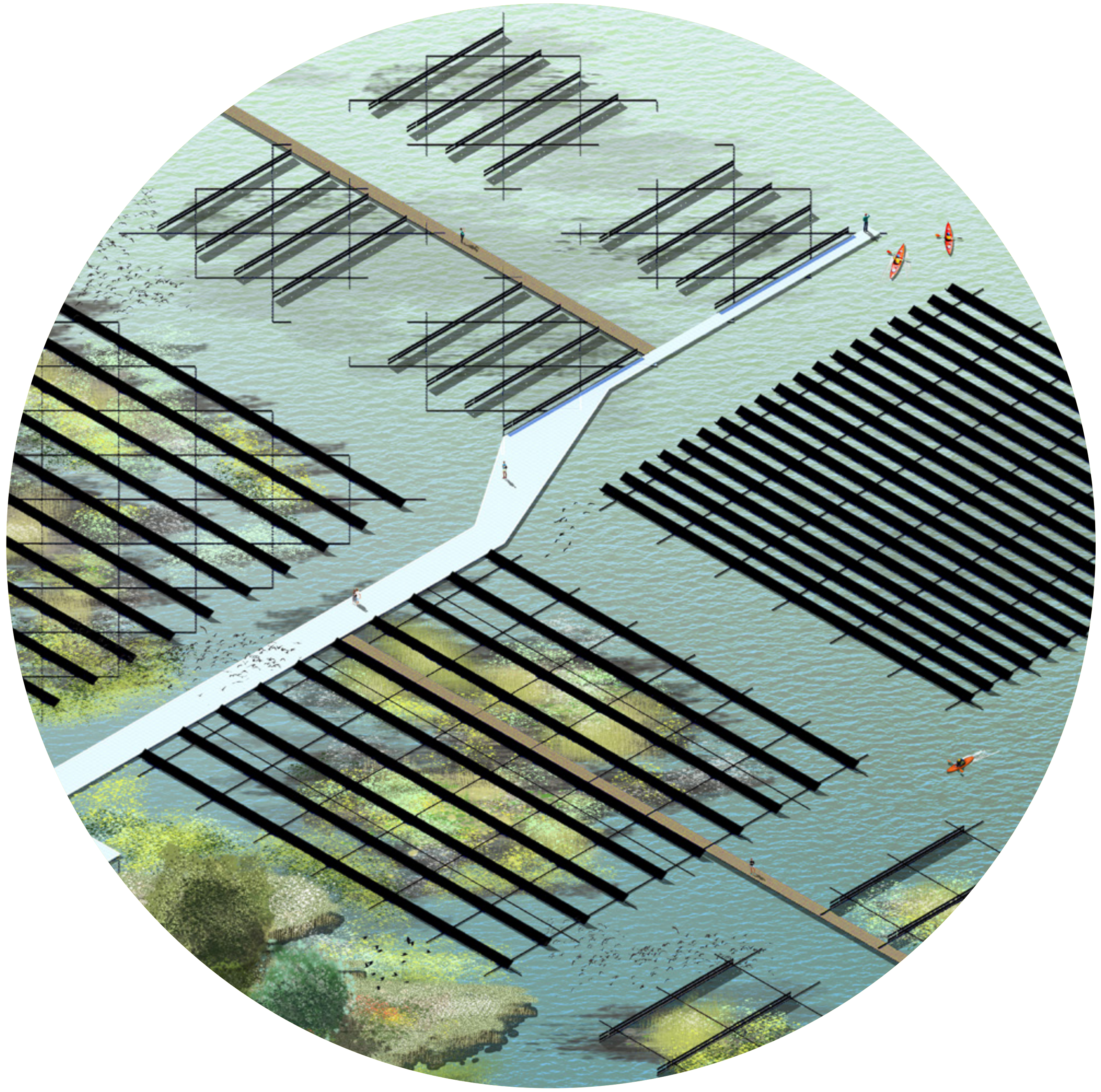
SOL ARCH IPEL AGO



DESIGNING ENERGY TRANSITION IN THE IJMEER ALONG ECOSYSTEM CHANGE

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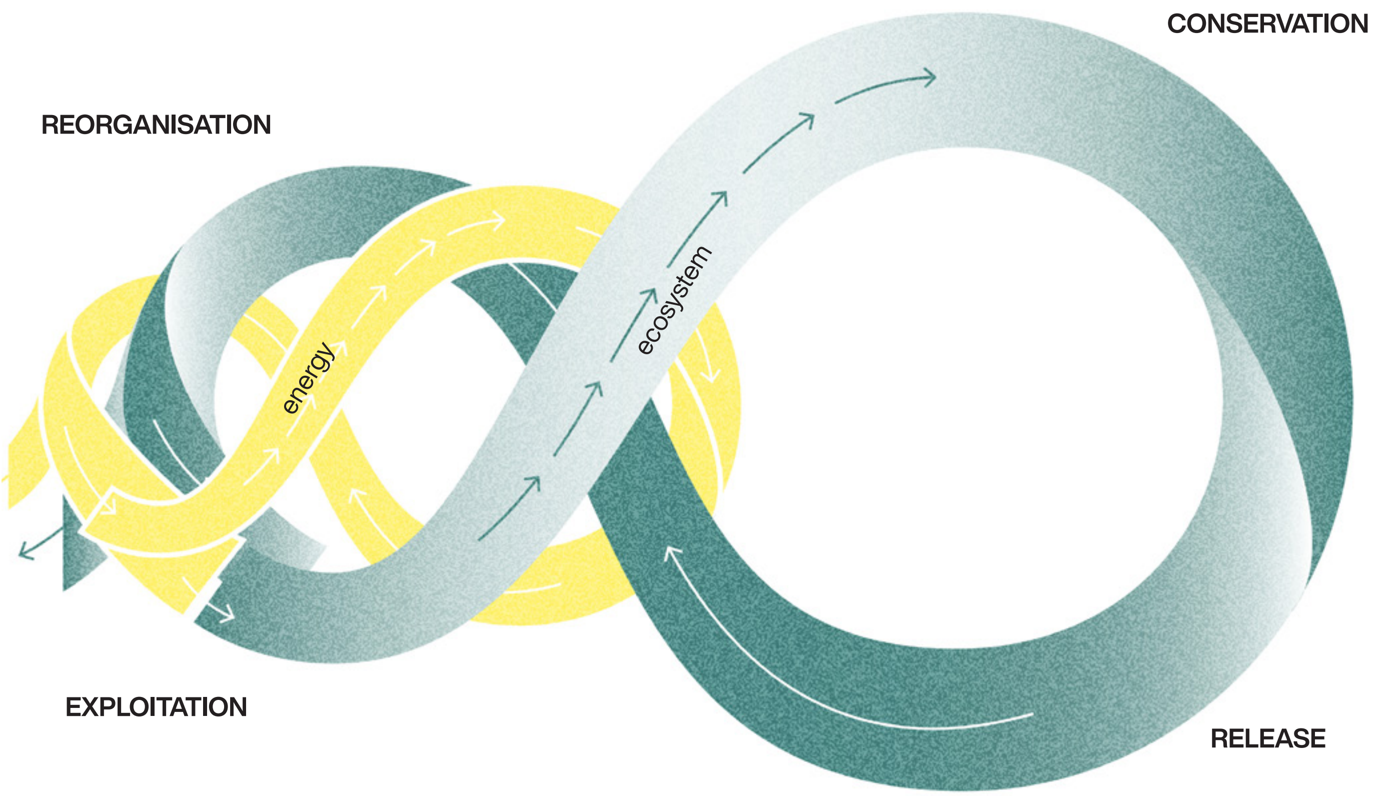
SUCCESSION & ENERGY TRANSITION

Dense metropolitan areas in the Netherlands must allocate space for renewable energy, but 'unused' space is scarce. Even large water bodies near urban areas are ecosystems already under pressure. This is also the case for the IJmeer near Amsterdam. Ecological quality and sustainable energy technologies can sometimes contradict. However, by looking at them through a temporal perspective, energy transition and the changeable nature of ecosystems can be aligned.

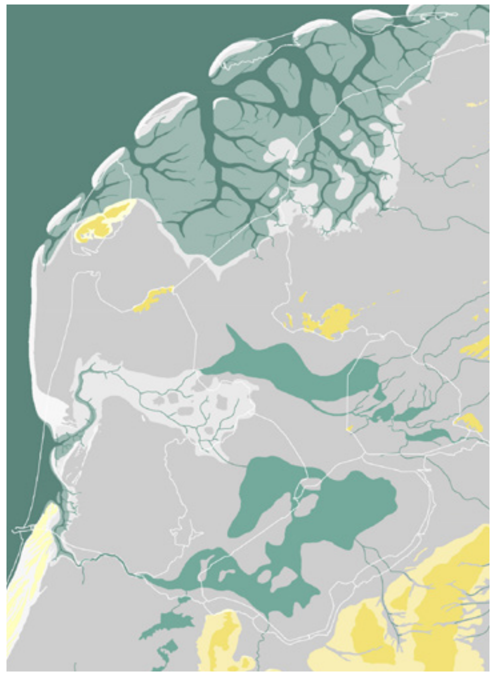
The objective of this project is to design an energy transition for the IJmeer that aligns with the change in ecosystems and while applying ecological concepts. Can we implement renewable energy while at the same time improving the ecological quality of the IJmeer? By studying ecological concepts such as succession and the way ecosystems change, ways were found to align a sustainable energy transition with ecosystem change. It is a misconception that ecosystems move towards a climatic end stage in which species richness and system intricacy excels. And even though humans are also part of ecosystems, we have a overwhelmingly large effect on them. Moreso, we as humans and designers have the capability to plan ahead according to our needs, which in comibination with a degree of nonlinear thinking and preparing for openendedness can be flexibly combined with the way ecosystems change.

Ecosystems move cyclical in stages of expoitation of resources, a buildup in intricacy and biomass in a conservation phase, followed by a phase of release in which a disturbance causes the system to decay. The system reorganises its remaining resources and a new phase in a new cycle begins. Anthropogenic forces have caused ecosystems to be strictly bound and controlled, limiting their potential. We have to accept the dynamic, indeterminate tendencies of ecosystem being a part of those ecosystems. Sustainable energy technologies can be an instigator to reignite self-organising and dynamic process in heavily bound-in ecosystems. By letting renewable energy form a framework in the ecosystem for processes to latch onto, this framework can function as a resources for the 'exploitation phase. After the life cycle of a renewable energy system, the ecosystem has gained enough traction to self-organise to a larger extent. Meanwhile, human systems can also utilise the initial phase and ecosystem processes.



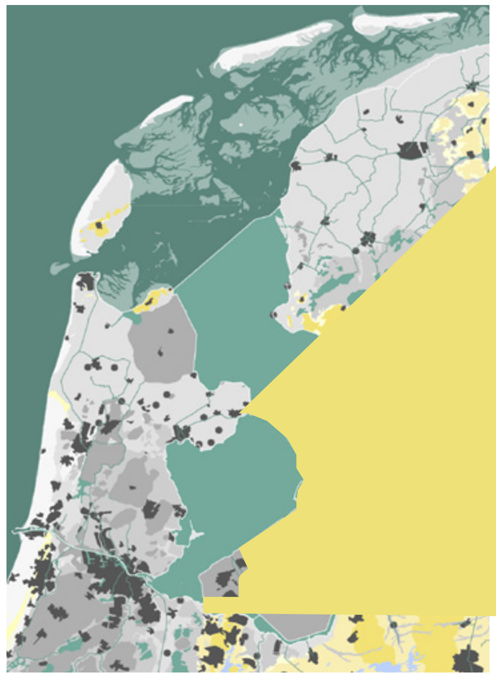
A proposition for an adapted 'holling figure 8', where a cycle of energy transition builds the exploitative phase of the ecosystem. Further on, it develops parallel to the ecosystem while interchanging effects with it.

