative feedback loops have their own objective: ensuring that the ambient temperature is 20°C, a preferred water quality, water level, water temperature. These objectives are important levers for parts of the system. But there are higher, less clear objectives that will determine how the system will be organised and what the above sub-objectives will be.

Formulating an objective for a long-term robust water system goes beyond the scope of our meetings, but a suggestion was made that could potentially mean a step in that direction: Independent structure that ensures that things are viewed from a system structure and that breaks through pigeonholed thinking in relation to own resources.

Changing mindsets or paradigms

Each system is driven by certain mental models/ /thinking patterns. As mental models are seen or experienced naturally or indisputably, they are very difficult to change – ensuring that the situation remains as it is or even deteriorates. The focus of the mental models/ /thinking patterns + from which environmental context do they originate d and the questioning whether these mental models are still relevant in the in the current or future context is an important lever to realize system changes.

Conclusion

By sketching a long-term perspective (dreamscape), it is possible to consider which actions should be deployed as a priority. The participants of the sessions selected the following solutions as a priority, based on the estimated (positive) contribution to the water sediment system:

- Preventive measures:
  - Relocate ports in such a way that economic activities and ecosystem services are combined;
  - Deployment of other forms of water-related transport or infrastructure (smaller ships, flushing systems at locks, autonomous sailing, ships that dredge themselves, etc.);
- Management of the 'legacy' on contaminated sediments:
  - Let nature act as a self-regulating system for cleaning, transport, dikes;
  - From an emission-based policy - with emphasis on discharge points - to an immission- based approach - with emphasis on the quality in the living environment;
  - From the polluter pays principle to the beneficiary pays principle (e.g. project developers who help pay for the purification of local water courses) and / or stewardship principle (everyone bears responsibility and acts)?
  - (re) use of uncontaminated sediments for local agriculture;
  - Optimal use of the available space through gradual change of focus.

It was the intention of this co-creation project to look for new solutions for sediment policy. An exploration of a systemic perspective was set up and through the identification of underlying mental models (next to events), the underlying problem was (with their associated opportunities) explored. This resulted in a strongly broadened and enriched view of the factors that underlie several persistent mechanisms within this policy field, and a broader view of possible causes.

Incidentally, the difference between what is called endogenous versus exogenous perspectives in systems theory can be recognized throughout the mental models. In an endogenous perspective, the system boundaries include as many relevant variables as possible in relation to the problem in question, where the exogenous perspective will state that the causes are beyond our control. Both perspectives obviously influence the attitude of the various actors involved. It also demonstrates how working on mental models rather than on direct events has greater leverage to make the water sediment system more sustainable / resilient. The current framework of thought may have its limits to arrive at sustainable solutions to this problem.

A non-exhaustive set of possible systemic levers has been listed throughout this report and should be explored further - preferably in a co-creative context. To decide what priority solutions or directions are, it is important that the proposed interventions, which have been discussed throughout the report, can be assessed in terms of impact and feasibility. On the one hand to legitimise them, but also for an investigation into possible measure ecosystems. Some measures will only lead to systemic change in combination with other measures. Systemic interventions will also influence each other.

In any case, the most important first step is to further deepen and thereby legitimize lines of thought and determine the priority solutions. It is best to distinguish between low-hanging fruit, preferably with a large positive impact, and systemic solutions, through co-creation with both ' challenge owners ' and knowledge carriers and 'solution providers'. For the low-hanging fruit, it can be clearly indicated who can or should do what now or in the short or long term. The direction of systemic solutions may not be immediately clear. The question of what needs to be done and with whom may require further insights, which can be built up either through further system analysis or through transition experiments. From the resulting basket of simple, less simple, and even difficult solutions, a balanced trajectory can be drawn up for structural covers.

References

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Acknowledgements

‘Sullied Sediments’ has been co-funded by the European Regional Development Fund through the Interreg VB North Sea Region Programme with a grant of 2.043.413 euros with equivalent match funding from the partners involved. The project partnership includes public, private and third sector organisations based in the United Kingdom, Germany, Belgium and the Netherlands

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Partners

The Sullied Sediments project partnership comprises 13 project beneficiaries:

Canal and River Trust (UK)

East Riding of Yorkshire Council (UK)

Ecossa (Germany)

Hamburg Port Authority (Germany)

Hamburg University of Applied Sciences (Germany)

Institut Dr Nowak (Germany)

Openbare Vlaamse Afvalstoffenmaatschappij (Belgium)

Radboud University (The Netherlands)

Socotec UK Ltd (UK)

University of Antwerp (Belgium)

University of Hull (UK)

University of Leeds (UK)

Vlaamse Milieumaatschappij (Belgium)

The partnership also receives expert advice from 12 strategic partners who form our Advisory Group:

East and North Yorkshire Waterways Partnership (UK)

Elbe Habitat Foundation (Germany)

Environment Agency (UK)

Federal Institute of Hydrology (Germany)

Foundation for Applied Water Research (Europe)

Hamburg Ministry of the Environment and Energy (Germany)

Northumbrian Water (UK)

River Hull Board (UK)

Sediment European Network Steering Group (European)

Thames Water (UK)

Vlakwa (water research consultancy) (Belgium)

Yorkshire Water (UK)

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Appendix

System analysis of sediments in the water system - Report

Co-creation and transition process with the aim of promoting the reuse of dredged sediments

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System analysis of sediments in the water system

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Publication date / 31.12.2020

Flanders
State of the Art

www.ovam.be

DOCUMENT DESCRIPTION

1 *Title of publication:*
System analysis sediments in the water system

2 *Responsible Publisher:*
OVAM

3 *Legal deposit number:*
D/2020/5024/04

4 *Key words:*
sediments, system analysis, reuse

5 *Summary:*
The aim of this co-creation project is to look for new solutions for sediment policy. To this end, an exploration has been set up from a systemic perspective. By identifying underlying mental models (in addition to events, patterns, etc.), the deeper problems (with the associated opportunities) have been explored. This provided a widely broadened and enriched view of the factors that underlie several persistent mechanisms within this policy field and provides a broader view of possible causes. A non-exhaustive range of possible systemic levers have been listed throughout this report and may be explored further - preferably in a co-creative context.

6 *Number of pages: 70*

7 *Number of tables and figures: 2T / 12 F*

8 *Date of publication:*
31 December 2020

9 *Price: /*

10 *Steering committee and/or author:*
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12 *Other publications about the same subject:*

INDEX

1 INTRODUCTION

Every year, a destination is sought for large quantities of dredged sediments. Many valorisation routes have been mapped out, but still too little sediment is finding its way to the market for beneficial use. To respond to this challenge, OVAM, as a partner in the European Interreg project Sullied Sediments (Interreg VB North Sea Region Programme), further investigated how to promote the reuse of (contaminated) sediment. To this end, studies have been carried out that focus on the environmental, policy and legal aspects concerning the reuse of dredged sediments.

The above challenge is a valorisation problem. The need for valorisation tracks, due to the large amount of dredged sediments, however, is a social choice: we are dredging to provide a sufficient draft for shipping, because of coastal protection, to ensure efficient water drainage, etc. Functions that in the light of climate change and in case of an unchanged approach will increase in importance.

In order to make, in the short term, the right choices for the long term, it is necessary to build up a shared understanding of the main underlying processes that contribute to these volume of sediments, the dynamics that play a role in the reuse and, if possible, how these dynamics are (or will be) influenced by climate change.

In order to increase this understanding, OVAM has set up an additional trajectory within the framework of the Sullied Sediments project to use systems thinking to get a clear picture of the complexity of the problem and to identify solution corridors. To this end, several co-creation sessions were organised at Flemish and European level, starting from the joint creation of a connection map. The study on systems thinking/co-creation transition and the studies on environmental, policy and legal aspects will complement each other.

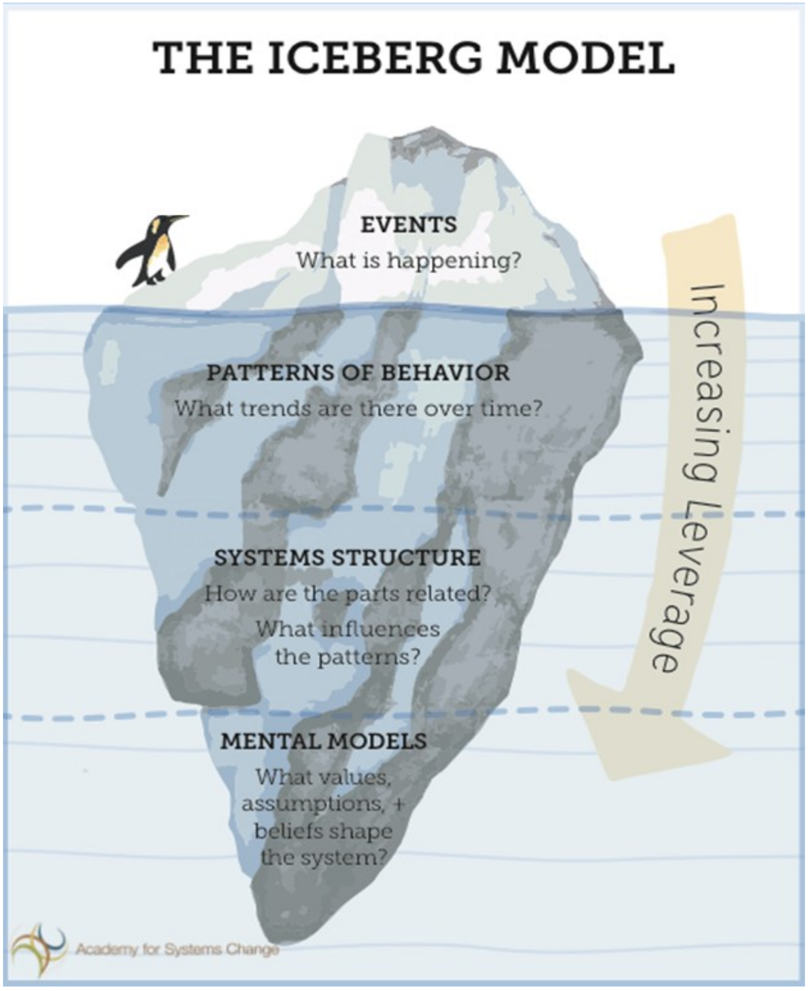
2 APPROACH

For this assignment, the study “System exploration for the transition to a Robust water system (2018)” was further developed and the concepts of system thinking and system analysis were applied to reveal the underlying causes of water scarcity, water nuisance and water quality and the possible solutions.

A fundamental concept within system logic is that - regardless of the person / organization who makes decisions within the system - the same results / events will be achieved within the same system structure. The system structure is thus responsible for a substantial part of all events that occur. If we want to change the course of a system, we must therefore first focus on the system structures and underlying mental models / thinking patterns. A valuable model that can be used as a guideline to gain insight into this is the iceberg model, within which 4 clear levels can be distinguished (see box 1).

Integral system view: deeper than the tip of the iceberg

With an iceberg, only the tip is visible. Beneath the tip, there is a lot of mass that remains hidden. If we only react to the tip, the iceberg will keep coming. If you do not investigate the underlying structure / logic, you will stay busy with everyday events and never tackle anything structural. It is necessary to focus on the cause and not just on the symptoms. Systems thinking is thinking about the hidden part of the iceberg. It is sometimes better not to react directly to an event (drought, flood, fish mortality, etc.), but to wonder why it happened. Systems thinking is looking for the causes.



The analogy with the iceberg is nice here because it indicates that 90% of the causes of these events are below the waterline and are not directly visible to us.

- The first level is above the waterline and are the events we can see. If we focus on these events, we can only take reactive measures aimed at short-term remediation:
  - The damage suffered by agriculture because of a long-term drought is compensated from the disaster fund;
  - An operator in the port that is confronted with large volumes of dredging sediments sets up new sites to dump the sediments;
  - …

- The second level is just below the 'waterline' and these are the patterns or trends. At this level, insight is gained into how certain events evolve over time. These insights allow you to act more proactively, or to detect underlying explanations for certain events. Some important observed patterns are:
  - The drought is increasing year after year, so farmers / province governments, etc. will invest in buffers / basins to deal with prolonged periods of drought;
  - Year after year, a port is confronted with important quantities of dredged sediments and invests in a structural solution to process and store these dredged materials;
  - New forms of contamination are emerging (especially in the medical field) that are currently escaping from the existing and ingrained control structures;
  - …

- From the third level, we begin to gain insight into the system structures and look for the relationships between different patterns, which already allows us to start working on the design (e.g. by weakening reinforcing patterns). Some important observed structures are:
  - Decrease of the organic matter content in the soil results in a reduced water retention capacity and an increased erosion to watercourses. This erosion, in turn, further reduces the organic matter content (example of strengthening pattern - reinforcing loop). Initiatives that aim to increase the organic matter content in the soil (for example by assigning a financial value to it) can break through this reinforcing loop;
  - Certain types of (historical) pollution are only activated and thus acutely problematic when they are taken out of the water and come in contact with the air;
  - …

- The fourth level are the mental models. These are beliefs, apparent evidence, thought patterns that underlie how the system is structured and ensure that the situation remains as it is. Focusing the mental models as well as finding out from which (historical) environmental context these have arisen and questioning whether these mental models are still relevant in the current resp. future context is an important lever to achieve system changes. Some important observed mental models are:
  - Added value in the future is not included in short-term considerations, and therefore remains 'out of the picture'. As far as the dumping of contaminated sediments at the current landfills is concerned,

there may still be room for about 10 years. Afterwards, space needs to be looked for again, which is not evident in permits and the limited space (costs for dumping will increase). In addition, nature compensation is often required for such activities. In this way, twice as much space may be taken up. Space for a mono-functional purpose of landfill and space for a mono-functional purpose of nature;

- Solutions are very strongly framed within considerations of pure economic utility and bilateral transactions between parties. If costs and benefits cannot be balanced in an agreement between two parties, a solution is not considered feasible or realistic. As a result, other added values, or value models at the level of possible networks between different actors may not be considered. But also, damage is sometimes resolved through compensation, without that compensation being linked to the root cause of the damage. Expanding water-related activity, which increases the intensity of dredging activity, compensated by providing elsewhere nature reserves, does not change the link between water-related activity and its impact on the watercourse system. Only in the tables the account of compensation is correct. At system level, the imbalance may be exacerbated;
- Another archetypal mental model within systems thinking is the " tragedy of the commons ', in which common goods (such as a river) are intensively and unlimitedly used by several actors separately, until at some point it can no longer be used by anyone. A classic example is when, due to increasing competition and demand, a lake is emptied more quickly than the fish can reproduce, so that ultimately no one can fish, and no one gets more fish.

This co-creative transition process was aimed at developing a shared understanding of the system structures and underlying mental models to arrive at sustainable intervention strategies at the dredging and clearance level. To this end, various co-creation sessions were organized on Flemish and European level, in which people with different and additional perspectives on the problem in question, with fresh ideas and an open mind were brought to the table. The focus on having different perspectives around the table is essential as we do not make decisions based on reality, but on our perception of reality. By looking at a challenge from different angles, the quality of our perception is improved and so is the quality of our decision / intervention strategies

The table below gives an overview of the different co-creation sessions and expertise that contributed:

Date	Target audience	Location	Number of participants	Expertise
18/03/2019	Flemish	Mechelen (Baarbeekhoeve)	20	Policy (water, waste, materials, earthmoving), knowledge institutions (reuse, ecosystem services), agriculture, construction, technology, remediation, dredging
20/05/2019	European	Antwerpen (Port of Antwerp)	35	Policy (water, waste, materials, earthmoving, mobility and public works, port authority), knowledge institutions (reuse, ecosystem services, nature-based solutions), energy, agriculture,

				construction sector, technology, remediation, dredging, legislation
11/06/2019	Flemish	Antwerpen (Amoras)	21	Policy (water, waste, materials, earth moving), knowledge institutions (reuse, ecosystem services), agriculture, construction, technology, sludge treatment, waste treatment and soil remediation and water treatment, mining
23/10/2019	European	Bremen Ports, Germany	27	SEDNET – WG Circular Economy

Table 1: Overview of the different co-creation sessions during this process and the expertise that contributed

During the different co-creation sessions, various exercises were set up to let the participants get in touch with:
- The different levels of the iceberg model (see Appendix 1 – Iceberg model);
- Drawing up connections to focus on the system structure (see appendix 2 - Minister of Sludge);
- Mental models (see Appendix 3 - Illegal dumping);
- Further refining these analyses and identifying high-impact relationships (see appendix 4 - Enrich, validate, and deepen the link analyses);
- Making the transition from diagnosis to action (See Appendix 5 - Turn the stream);
- Finding new alliances (See Appendix 6 - Unusual suspects);
- Defining priority actions from a long-term perspective (see Appendix 7 - E- article).

The resulting insights were then structured in the chapters below. The system structures and mental models are briefly presented in Chapter 3 and Chapter 4. The starting points for interventions are listed in Chapter 5. A start with prioritization, conclusions and follow-up steps are described in Chapter 6 and Chapter 7 respectively.

Figure 1. Impressions of co-creation sessions.

3 FOCUSING THE SYSTEM STRUCTURES (RELATIONSHIPS BETWEEN PATTERNS)

During this trajectory, three connection analyses that were made and validated, are briefly described below:

- Sedimentation relationship analysis (risk of flooding & non-navigability);
- Contamination relationship analysis (delay in clean-up);
- Treatment relationship analysis (disposal/landfilling vs. cleaning of sediments).

3.1 SEDIMENTATION RELATIONSHIP ANALYSIS (RISK OF FLOODING & NON-NAVIGABILITY)

The following events occur due to sedimentation in navigable/unnavigable watercourses:

- The less rapid discharge of excess water into the watercourse;
- Flooding and flooding of farmlands, due to insufficient water storage capacity in the watercourse, which mortgages the potential uses of this area;
- Due to high water levels a possible problem with too low bridge heights (and therefore possible problems with shipping);
- An increased energy demand for shipping (sailing with too little space under the keel, requires extra energy);
- To avoid stalling, it can be decided to load ships less or to use smaller ships. It may be decided to choose a different shipping route, to switch to rail or road transport or to postpone transport. In general, the sailing time and waiting time will increase;
- …

Increasing sedimentation increases the risk of flooding and the navigability of waterways (1). To remedy this, dredging works are carried out (2-3). However, carrying out dredging works at a specific location results in a reduction of the flow velocity, as the flow profile of the waterway increases at the location of the dredging works, (4) as a result of which the capacity of the water to transport sediment decreases (5), causing sedimentation to occur again (6) and the waterway clogs up again.

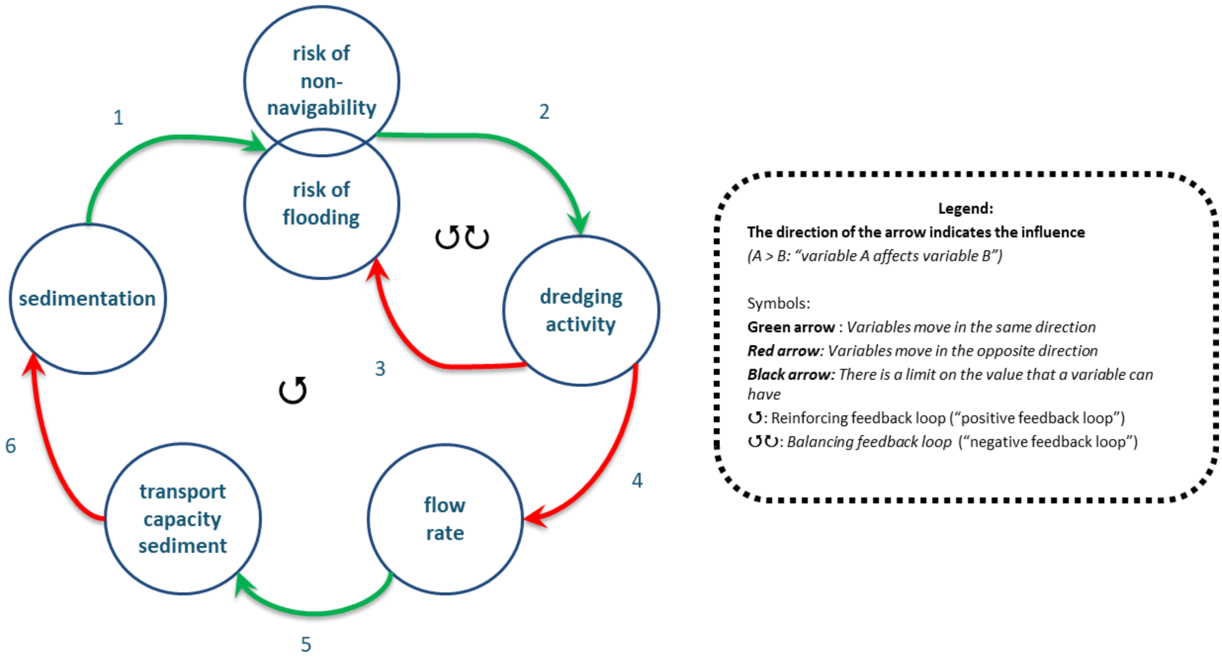


Figure 2 System analysis sedimentation (CLD 1)

3.2 CONTAMINATION RELATIONSHIP ANALYSIS (DELAY IN CLEAN-UP)

The contamination of the waterbed leads to higher dredging costs. Given that there are only a limited budget available, certain dredging activities are temporarily postponed. This mainly concerns small waterways and unnavigable waterways. This increases the risk that the pollution will spread over a larger area (1) e.g. because of:

- Erosion in the river;
- A lowered water level in the waterways. Sailing at the limits will result in sediment spreading. At the same time, oxidation processes will take place because of turbulence in the sediment and heavy metals, will be released out of the sediment;
- Reduced storage capacity with an increased risk of flooding, which may also leave contaminated sediment on the banks;
- …

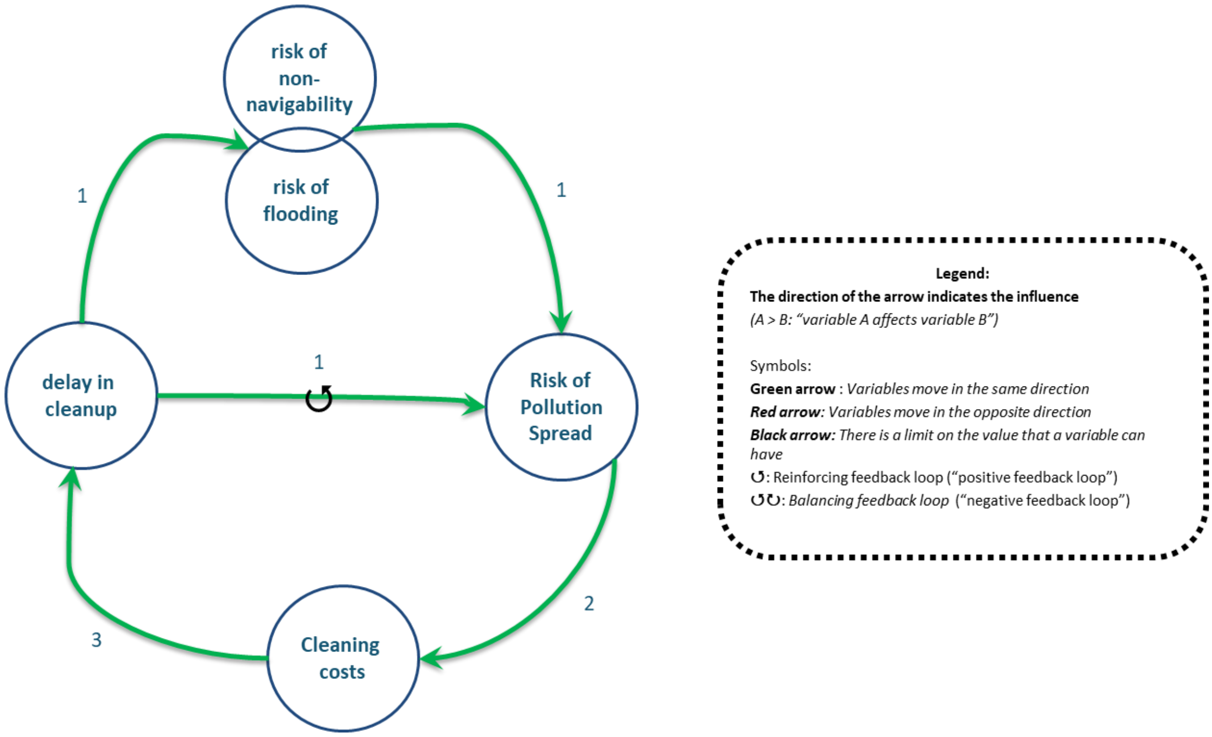


Figure 3. System analysis Contamination (CLD 2)

Further dispersal of pollution will further increase costs (2), which means that certain dredging activities will be postponed even further over time (3).

3.3 TREATMENT RELATIONSHIP ANALYSIS (DISPOSAL VS. CLEANING)

Every year, a solution must be found for a significant volume of contaminated sludge. As a back-up solution (safety net), the choice is made to dump it (the more the sediment is disposed of (1), the less contaminated sediment remains in the waterway (2)). However, for the transport of the sediment to the landfill sites and the storage of the contaminated sludge, capital is withdrawn from the track to clean these sediments (the more sediment that is cleaned (3), the less contaminated sludge is left in the waterway(4)). The greater the possibilities of giving a second life to the stored or cleaned volumes, the lower the storage or cleaning costs. The potential for valorisation, however, depends on different factors:

- developments in the market for primary raw materials and other secondary raw materials (e.g. resulting from excavations);
- the environmental quality of the dredged sediment (whether it has been cleaned);
- The structural quality of the sediment.

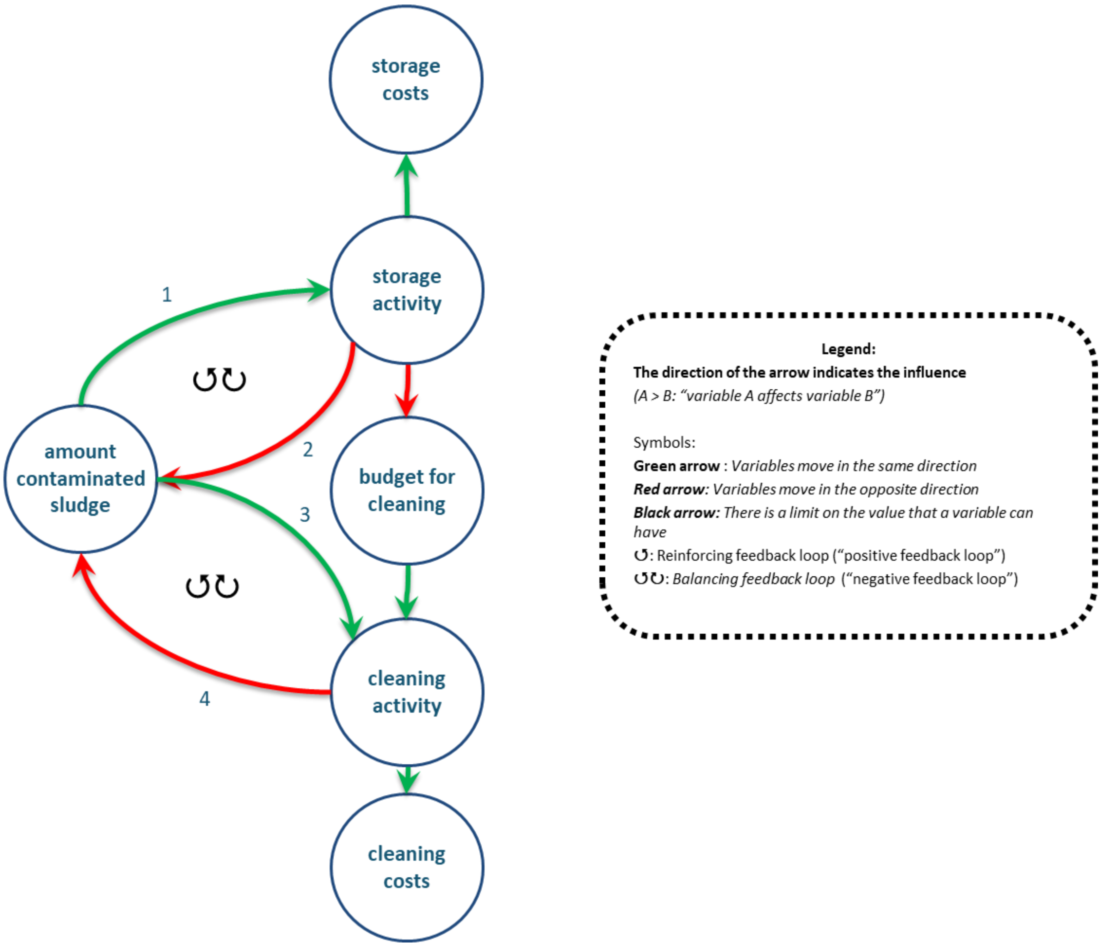


Figure 4: System analysis – disposal vs cleaning (CLD 3)

A variable that has a specific impact on landfill costs is space. Space is required for the storage of dredging and clearing sludge. But that space is limited, so that the cost of landfilling will only increase (to a level where it becomes interesting to clean the sludge immediately). In addition, there is a decreasing acceptance towards landfilling, because of which obtaining permits for the expansion of the landfill capacity is not obvious (this is already an incentive to reconsider whether certain fractions can be valorised. If volumes are reduced, one can dump longer within the licensed landfill capacity).

4 IDENTIFYING MENTAL MODELS

The above-mentioned system structures are driven by certain mental models (beliefs, apparent evidences, thought patterns). Usually they are part of a broader worldview, within which the mental models acquire a certain coherence. The following mental models could be identified throughout the discussions in the thinking sessions.

4.1 WE NEED ECONOMIC GROWTH FOR OUR PROSPERITY (CLD 1)

The general mental model is that we need economic growth for prosperity and that nature is at the service of human activity (cutting of natural environment e.g. of new docks, straightening, widening watercourses for increased shipping, etc.).

4.2 NO INCENTIVE TO TACKLE PROBLEMS IF NO ONE CAN BE BLAMED, WITHOUT A GUILTY PARTY THE RESPONSIBILITY AUTOMATICALLY LIES TO THE GOVERNMENT (CLD 2)

If the debt cannot be allocated to an existing / specific actor, and the problem has no immediate unambiguous consequences for a particular social actor, then there is usually no incentive to solve the problem. (e.g. remediation or dredging and clearance is postponed). Observation formulated for the mental model: "when no culprit can be identified, there is no incentive to solve the problem". In that case, in Flanders one almost automatically look to the government to take responsibility and therefore the costs.

> "This is certainly the case in the US, where the criterion of techno-economic optimization to determine if the sediments must be remediated has been abandoned. As a result of which the costs of remediation are exuberantly high and there are very lengthy legal proceedings pending against the guilty party who will eventually have to pay for this remediation. In Flanders and the Netherlands, there is rather a state model, in which the remediation is carried out from the collective resources and this from public interests regarding safety / redevelopment / water scarcity".

4.3 TACKLING PROBLEMS IS PUT IN FRONT UNTIL ALL KNOWLEDGE IS AVAILABLE (CLD 2 & 3)

Delay behaviour is not only the result of not being able to identify the guilty party, but also from the fact that we want to have all knowledge available before acting. An approach that is generally known as evidence-based policy (or evidence policy): only if one perfectly knows the effects of a particular policy measure or policy approach, one will make responsible decisions. During one of the workshops the following conclusion was drawn:

“The lack of knowledge leads to a non-integrated approach, which means that limited financial and human resources may not be used sparingly. It is therefore important to invest very strongly in new knowledge models. However, it takes time to produce new knowledge for each new pollutant. It is therefore an illusion to have all knowledge available to determine the 'right' prioritization.”

4.4 NEED FOR OWNERSHIP TO GENERATE ADDED VALUE

If there is no ownership, there is little incentive to generate added value. As a private owner, with real estate you have a value of bare ownership and a value for usufruct (read = utility value). Remediation of a land will increase the value of the bare property. When remediating a waterbed (in public ownership), the utility value will increase, but the bare ownership will not be valorised. In that respect, the government is well placed to take ownership, but it is faced with a short-cycle political system that often makes long-term 'ownership' difficult.

4.5 INABILITY TO ADVANCE ADDED VALUES FROM THE FUTURE TO THE PRESENT (CLD 2)

Another mental model is concerned with the fact that it is difficult dealing with delays We don't find it easy to draw added value from the future into the present. There may still be room for dumping contaminated sediment in the current landfills for about 10 years. Afterwards, space will have to be searched for again, which is not obvious regarding obtain permits and the limited space available (cost for dumping will increase). Moreover, nature compensation should be provided for such activities. In this way, twice as much space is taken up. Space for a mono-functional purpose of landfill and space for a mono-functional purpose for nature. A lever that can be used to reduce dumping is to levy a dumping tax;

- In addition, much more can be done to selectively deposit various qualities that can then be mined later (Appendix 4 - Box 6).

The amount of raw materials is also finite:

The inability to deal with delays is also manifests itself at the type of measures we take. If it is decided to act, preference is given to measures in which we can see the results immediately - these are often also measures at the end of the chain. For example, the proposed interventions are very focused on finding solutions for the contaminated sediment. Not on avoiding the contamination. We prefer to focus on measures that heal curatively and proactively (the increasing share of medicine residues, however, puts a mortgage on the health of our environment).

4.6 DOWNSCOPING TO TACKLE MAJOR CHALLENGES

By dividing large problems into small problems that can be tackled quickly, our natural need for quick feedback and results is met. This may have led to the creation of silos with a division of disciplines and powers, among other things. For example, in the sediment story this is expressed at the level that remediation works are carried out downstream by a certain authority without tackling the upstream point sources that fall under a different competence, as a result of which the problem simply returns.

Take, for example. Consumption. Consumption is integrally linked to our quality of life. Clean air, soil, sediment, water should also be an integral part of this equation.

4.7 POSTPONE INTERVENTIONS UNTIL AN EMERGENCY OCCURS

"Give us our daily bread, and the occasional flooding" (Dutch proverb)"

There is a mental model that we first need a disaster / catastrophic / impactful event to take steps towards our dream image. But do citizens really want a disaster to happen first? Rather, need to think about it:

- The role of education;
- The way we interact with citizens. We need to think carefully about the way scientific results are published. In addition, we need to make a much stronger effort to involve citizens more closely in the projects we set up. This is to ensure that citizens are better informed, understand the importance of certain initiatives and create support for them;
- Learning to deal with uncertainties. Within this framework, you can only judge whether a measure is effective/efficient when you are confronted with a calamity (and these calamities only happen a few times in a decade).

4.8 A LINEAR THINKING

Another mental model relates to our linear thinking. We are convinced that by remediating the sediments at the end of the chain, we safeguard all possible social functions that sediment fulfils (I. Security - e.g. attenuation of tidal amplitude, ii. avoiding erosion in the river which could cause damage to infrastructure, ecology: distribution of nutrients, nurseries for fish, biodiversity, etc.),…

Other mental models that have been identified include that waste - regardless of the cleaning steps undertaken - continues to be perceived as waste, that the location of a port cannot be changed, that the price of a good is determined by the market logic of supply and demand, that the SPECS that are set by the industry to determine which type of raw materials they need are sacred, that the responsibility for a clean waterway / sediment lies with the government (there is a low social responsibility), in order to remain competitive as a port, the requirements of the shipping companies must be met.

5 STARTING POINTS FOR INTERVENTIONS

Based on the above insights (e.g. at the level of the system structures and the underlying mental models) it is then examined how the system can be influenced in a positive way. This exercise uses the system levers as drawn up by Donella Meadows, which can be used as a starting point for this exercise:

– Events and patterns (variables, quantities, delays, etc.);
– System structure (introduce balancing loops, slow down reinforcing loops, change system rules) – see the causal loop diagrams higher up in the report;
- Mental models.

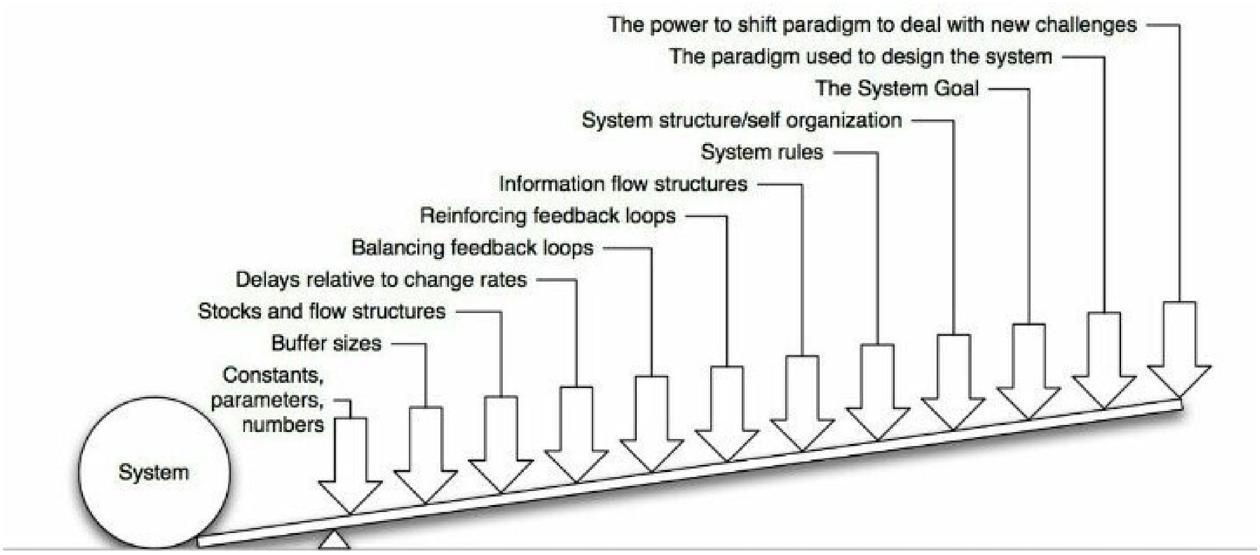


Figure 5. The system levers as drawn up by Donella Meadows.