1500 BC



1500 AD

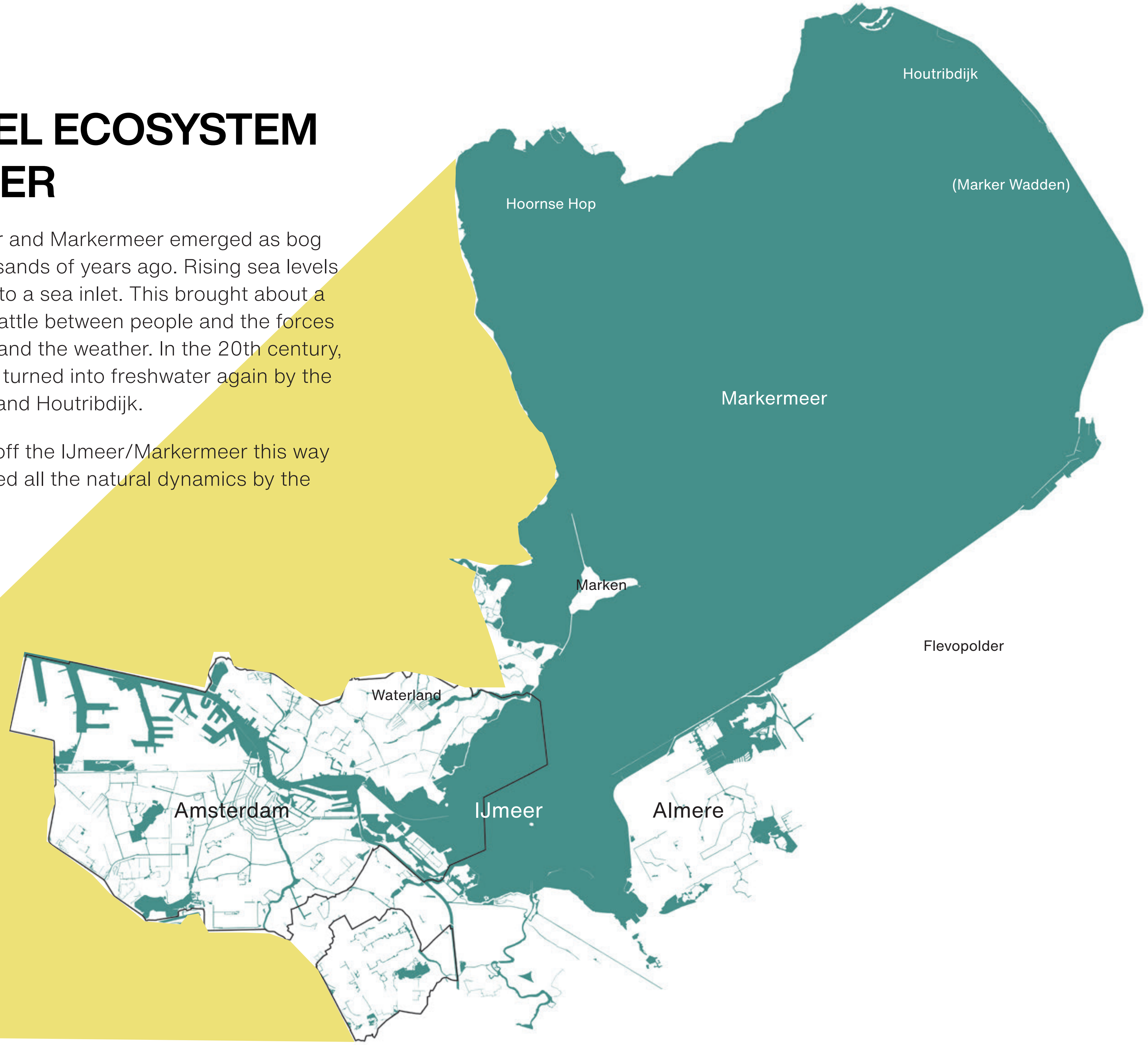
2000 AD



NOVEL ECOSYSTEM IJMEER

The IJmeer and Markermeer emerged as bog lakes thousands of years ago. Rising sea levels turned it into a sea inlet. This brought about a constant battle between people and the forces of the sea and the weather. In the 20th century, the IJmeer turned into freshwater again by the Afsluitdijk and Houtribdijk.

Bounding off the IJmeer/Markermeer this way has removed all the natural dynamics by the sea.

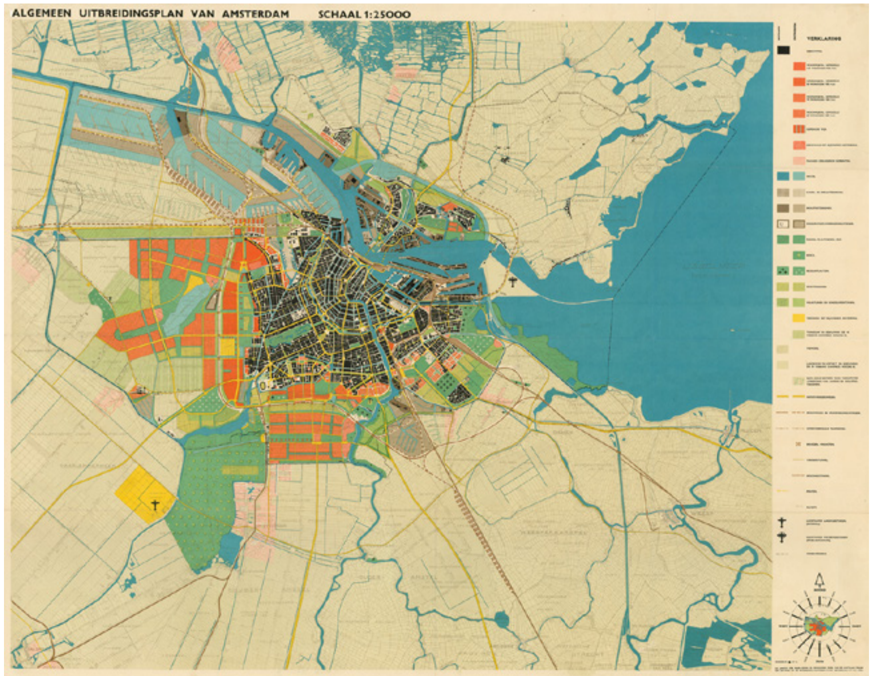


AN EXHIBITION OF DUTCH LANDSCAPE PROJECTS

The IJmeer is defined by its edges and is circumferenced by a timeline of large landscape projects in the Netherlands. All these different projects in different time periods left their mark on the IJmeer. The dikes and polders of Waterland, the new polders of Flevoland, the expansion of Amsterdam at the bay, the historic surroundings of Muiden, the military defence at Pampus, and the IJmeer itself being dotted and intertwined through busy infrastructural networks and nature compensation measures.

Clockwise: the coast at the Diemer Vijfhoek, Polder IJdoorn near Durgerdam, Fortress island pampus and the polders near Muiderhoek at the Flevopolder.

Water system design with culverts and locks for Waterland, Jan Janszoon Backer, 1631



Algemeen UitbreidingsPlan (AUP), Cornelis van Eesteren, 1934

Plan Pampus with in the background the Markerwaard (both never constructed) and the Flevopolder, Van den Broek en Bakema, 1964

CIRCUMFERENCING CONTEXTS

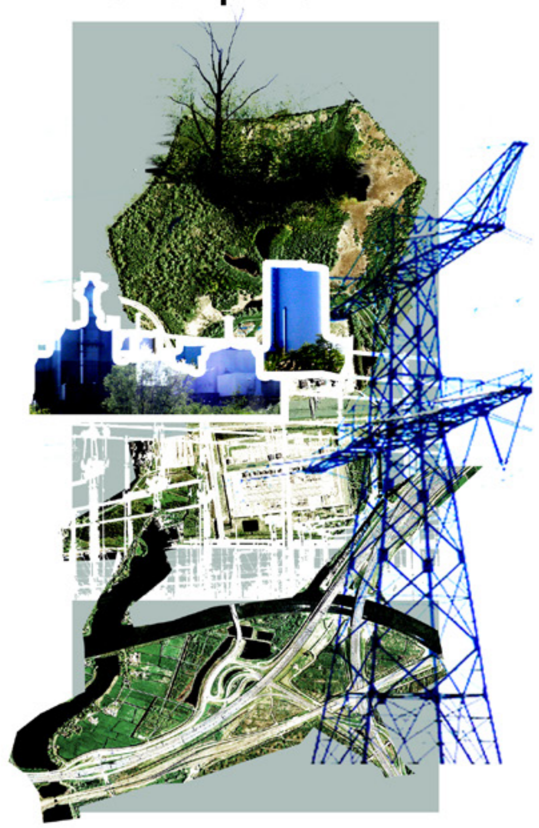
All these landscape characteristics significantly affect the experience on has in the landscape. The Waterland coast has bays and capes, following the old rugged dike. Flevoland is defined by its modernist grid. The corner near Amsterdam is dominated by large infrastructures and urban expansions. The historic town of Muiden offers a varied landscape together with the modern Diemen power plant and nature compensation measures. Dead centre in the IJmeer lies the Pampus fortress; being on the island one can experience its panopticon function.

Besides the result of large landscape projects, there are a large number of projects in and around the IJmeer that were never carried out or can be carried out in the future. The latter include a rail infrastructure across or underneath the IJmeer and an outer dike urban expansion at Almere.