5.1 CONSTANTS, PARAMETERS, NUMBERS (SUCH AS SUBSIDIES, TAXES, STANDARDS)

These are measures with which you typically try to adjust the speed of the inflow and outflow from a system to ensure that the system is ultimately in the preferred state (e.g. no contaminated sediment in the waterway / no storage of dredging and clearing spoil). Metaphorically, it is about turning on the tap and closing the drain tighter or looser to have or keep a desired amount of water in the bath. The focus is on the water in the bath, not where the draining water is going, nor where the water for the bath should come from.

The following suggestions for these types of interventions were received during the sessions:
- Granting subsidies for the construction of buffer strips to prevent erosion
- To tighten/increase the discharge standards to increase the quality of the sediment in the waterways
- Increasing taxes on the use of primary raw materials or imposing landfill taxes to promote the use of secondary raw materials
- Increasing the budget for the cleaning of sediments
- Increasing the budget for innovation, e.g. for cleaning sediments or making polished sand suitable for building applications (increasing tear resistance)
- Municipal taxes for discharged rainwater from sewerage

If you remove the above taken measures, the negative consequences will simply reoccur. It will therefore in any case be necessary to start activating levers 'sideways' in the system to achieve a longer-term impact. For example, we can think of the following suggestions that were mentioned by the co- creators:
- Increasing taxes on the use of primary raw materials or imposing landfill charges to promote the use of secondary raw materials;
- Limiting the amount of space, we reserve for the landfilling of dredged sediment (this as an incentive to clean the sediment);
- Imposing sediment tax for ships with a deep draft (intervening in the relationship between the driver of the dredging works and responsibility for its impacts, via the cost structure).

5.2 CREATING BUFFERS

You can often stabilise a system by increasing the capacity of a buffer. We noted the following suggestions for changes in buffer capacity:
- Increasing the landfill capacity for dredging sediments
- The multifunctional design of spaces to increase the optimal stock of the available space
- Optimal use of available space through progressively changing destinations
- The construction of intersections
- Construction of water buffers to reduce the flow rate of the water can reduce sediment transport.

However, large buffers cost a lot of money in construction and maintenance. That is why it is important to always look at deeper drivers, which control the necessity and often also the costs of buffers. During the session, for example, there was an exchange of views on solving historical contamination. Today, a plastic foil is placed along the bank on which the dredged material is temporarily deposit - after so many days the dredged material is collected, and the foil is burned. Consequently, there are many actions and costs involved. However, if the sediments were not contaminated, they could simply be returned to the field and used by the farmer. The foil then becomes superfluous, and a series of transport movements will become superfluous. In addition, this issue also ties in with what is further discussed, namely the improvement of physical infrastructures: an important source of contamination of the watercourses are sewer pipes that are not yet disconnected.

5.3 IMPROVING PHYSICAL STRUCTURES

The way in which (in/out) flows and buffers are physically organised can have a major impact on the functioning of the system. The challenge with this lever is (1) that it usually takes a long time before the physical structure is adjusted (is it still up to date upon delivery?), and (2) it is very expensive and often has a long depreciation period, causing you lose flexibility. It is therefore worthwhile to first identify which approaches are the least infrastructure-dependent for achieving your system's objective. Avoiding pollution at source probably requires relatively little infrastructure, but perhaps more regulation.

Some suggestions from the thinking sessions:
- Repurposing of hills;
- Constructing sediment traps;
- The remodelling of watercourses;
- The uncoupling of sewage pipes to minimise overflow effects;
- Providing small water purification areas for overflows;
- Improvement of the collection of 'run-off' water in urban areas and residential centres. Rinsing off rainwater from buildings, roads, etc. is after all enriched with all kinds of (new) substances (in paints, car tyres, ...);
- Provide for the cleaning of polluted rainwater that rinses off the roads and ends up in streams;
- The construction of sediment bypasses (e.g. to avoid sediment accumulation at reservoirs on the one hand and to have sufficient sediment supply downstream to prevent erosion in the lower reaches of the river on the other hand);
- Optimising the waterway flushing systems – operate/design locks so that they can hold water and discharge it in such a way that excess sediment is washed out (also considering the effect on lifeforms);
- Building bottleneck constructions (e.g. on waterways on slopes);
- Investing in blue green infrastructure;
- Optimising the transport infrastructure;
    - Developing hyperloops will drastically change the way in which we transport goods and people, and thus also the way in which we organise our (water) road infrastructure;
    - Developing autonomous navigation can cause a shift to the use of smaller vessels (with a lower draught) – in view of the availability of personnel that is no longer a shortage (inland navigation is currently a bottleneck profession). This will also increase flexibility so that water transport can be

better deployed in synchro modal transport. As a result, the waterway will no longer have to be adapted to the dimensions of the ship (which is often the case now);

- Natural solutions for structural coastal works;
- Use filter cakes in the brick industry (however, the presence of arsenic is not preferred – problem at the end of the home's life cycle – demolition work);
- Provide a legal framework for autonomous sailing.

5.4 THE DURATION OF DELAYS

If you try to adjust a system to your target but you only receive delayed information about the impact of your actions, you will under- or over- achieve your objective. The same applies if you receive timely information but there are significant delays in the response (e.g. the required planning and construction time / adapting the legislation based on new insights into contamination). It therefore requires a different set of links in information flows and often also different knowledge or statistical insight.

- Faster linking of information by increasing the speed of reliable data. If the clearing sludge were of good quality, the farmer would be able to bring this material back onto the field. However, farmers do not have detailed information on the sediment quality (data that is too outdated). Farmers do not want to run the risk of polluting their fields. Given the direct link with food, contamination could mean that a plot of land cannot be used to produce food crops for several years
- The speed with which legislation is adapted to detect problematic substances
- Accelerated insight into the use of new chemicals and their accumulation in sediments
- The speed at which new, innovative approaches can be introduced
- Capping contamination to create enough time to find a sustainable solution
- To provide insight into future added values if all waterbody beds were to be remediated more quickly.

5.5 ENHANCE NEGATIVE OR BALANCING FEEDBACK LOOPS

Each negative feedback loop has a target, a monitoring tool to detect and signal deviations from the target, and a reaction mechanism. A classic example is the thermostat, which has the objective of keeping the ambient temperature at a certain value. The thermostat controls the supply of heat (balancing loop) and reacts when there is a discrepancy between the desired and the real temperature, which tends to decrease continuously due to heat losses. Balancing loops that were identified within this trajectory related to:

- Increasing dredging activity when navigability is compromised or there is a risk of flooding due to a decrease in the storage capacity of the river due to sediment accumulation;
- Increasing the cleaning activities when too much contaminated dredging and clearing spoil is brought ashore.

These loops are often limited by a certain limit in one of the variables. As an example, here, the available space can be taken for the dumping of dredged material. Because it is finite (physically or policy-wise), a feedback mechanism arises: if more is deposited than the available space decreases and the storage cost increases, so that less will be deposited (search for other routes).

5.6 WEAKEN POSITIVE FEEDBACK LOOP

A negative feedback loop is self-correcting, while a positive feedback loop is self-reinforcing. Positive feedback loops are sources of growth, explosion, erosion, and system collapse.

-Positive feedback loops include

- Increased dredging activity at a certain location → leads to more sedimentation at that location → leading to more dredging activity at that location;
- Delayed remediation → leads to an increased risk of spreading contamination → leading to higher costs (less can be done with the available budget) → leading to delayed remediation.

Possible interventions to attenuate reinforcing loops

- To reduce the need for dredging: Increasing the organic matter content in the soil has a positive effect on the susceptibility to erosion (e.g. by removing the crop residues). The organic matter mainly binds to clay and loam (charged particles). This is a problem in sandy soils. Filter cakes could contribute to increasing the C content in sandy soils. Disadvantages:
  - Presence of possible contamination (risk of plot of land being unusable to produce food crops),
  - High lime content (lime milk is added to drain the filter cakes; calcium bridge is needed to neutralise repellent forces between charged particles)
  - In the past, sewage sludge from sewage treatment plants was also used – but because of the risk of spreading contamination, this is no longer done in Flanders
- Even better is to work on a good soil texture (non-inversion tillage has a positive effect on the texture). It has also been demonstrated that it has no impact on yields
- If the sludge had not been contaminated, it could simply be returned to the field by the farmer. A major source of contamination of the waterways is sewer pipes that have not yet been disconnected.
- Reducing the degree of sealing to reduce the peak flow rates and thus the risk of flooding
- The use of smaller vessels so that dredging with a lower frequency is necessary
- E.g. Focus on faster remediation of sediments,
  - Budgets certainly provide for clear win-win remediation projects
  - Improve cleaning techniques + make them cheaper / more innovative.

5.7 IMPROVING THE STRUCTURE OF INFORMATION FLOWS

Providing information can be an important lever and much cheaper than adjusting the physical structure. An important precondition is that it is delivered in the right place and preferably in a compelling form (information must encourage people to take the right action). We noted the following suggestions during the meetings:

- Central database (Linking of databases to get a better idea of where the sources of sediment and contamination are located);
- Linking biotic data with contamination data;

- Gaining Insight into sources of leaching sediment (from insights into sediment origin – focus on prevention);
- Understanding sources of contamination;
- Integral data on water quality;
- Stimulating open data;
- Applying blockchain in monitoring;
- Improvement of monitoring → passive sampling;
- Real-time reliable data on dredged sediments to determine whether it can be spread on the fields;
- Overview of supply and demand for dredging and clearing spoil (usability/accessibility);
- Improved characterisation of the end products of sludge treatment;
- Knowledge sharing and exchanging experience between different water managers;
- Citizen science to improve overall involvement;
- Compulsory material passports for products;
- Tailoring information flows to value networks where innovation potential appears to be present

5.8 CHANGE OF SYSTEM RULES (E.G. LAWS, PENALTIES, SOCIAL AGREEMENTS)

The rules of the system determine the room to manoeuvre, the limits, the degrees of freedom:

- Several rules came up as possible game changers (in a literal sense) for the current handling of sediment;
- ‘polluter pays’ principle vs ‘beneficiary pays’ principle. The ‘polluter pays’ principle must be implemented more clearly;
- From emission-based to immission-based approach;
- It is currently not logical that all possible legislative obligations must be met to be able to use treated sewage water for irrigation. When the treated sewage water is discharged and pumped up 100 meters further downstream, there’s no problem?
- Extend producer responsibility to the entire life cycle of products;
- Improved legislation on chemicals: there is REACH, but apparently there are still many 'issues'. Companies should be obliged to release more (all) information about the substances they produce and use, including the volumes they produce;
- Medicines are not currently examined for their environmental impact and this needs to change. Medicines are becoming an increasingly more significant part of the contamination that we find in the waterways/waterbody beds (e.g. because of an ageing population). The environmental impact must be assessed before a medicine is put on the market. In contrast to pesticides, for example, it is difficult to stop drug residues by means of active carbon filters. Medicines that release a lot of residue into the water after consumption could be more heavily taxed, creating an incentive to develop medicines that work with full absorption by the body;
- Farmers plough across the contour lines. In the event of heavy rainfall, this can lead to large flows of mud (damage to houses / costs of cleaning up by the fire brigade) – damage would have to be compensated by the person who caused it. Free choice of cultivation on fields with a high slope can be questioned – actually, these should be permanently overgrown (e.g. grassland). The problem is the low level of

confidence shown by the agricultural sector because the government may suddenly decide to suddenly turn grassland into permanent grassland;
- Obligation to use secondary materials (e.g. through the specifications)
- Obligation to process/use contaminated sediment in products and constructions.

5.9 SELF-ORGANISATION = SYSTEM REPAIRS ITSELF

The most amazing thing that systems can do is to completely change themselves by creating entirely new structures and behaviour. In biological systems, that power is called evolution. In the human economy, we call it technical progress or social revolution. In system lingo, it's called self-organisation. Self-organisation is the result of a supply of a raw material for innovation, from which a large variety of patterns can emerge as well as a test mechanism to evaluate the new patterns:
- In biological systems, the stock of raw material for innovation is DNA, from which different species can evolve and the test mechanism is Darwinism;
- In technological systems, the raw material for innovation is the accumulated knowledge gathered from people, in libraries, etc., that is a source of creativity and the testing mechanism is e.g. the market that will or will not appreciate the new developments;
- In social systems, the raw material is the different cultures of the past thousands of years, from which new social structures may emerge.

Any system that sweeps away the incentive for innovation is doomed to fail in the long run. Therefore, it is extremely important to pay attention, among other things, to the preservation of biodiversity. Allowing species to become extinct is a systemic crime, just as arbitrary eliminating all copies of certain scientific journals, or certain scientists, would also be. A few examples:
- Micro-organisms (or other flora and fauna) not only can adapt to a new contaminated environment, but can also evolve so that they are able to break down the contamination;
- Commitment to 'Natural remediation' and 'nature-based solutions';
- Green infrastructure/building with nature: e.g. construction of mangroves for coastal protection;
- Self-regulation of the Flemish waterway: costs + income;
- Possibility to test innovations in less regulated zones.

5.10 ADJUSTING SYSTEM OBJECTIVES

Most negative feedback loops have their own objective: ensuring that the ambient temperature is 20°C, a preferred water quality, water level, water temperature. These objectives are important levers for parts of the system. But there are higher, less clear objectives that will determine how the system will be organised and what the above sub-objectives will be.

Example of system objectives: "All functions that we expect from a water system must at all times be able to be performed at a socially acceptable cost and must be socially inclusive" On the other hand the objective could be a water system suited devised for a maximum use of waterborne transport. It then quickly becomes clear that for both objectives would require a very different management, but also other structures, both physical (navigable watercourse network, e.g.) and non-physical (price setting of water, e.g.).

Formulating an objective for a long-term robust water system goes beyond the scope of our meetings, but a suggestion was made that could potentially mean a step in that direction: Independent structure that ensures that things are viewed from a system structure and that breaks through pigeonholed thinking in relation to own resources.

5.11 CHANGING MINDSETS OR PARADIGMS

Each System is driven by certain mental models/ /thinking patterns. As mental models are seen or experienced naturally or indisputably, they are very difficult to change – ensuring that the situation remains as it is or even deteriorates. The focus of the mental models/ /thinking patterns + from which environmental context do they originate d and the questioning whether these mental models are still relevant in the current or future context is an important lever to realize system changes.

Mental models/patterns of thought that were identified during this process:
– See chapter 4;
– We need economic growth for our welfare state;
– Dredging and clearing sludge = waste (perception and therefore social acceptance of recycled materials is low);
– The location of a port cannot be changed;
– The SPECS established by the industry to determine what type of raw materials they consume is sacrosanct;
– The price of a good is determined by the dynamics of supply and demand (this is not the case within e.g. the diamond sector);
– The responsibility for a clean waterway/waterbody bed lies with the government (there is a low social responsibility);
– To remain competitive as a port must comply with the requirements of the shipping companies;
– …

Possible interventions:
– Prioritising measures with a preventive effect (we mainly focus on measures that are curative rather than proactive – which also ensures that we always find significant quantities of drug residues in the environment)
– ‘Mudfullness’ campaigns
– Wild garden campaigns – decline in the use of hazardous substances
– Circular label – perception of secondary raw material
– Abandoning the dream of a detached house in the open space as a mindset
- Promotion of soil+land stewardship;
- ...

6 INITIATION OF PRIORITISATION

By sketching a long-term perspective (dreamscape), it is possible to consider which actions should be deployed as a priority. The results of this exercise can be found in Appendix 7, some of which have already been cited at the starting points for intervention in Chapter 5.
The participants selected the following solutions as a priority, based on the estimated (positive) contribution to the water sediment system:

- Preventive measures:
    - Relocate ports in such a way that economic activities and ecosystem services are combined;
    - Deployment of other forms of water-related transport or infrastructure (smaller ships, flushing systems at locks, autonomous sailing, ships that dredge themselves, etc.);
- Management of the 'legacy' on contaminated sediments:
    - Let nature act as a self-regulating system for cleaning, transport, dikes;
    - From an emission-based policy - with emphasis on discharge points - to an immission- based approach - with emphasis on the quality in the living environment;
    - From the polluter pays principle to the beneficiary pays principle (e.g. project developers who help pay for the purification of local water courses) and / or stewardship principle (everyone bears responsibility and acts)?
    - (re) use of uncontaminated sediments for local agriculture;
    - Optimal use of the available space through gradual change of focus.

7 CONCLUSION AND FURTHER STEPS

It was the intention of this co-creation project to look for new solutions for sediment policy. To this end, an exploration of a systemic perspective was set up. Through the identification of underlying mental models (next to events), the underlying problem was (with their associated opportunities) explored. This resulted in a strongly broadened and enriched view of the factors that underlie several persistent mechanisms within this policy field, and a broader view of possible causes.

Incidentally, the difference between what is called endogenous versus exogenous perspectives in systems can be recognized throughout the mental models. In an endogenous perspective, the system boundaries include as many relevant variables as possible in relation to the problem in question, where the exogenous perspective will state that the causes are beyond our control. Both perspectives obviously influence the attitude of the various actors involved (if the cause is placed outside your control, you will probably be reluctant to take action to deal with the causes). But it also has policy implications, as shown in the table below [2][1].

[1] ‘Systems Thinking & Systems Modelling. A course for Understanding Systems and Creating Systems Models’ van The Sustainability Laboratory uit 2019.

Water damage	Analysis	Policy implication
Exogenous perspective	Flooding sometimes happen; the heavier, the more damage	When flooding occurred, restore, and rebuild
Endogenous perspective	Damage occurs when risk and vulnerability converge, vulnerability is the result of choices made by people and policy	Recognize the role of humans in the damage. Involve stakeholders to reduce vulnerability

Table 2: Overview of the different co-creation sessions during this process and the expertise that contributed

It also demonstrates how working on mental models rather than on direct events has greater leverage to make the water sediment system more sustainable / resilient. The current framework of thought may have its limits to arrive at sustainable solutions to this problem.