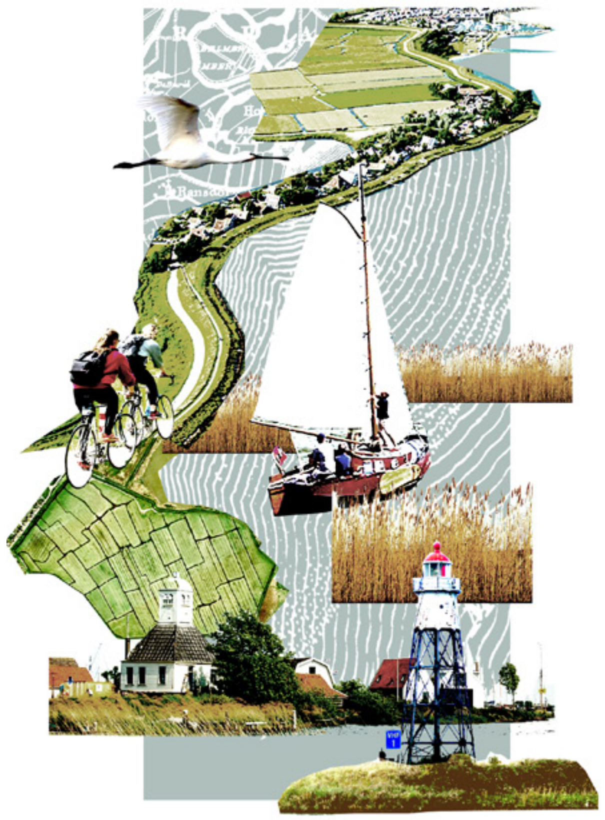
Muiden & Vecht

Pampus fortress

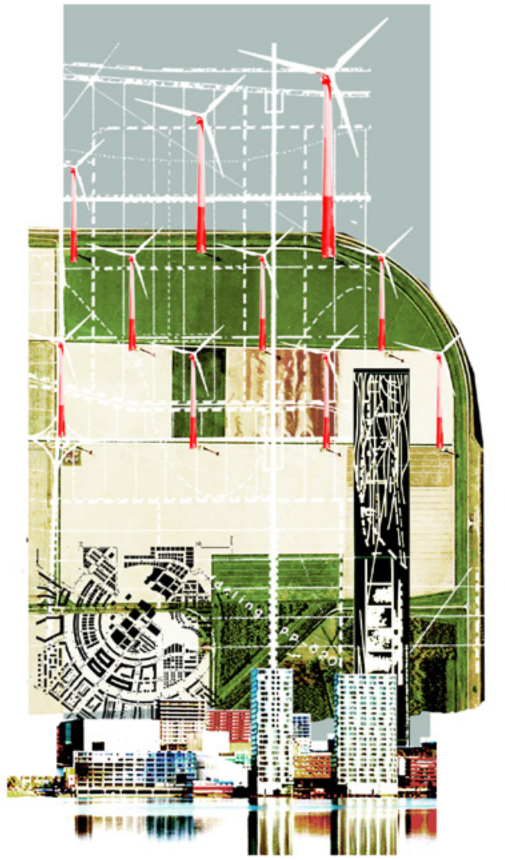
Diemen plant



Waterland



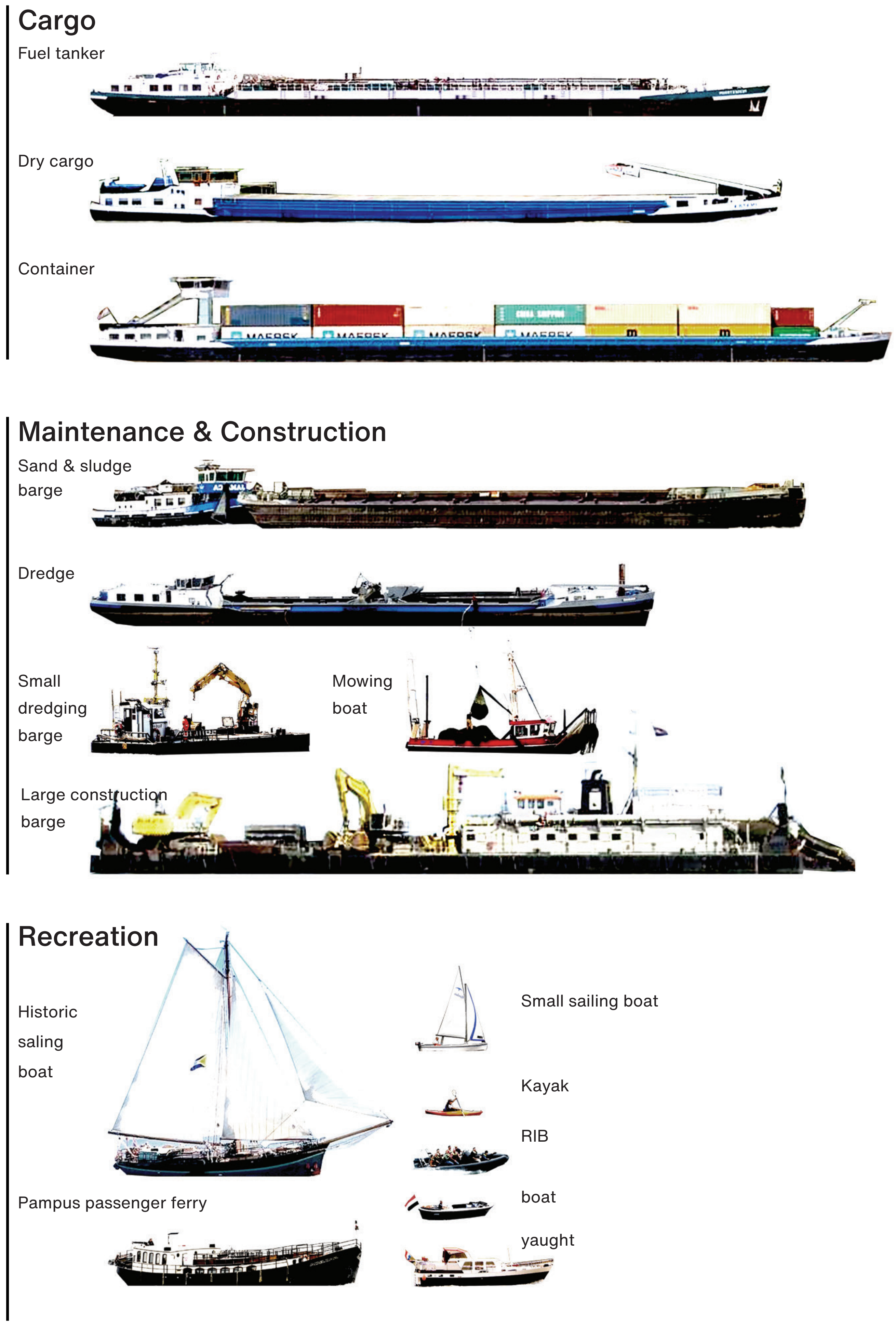
Almere Muiderhoek

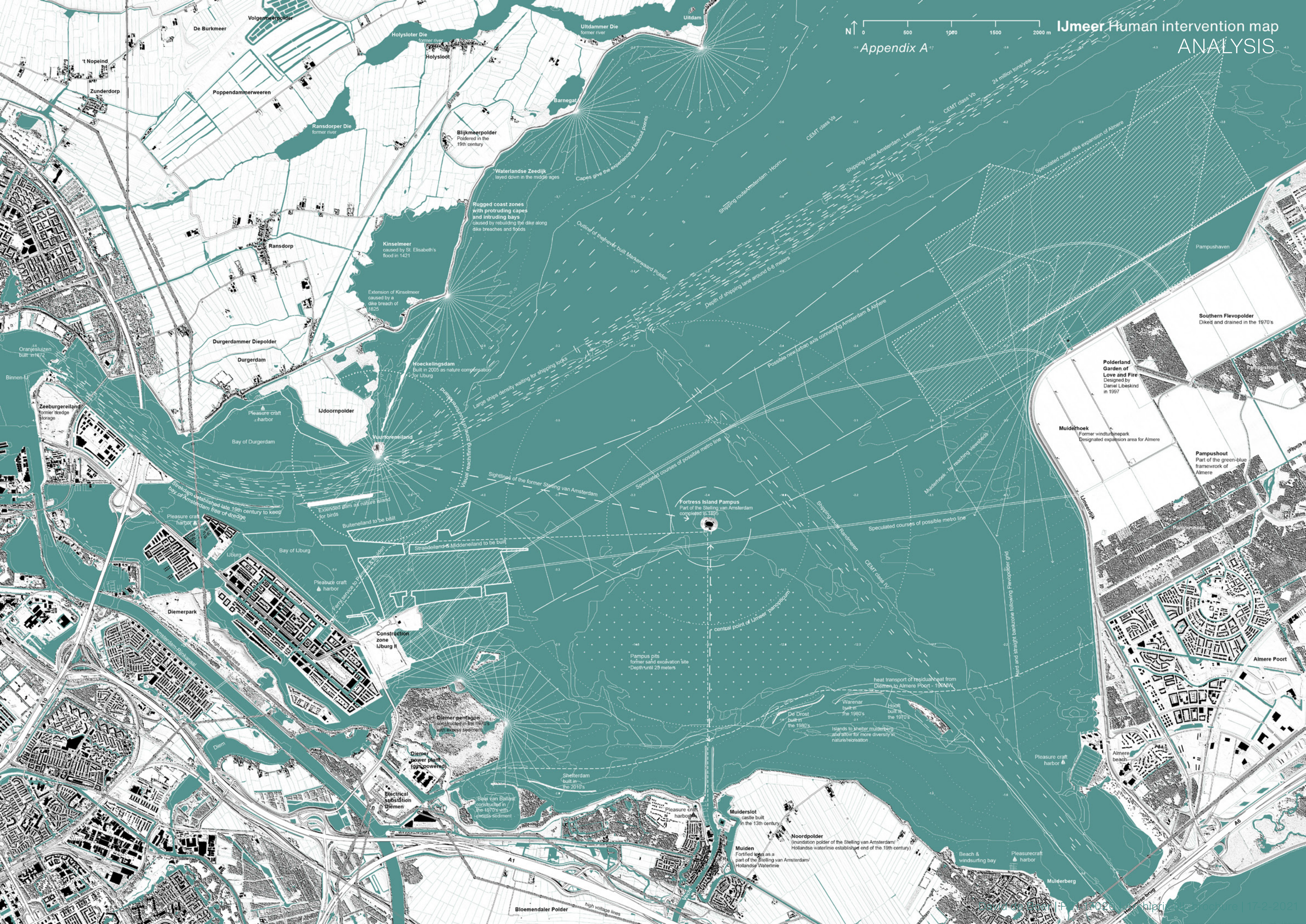


Bay of Amsterdam

A HUMAN ECOSYSTEM

The context of the large landscape projects around the IJmeer have to be viewed in combination with their networks and ongoing processes. Although the IJmeer appears to be a ‘empty’ body of water, it provides the aquatic infrastructure for cargo ships, water based recreation and recreation along the shorelines. Meanwhile, both Amsterdam and Almere are both expanding towards and already within the IJmeer, closing in to each other and providing possibilities with linking them. Lastly, besides contexts and processes, the spatial characteristics of the IJmeer and its shorelines are also considered as experiencing related the historical development into todays context.




IJmeer Human intervention map
ANALYSIS
Appendix A
N
0
500
1000
1500
2000 m
Volgermeerpolder
De Burkmeer
't Nopeind
Zunderdorp
Poppendammerweeren
Holysloter Die
former river
Holysloot
Uitdammer Die
former river
Uitdam
Barnegat
Ransdorper Die
former river
Blijkmeerpolder
Poldered in the
19th century
Waterlandse Zeedijk
layed down in the middle ages
Capes give the experience of lookout points
Rugged coast zones
with protruding capes
and intruding bays
caused by rebuilding the dike along
dike breaches and floods
Ransdorp
Kinselmeer
caused by St. Elisabeth's
flood in 1421
Extension of Kinselmeer
caused by a
dike breach of
1825
Outline of the never built Markerwaard Polder
CEMT class Va
CEMT class Vb
24 million tons/year
Shipping route Amsterdam - Lemmer
Shipping route Amsterdam - Hoorn
Depth of shipping lane around 6-8 meters
Speculated outer-dike expansion of Almere
Pampushaven
Southern Flevopolder
Diked and drained in the 1970's
Possible new urban axis connecting Amsterdam & Almere
Large ships density waiting for shipping locks
Oranjesluizen
built in 1872
Binnen-IJ
Durgerdammer Diepolder
Durgerdam
Hoeckelingsdam
Built in 2005 as nature compensation
for IJburg
Zeeburgereiland
former dredge
storage
Pleasure craft
harbor
IJdoornpolder
Bay of Durgerdam
Vuurtoreneiland
Polderland
Garden of
Love and Fire
Designed by
Daniel Libeskind
in 1997
Pampushout
Muiderhoek
Former windturbinepark
Designated expansion area for Almere
Pampushout
Part of the green-blue
framework of
Almere
Speculated courses of possible metro line
Sightlines of the former Stelling van Amsterdam
Muiderhoek - far reaching viewpoints
Lunetdijk
Fortress Island Pampus
Part of the Stelling van Amsterdam
completed in 1895
Steigerdam established late 19th century to keep
bay of Amsterdam free of dredge
Extended dam as nature island
for birds
Buiteneiland to be built
Strandeiland & Middeneiland to be built
Shipping route Randmeren
Speculated courses of possible metro line
Pleasure craft
harbor
Bay of IJburg
IJburg
Pleasure craft
harbor
CEMT class IV
Hard and straight banks following Flevopolder grid
Diemerpark
Construction
zone
IJburg II
central point of IJmeer "panopticon"
Pampus pits
former sand excavation site
Depth until 23 meters
Almere Poort
heat transport of residual heat from
Diemen to Almere Poort - 150MW
De Drost
built in
the 1980's
Warenar
built in
the 1980's
Hooft
built in
the 1970's
Islands to shelter mulderberg
and allow for more diversity in
nature/recreation
Diemer pentagon
Diemen
power plant
(gas powered)
Diem
Almere
beach
Pleasure craft
harbor
Electrical
substation
Diemen
Baai van Ballast
constructed in
the 1970's with
excess sediment
Sterrendam
built in
the 2010's
Pleasure craft
harbor
Muiderslot
castle built
in the 13th century
Noordpolder
inundation polder of the Stelling van Amsterdam/
Hollandse waterlinie established end of the 19th century
Muiden
Fortified town as a
part of the Stelling van Amsterdam/
Hollandse Waterlinie
Beach &
windsurfing bay
Pleasurecraft
harbor
Muiderberg
A6
A1
A10
Bloemendaler Polder
high voltage lines

Characeae
Stonewort
Kranswier

Potamogeton perfoliatus
Claspingleaf pondweed
Doorgroeid fonteinkruid

Sterna hirundo
Common tern
Visdief

Phalacrocorax carbo
Cormorant
Aalscholver

Mergellus albellus
Smew
Nonnetje

Aythya ferina
Common pochard
Tafeleend

Osmerus eperlanus
Smelt
Spiering

Dreissena polymorpha
Zebra mussel
Driehoeksmossel

Sander lucioperca
Zander
Snoekbaars

Cottus perifretum
Cottus perifretum
Rivierdonderpad

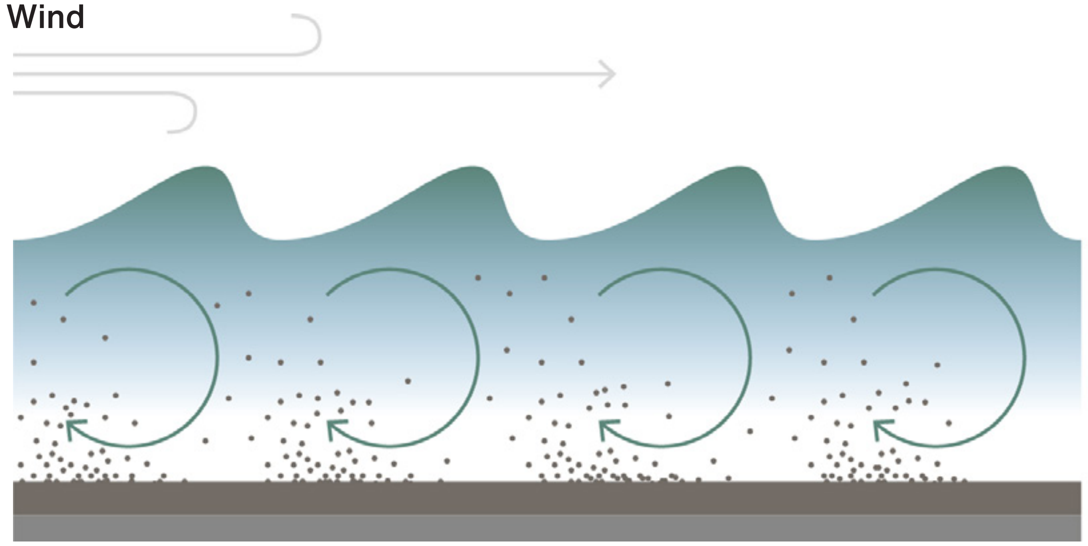
Anguilla anguilla
Eel
Paling

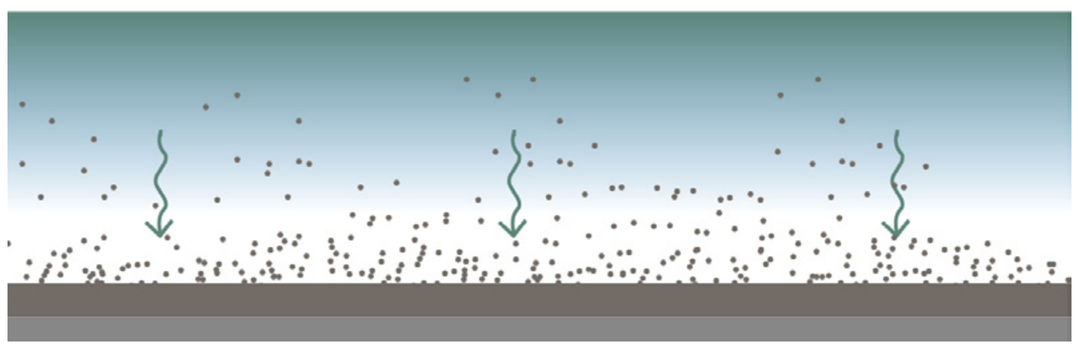
AN ECOLOGICAL CONSTRUCTION

Bounding off the IJmeer/Markermeer this way has removed all the natural dynamics by the sea. The only way the water moves in the IJmeer is by wind. A mostly southwestern wind, even at very low wind speeds, creates waves and turbulence below the water level. The waterbed of the IJmeer is covered with fine Holocene sediment and sludge. The IJmeer is also very shallow in depth, only around 3-4 meters at most places. When the wind picks up, sludge on the waterbed is suspended by the turbulence and moves along with the wind direction. Not just across the waterbed, but also close to the water surface. Because the sludge and fine sediment are so light, they are very volatile. When the wind dies down, the sludge settles slowly on the waterbed.

This is a problem for many flora and fauna. because the waterbed is in constant motion and made up of volatile material, many water plants and benthos, such as the zebra mussel, have trouble finding a substrate to grow on. The cloudiness and murkiness caused by suspended sediment also prevent light from reaching into the water, obscuring visibility for many fish. This also causes problems higher up the food chain, as fish and mussels are important food sources for many bird species nesting and spending the winter.

Implementing large areas of renewable energy technologies can deminish the living area of these species even further. However, we can also implement more variety by creating breakwaters to stop the wind or turbulence, or measures to catch and store sludge.





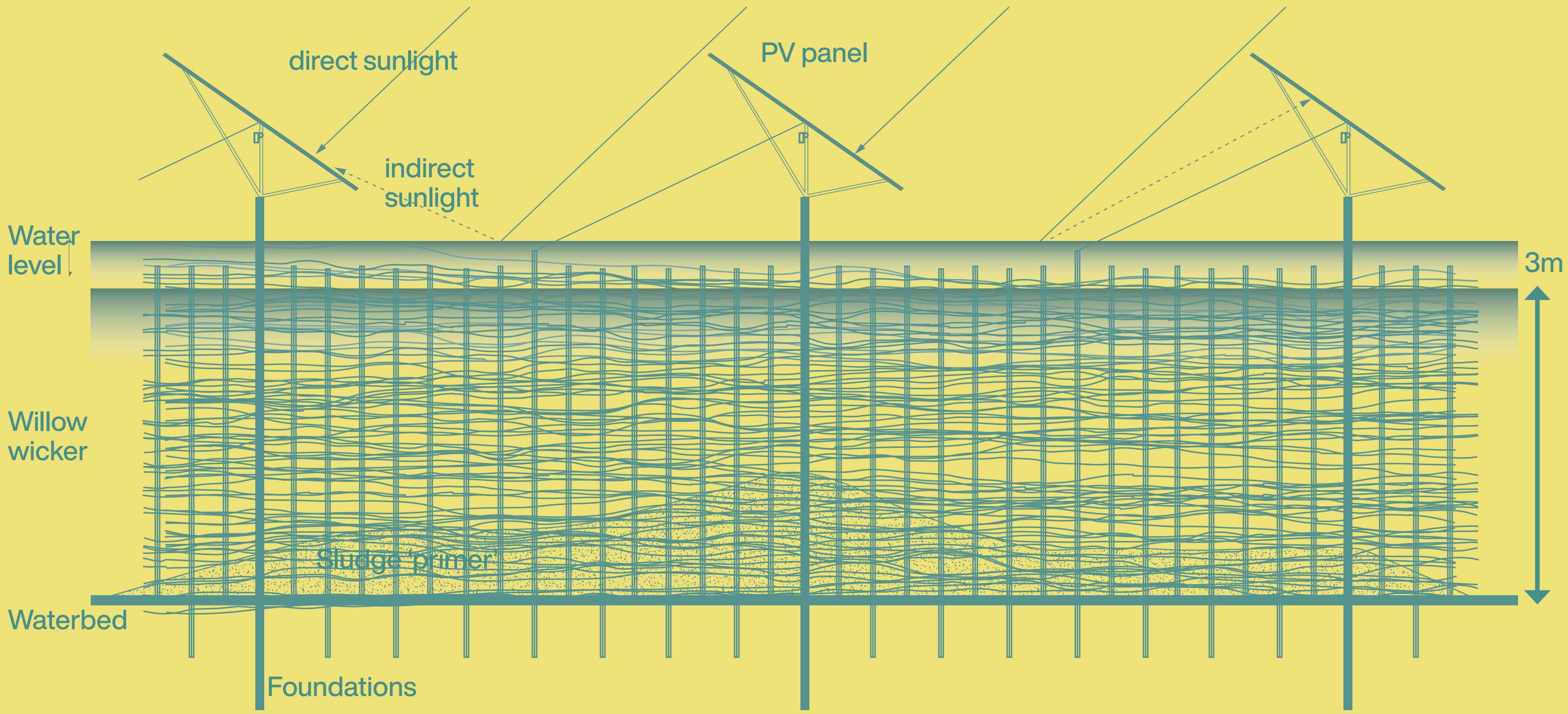

N
0
500
1000
1500
2000 m
IJmeer Ecosystem map
Appendix B
-X Depth of pleistocene layer below N.A.P.
Density of water plant presence
Relief lines and depth of waterbed
ANALYSIS
Water plant density decreases as water becomes more open
Open waters kan be fouraging grounds for birds like sterns and cormorants
Waterland is a very important habitat for meadow birds
Lakes and canals surrounded by reeds are important resting and hiding areas for waterbirds
Kinselmeer
Shipping lanes are often avoided by wildlife
Posts in the water are important lookout and resting areas for waterbirds
Water level bandwidth
Summer: -0,30/-0,10 N.A.P.
Winter: >-0,40 N.A.P.
N
E
S
W
STIL/VAR 3%
10%
20%
Hoeckelingsdam
New spawning areas for fish made in polder canals
Ecological infrastructure Almere connecting Lepelaarsplassen & Weerwater
Natura 2000
Birds directive
Large problem for birds in the area is a lack of food due to limited presence of fish and waterbed fauna
General and strongest wind direction is SW
Extension strekdam
Bat colonies, especially pond bats (Myotis dasycneme) use the IJmeer as a fouraging area
Smooth and straight IJmeerdijk causes little gradients and variation
Diving ducks prefer calmer areas near coasts
Deep waters allow for cooling and habitats for certain fish species
deepest point around 20 meters
Diemer pentagon has diverse habitats like swamps and marshes
Natura 2000