A non-exhaustive set of possible systemic levers has been listed throughout this report and should be explored further - preferably in a co-creative context. To decide what priority solutions or directions are, it is important that the proposed interventions, which have been discussed throughout the report, can be assessed in terms of impact and feasibility. On the one hand to legitimise them, but also for an investigation into possible measure ecosystems. Some measures will only lead to systemic change in combination with other measures. Systemic interventions will also influence each other.

In any case, the most important first step is to further deepen and thereby legitimize lines of thought and determine the priority solutions. To this end, it is best to distinguish between low-hanging fruit, preferably with a large positive impact, and systemic solutions, through co-creation with both ' challenge owners ' and knowledge carriers and 'solution providers'. For the low-hanging fruit, it can be clearly indicated who can or should do what now or in the short or long term. The direction of systemic solutions may not be immediately clear. The question of what needs to be done and with whom may require further insights, which can be built up either through further system analysis or through transition experiments. From the resulting basket of simple, less simple, and even difficult solutions, a balanced trajectory can be drawn up for structural covers.

8 ANNEX

ANNEX1: EXERCISE ON BECOMING FAMILIAR WITH THE DIFFERENT LEVELS WITHIN THE ICEBERG MODEL

in this exercise, participants indicate which events, patterns, system structures and mental models come to mind when we consider the challenge of valorising dredging and clearance spoil. The results of this exercise (1st European workshop can be found below):

Events:
- The volume of dredged material;
- Demand of sediments;
- Export of sand;
- Biodiversity;
- Size of the boats: required depth;
- Stock surface;
- Importance of sustainable development;
- Sea level;
- Quality of sand for construction;
- Economic activity;
- Price of sand;
- Differentiation in quality;
- Jobs;
- Emissions;
- LCA: what is better re-use or new material;
- Surplus of sand;
- Many capital projects;
- Demand for sand for coastal protection;
- Demand for sand for construction;
- Infrastructure works;

Patterns (trends in events):
- Efficiency of current infrastructure;
- Increased dredging activity;
- Increased sand production;
- Delay between supply and demand for sediments;
- A lot of sand comes available in shorter timeline;
- Increasing population growth;
- Increasing prosperity;

- Increasing construction activities;
- Increasing demand for sand - the global demand for sand increases by 5.5% every year;

System structure (relations between patterns: increase of X results in decrease of Y):
- Economic activity increases → dredging activity increases;
- Population growth, prosperity → building activity → demand for sand;
- The higher the economic development the more sand is needed;
- The more knowledge we have the more we can reuse / relocate within the system;
- The more contaminants the less reuse;

Mental models (these are beliefs, apparent evidence, thought patterns that keep the situation as it is):
- Industry demands are sacred;
- Location of the port is fixed;
- Market logic (price in function of supply and demand (not the case for diamonds);
- Social acceptability of reused materials;
- Social responsibility is low;
- End-users perception towards reuse (is bad);
- Economic growth necessary for our welfare;
- Looking inside-out;
- Linear thinking;
- Sand is being used too little;
- Disbelief of its practical use;
- Sediment = waste;
- Maximum depth for ships -all harbours must agree;
- Lack of Long-term thinking;
- Silo thinking;
- Co-creation;
- Pre-calculating risk /Precautionary principle;
- End-user perception towards re-use.

ANNEX 2: MINISTER OF SLUDGE

In this exercise, each participant must indicate on a sheet which variable he would give priority to have the system evaluated in the right direction (e.g. raise variable A because then variable B will drop). This sheet is then passed on and another participant must indicate what would be the consequence of the previous action (e.g. because variable B decreases, variable C will increase). This transfer process is carried out 5 times after which the sheet is returned to the original participant. Subsequently, important findings / insights are shared in the group. The results of this exercise (1st Flemish Workshop) can be found below:

- Intensify erosion policy → less sediment input in water → increased flow rate → new erosion (question: does more sediment in the watercourse lead to an increased or decreased flow rate));
- Erosion → draft restrictions → number of transport movements increases → shipping costs / ton km increase;
- Decrease in pollutant input → results in better water and sediment quality and lower amount of contamination to be removed. Removing pollution from sediment results in less spread and more possibilities for reuse;
- Increase in current → more sediment transport → more distribution of contaminated sediment. Emissions to water also contribute to sediment pollution. With a certain budget, only a limited amount can be cleared;
- Erosion decreases - this also reduces the amount of sediment in the watercourse more transport by water → question: what are the consequences for water quality + does this have international consequences? What is the impact of less overflows on water quality;
- Expand the list of architectural land use, which reduces the cost of sales. If the cost of sales falls, more can be dredged with the available budget;
- Implement dredging for ensuring the necessary depth of ships has a negative impact on the stabilization of the sediment → increased stabilization of sediment leads to less need for dredging / nourishment. Stabilization ensures a higher self- cleaning capacity of the river;
- If there is more space for landfill sites for spoil, the cost of clearing the sediment will decrease. As the cost of a dredging works increases, the number of works decreases. If the number of dredging works decreases, the risk of flooding increases, causing the number of flood areas to increase;
- The higher the compensation for farmers → the less erosion → the less sediment in the watercourse → the less need for clearance → the less disturbance of the watercourse by working
  - The more sediment in the watercourse → the higher the flow velocity;
  - The more sediment in the watercourse → the lower the draught;
  - The lower the depth → the more there must be dredged;
- Bank management → the less erosion to the watercourse → the less disturbance of the watercourse by works;
- Reuse dredged material → reduces the cost → increase of volume that can be dredged with the same budget;
- Sediment quality is determined by historical contamination but also by the input of new contamination. This is possible, among other things, by the mobilization of heavy metals in the water bottom when they

come into aerobic conditions. By increasing the groundwater level (e.g. less drainage), the sediment quality and the application possibilities increase;

- Controlled sedimentation - improves homogeneity → better outlets;
- Erosion control measures → decrease in the volume of contaminated sediment;
- Densification of cities → contaminated rainwater;
- Coordinate landfill with spatial planning → earthmoving for development → rigid recording of future application possibilities of sites;
- Area-specific standards (application of sediment within the system: importance of demarcating areas -need for framework: how to deal with flows from different areas) → this approach does not result in an improvement in quality (also questioning the stand- still principle?);
- Drawing up an assessment framework for the use of water in case of scarcity (nature has higher priority compared to shipping) + compensation of users with a lower priority (necessary to arrive at an area-specific assessment?).

ANNEX 3: MENTAL MODELS THE CASE OF ILLEGAL DUMPING

Mental models are beliefs, apparent evidences, thought patterns that underlie how the system is structured and ensure that the situation remains as it is. In the second, the Flemish Workshop was dedicated to the mental model "no incentive to address problems when no one can be blamed."

This is a mental model that can be found in various domains. One of these domains concerns “illegal dumping”. Again, it is not obvious to identify the polluters, which blocks action. You could place cameras in places where illegal dumping is done, but this just causes the problem to move (in the end you should place cameras everywhere). The participants in the co-creation trajectory are asked to think about systemic solutions that tackle the problem of illegal dumping:

- Lifting a deposit on cans (+ - 50% of the volume of illegal dumping is caused by cans), so there is an incentive to return the cans. If you get used to keeping track of certain debris, this can be a trigger to keep track of the residual waste;
- Removing trash cans (which are often a source of illegal dumping) - dirt attracts dirt
- In addition to cans, a lot of household goods are also dumped (sometimes with the sign “free to take along” - which is also a form of illegal dumping);
- Engaging the community to keep the neighbourhood clean - “Mooimakers” campaign”
- Social shaming (putting photos of, for example, candy wrappers on social media) - linked to the GPS location where those photos were taken - this way you can clearly map where in a municipality the most illegal waste dumping takes place;
- Return to sender - waste is sent back to the producer - respond to producer responsibility;
- Great importance is attached to the value that a circular economy can generate. It is strange that you still must pay for the waste you put outside. This means that the different separated groups are still regarded as waste by the citizen. If we thus consider litter, no distinction is made between “GFT litter”, “PMD litter”, “Household litter”.

ANNEX 4: ENRICHING, VALIDATING AND DEEPENING THE RELATIONSHIP ANALYSIS

The various relationship analyses were subjected to an open discussion to determine whether relationships are correct, whether certain core variables are missing or need to be added, etc.

System analysis sedimentation

The system analysis on sedimentation (Figure 2) was validated. The following points for attention were additionally formulated:

– Reducing the risk of flooding or navigability is not only determined by the amount of sediment in the watercourse, but also by other factors such as:
  - The amount of water that flows (accelerated) to the river. The degree of sealing plays an important role here, the water storage capacity of the soil…;
  - The required draught of the ships;
  - ...

Box 2: Impact of drought on the quantity and quality of sediment

As a result of climate change, the frequency and intensity of drought is increasing, causing:

- Increases susceptibility to soil erosion (spraying), resulting in increased erosion from the soil to the watercourse;
- The natural drainage / sponge effect of the soil decreases, because of which the level of groundwater / surface water also decreases. This gives you aerobic conditions that can potentially degrade organic pollutants, but also result in a mobilization of heavy metals and thus a possible contamination of the water / sediment;
- - Due to the increase in intensity / frequency of drought, the focus is on:
  - o the construction of buffer basins (driven by economic pressure to achieve very high efficiency), resulting in earthmoving / raising the flood area, which reduces the natural flooding capacity of the floodplains;
    [NOTE: It is sometimes argued that these buffer basins can also be used to smooth peak flows. However, the volumes of these basins are far too small to have a significant effect of this].
  - o The pumping up of water by agriculture (also from the historical law of the landed [3] to pump water from the adjacent watercourse). This landed right is also taken up by private individuals and influences the depth of the water levels;
- To guarantee the discharge, but also the buffer capacity of these watercourses, dredging must be carried out regularly. The clearing spoil is laid on the riverbank but cannot be spread due to the contamination. Moreover, this bank deposit prevents the water from

draining from the fields (on the other hand, these 'raised' banks do prevent erosion material, which results in less sediment in the watercourse). If the dredged material was not contaminated, it could be returned to agricultural land:

  - Many fertile agricultural soils are lost due to erosion. Via gullies, rivers and the sedimentation processes, the particles eventually end up as sediment in watercourses and the sea. It would be interesting to see to what extent the cycle can be closed. To what extent is it possible, realistic, and safe to return dredging and clearance spoil to agricultural land, from which the sediment ultimately (partly) originates. - System issue?
  - *The International Atomic Energy Agency uses nuclear detection techniques to conduct research into erosion and sedimentation processes. In this way, they would be able to track soil particles and trace which road the sediment eventually travelled [4]. Such tracer tests with radioactive material were also used in the 1980s to monitor the dredging dumps at sea off the Belgian coast (an assignment that was carried out by HAECON at the time). The results were very interesting and clearly reflect the flow pattern and distribution of the dumped spoil at sea. It should certainly be possible to set up such research along waterways. The question is what information can be obtained with it. There are so many parameters that play a role in sediment transport in watercourses. - Research question?*

Box 3: Required draft of the ships

Projects are underway to see whether ships can also sail at lower water depths (Project: Port of Hamburg). The criteria used today to manoeuvre responsibly and safely are:

- Criteria 1: echo at 210 kHz (transition between water and water with a little sediment) - nautical bottom:
  - Distance between keel and echo at 210 kHz must be a certain percentage of the distance between echo at210 kHz and the deck:
  - If you drive this to the limits, the black water (bottom water) will fluctuate, and the boat will become unmanageable. So, it is better not to sail just above this black water (it is better to sail in black water than to sail just above — in sediment = aquaplaning):
  - Sailing to the depth-limit increases the energy demand and disturbs the water bottom (oxidation processes that can result in an exemption of heavy metals):
- Criteria 2: (density criterion of the medium through which is sailed): <1.2 ton / m³:
  Agreements on thresholds are coordinated internationally - IMO (International Maritime Organization).

The shipping companies have a strong position, particularly those that do sea transport. Shipping companies go for ever larger ships and then the ports have to adjust their infrastructure (if you do not follow as a port, the shipping companies go to another port - ports are played off against each other).

- Questions that arise:
    - How do we manage to make the required draft for shipping less decisive in controlling the water system?
    - What motives are behind the trend of increasingly larger ships (savings in personnel costs, fixed costs related to transportation, delivery speed) and what the future → There possibly also should take into account the growing customer requirements - e.g. at the level of speed of delivery (analogous to parcel services) which will have an impact on the number of transport movements, energy requirement, dimension of ships, etc.
    - What makes increasingly larger ships more cost efficient than smaller ships (energy cost?).
    - Desirable to levy a sediment tax for ships with a deep draft (ultimately who does the dredging works on behalf of who pays?)
    - We can devise adapted infrastructure that minimizes the impact on the watercourse. Do the financial costs related to this outweigh the social and (individual) financial benefits?
    - Can alternative modes of transport counteract the trend of increasingly larger ships?

– The lower the flow rate, the lower the transport capacity of the sediment. In a river, therefore, more sedimentation occurs in the lower reaches, in comparison with the middle and upper reaches. Transport capacity also decreases, and sedimentation increases at locations of structures (locks, barrages, etc.) - where the flow decreases. Increasing pavement, on the other hand, ensures an accelerated flow of water to the watercourse (peak flows) and thus a higher flow rate and transport capacity (conflicting interests - the location where we harden may have an impact where we will (whether or not desired) sedimentation receive or flush out)*;*
– In addition to the flow rate, other factors also have an impact on the transport capacity of a river:
    - The greater the slope, the greater the transport capacity. The meandering of a river thus reduces the transport capacity. Meandering has a positive effect on slowing down the watercourse, which is positive compared to the risk of flooding. However, due to the increased risk of sedimentation, stippling can increase the risk of flooding (FEEDBAK-LOOP);
    - The larger the particle size / particle density, the lower the transport capacity;
    - Particles remain in suspension because of charges that repel each other. Salt neutralizes these charges, causing sediment (especially clay particles) to start to flocculate. The further the salt penetration inland, the further upstream the particles begin to flocculate. This effect is also seen in the presence of micro-plastics (would also play a role in neutralizing charges);
    - The greater the roughness of the water bottom, the lower the transport capacity. For example, water vegetation increases the roughness. See, for example, projects with the construction of mangroves, alders, willows to allow controlled sedimentation to take place in the watercourse (however, too high

a resistance can result in backwater and flooding upstream, which requires periodic management of these mangroves, alders, willows):

- Specifically, for tidal rivers, the removal of sediments from the river (e.g. removal of riverbanks by dredging to allow larger ships to access ports) increases the tidal wave. More sediment is deposited upstream then is discharged during low tide (tidal pumping). Only a sufficiently high upper flow rate can reverse the vicious circle - slowing or even reversing the advancing silting up (based on the principle of drain bowls that fill during high tide and release the water at low tide to flush the sediment out of the harbour). If the above rate is too small to prevent tidal pumping, only regular dredging can prevent the silting of the river. Dredging to compensate for tidal pumping illustrates how inherently profitable human interventions in the river system (removing bottom thresholds to allow larger ships access to ports) can trigger expensive additional human interventions (continuous dredging)).

<u>Questions that arise</u>:

- Can sediment from waste bowls be extracted economically? How quickly and how much sediment is deposited. If so, can this sediment be harvested and are there applications for it?
- What is the impact of climate change on upper flows?
  - Moreover, with the drought of 2017 and 2018, it was also established that the upper flows were not sufficient to fill the docks of the Port of Antwerp. The water in the Antwerp docks comes from the Albert Canal and the Scheldt-Rhine Canal, but in summer the flow rates of those channels are sometimes insufficient. To continue normal port activities, the docks must then be partly filled with water from the Scheldt. Along with the Scheldt water, however, salt and sediment also enter the docks, and the latter requires additional dredging - the consequences of salt:
  - Extra rinsing of dredge spoil necessary with fresh water to increase reuse potential (chlorine and sulphates are not desirable in various applications
  - Efficiency of water reuse installations decreases (the more salt, the lower efficiency of membrane installation - just when water availability is low));
  - Corrosion of, for example, cooling water circuits (type of material from which the cooling installations are made or coatings that are used, determined degree of corrosion);
  - ...
- How does the water demand of the various water users evolve and what is the impact of this on the water availability / upper flows (see analysis system analysis Robust water system), including mobility itself: increasing number of transport movements → increasing number of surprises → increase in water demand?
- What is the impact of the increasing pavement (urbanization) on the upper flows? The rapid increase of paved surface in Flanders, because of which an increasing amount of precipitation can no longer simply penetrate the ground but ends up in rivers at an accelerated rate. Does the flow increase?
- What is the impact of climate change on tidal energy - and can this tidal energy be captured?
- What is the cost / benefit analysis of ports in function? The external pressures around mobility and climate change. Higher yields due to accessibility for larger and more ships compared to costs for

managing the port / docks (removal of sediment by tidal pumping , opening of sluices to compensate for too low upper flows , extra costs for treatment of saline dredging spoil….)?

- It is also important to pay attention to the fact that a river always tries to balance its transport capacity with the amount of sediment in its water column:
  - If the transport capacity increases, the amount of sediment in the water column decreases and erosion takes place at that location in the river / watercourse (various cases are known in which beaches erode, river profile degrades with damage to infrastructure). To remedy this, sediment is sometimes added to the water;
  - If the transport capacity decreases, the amount of sediment in the water column increases and we get sedimentation at that place in the river / watercourse. The avoidance of external sources of sediment supply is therefore certainly desirable (e.g. erosion from agriculture);
- Considering the above equilibrium rule and the various parameters that affect the transport capacity of the river, it is possible to:
  - allow sedimentation to take place in controlled places in the river (e.g. sediment traps are based on locally reducing the flow rate);
  - prevent erosion from taking place in certain places (e.g. contamination hotspots), which would result in a wider spread of contamination and thus higher dredging costs;
- The dredging costs are not only determined by the quantity, but also by the quality. The quality of (maintenance) dredging spoil (extracted from navigable waterways) or. clearing spoil (extracted from unnavigable watercourses) is determined by:
  - Historical pollution but also;
  - New pollutants (PFOS / PFAS, run-off from road transport, pesticides, medicines, etc.):
    - Sources: point sources, diffuse, overflows;
      - > The way in which we organize the discharge of rainwater in cities can have an impact on the quality of the water bottom quality;
      - > Climate change (increasing frequency and intensity of rain showers) has an impact on the frequency at which overflows take effect. The more overflows come into effect, the more sources of pollution, the higher the dredging costs
      - > Research question: Are data available on the quality of rainwater from urban areas? It can be imagined that after a heavy rain gust a lot of pollution washes off the roads and thus ends up in the streams. What is the impact of compaction on the quality of the contaminated rainwater? Have any options been considered to provide (limited) treatment in the event of an overflow? For example, to catch at least floating parts, settling basins for probably heavily contaminated sludge, etc.? (There is a great deal of knowledge of the quality of sewage sludge that is collected in cities. When it is removed, this material ends up at a soil cleaning centre). Municipal taxes in function. discharged flows from rainwater drainage?
- Regarding historical pollution, it is difficult to apply the polluter pays principle to this:
  - In the past, companies may have acted in accordance with their (environmental) license;
  - Companies are gone/bankrupt (tanneries, shipyards, gas factories, etc.);
  - There is no clear owner.