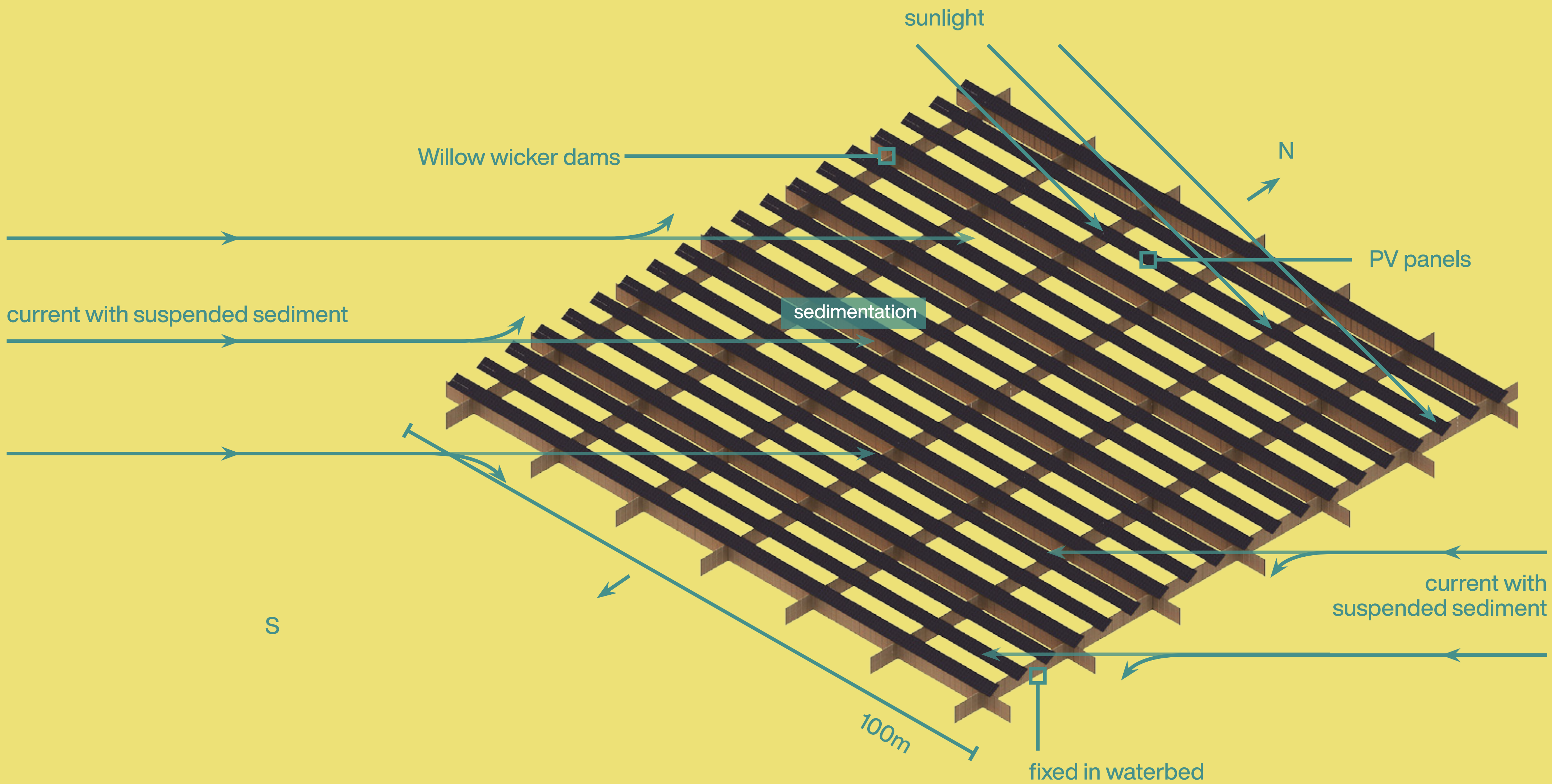
WICKER GRID MODULE

Two modules are designed to create hybrids for improving the ecological quality along certain processes and installing renewable energy technologies in the IJmeer.

The first module is based on fixed photovoltaic panels and the technology of the Marker Kwelderwerken, the wicker dam grids discussed in the previous chapter. The basic principle here is that the wicker dams provide foundations and fixtures for the solar panels to be mounted on. In other words, large vertical foundations in the waterbed rise above the water and provide the attachment base of the solar panel, but also provide a wicker structure between them below the water surface, which add to its stability as well. These are the basic principles which can vary along multiple parameters, to allow a different system response.

First, the wicker between the foundations is made from flexible willow branches. These branches can be partly regionally sourced from knotted willows present in the Vecht area or the polders of Waterland. The module grid is a square set up with a grid size of 15 to 20 meters. The first variation is in total square size, being either 40 by 40 meters, 100 by 100 meters or 150 by 150 meters. The module also varies in its orientation. The grid can be either laid out diagonally or horizontally and vertically in relation to the south. Lastly, the grid can vary in the density of the willow wicker. The willow wicker can be very thick and impermeable, or thinner and allowing small animals to pass through. These variations will likely affect the ability to slow



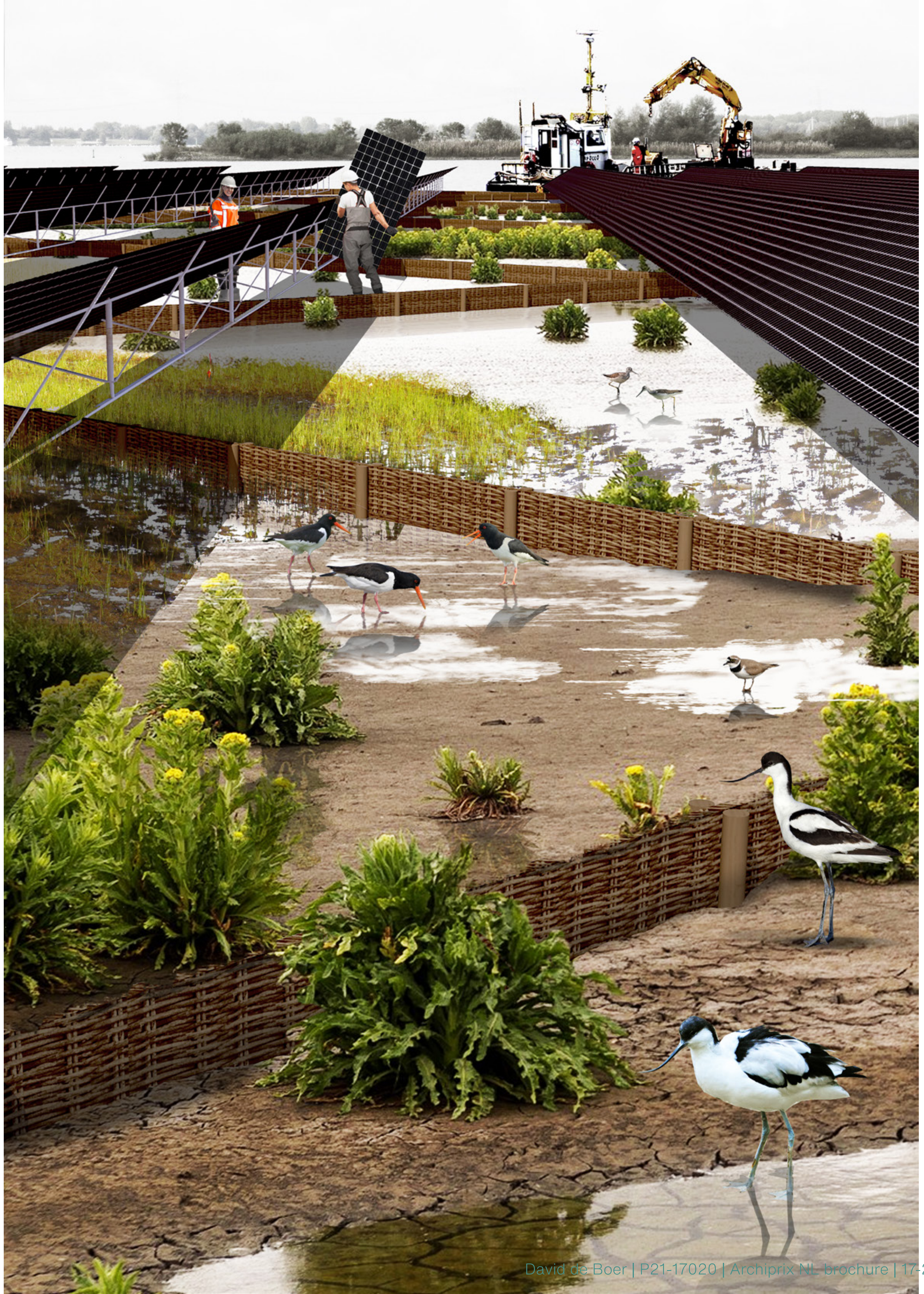


down turbulence, accumulate suspended sludge and the location of that accumulation. The wicker can vary in density for habitats as well, as certain fauna can either pass through the wicker or not.

The second set of variation lies in its partial filling of sediment. This filling can consist of either sand or sludge and clay, or a mixture of the two. Sludge and clay are often undesirable residual after sand excavation, dredging shipping lanes, or preparing building ground for urban expansion into the water. The wicker grid module will make use of this 'waste' product. Therefore, sludge and clay will provide the main fill, also because of the need for valuable sand elsewhere. The sludge will provide a shallower water layer in which suspended sludge can possibly settle, accumulating and 'catching' more sludge over time. The filling of the grids can also differ in location on the grids, with an uneven fill more to the middle or the sides. To differentiate between the filling of the grids done by humans and the accumulation done by system processes, the purposeful preconditional filling done by humans will be called the 'primer'. Sludge can also be added later to top up the already present sludge, or can be mixed with sand to create more diverse areas. It should also be noted that a large amount of unwanted sludge around Amsterdam comes from polluted harbours and sewage treatment. This sludge cannot be used in open contact, or semi open contact with the water of the IJmeer due to its toxins.

The last set of variables lies in the use of mounted PV panels. PV panels can be mounted on the foundations in a modular fashion. This way they can be removed later, which will be further discussed in the next chapter. Two different types of PV arrays will be used. One is an east-west oriented row of south facing panels under a 30-degree angle. The other array type is a north-south oriented row of vertical bifacial panels. Different types of panels provide a better distributed power output, but also provided different shade patterns on the water surface having different ecological effects (fig. 6.5). The solar arrays can also vary in density, effecting the shade patterns on the water surface. The rows of solar panels are not completely optimalised in their density and are somewhat generous in the space between the rows. This is to allow some more light to reach the spaces in between and to prevent a 'lake effect' for water birds.

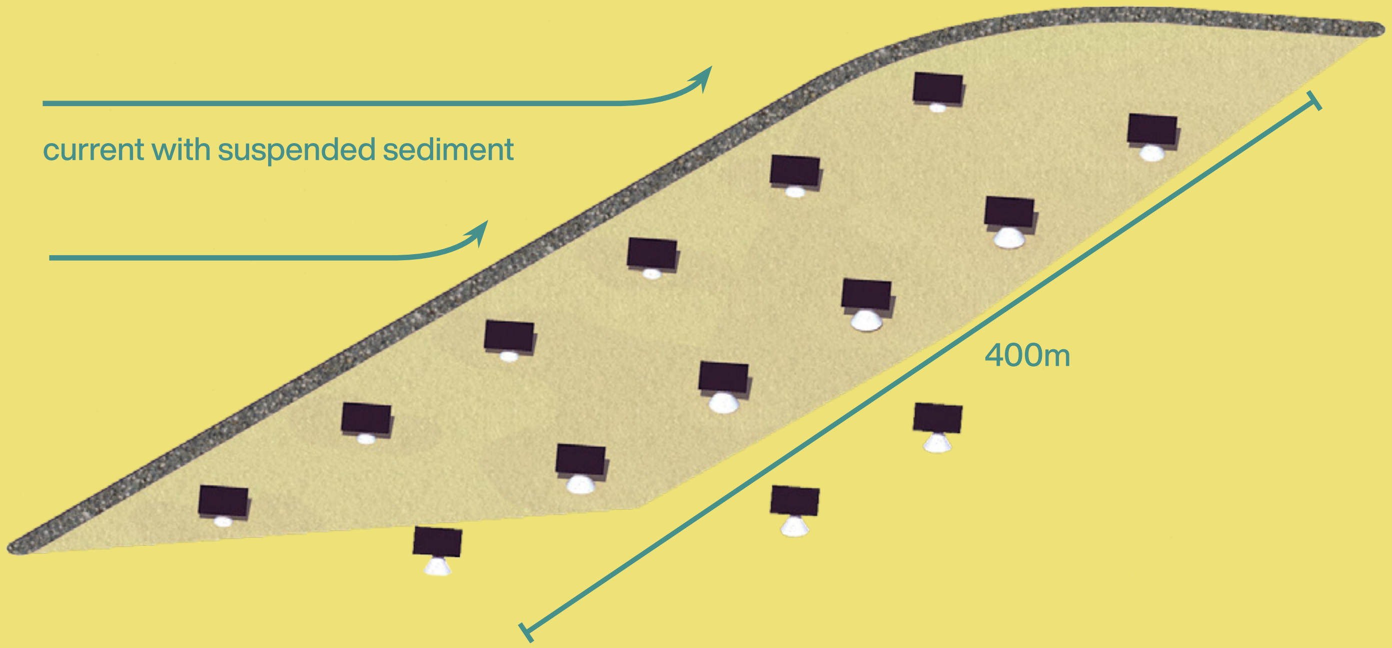
Finally, there is a constant in orientation of this module. Due to orientation of solar panels and their fixtures, each grid is oriented perpendicular on the south. This also allows them to be placed more efficiently in series. This produces a very rigid, technical geometric structure as a framework. However, the varying responses to ecological processes will cause each module to be different from one another.



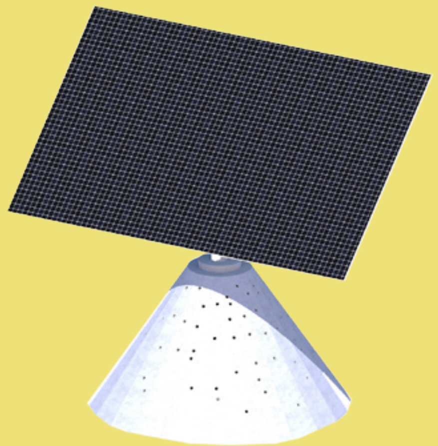
BREAKWATER MODULE

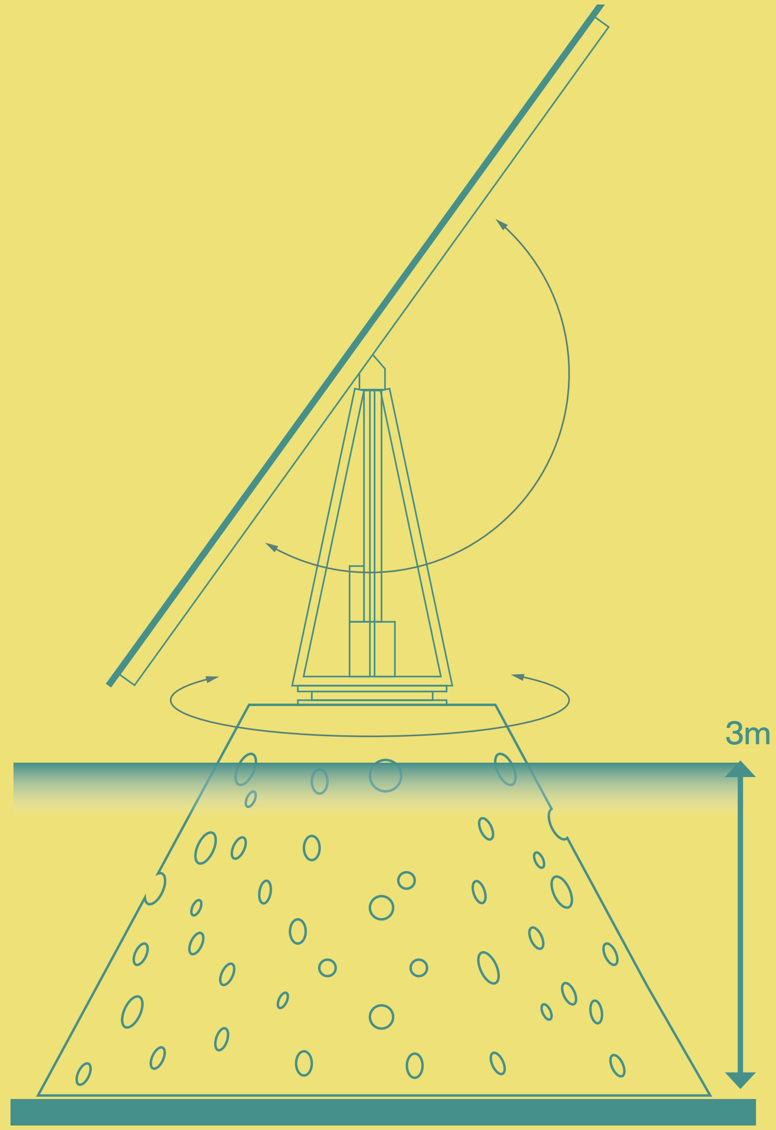
The other module has more of a supporting role to the wicker module. This module is based on the implementation of armour rock breakwater dams combined with a sandy gradient, eco-concrete and the technology of solar trackers. The wicker dam grids cannot withstand large waves, nor can they be placed in waters that are too open and exposed. A linear breakwater will provide the necessary protection, as well provide a sheltered zone right after behind it. The dam also provides the energy infrastructure for the solar panels on the wicker modules to transmit energy to the mainland. The sheltered zone features a shallow gradient made from sand. In this gradient, solar trackers will be placed on an eco-concrete base, allowing the foundation to perform for biodiversity.

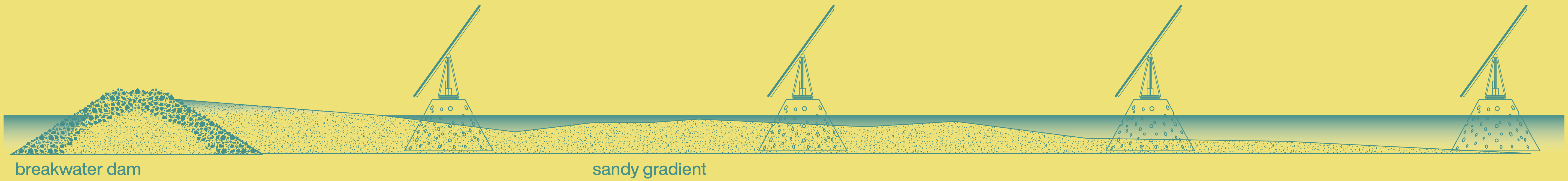
One of the variables for this module are the length and orientation of the breakwaters. Different wind directions will allow suspended fine sediment to be carried around the breakwaters in different ways, causing differences in sedimentation of the suspended sludge. At the ends of the breakwaters, pits in the waterbed can be dug to ‘lead’ the sludge there as well, allowing it to settle. The sediment that is dug out to create these pits can be used as building material for the core of the breakwaters (sand) or as the primer for the wicker dam grids (sludge).



Solar tracker on eco-concrete base

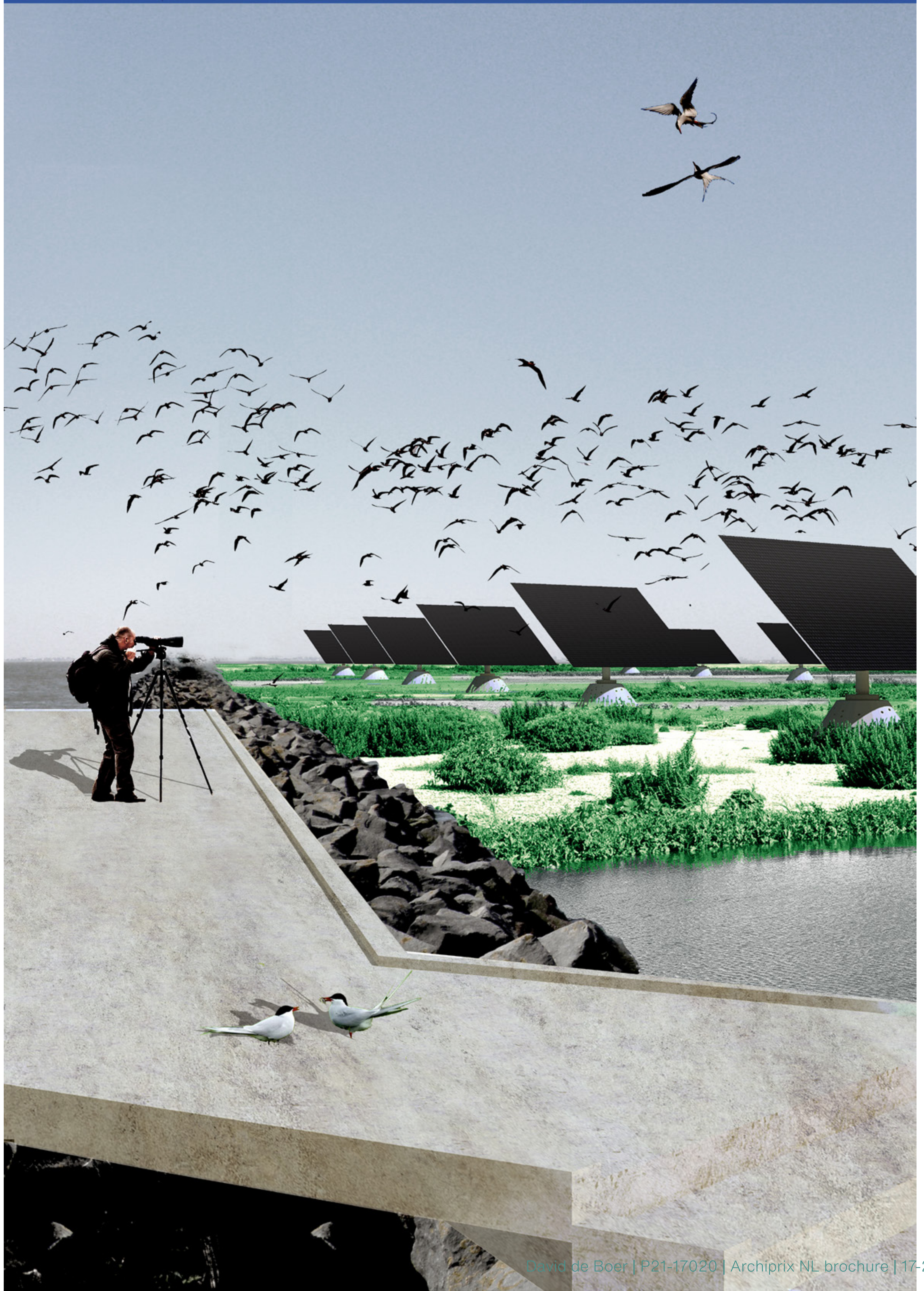






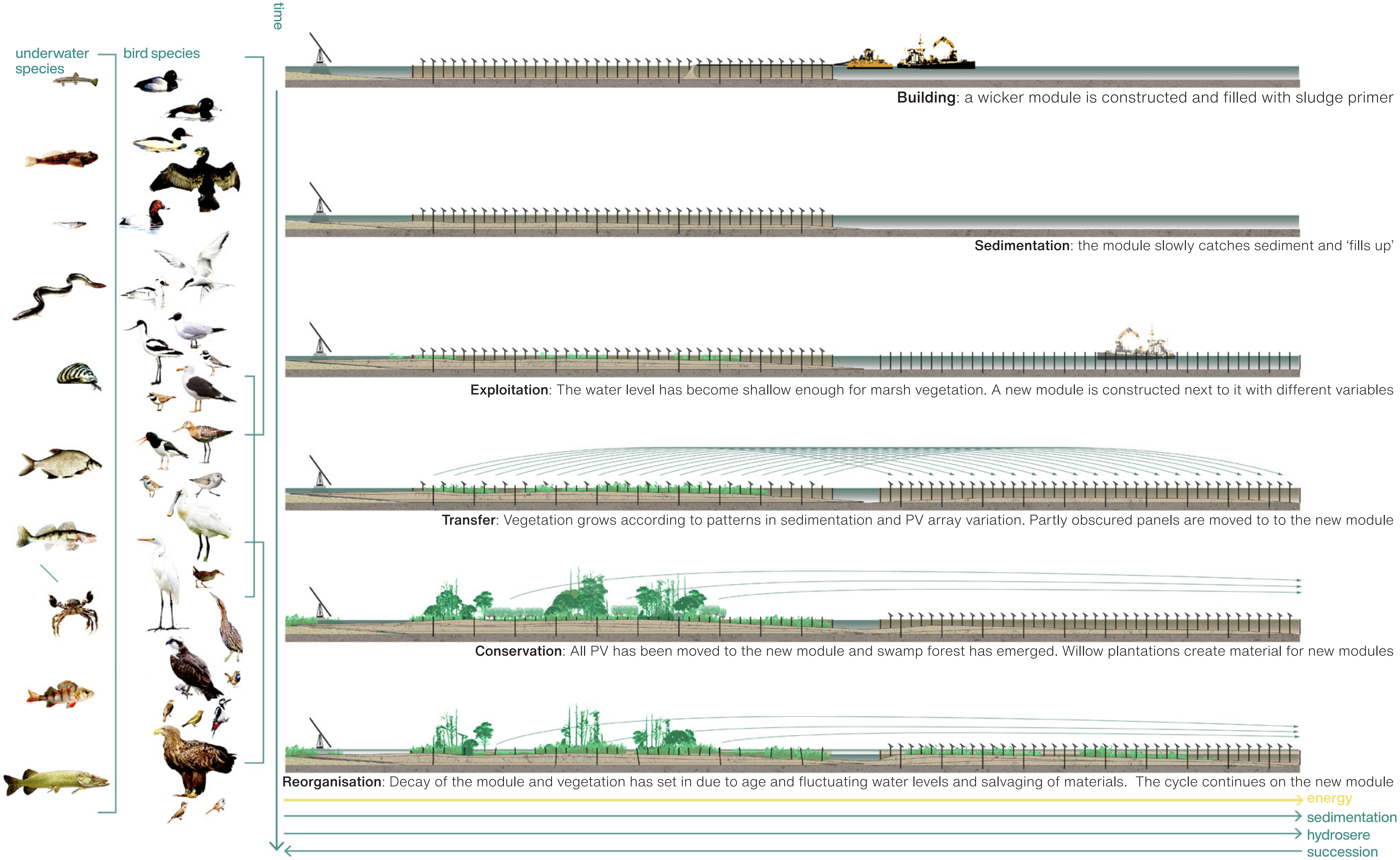
Another variable is the slope of the sand gradient on the sheltered side of the breakwater. Different flora and fauna make use of different water zones, and a variation of the slope can create these differences. The sheltered zones also allow the wicker dam grids to be placed, being protected by the breakwaters to a certain extent, but also having openings to allow suspended sediment to enter.