This means that such files are good for years of legal battle and the ultimate social benefits are very limited (only the lawyers win from such a story) - In the cases of Tessenderlo / Umicore , a deal was made to avoid the above.

<u>Questions that arise</u>:

- What is the added value of forensic sciences to detect polluters?
- What is the interaction between the sediment and the water column (e.g. in view of water quality → discussion about the leakage of phosphorus from the sediment → how big is the problem?
- Can the approach on black fields also be applied for the remediation of aquatic soils?

- The Approach in the Netherlands is a “dredged material that is brought onto land must be reused” - a problem that arises with this approach:
  - Detection of new substances such as PFOS (used in textiles) for which the impact is not yet known. In this case, the acceptance limit is the detection limit. Dredged material is no longer brought onto land until there is clarity about the impact of these new substances (postponement of dredging works);
  - It is also noted that that there is often a need to get behind the facts:
    - Example: PFOS is detected in the watercourses / sediments and then it is modified by the producers:
      - The concentration of PFOS starts to decrease but the concentrations (s) of new substance (s) starts to increase.

Questions that arise:

- What role can REACH play: e.g. are costs for the producer if it appears that this causes pollution? - Extended producer responsibility.

Box 4: Evolution of contamination in aquatic soils in Flanders - (only 2% of the investigated aquatic soils are not contaminated)

- Metals
    - Little evolution for lead, arsenic, copper, and zinc (info: under water arsenic is strongly bound to sulphur - when exposed to oxygen the sulphur oxidizes and arsenic is released!)
    - Moderate evolution for chrome
    - Favourable evolution for cadmium, mercury, and nickel
- PAHs: positive evolution
- K mineral oils remains a problem
- Organochlorine pesticides: negative trend in recent years

- Sedimentation also plays a role at the level of energy production (water as an energy carrier). The hydropower capacity that we lose annually (due to sediment accumulation in the dams) is greater than the capacity that is built annually;
- As a result of the drought in 2018 and the resulting low water levels on the Rhine, there was a shortage on the market for smaller inland vessels (which is also a bottleneck profession). Germany has put a lot of money on the table to have these boats available, which jeopardized the supply of raw materials to Flanders - resulting in, among other things, strong price increases for various raw materials (e.g. sand & gravel).

Questions that arise:

- What opportunities are there in the mobility transition (e.g. autonomous sailing)?

- There is often still the problem that activities between different organizations are not well coordinated, which entails high costs:
    - Reference is made to a case in which very large quantities of soil / sand are required for a project. It would be valuable to be able to use soil / sand for this, which will be released during the planned infrastructure dredging works within the Port of Antwerp. If not, sand extracted from the sea will have to be used, for which there is an important cost. The infrastructure works within the Port of Antwerp will only start 3 months later compared to when the other project needs the quantities of soil / sand. This is a missed opportunity, especially in view of the fact that it is very difficult to find outlets for these large quantities and that a high cost may have to be paid to get rid of them (40-50 EUR / m³).
- In any case, it is not obvious to come to good solutions if there is late information available on the supply and demand side, especially if the market is subject to large fluctuations (both in the supply and demand side):

- It is also not always obvious to properly match supply and demand, leads to many uncertainties:
  - Will the permits be delivered on time?
  - Will the necessary budgets be released?
  - What is the status of the dredged material (waste / raw material)? With the regulation of dredged and clearance spoil in VLAREBO, there is more clarity;
    - Dredging and clearance spoil used to fall in Flanders under VLAREMA (Decree of the Flemish Government establishing the Flemish regulations concerning the sustainable management of material cycles and waste). As soon as the spoil was brought on land, it was regarded as waste and it was necessary to evaluate case by case whether it could be used as a raw material for certain applications (depending on the assessor, other analyses and analysis methods should be used). A solution was offered to the latter by embedding dredging and clearance spoil in VLAREBO (Decree of the Flemish Government establishing the Flemish regulations concerning soil remediation and soil protection). Within VLAREBO there is an objective assessment framework for assessing whether spoil may be used for a specific application.
  - ...

- The Flemish Waterway has both powers at the level of protection against flooding and power at the level of water transport. This means that they can coordinate activities better:
  - The timing of construction of docks / quay walls where a lot of sediment becomes available is coordinated with activities of ecological redesign / construction of dikes, etc.
- It is also forth seeing to consider the sediment challenges already at design level:
  - Design quay walls in such a way that the flow is reflected away from the docks - so that less sediment build-up takes place within these docks;
  - Include in the tender the obligation that e.g. 10% of the sand must come from recycled sand:
    - This will allow for increased confidence in to use this material;
    - The local reuse of materials will also have a positive impact on the number of transports movements;
  - Quay walls can be constructed in such a way that less sediment need to be dredged;
  - Construction of sediment by- passes in response to the problem that in certain places there is too much sediment accumulation (e.g. in reservoirs for irrigation or hydropower) and a shortage downstream, which leads to erosion there (and, for example, the need for sand replenishment in the coastal region).;
  - Is it necessary to remove the sand from the water system?
    - We need to think about disposal strategies where the sediment should not be dredged back later;
    - Is there also no possibility that the sediment on the dredging boats is cleaned and then dumped back?
    - Attention to the stand still principle;
  - Reinforcing the banks so that there is less problem with erosion - including with the help of vegetation / oyster reefs. As a result, less sedimentation and positive towards biodiversity - but:

    - Need for space and a certain incubation period is needed before this vegetation is sufficiently robust (during planting the transport continues and the waves cause significant damage - therefore work is being carried out on combined Gray-green structures;
  - Rebuilding by design – design in function of nature or in function of the economy (transport?)
    - Redesign river by river:
      - Relocation of companies;
      - Restoration of levees (Nature- technical Environmental Construction of banks));
      - Construction and demolition waste (CDW) management;
      - Meandering;
    - However, very high costs, existing contracts / permits must be broken / people have to move;
- Expected evolutions are considered in the construction of the waterway infrastructure. However, it is not obvious to correctly predict this:
  - How will the shipping fleet evolve? In inland navigation, it was expected that the fleet would consist mainly of large boats. So many years later, this trend appears not to have continued. In addition, more and more cities want to bet on smaller boats to bring the goods into the city via the waterway;
  - We rather go for container transport or for bulk transport on inland waterways. Container transport will allow us to transport up to 3-high containers. In the context of the Seine Scheldt project, for example, the bridges on the route must be raised;
  - The analogy is extended to aviation. At some point Airbus made the decision to build the Airbus A380 based on the idea that the aviation sector would evolve into a hub- to- hub business model. With large planes flying between the hubs and being fed by passengers on smaller flights flying to these hubs. However, the sector has evolved to a point-to-point business model, including the development of smaller, more efficient aircraft that can also bridge these long-distance flights:
    - These last planes were therefore easy to fill with people (unlike the Airbus A380 with little passengers in winter)
    - Passengers also want to transfer as little as possible and prefer not to spend too long in airports / transit zones;
- The evolution towards ever larger ships has an important impact on the need for dredging (the drivers for this upscaling are personnel and energy costs). Both infrastructure dredging works (one-off - deepening of the watercourses, quay walls) and maintenance dredging works. The draft in the Panama Canal (+ - 18 meters) is the benchmark for the international ports. The question is whether the costs of meeting this depth demand are in proportion to the benefits:
  - What is the cost of the infrastructure and maintenance dredging works in relation to the benefits? And to what level these benefits are considered. The admission of large container ships on which we carry out little further handling and mainly serve for transit will place a significant burden on our road infrastructure and generate little economic return;
  - Shouldn't we question the location of a Port? It may be desirable to bring large ships to the coast and then bring them further inland via smaller ships. There may be more and more competition between ports close to the coast (which will grow) vs inland ports → which in turn can lead to social tensions. It is also unclear what the impact of this will be on road transport (goods must be

transported from these coastal ports to the hinterland: risk of congestion / air pollution / accidents, etc.);

- The size of ships is sometimes limited from the insurance angle. Oil tankers first grew, after a few accidents, this trend has stopped under the influence of the insurance sector. The question is of course whether you should wait for accidents;
- If a port imposes limits on draft, the shipping companies simply go to the nearest port that wants to implement the changes (a choice between Antwerp or Rotterdam is quickly made). In this it is important to make European agreements. Today, each port has its own strategy. Important to think about the European interest. What is the global benefit for Europe? It is time for sustainability / biodiversity to take over the idea that economic growth is necessary for our prosperity (evolution towards the doughnut economy);
- Today the starting point is that the rivers must be adapted to the ships. This should be reversed → adaptation of the ships to the rivers:
  - Case of the Danube River:
    - Ask to make the Danube navigable for large ships. This while there is an efficient train track next to it. Is it desirable to take such drastic measures then?
    - By increasing the navigability, the local skippers risked losing their job (competition by larger shipping companies);
  - You could work based on the tides. Large ships can only reach the harbour at high tide. However, time is money (long waiting times) - moreover, only a limited number of ships could reach the port. The advantage of autonomous sailing could be that boats can sail closer together and this number could already be increased;
  - Large ships also disturb the water bottom, which would get a lot of suspended matter into the watercourse and spread of pollutants. If we were to increase the frequency of ships by, for example, autonomous sailing, this problem could become even greater. In addition to frequency, speed also plays a role - that is why speed restrictions are also imposed on navigable waterways (aimed at speed boats, among others);
  - We should not revise the concept of a ship. Vessels must be able to dredge for themselves / be able to sail through sediment / etc.;
- Dredging works are also carried out to prevent flooding. The risk of flooding is not only influenced by the amount of sediment in the watercourse, but also by the speed at which the water flows into the watercourse. In this it is important to prevent the hardening of the soil (in Flanders = the concrete stop / construction shift). Given that rivers have no state borders, there is a challenge around cross-border approaches here;
- Look for other useful applications of dredging spoil:
  - ▯ Fixing the carbon in sandy soils (the carbon content in the Kempen decreases. In the Netherlands, peat oxidation is confronted).

System analysis contamination

The system analysis (Figure 3) was validated by the participants. The following points of attention were formulated:

- - It is not considered evident to avoid contamination. Possibilities are:
  - Prohibition of new contaminants (prevention) by the government (avoidance of pollution → avoidance of costs)
  - The introduction of mandatory evidence by the producers of biodegradation and non-harmfulness of their products and processes → if effluents then enter the watercourse, the natural ecosystem should be able to treat it. (avoidance of pollution → avoidance of costs);
- According to the participants, there is too little knowledge about the problem: where is the pollution located? How bad is the pollution? Which contaminants? Which risks are associated with this? What should we do first? The following intervention strategies have been proposed:
  - Preparation of knowledge database regarding
    - Type of contaminants / pollution → in such a way that it is better (and faster?) To determine how to combat the pollution and thus make a better estimate of the costs (dredging and remediation);
    - Determination of the volume of contaminated sediment, in combination with the concentration of the contaminants;
    - Mapping of all contaminated areas, including the above data → this makes it easier to determine the risk of contamination (→ contaminated areas with high risk must be tackled first);
  - Tackling historical pollution through smart alliances and coordinated interventions:
    - Nature conservation organizations monitor the quality of the water and sediment and, if necessary, raise the alarm (in time);
    - "River Trust" (UK) and other civic organizations conduct pressure on governments to release pollution to address sex and through cooperative financing money (in exchange for tax deductions);
    - Project developers participate in the remediation costs to increase the value of the area (including the water).
- Remediation of contaminated sediments in the urban environment increases the attractiveness and increases the interest in living in the city, resulting in less pavement in the rural area (which would be associated with high costs for expanding the utility infrastructure / mobility problems). These advantages make it more interesting to accelerate the remediation of contaminated water-bound sites, so that the benefits (especially benefits linked to compaction) can be used more quickly. The following points of attention were formulated in this approach
  - If contamination is not tackled upstream - the remediation of water soils, for example, in the city makes little sense;
  - What motivation is there to carry out (upstream) remediation - it is not possible and even desirable to set up project developments in all places where water bottom pollution occurs;

Box 5: WATERFRONT CONTRIBUTION: A NEW FINANCE PARADIGM FOR CLEANUP OF CONTAMINATED SEDIMENTS – Philip Spadaro -2019

“The status quo approach to waterway remediation and waterfront development is bifurcated at best and splintered at its worst. Inherent in the current regulatory process is **cost uncertainty** and **inaccuracy** as well as adversarial postures among potentially responsible parties attempting to

reduce their own burdens of **responsibility**. We attempt to show that the current model of divorcing the processes, the players, and the payers in the regulatory phase from the redevelopment phase serves neither the short-term nor the long-term interests of waterfront communities.
We propose instead a new paradigm for waterway clean-up and waterfront redevelopment. The new paradigm requires vision to adopt any or all the following strategies:
• Reframing and redefining the **responsibilities for costs**, including distributing more costs to those who benefit from waterway clean-up
• Encouraging **municipalities and port authorities** to catalyse clean-up efforts by adopting more proactive roles
• Driving **real community investment** through vision, leadership, and engagement
• Finding and leveraging **alternative financing approaches**, such as tax increment-based investments; funding for economic development, environmental protection, and sustainability; and public-interest capture of the inequitable windfalls that disproportionately benefit land speculators
• Tying some **long-term investment gains to social and environmental benefits**, such as ensuring that legacy residents can afford to remain in place, creating or reclaiming urban green spaces, and building resilience in the face of climate change.

- An important factor in this story are project developers. Upgrading a watercourse (e.g. even to bathing water quality) has a major impact on the property value. New forms of cooperation must be developed in which those who will enjoy the benefits contribute to the remediation of the watercourses. Certain forms of cooperation are already known today:
  - Project developer / contractor wants to do project development on a certain site (presence of pollution without fault). Project developer does the excavation work - OVAM (in the context of official sanitation) takes care of the processing costs;
  - In the context of an administrative clean-up, a negotiation is sometimes initiated with the project developer:
    - Due to clean water and beautiful banks → greater added value → remediation costs can be translated into the rental / sales price (consideration: If the added value is for the project developer, then the cost should also be for the project developer
    - In the context of a Spatial Implementation Plan, the project developer will receive additional options (e.g. they may build higher than normally prescribed) - income from the extra floors can then be used for remediation;
    - Excavation work + dewatering for basement construction at the expense of the project developer - remediation at the expense of OVAM;
- In the United States, the spread of pollution is linked to very serious liability issues (this risk of spreading increases with climate change - read increasing frequency and intensity of flooding and thus risk of pollution spreading). It is therefore used to immobilize contaminated hotspots, for example by mixing the contaminated sediment in situ with Portland cement. Points of attention in this approach are the (temporary) increase in pH in the water (resulting in toxicity + release of heavy metals / contamination of surface water / groundwater) and a possible impact on groundwater fluxes (since groundwater flux is prevented at this location);

- Use of reactive mats to keep pollution in place and to clean it in situ (see Project De Lieve in Ghent);
- By analogy with buffer strips or the introduction of organic material to combat erosion on, for example, agricultural land - by adapting the (polluted) water bottom texture / structure, the spread of pollution can be prevented;
- If the groundwater level drops, you go from anaerobic to aerobic conditions and there is an increased mobilization of heavy metals that in this way end up in the watercourse and then in the water bottom. You could choose to drain less - but it is detrimental to the profitability of the agricultural enterprise (aerobic conditions, on the other hand, degrade organic pollutants);
- - In any case, it is valuable to see how the link can be made with other opportunities (this requires more knowledge → database of possible synergies):
  - Climate mitigation;
  - Climate adaptation via blue green networks;
  - Economic interests of shipping companies;
  - Waterfront development via project developer.

System analysis: landfilling vs cleaning

Points of attention that were formulated in the analysis on dumping vs cleaning (Figure 4):
- Space is also required to deposit dredging spoils. Space that is limited, so that the cost of dumping will only increase (to a level where it becomes interesting to clean the spoils immediately):
  - In addition, there is a declining acceptance for landfill , so obtaining permits for expanding the landfill capacity is not evident (this is an incentive to reconsider whether certain fractions on the landfill can be valorised in order to be able to deposit longer in and the licensed dumping capacity);
    - Space is a limiting factor: you need space for dumping and space for the extraction of natural raw materials: Circular economy can solve the problem of space scarcity (Question: you don't need extra space for cleaning / filtering either) of secondary raw materials from dredged material)?

Box 6: Linking space and circular economy - Optimal use of available space through progressively changing destination

For the valorisation of dredged material, not only the chemical quality is important, but also the sedimentological one. Linked to this is the area where the mortar comes from. Erosion of the areas of the Upper Scheldt and the Leie results in a different sedimentological quality than areas of the Lower Scheldt and Meuse. The sediments of the Bovenschelde and Leie contain more clay and loam particles since the erosion occurs in areas with loamy and clayey sediments. If these are dumped separately (eg. the test dumping in Beernem, and even Callemansputte), there is a well with a sedimentological quality that corresponds to that of the extraction areas in the same region (loam extraction, clay extraction). After sufficient consolidation, such a well can serve as a reclamation area and make room for new dredging sludge. However, this picture is not in line with the current regional plans and political courage is needed to change things such as a progressively changing destination / use of sites until finally a new destination can be reached. We could call this 'optimal use of available space through progressively changing destination'. The question is whether politicians and administrations are ready for this.

At present, permits for dumping dredged material are simply too easily refused, while perfect raw material depots could be created. Finally, there is still a large part of the upstream dredging spoil that is not contaminated and is only enriched to a lesser extent.