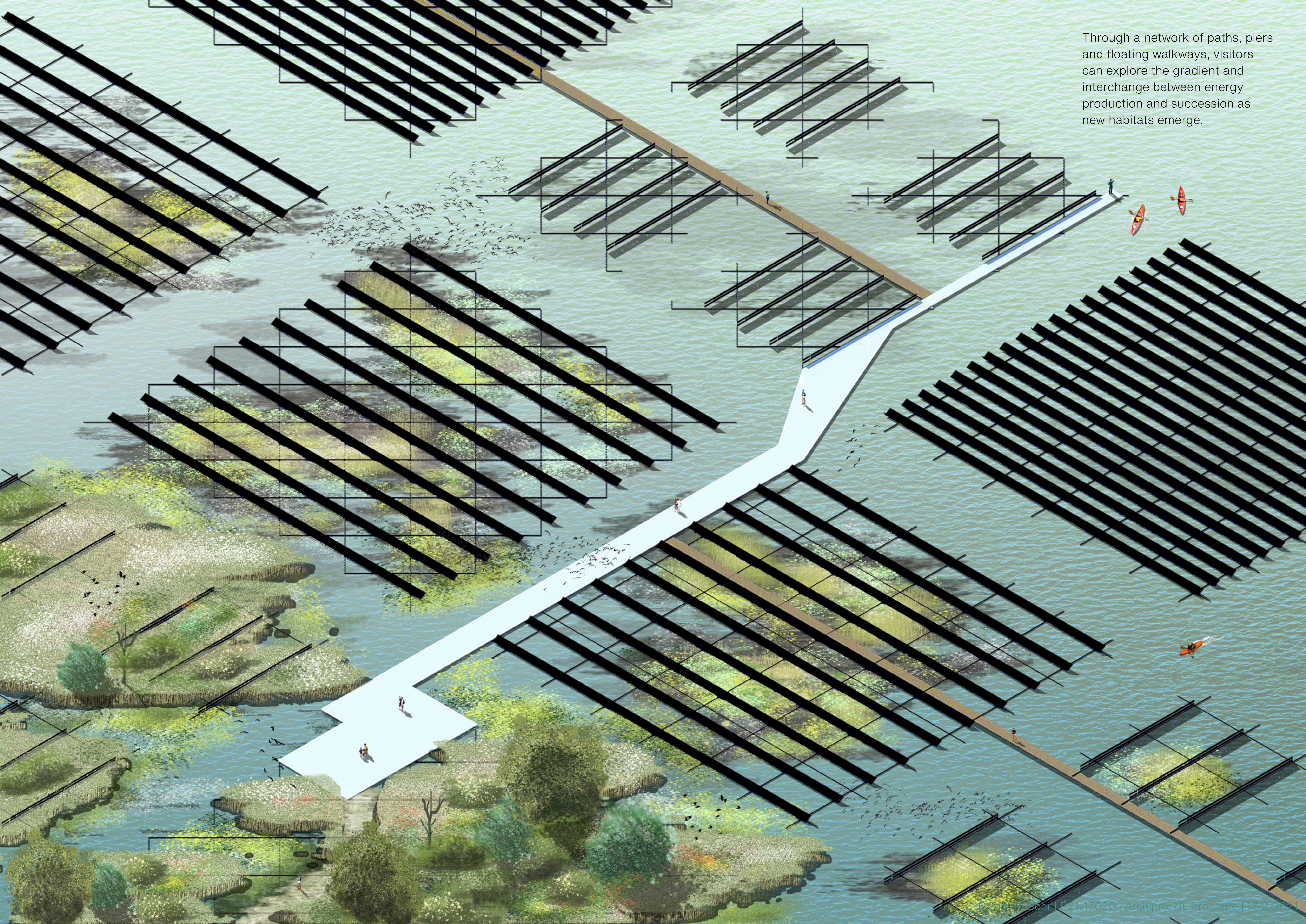
The other variable is differences of construction of the breakwater. In the middle, it is made with a fixed sand interior and armour rock exterior. This construction is very solid, providing strength but making it difficult to remove. The ends of the dams are therefore made from gabions, or cages with armoured rocks. These gabions can be removed later, changing the context for the processes impacting the dam.



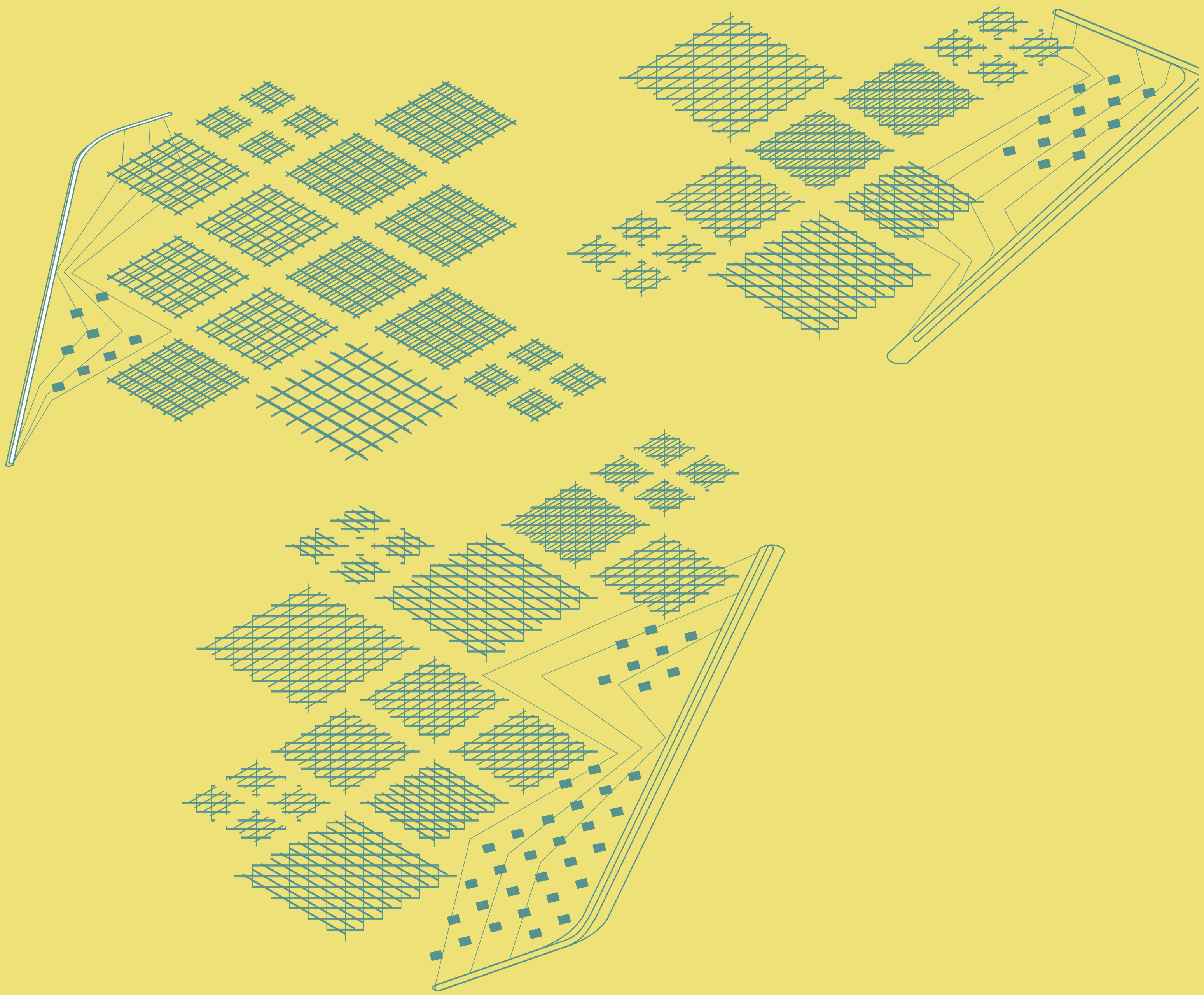
TRANSITION AND MULTIPLICATION

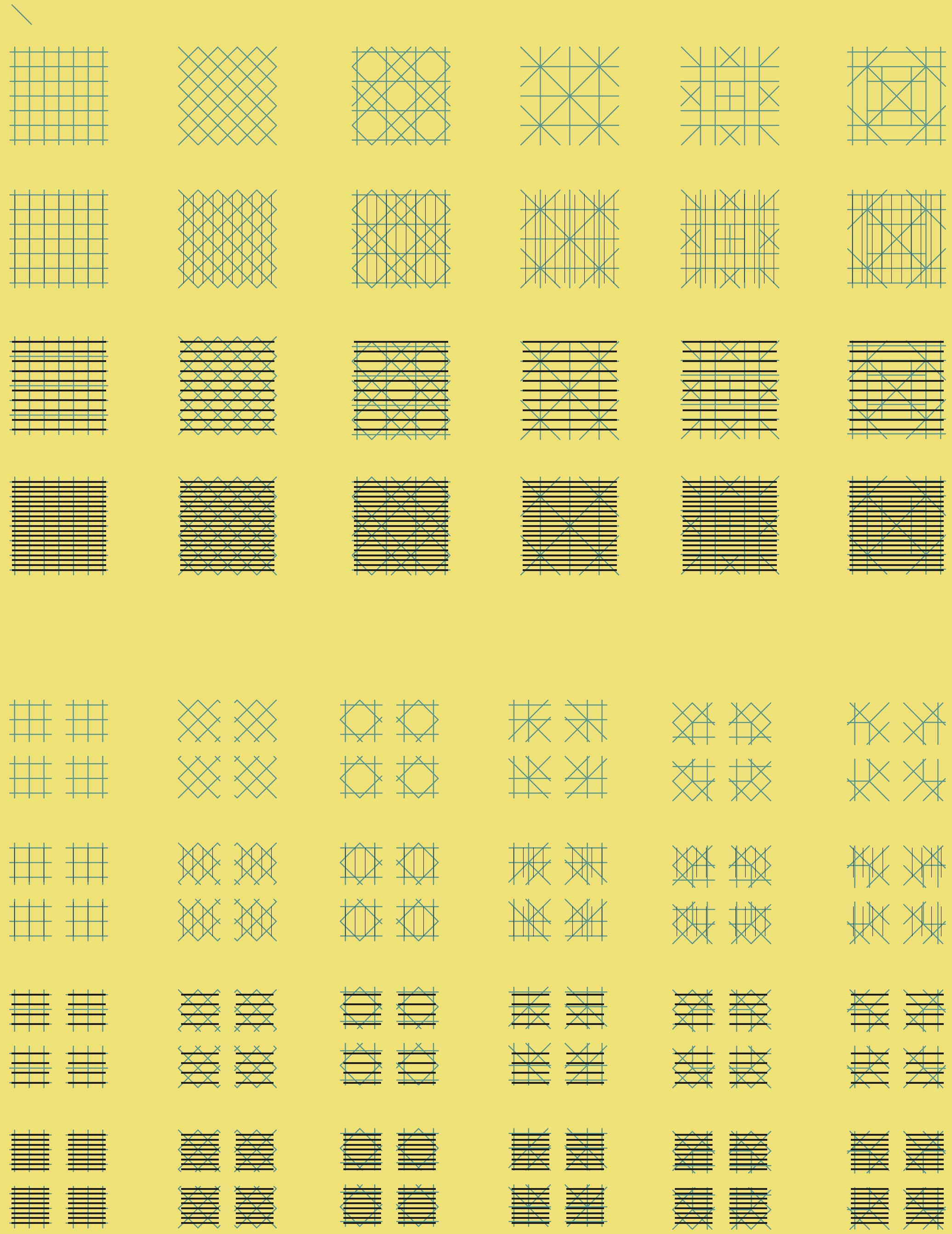
The modules are placed next to each other according to conditions depending on hydroseres and energy demand. First, a module is installed and filled with a primer. Next, the module catches suspended sludge, making the water shallower. Water vegetation emerges, turning into marsh vegetation together with increasingly reduced depth. At that point, a new module is constructed on one of the sides next to the existing module. As vegetation takes over, obscuring the PV array, the modular solar panels are (partly) moved towards the newly constructed module where they can keep producing electricity. Meanwhile, the first module turns into land and subsequently into swamp forest, along with small scale willow plantations to grow the materials needed for new modules. This causes renewable energy production to depend on ecological processes and vice versa. Because multiple stages in the hydrosere process are present at the same time, a large variety of habitats for both above and under water wildlife is present.