- Can project development be carried out in landfills with a high node value, whereby the income from this can be used for the remediation of the aquatic soils? [point of attention the income from the project development will only start after the project has been delivered - will this income be used for the remediation of the local sediment or deposited in a general soil remediation fund or used for the remediation of upstream pollutants?];
- - The idea of a water bottom remediation fund was suggested: the question is where the income should come from (see point above);
- - It is also possible to deploy multifunctional use of space. The Slufter -NL (landfill for heavily contaminated dredging sludge) is also used as parking places, space for solar panels n;
- By cleaning / sanitizing the dredging and clearance spoil, the pollution is not gone ("maintenance of the shit"):
  - Organic compounds may be degradable - but the inorganic contaminants remain (perhaps in a smaller volume) - e.g. heavy metals (are there economically viable solutions for removing heavy metals from dredging and clearance spoil - are there valorisation routes for these metals?));
  - Decontamination / cleaning will reduce the volume - This is also the approach at Amoras (Antwerp Mechanical Dewatering, Recycling and Application of Sludge). The maintenance dredging sludge originating from the Port of Antwerp is separated into a sand fraction and a clay / silt fraction - this clay / silt fraction contains the most pollution (including the attraction between charged particles). This clay / silt fraction is then transported further via a tube (5km) to be dewatered there (from 2m³ grout to 0.5m³ grout). Because the sand (originally 20-30% of the original volume) is no longer present, there is less corrosion on the pipeline. (for your information: soil contains about 60% sand). However, the presence of sand is an added value at the level of dewatering. If you remove sand, dewatering becomes more difficult (greater energy demand required for the same result);
  - In addition to the presence of contamination, the presence of organic matter, water, salts, homogeneity is also an important factor for recycling options:
    - The Netherlands allows the spoil to mature (ripening) / lagooning - but this requires great amounts of land):
    - By ripening:
      - > Decrease in organic matter (via oxidative degradation processes);
      - > Decrease in water content;
      - > By flushing with rain. Drop in salt concentration;
  - The problem with dredging and clearance spoil is that it concerns very large volumes with relatively low pollution, which makes remediation very expensive (question: Are there applications that allow low levels of pollution?);
  - - Dredged volumes are much higher than the volumes with possible beneficial use**:**
  - In the coming years, several large infrastructure works are planned (Saeftinghedok, Oosterweel, etc.), whereby a lot of infrastructure spoil / excavated soil will become available. The contractor is

responsible for finding a use for this. If these spoils ground can be used and disposed in the river (see feather), the dredging boats can be used for transport. If not, inland shipping will have to be used to have these spoils deposited somewhere inland. In the latter case, these works will mortgage the available capacity for water transport (no more inland vessels available for other activities - analogous story to competition after low water levels on the Rhine);

Question: what the impact of climate change will be - which will include looking at raising and strengthening dikes.

System analysis Soil surpluses

Box 7: Box 7: Problem of sediment surplus
21/01/2019 (De Standaard): ""In a lake in the outskirts of Ghent, a contracting company wants to dump sediment in large quantities for many years. Residents fear dangerous traffic situations and noise nuisance. "Is there no free space in the harbour?"
21/02/2019 (De Standaard): "When building locks and docks in the Flemish ports, it is increasingly puzzling to get rid of the excavated sand, clay, peat and shell sand. A new expansion of the port of Antwerp near Doel is looking for a solution for 15 million cubic meters of land surplus. It won't be cheap ..."

- Every year, 500,000 tons of DS dredging, and clearance spoil (excluding sand fraction) are released After dewatering, still 30% water = 700,000 tons of spoils;
  - In theory, 5-10% of this spoil could be used to produce bricks:
    - You would need sales of 7 million tons of bricks - you don't have this production capacity (need) today
      - With a massive reuse of bricks (circular construction), the demand for bricks will decrease even further;
- The largest client in Flanders is the Flemish government itself - yet it is not obvious that works are connected in time to each other and thus balance supply and demand. The contractor is often responsible for finding a solution:
  - Case: Two works by the Flemish Waterway:
    - 1° Carrying out dredging operations;
    - 2° The construction of embankment around flood area;
    - As a contractor you should win both projects to make the match between supply and demand;
  - If the government is held responsible for finding a solution for the sales (rather than shifting this responsibility to the contractor), this will also encourage them to always weigh up whether, for example, dredging is necessary;
  - In the construction world, there are alternative tendering methods for this, such as DBFM and construction teams, which stimulate cooperation;
- The way of tendering is also important. In certain tenders, points are given for the price, but also for the% of dredging and clearance spoil that is used and that meets the criteria of shape, stability, and permeability. Cooperation can also be an additional criterion;

– You could temporarily store the land, but interim storage also costs money. [Often in municipalities you see large mountains of land from the belief that they can use it sometime in the future - but it is found that this mountain is getting bigger and bigger];
– What are the drivers for timing?
    - How much stretch is there on the timing of the dredging and clearance campaigns in the various Flemish river basins to align them with the question?
– There is insufficient insight into the quantities of the different quality of spoil and their resp. outlets;
– For the non-navigable waterways, a 5-meter zone is provided where the waterway manager can deposit the riverbank (the condition is that the clearing spoil must not be contaminated). In any case, navigable waterways should not be subject to bank deposit and must therefore be sold externally;
– It is the authorities that have the most important budgets for carrying out dredging work:
    - Maritime access: guarantee focus on navigability;
    - Vlaamse Waterweg: guarantee navigability / avoid flooding;
    - Ports: focus on navigability;
    - VMM: focus on avoiding flooding + specific attention to spearhead and focus areas (regarding quality).

  A large part of the problems (including pollution) can be tackled upstream. But municipalities, provinces have very little budget. Today's finding is that recurring expenditures are being made to clean up contaminated sediments in the lower reaches - while an action upstream (e.g. removing or capping historical pollution) would solve the problem:
    - Question: where could municipalities / provinces find alternative financing?
        - The adjustment of the morphology of a river (e.g. greater draft) is often at the service of the economy / industry - the costs for dredging are passed on to those who benefit from it - e.g. via the levies / mooring fees (or is this rather via general tax means);
        - Approach NL: Area-specific material can be applied regionally (if the ecosystem is in a good state in a certain area. The starting point is the biotic qualities) - the stand- still principle for a certain area is accepted.

The costs for cleaning resp. depositing also depends on the valorisation options. However, these valorisation options depend on several factors:
– The environmental, but also the constructional characteristics;
– The cost of the primary raw materials (e.g. sand & clay). As long as new permits can easily be obtained for new sand extraction, there is little pressure to innovate / adapt production processes in order to use the dredged material fractions (e.g. innovation where the use of fine round sand can be used in construction applications / cleaning methods to removing or recovering organic substances, metals , etc.)
– Competition with other secondary raw materials (e.g. from excavations - see box above;
– Transport costs: sand / clay / loam have a low value, because of which the transport costs weigh very quickly, and especially local applications must be sought;
– Extra costs linked to energy (dewatering of dredging and clearance spoil) / removal of contamination (including flue gas cleaning).

Box 8: Primary Minerals Sector

Locations for sand extraction on land are increasingly difficult to find. Sea sand is therefore an interesting alternative in both Belgium and neighbouring countries. Since the 1970s, the share of extracted sea sand in Belgium in total sand production has been increasing.
This sand is used on the one hand in the construction sector and on the other hand used to protect the Belgian coast. Since sea sand has become one of the basic raw materials for the construction sector in the past thirty years, it has undoubtedly acquired a great social and economic importance in Belgium.

To date, approximately 3,000,000 tons or 2,000,000 m³ of Belgian sea sand is extracted per year, of which more than 80% is used in the construction sector. In addition, the implementation of sand replenishment (spraying) is currently the most important measure for sea defences along the coast. Sand nourishments ensure that the beaches are wide and high enough to protect the coast from flooding during heavy storm tides.

- [However, if the sand demand for coastal safety increases and if one dug up coast-near sandbanks for it, we end up in an undesirable reinforcing course
- [A specific location is planned near De Panne to conduct experiments around sea defences, for example to check the effect of raising sandbanks on the safety of the coast -

Possible restrictions on the amount of sand that can be mined off the coast could curb important initiatives with a great need for sand and have a significant socio-economic impact (+ higher import dependence)

[Socio-economic importance: In 2017, 13 private companies had an ordinary concession to mine sand off the coast. The Flemish government has three concessions for exceptional projects, two for the Coastal Division in the context of coastal defence and one for the Maritime Access department in the context of environmental compensation for the expansion of ports. During the past 5 years, 2.0 to 3.0 million m³ of sand has been mined annually for the construction industry and 0.3 to 3.6 million m³ for the projects of the Flemish government. The thirteen private companies with a concession license employ 130 people in Belgium and 138 people in the rest of Europe. The annual turnover of the sale of sea sand and sea gravel in Belgium amounted to more than 70 million euros in 2016]

Attention to environmental aspects:

- The presence of pollution in dredging and clearance spoil forms a psychological barrier - "who would want to use slightly cheaper bricks in which arsenic and mercury are present" + what if you then also have to demolish the building / what implications does this have?

- You concentrate the pollution in the finest fraction (silt / clay), you make stones from it and then you spread it back into society? What are the implications if these buildings are demolished / is there a trace where these materials go in our society?
  - This could be done through material passports;
  - In addition, it is also not easy to place contaminated materials on the market - resulting, among other things, from the REACH regulations. Hazardous substances (arsenic, heavy metals) will not be allowed on the market. See i.e. the implications of the recently published chemicals strategy: “Towards a Sustainable Chemicals Policy Strategy of the Union” as well as the European Green Deal with “A zero pollution ambition for a toxic-free environment”;
  - In contrast, there are already studies that have investigated second-life and showed that there is no problem
  - There is a difference in quality between upstream and downstream (regional). Arsenic is indeed a problem in downstream regions, but not necessarily in other regions. This calls for a fractionation of the volumes of dredged sediment;
- In the brick industry, there are other more important problems to valorise dredged material, one of which is the continuous availability of one specific quality of raw material in order to meet the production criteria of one specific type of brick. Many tests must be done per recipe to produce stones that are in accordance with BENOR. Stable availability of a stable raw material quality is therefore very important. In fact, the chemical (contamination) quality is of minor importance. Organic compounds are burned, metals are fixed by the sintering process. Subsequent leaching, even in two e life happens hardly. So, it is simply more difficult to work with dredging sludge instead of primary clay and loam (due to the demand for homogeneity). And as mentioned earlier, if permits are easily issued, both for mining primary minerals and dumping dredging spoil, little will change. And even if there were no more permits to be issued for mining, there is still the possible supply of raw materials from abroad. Clearly, good will is also needed, but how to stimulate it?

Attention for construction aspects:
- If there are too many sulphates in the sand, they will react with the calcium hydroxide in the cement and you will get calcium sulphates. Calcium sulphates tend to swell, making the concrete or brick toe more susceptible to cracking;
- During the thermal cleaning of sediment/ soil, the silicates present therein become reactive. Reference is made to a case in the Netherlands in which thermally cleaned soil was used for the construction of a dike. However, the silicates have different chemical properties (reactive) after thermal treatment, resulting in i) leakage of water from the dike with a high pH, ii) compaction phenomena (dike must be permeable due to the pressure differences between both sides of the dike) with problems to stability. These dikes now must be reconstructed (which leads to high costs). Question that must always be asked: “are you going to improve or deteriorate the construction / geotechnical quality of the secondary raw materials due to the remediation technique used.
  - This is also a point of attention at the level of the European Waste Frame Directive:
    - On the one hand, it is too strict because it only considers concentrations and not leaching (leachable contamination);

- On the other hand, it is too weak: if the environmental requirements are met, it can be used in construction applications. There are no standards included in the Waste Frame Directive for construction engineering applications:
  - In principle, the latter is covered by the product-specific standards? 'Concrete or bricks consisting of secondary raw materials must meet the same technical preconditions as with primary raw materials;
- The sand present in dredging sludge is too much polished / rounded, so that the constructional applications are limited (e.g. in the construction sector). On the other hand, there is no drive for innovation to see if there are any valorisation options for this rounded sand:
  - The production processes are geared to the use of coarse sand → can these processes be adapted? Can the tear resistance be enlarged from round sand?
  - Can techniques in the construction or mining sector be applied to change the sediment's property?
  - If it is too easy to obtain a permit for the extraction of primary raw materials, innovation will be slowed down. It is still too easy to cut down a forest for the construction of a sand quarry:
    - Digging a pit to be able to fill it up afterwards is shifting the problem;
  - We do know that the reserves of coarse sand are shrinking drastically (click here - “The cost of the worldwide construction frenzy - what if there is no sand anymore with, for example,“ the global demand for sand increases by 5.5% every year ”and“ in the current pace will run out of moderately coarse and coarse sand in our part of the North Sea by the end of the century ”);
- The homogeneity in the production of (building) materials is also important. During the extraction of clay, a mixed sample of different layers with a (slightly) different composition is always taken to always be able to deliver a homogeneous product.
- Construction sand needs coarse sand (grain size from 210 to 2000 µm) that must be extracted further and further at sea - grain size from dredging and clearance spoil is much finer?

Questions that arise:

- How can the link be made with the climate story? In the context of the fight against climate change, the Flemish Government approved its Climate Action Plan on 29 March 2019 (click here). To accelerate investments in greenhouse gas emission reduction measures via the Climate Fund, the Flemish Government is already deciding on the use of 75 million euros that will enter the Climate Fund from May 2019. These resources are divided over various domains, including at the level of the circular economy, CCS, demolition, and reconstruction premium:
  - Under which heading could activities related to dredging, cleaning, and reuse fall.
  - What is the impact of different approaches (dredging / storage / different types of cleaning / etc.)? On the total CO2 balance
  - Within the framework of VLAREBO, a multi- criteria assessment must be carried out for contaminated soils to determine which cleaning method is most desirable. Criteria include
    - CO_2 balance
    - The use of primary raw materials
    - Waste generation
  - At the level of dredging activities, there are CO 2 emissions at various levels:

- Energy consumption for dredging;
  - Energy consumption for transporting;
  - Energy consumption for treating the spoil - a frequently used technology is the regular reversal to promote oxidation: this means an exemption of CO 2 into the atmosphere. How much greenhouse gas is avoided by avoiding extraction of primary raw materials (by using dredging and clearance spoil)?
- - If you dredge and clean up the contaminated sediment in the upper part of the watercourse, there will be much less contaminated sediment (in the lower course), so that the dredging sludge can be dumped (in another place) and the outlets are increased - "How can we keep sediment in the system for as long as possible*"*.

Possible applications of dredged material:

- Brownfields contain a lot of concrete (surface sealing)- for the development of these sites there is a need for materials with better hydraulic properties;
- Use of sand in horse tracks, golf courses, football slopes;
- Foreshore-deposition: however, sand from dredged material is often polished and therefore rolls easily. You basically need sand with greater friction (read: tear resistance). Density would also play a role. The density of maintenance dredging spoil is too light. Foreshore-deposition can be cheaper than the shore reclamation of beaches;
- The problem of tear resistance also arises when building dikes. A dike has an aspect ratio of 1 to 3. You could build dikes with a less steep slope, for this you could use round grains, but often you don't have the place;
- Soil improvement (organic matter replenishment) for the farmer - here you may compete with other secondary raw materials (e.g. compost
- The PIANC report contains a nice description of the various applications for dredging sludge - we must not reinvent the hot water - important to look at new applications
  - Increasing the nature value;
  - Safety / coastal protection;
  - ...

ANNEX 5: TURN THE TIDE

The first important step to change a system is to understand it. A second valuable step is to take a look ....

- What would be the consequences if we reversed the main cause-effect relationships: What added value is coming into view? Are there also unwanted side effects??
- What solutions can we come up with to effectively reverse that cause-effect relationship

During the second, Flemish Workshop following relationships were reversed:

1. Increasing the intensity on the waterway results in reduced dredging activity;
2. More cleaning of contaminated sediments leads to lower costs;
3. More infrastructure works reduce the quantities of dredging and clearance spoils.

Increasing the intensity on the waterway results in reduced dredging activity

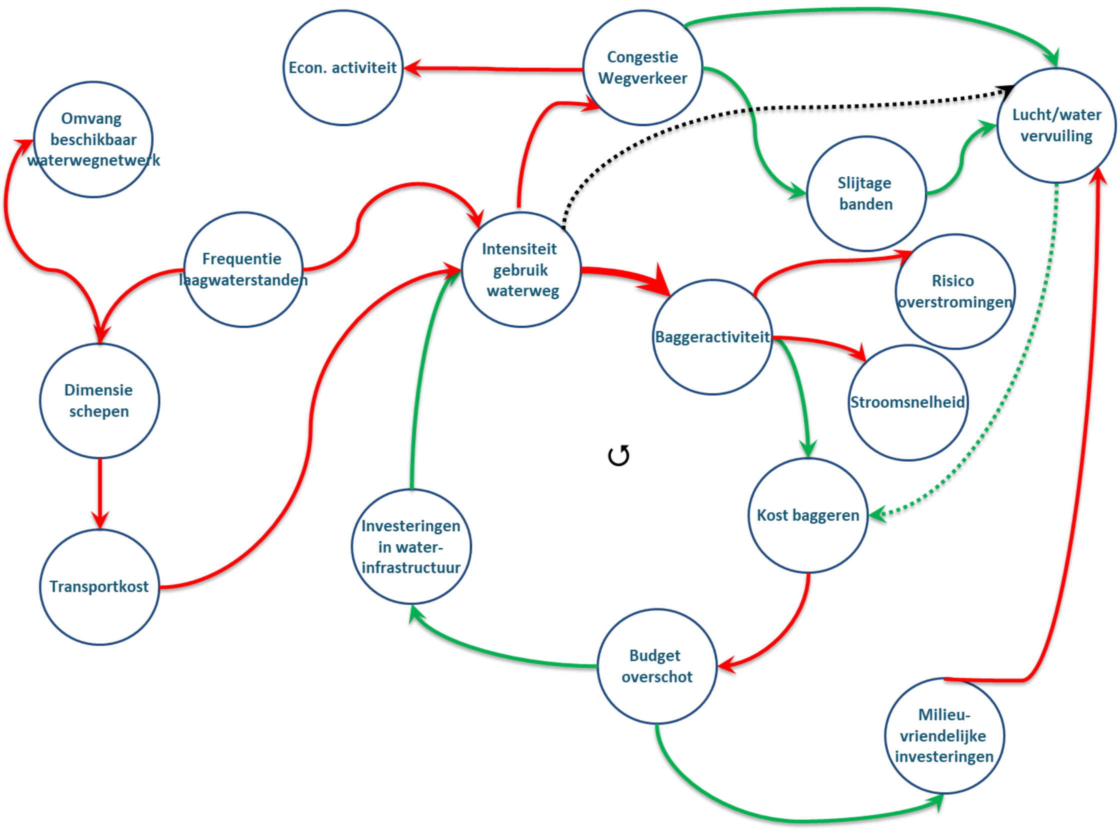


Figure 6. Relationship beteen use of waterway and frequency of dredging

Some findings:

- If there is less dredging, more budget is available that can be used for investments in the water infrastructure, which makes it even more efficient (and budget surpluses will also make more use of environmentally friendly technology with a positive impact on what is / air pollution);
- It is not clear whether the modal shift contributes to air pollution - the belief is that there is a positive effect - certainly if we only look at inland shipping. The story may be different regarding an increased deployment of sea-going vessels (cf. largest luxury cruise operator emits more sulphur compounds than all European cars);
- A possible side effect is that there is an increased risk of flooding (in addition, the flow velocity in the river will also increase and - a smaller flow profile);
- In addition, there are external factors that have an important impact on whether the waterway can be deployed, especially during periods of long drought (low water levels). By the summer of 2018, it was already clear that there was a very high demand for smaller ships. Since captain / skipper is a bottleneck profession, the supply is smaller than the demand and a lot of money was put on the table to have these smaller ships available
- It is not necessary to dredge the entire watercourse to keep / create watercourses navigable. It often involves removing several thresholds in the fairway. If it is used on smaller ships, dredging will have to be carried out less frequently and a larger amount will have to be dredged at once, which would be better in terms of cost efficiency. On the other hand, the dredging boats will also have to be smaller - so again demand for cost efficiency:
- **Question:** Switching to smaller ships is not an extension of the problem. It just takes a little longer before the watercourse becomes unnavigable. On the other hand, the realization of a certain buffer capacity also gives the 'time' to roll out other measures
- By using smaller ships, you increase the network that you can use for water-related transport (use of smaller watercourses, for example the Kempische canals);
- Research is being conducted in which a larger ship can transform into several smaller ships (ship adapts to the morphology of the river);
- Smaller boats have several drawbacks:
  - **Personnel cost → this could be covered by autonomous sailing**:
  - Question: To what extent is autonomous sailing already realistic? At NMBS, experiments with automatic driving are also carried out. This shows that there is up to a 30% gain in energy consumption and the risk of (human) accidents is reduced. But many interventions still require human intervention. So, now a driver is still needed and therefore personnel costs will not immediately decrease. In system terms you could therefore say that there is a delaying effect between the relationship ' autonomous sailing' and 'personnel costs';
  - Investment costs / depreciation costs: for a ship twice the size you do not need twice as much steel + operating system for small or large ship will not differ much;
  - This could give rise to higher transport costs (due to lower loading capacity) and therefore less interest in the use of water-bound transport

Subsequently, the question was asked “How can we devise a water system in which more intensive use of the waterway results in less dredging” and considering some possible side effects (including flood risk):

- Bring sediments in suspension so that they can be flushed:
    - via propellers of ships;
    - pump installations (which run during energy peaks) - remark: how much extra energy is needed for this;
    - water injection (e.g. at locks) - remark: how much extra energy is required for this].
- In a river you have depth differences, with 'banks' and 'valleys. Shallowing by filling the valleys with sediment that lies between the banks:
    - However, the challenge remains that too much sediment flows into the watercourses and these sediments cannot be flushed out to the sea - given strong current from the sea, as well as very low slope (typical of a river delta),
    - Efforts must therefore be made to avoid sediment leaching to the watercourses (including via permanent grass strips).

More cleaning of contaminated sediments leads to lower costs

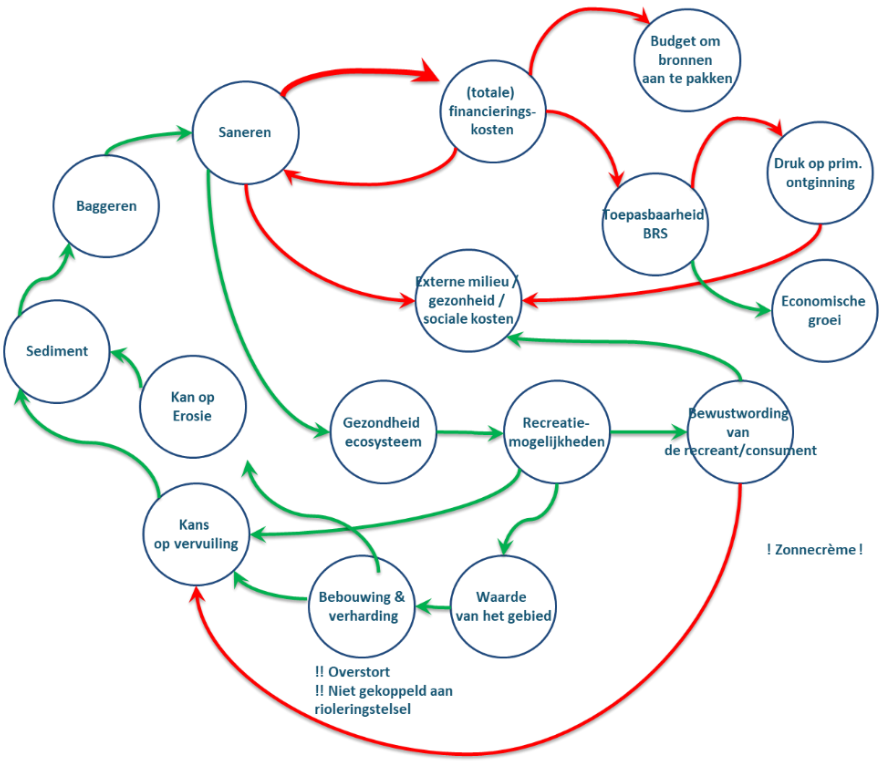


Figure 7. Relationship frequency of remediation contaminated sediment and remediation cost

Some findings:

- The more dredging and clearance spoil is remediated, the smaller the total financing cost (dredging, storage, transport, and remediation costs) becomes:
  - The remediation of dredging and clearance spoil increases the (potential for) income from secondary raw materials in new applications (see also point 3), such as (fertile) soil (for agriculture) or building material (e.g. cement substitute). Note: the yields of secondary raw materials depend on the demand for it, which can vary, for example in relation to the price of competing primary raw materials;
  - Remediation frees up storage space; as a result, the (internal or external) rental cost decreases or no new space must be used → storage cost decreases;
  - Since storage space will become available, dredging work will not be postponed and smaller quantities of spoil will be deposited → less chance of contamination of the water bottom, which will ultimately result in less remediation (balancing loop). Questions: To what extent does the reduction of storage costs and the reduction of the spread of contamination in the soil account for the final dredging and remediation costs? To what extent will more frequent dredging activities accommodate a (more) constant supply of secondary raw materials for new areas of application?
- Due to the decrease in total financing costs, a budget is eventually released to tackle the sources of pollution, both by detection and by remediation;
- The use of (remediated) secondary raw materials increases the applicability of dredging and clearance spoil for new (economic) purposes, which will lead to a growth in new business activities. The use of secondary raw materials reduces the pressure on the extraction of primary raw materials. Mining less primary raw materials will reduce the pressure on the environment, reducing external environmental costs related to the new applications;
- An increase in the remediation of contaminated dredging and clearance spoil leads to a healthier ecosystem in both the water and the bottom of the watercourse. This will increase the interest to use the watercourse for recreational purposes. As holidaymakers get closer to nature (and see, feel, smell, ... a clean watercourse, awareness increases to consume more environmentally friendly (e.g. less organic oil residue from sun cream in the water). If we consciously choose more environmentally friendly and healthy products, there will be less pollution and the external costs of the products will decrease (reinforcing loop)
- A possible side effect of the increase in recreational opportunities - and therefore an increase in the intrinsic value of the area - is a local increase in buildings and pavement. This, in turn, can lead to a host of other unwanted side effects
  - Greater risk of flooding and flooding (due to the possible absence of a sewage system or overflow of polluted water in a separate sewer system to the watercourse);
  - Greater risk of pollution, leading to a decrease in health of local ecosystems (balancing loop). If the polluted water is not drained by a sewer system or if polluted water still ends up in the watercourse due to the overflow of a separate sewer system, more remediation must be done. (strengthening loop);
  - Greater chance of erosion, which leads to more sediment in watercourses and more dredging is required, and therefore also remediation (reinforcing barrel).

Clearly, more efforts should be made to remediate dredging and clearance spoil, with numerous environmental, social, and economic opportunities, but care should be taken to avoid undesirable side effects regarding recreation activities.

More infrastructure works reduce the quantities of dredging and clearing spoils

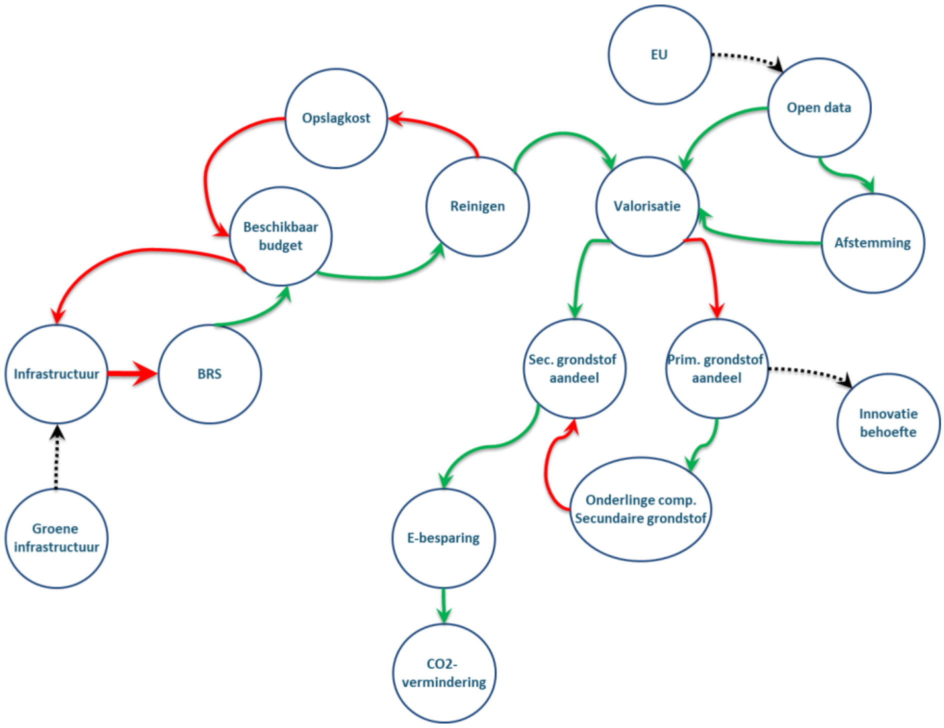


Figure 8: Relationship between infrastructure and quantity of dredged sediments.

ANNEX 6: UNUSUAL SUSPECTS & POSSIBLE CONTRIBUTION TO THE SYSTEM

When looking for solutions, the usual suspects are often looked at. An exercise was set up in which the participants were presented with a list of stakeholders who (seemingly) have no (or will not) play a role in the sediment challenge. Subsequently, the question was asked to devise a way to involve this actor in a solution regarding the outlined problems. The general message is that it can be valuable to consider how unusual suspects can be involved in the development of future projects.

Clini Clowns:

- Is in contact with sick children and can convey the message that a healthy living environment is essential.
- Hospitals discharge wastewater with many (new) medicine residues → these medicine residues can eventually end up in the water and sediment → for the reuse of dredged material in building materials (including for the construction of a hospital) it is important that we have good environmental hygiene quality: hospital can make efforts here to limit the discharge of drug residues;
- Medicines / veterinary products are not currently assessed for their environmental impact (exemption via REACH.

Malaysian Minister of Environment, Yeo Bee Bin

- Borneo is low-lying - knowledge exchange regarding the use of alternative raw materials e.g. for coastal protection / land elevation (also in view of the fact that primary sand is increasingly becoming a scarce commodity worldwide);
- Increased attention to the problem of plastic pollution, which gives rise to micro-plastics. Little is known today about the impact of micro-plastics, including on the food chain / reusability of sediment.

Morality teacher

- Role in changing thinking patterns:
    - "Proper use of water / Using water cleanly is evident"
    - "When taking measures, we must keep the various functions open". Sediment-functions: habitat, recreation, safety ,….;
    - "Nature and ecology are central to our decisions";
    - "We make new materials from old materials";
    - "Avoid using single-use plastics";
- Creating support for the use of recycled materials (analogy with sorting household waste was learned on the school desks - "we must educate the new generation".

Rotary Club

- Role in financing theses concerning e.g. monitoring / reuse - development of an application for the irrigation (e.g. with surface water) of the golf courses with a positive impact on the quality of the water bottom;
    - Co-financing the remediation of local aquatic soils and in this way creates value for the members of the Rotary Club - including at the level of real estate projects / reduction of the water bill.

Telenet

- Presenting example projects + impact / role that the different target groups play in this:
    - Accessibility entertaining karrewiet) to crazy technical (panorama) ;);
    - Radiating the image that we are the world leader in tackling this challenge;
- Development of WiFi systems / use of remote sensing / LIDAR
- Monitoring of suspended matter;
    - Where is there erosion and where is the material deposited;
    - Where are the largest sources of pollution;
    - Today, the data is spread too much across different actors. Downstream, one is confronted annually with significant amounts of contaminated sediment - but it is not clear where the sources responsible for that contamination are (e.g. PAHs). There is also a reluctance to share this data (including between maritime Access, Flemish waterway, VMM, OVAM, Provinces, etc.) because it would then become clear who is guilty / responsible + combined with the limited budgets that are available. The above problem is not so much with contaminated soils: if you identify a plume of pollution, you can identify the cause relatively easily (e.g. leak in fuel oil tank);
- In certain cases, a watercourse disappears via a tube / siphon in the underground (Zwarte broek under Albertkanaal, Koker van 't Schijn) → if you get sedimentation here, you need to flush (extra pumps are sometimes used to get sufficient flow);
- Projects are underway regarding the smart use of waiting basins (use as a buffer against flooding or drought). We are now examining how these would ideally be emptied to prevent too much sediment from accumulating in the holding basin.

Terminal owners

- If costs are too high, they will move to another port;
- Now all profits lie with the shipping companies and the burden with the port and infrastructure managers;
- A 'solidarity tax' for all EU ports would (partially) relieve the burden on port and infrastructure managers.

Shipping companies

- Importing smaller and automated ships;
- Involving shipping companies in the development of the port and waterways;
- Can shipping companies / industry not co-finance the dredging and remediation of contaminated sediments, so that more ships can enter port and watercourses?

Families

- Consumers are possible (unconscious) pollutants of waterways;

- Sensibilisation of the risks associated with the use and disposal of products;
- (Re)educate the consumer.

Road transport
- The use of dredged and clearance spoil in roads.

Building material producers
- Certification of secondary granules;
- The use of dredged spoil from (public) procurement in waterfront ' development projects.

Project developers
- Developers should invest in the remediation of contaminated sediments and finding solutions for the use of stockpiled sediments. A result the value of sites beside watercourses (and port ???) increase and new development areas (in the city and along watercourses) can be developed;
- Search partnership with the construction industry (contractors, developers, manufacturers) for development of further use (of both fine and slightly larger grain sized fractions) in large local infrastructure / construction projects and resulting in fewer greenhouse gas emissions.

Agriculture
- Farmers responsible attitude of farmers to omit the use of pesticides - which end up in the watercourse - by creating (?? financial) incentives that they can use clean dredged spoils for their fields. How do you deal in a sustainable way with a possible competition with livestock manure?

Local authorities
- Seek partnership with local authorities to use clean dredges spoils to raise dikes (climate mitigation). Take care with thermal cleaning of sediments, as this can lead to glazing, which changes the chemical properties of the soil material and can lead to leaks and compaction phenomena. More research is needed here??

ANNEX 7: E-ARTICLE

The aim of this exercise is to consider which actions should be initiated in the short term based on a long-term perspective. The exercise goes through three phases, initially sketching a dream image in the distant future that adheres to several principles that solution directions must meet:
Principles for solution directions:

- Avoidance of too much sediment in the watercourse;
- Improve the quality of sediment in the watercourse;
- If the sediment must be removed from the watercourse anyway -> unlimited application possibilities of the sediment;
- Nature and economic interests go hand in hand

Phase 1: Sketching the dreamscape:

- What did we stop with?
- Which nice things can other people do?
- What is there now, what is needed, - and what else is needed, …

"Describe how great the situation is in 2099. What is happening now, that was impossible 80 years ago? What stopped, what is more?

Phase 2: Description of the current bottlenecks in 2019
"Describe the major issue(s) people/industry/policy makers were confronted in 2019. What didn't work

Phase 3: Description of key moments between 2019 and 2099 that brought us to this dream image
"Describe key event(s) that changed our world! Where and when did it all start? Use concrete dates and locations. Tell the story based on fictive and/or real people? Which smart alliances? What happened in 2020?
…

Newsflash (23 October 2099): "The last fossil power plant in Dubai Closed"

Today (23/10/2099):

- No more contaminated sediments;
- Systems knowledge and sustainable way of thinking to manage sediments;
- If there is waste in any production, it's combusted in the sun sphere;
- Local production leads to better agricultural practices → less erosion → less sediment input;
- We live in a balanced world (**economy and environment are in balance**) where we have a minimum/no waste. Most waste is converted into a resource.

This wasn't always the case:

- Excessive use of non-renewables;
- Problems of uneven education around the world;
- Problems arising from undesirable waste & CO_2 in the system;
- A lot of wastewater discharged;
- Need to frequently deepening harbours.

Fortunately, things changed:

- 2020: Young girl inspires people that we have to change;
- 2025 Due to sea rise the quantity of sediments needed exceeds available quantity (already the case in the US);
- 2025: Change in perception: we are mis-managing the critical resource called sediment → no more disposal, all returned to the regional sediment system;
- 2035: First "One World Government" to foster exchange of prosperity;
- 2045: a lift into the outer space started. Waste transport to the sun gets cheap;
- 2050: Paul Hus 3d world president implemented new spatial planning approach + added value should be created & no waste;
- 2050: Energy intensive industries are no longer profitable + lifelong warranty for every item: production volume decreases and product quality increases;
- 2055: The missing hyperloop links in the WNN are closed: ships and planes are no longer needed. Dredging only needed to avoid flooding + massive investments in renewable energy;
- 2065: Multi partner marriage/family allowed by law. Immediate reduction in birth rate (population decreases steadily towards 3,5 billion people). Introduced by the Family minister Mo Pelto in 2065 + disposal sites are dug out (we have well developed recycling systems) and hazardous waste is sent to space;
- 2075: All products are produced regional;
- 2099: Dubai, last city to reach energy/resource balance. Closing its last fossil fuel plant.

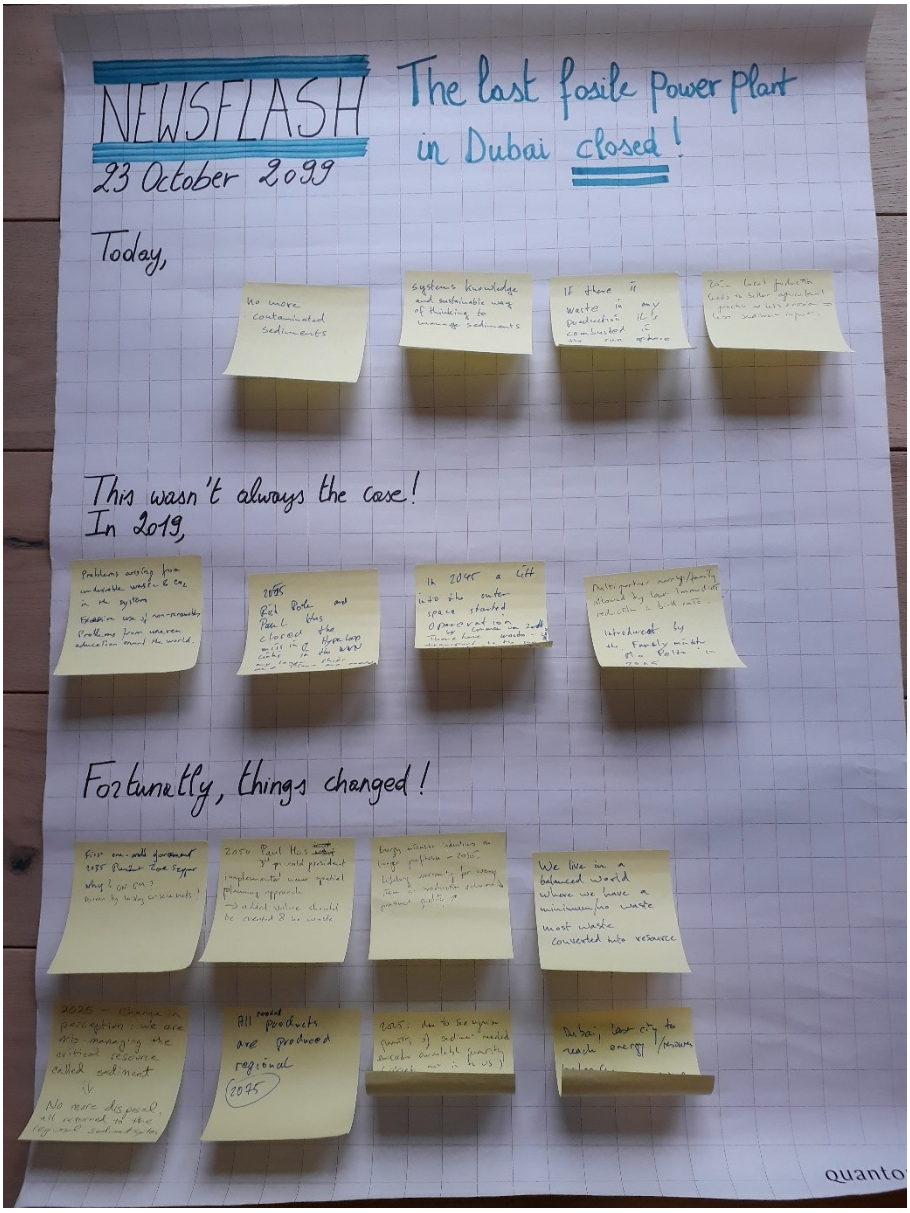


Figure 9. Newsflash 1 (23 October 2099).

Newsflash (23 October 2099): “Sediments for superfoods”
Today (23/10/2099):
- **All sediments are clean** and can be used to produce superfoods & vegetables;
- Dredging is cost neutral due to the value of the material;
- We have naturally sluicing systems.

This wasn’t always the case:
- Presence of contaminants such as PCB, PFOS & Plastics;
- **Lack of data and cheap analysis methods;**
- Clean sediments are still considered as a waste.

Fortunately, things changed:
- 2020: **Trade ware 2019** (US tax on Scottish whiskey);
    - US versus China, followed by US vs EU → China vs EU;
    - Reduction in import in ports: reducing port expenses (capital dredging) only maintenance dredging;
- Improvement of the Global Agricultural practices evolving towards a circular economy;
    - From a linear use of soil to a **circular use of soil;**
- Technology development in the field of dewatering and the removal of contaminants.

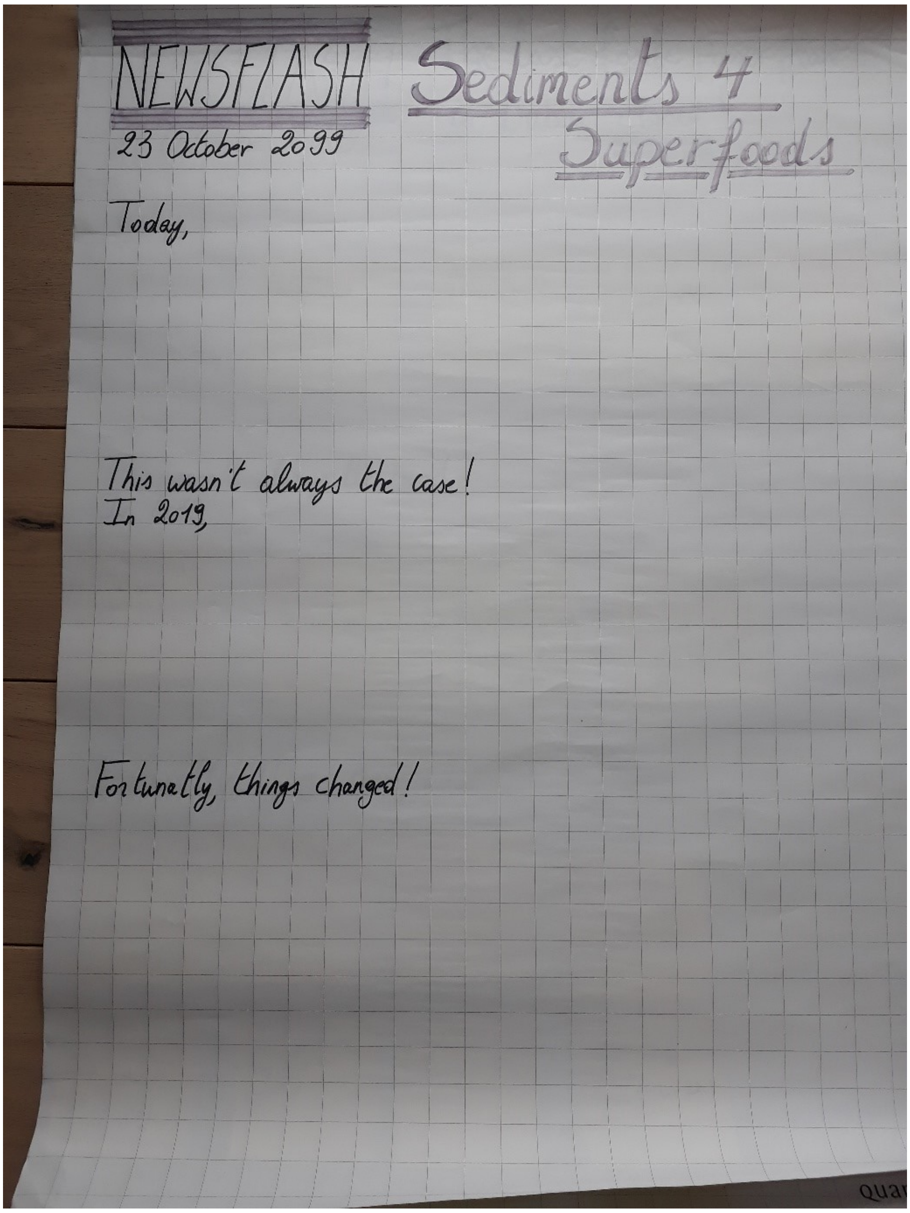


Figure 10. Newsflash 2 (23 October 2099).

Newsflash (23 October 2099): “Shangai aiming high: From dirt port to national parc”
Today (23/10/2099):
- All historical pollution has been clean;
- **Equilibrium: system is managing itself** (no outside contamination to the river / no outside sediment to the river.

This wasn’t always the case:
- People want everything cheap -don’t want to pay environmental costs;
- **Short term thinking;**
- **Society accepts discharge of pollution**: the use of Best Available Technologies (what is feasible);
- We have to many sediments in the system;
- Problem with emerging pollutants. Sources of pollution are not cut off from the system.

Fortunately, things changed:
- …

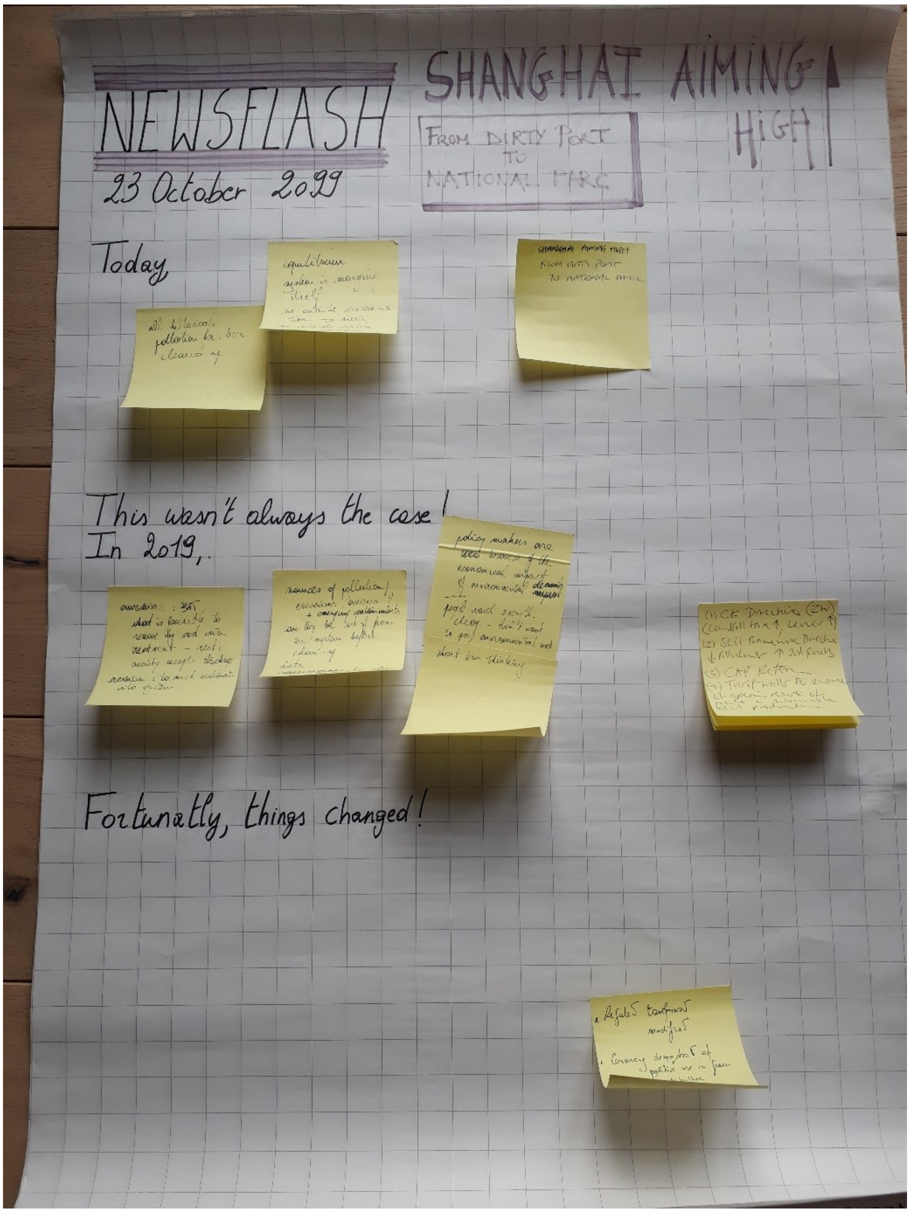


Figure 11. Newsflash 3 (23 October 2099).

Newsflash (23 October 2099): “Polluters” make final payment and we all benefit”

Today (23/10/2099):

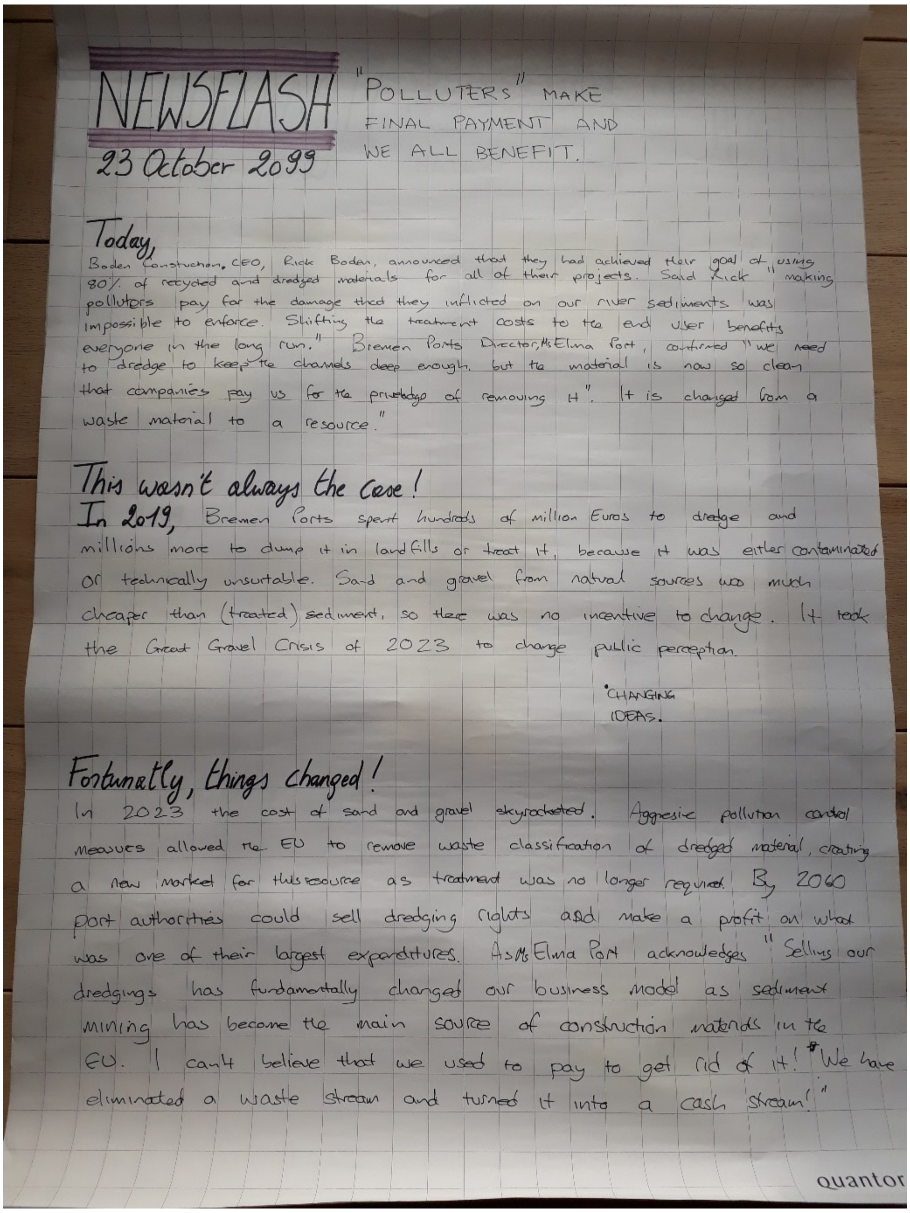
- Boden Construction CEO, Rick Boden, announced that they had achieved their goal at using 80% of recycled and dredged materials for all their projects. Said Rick “making polluters pay for the damage that they inflicted on our river sediments was impossible to enforce. Shifting the treatment costs to the end user benefits everyone in the long run”. Bremen Ports Director, Ms Elma Port, confirmed “we need to dredge to keep the channels deep enough, but the material is now so clean that companies pay us for the privilege of removing it. It is changed from a waste material to a resource”.

This wasn’t always the case:

- In 2019, Bremen Port spent hundreds of million euros to dredge and millions more to dump it in landfills or treat is, because it was either contaminated or technically unsuitable. Sand and gravel from natural sources were much cheaper than (treated) sediment, so there was no incentive to change. It took the Great gravel crisis of 2023 to change public perception.

Fortunately, things changed,

- In 2023 the cost of sand and gravel skyrocketed. Aggressive pollution control measures allowed the EU to remove waste classification of dredged material, creating a new market for this resource as treatment was no longer needed. By 2060 port authorities could sell dredging rights and make a profit on what was one of their largest expenditures. As Ms Elma Port acknowledged “selling our dredging activities has fundamentally changed our business model as sediment mining has become the main source of construction material in the EU. I can’t believe that we used to pay to get rid of it! We have eliminated a waste stream and turned into a cash stream.



NEWSFLASH
23 October 2099

"POLLUTERS" MAKE FINAL PAYMENT AND WE ALL BENEFIT.

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• CHANGING IDEAS.

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quantor

Figure 12. Newsflash 4 (23 October 2099).

Newsflash (23 October 2099): "Nobel Prize Winner for Climate Change solution""

Today (23/10/2099):

- 1 Millionth Mangrove park was built! The Mo Pelto Group used sediments as a natural barrier against hurricanes and to reduce the impact of waves. Furthermore, the mangrove swamp serves as carbon trap. Thanks to the development of the MeCoVis (methane collection vessels) the CH_4 impact could further be reduced. Nobel Price Winner Elma Port invented the vessels.

This wasn't always the case! In 2019:

- Sediments = waste;
- Legal constraints;
- Raw materials are too cheap;
- Lack of knowledge & data;
- Energy from fossil fuels are still allowed.

Fortunately, things changed:

- 2025: Once in a hundred-year storms are occurring every five years, but a clever reallocation strategy of sediments from the harbour before the coast prevents coastal erosion;
- 2030: Sediment contamination levels are evaluated against a water body stand still principle in Europe + EU directive looking at the technical functions of sediment → no longer waste;
- 2040: Last chemical plant discharges in rivers;
- 2035: Use of primary materials reduced with 50% in construction and increase of short chain reuse of materials reduces CO_2 emissions drastically;
- 2050: Use of primary materials banned by the EU as dredged materials are no longer contaminated;
- 2060: no old contaminants in harbours & rivers;
- 2062: dredged material is not considered as waste in Chinese legislation;
- 2070: Sediments are at background level contamination;
- 2075: a series of islands constructed before the coast with natural sediments creates a sheltered inner sea in a time with sea level rise;
- 2080: Technical knowledge on beneficial use options is fully developed.