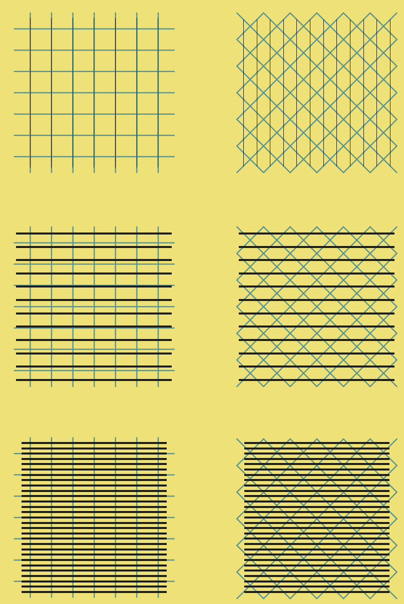




Through a network of paths, piers and floating walkways, visitors can explore the gradient and interchange between energy production and succession as new habitats emerge.







COMBINATION & COMPOSITION

Both modules can be combined to create 'permeable islands'. These islands are partly enclosed by the breakwater modules that provide shelter for the sandy gradients and the modules on this side. The breakwaters also can direct or block the flow of suspended sediment from certain sides. Other sides are left open to guide in the suspended sediment to settle among the wicker modules. The rate of multiplication is determined both by the speed of sedimentation and succession, but also by the demand for sustainable energy. These two developments are in constant interchange speeding up or slowing down the other one. In this way, islands can grow on the inside, or occasionally on the outside. The rate of sedimentation and succession is also influenced by the combination of variables within a wicker module. The density of the wicker in combination with its orientation and size can bring about different patterns of silt setting within the module. Wicker modules can therefore take on many varied ornamental patterns.

VARIABLE GROWTH

As sedimentation increases, the stage in succession called a hydrosere takes over where plant growth accelerates further sedimentation. The PV on the modules outline in combination with the sedimenatation patterns the vegetation patterns as they partly block sunlight from reaching the plants. The rate depends on the density and type of PV. The wicker modules reach a point in their hydrosere stage of succession where plants start to compete with PV panels for sunlight. At this point, the PV is moved to another module until the end of its life cycle.

Because every wicker module has a different set of conditions, it will go through its transition of succession at different times and rates. This causes different successional stages and therefore habitats to be present at the same moment in time while undergoing constant change. All these modules and their arrangements in islands form an archipelago for the IJmeer.

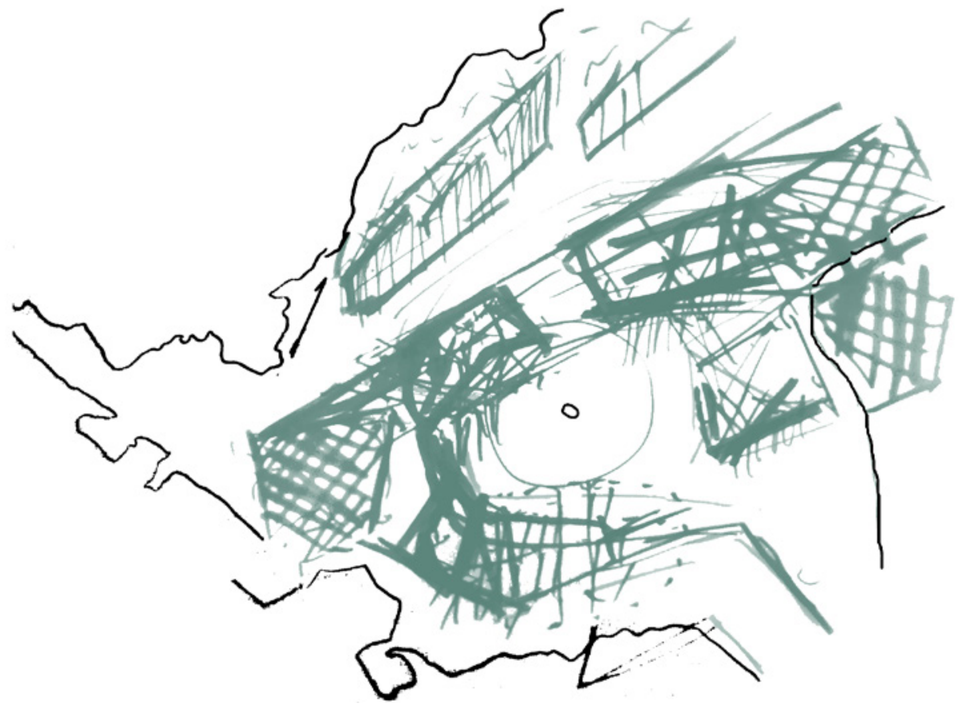
AN IJMEER ARCHIPELAGO

o allocate modules in the IJmeer, various characteristics of the region must be considered. Varied non-urbanised coastal areas will be used as foreshores, such as the Waterland and Muiden coastal areas. The foreshores will partly consist of permeable islands offsetting the coastline, placed in such an angle that a variety of wind directions can funnel in suspended dredge to be 'catched' in the wicker dam grid modules. The future urban axis of the extension of IJburg and the outer dike expansion of Almere, along with the possibility of an infrastructural connection, can be supported by a series of islands. In this way, the Muiden coast, the Waterland coast and the urban axis of Amsterdam and Almere are three 'strands' of a series of islands, with the space between them expanding further away from Amsterdam. In this way, an archipelago of solar and nature islands is created.

The placement of these islands in series also outlines the energy infrastructure that connect to the substation at the Diemen power plant. The strands of islands differ in size and orientation to diversify the effect of the processes in relation to the context. Between the islands in the strands, pits to supply the resources for the modules and as sludge 'catchers' are dug. The areas between the strings of islands is kept clear mostly because of shipping lanes, sand excavation and to keep some areas more open as a habitat for certain species. The fortress island of Pampus also plays a role in this sense and maintains its character as a panopticon in the IJmeer by keeping distance between the strings of islands and the Pampus island. It should further be noted that the regional design depicted is a hypothetical situation of the characteristics described above; indeterminacy relating to the hydrosere performances of the wicker dam grids means that full 'blueprint' designs cannot be made. Instead, it fully depends on how the wicker dam grid modules multiply, in what rate and in which direction.

Four subregions can be distinguished among these strands in the regional design, all relating to one or more of the large landscape projects discussed in the analysis: the Muiden coast, the Waterland coast the Pampus causeway and Almere Outer Dike. The modules perform differently in each subregion according to the characteristics and projected developments of the area. These are not only the physical conditions, but also the cultural meaning and experience of different spaces can be reflected by the module implementations. Each subregion will have its own set of guidelines relating to the application of the module in that specific area. The different subregions are also phased in the above other (with some overlap). More knowledge is gained over the course of decades and the use of the module can become more and more complex in relation to future challenges.

To give an indication of its energy performance, we can look at the number of modules shown in the hypothetical situation of the regional design. Based on number of modules, the region provides around 100 MW-peak, and 450 TJ of energy per year. This amount of energy can cover the yearly electricity use of around 42000 households. To illustrate, the situation covers 14% of the yearly domestic electricity use of Amsterdam, or 54% of the domestic electricity use of Almere

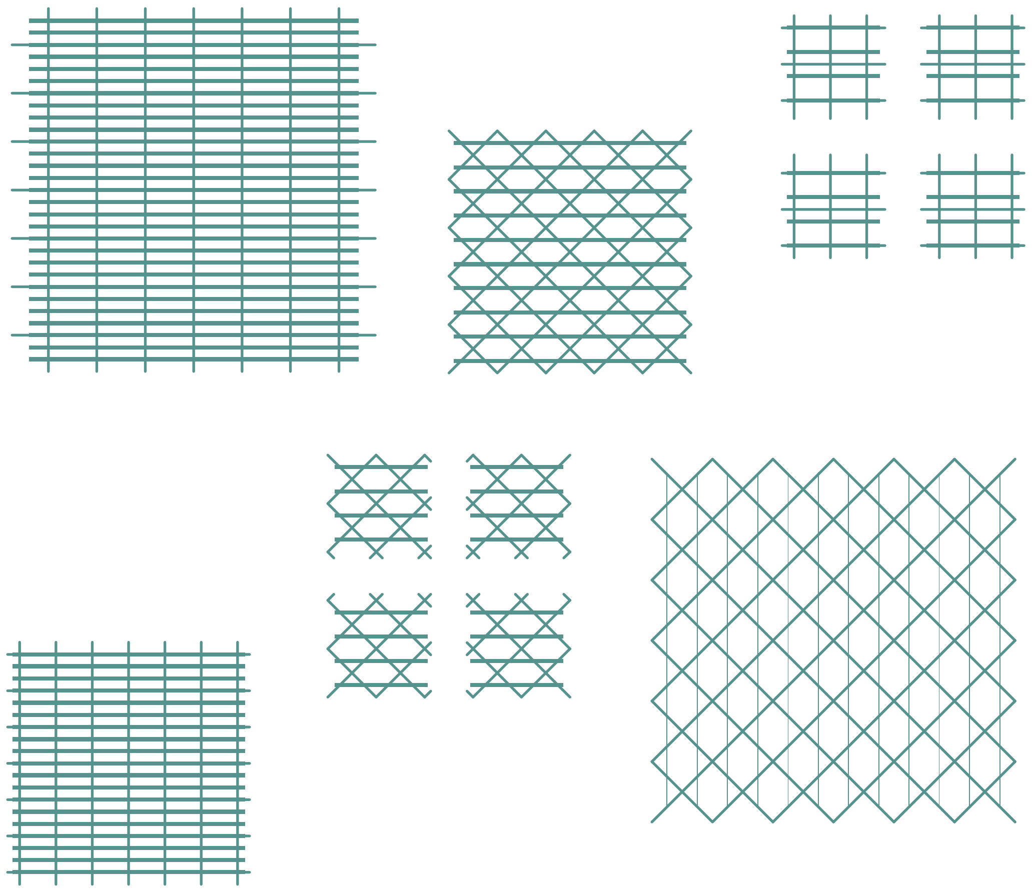


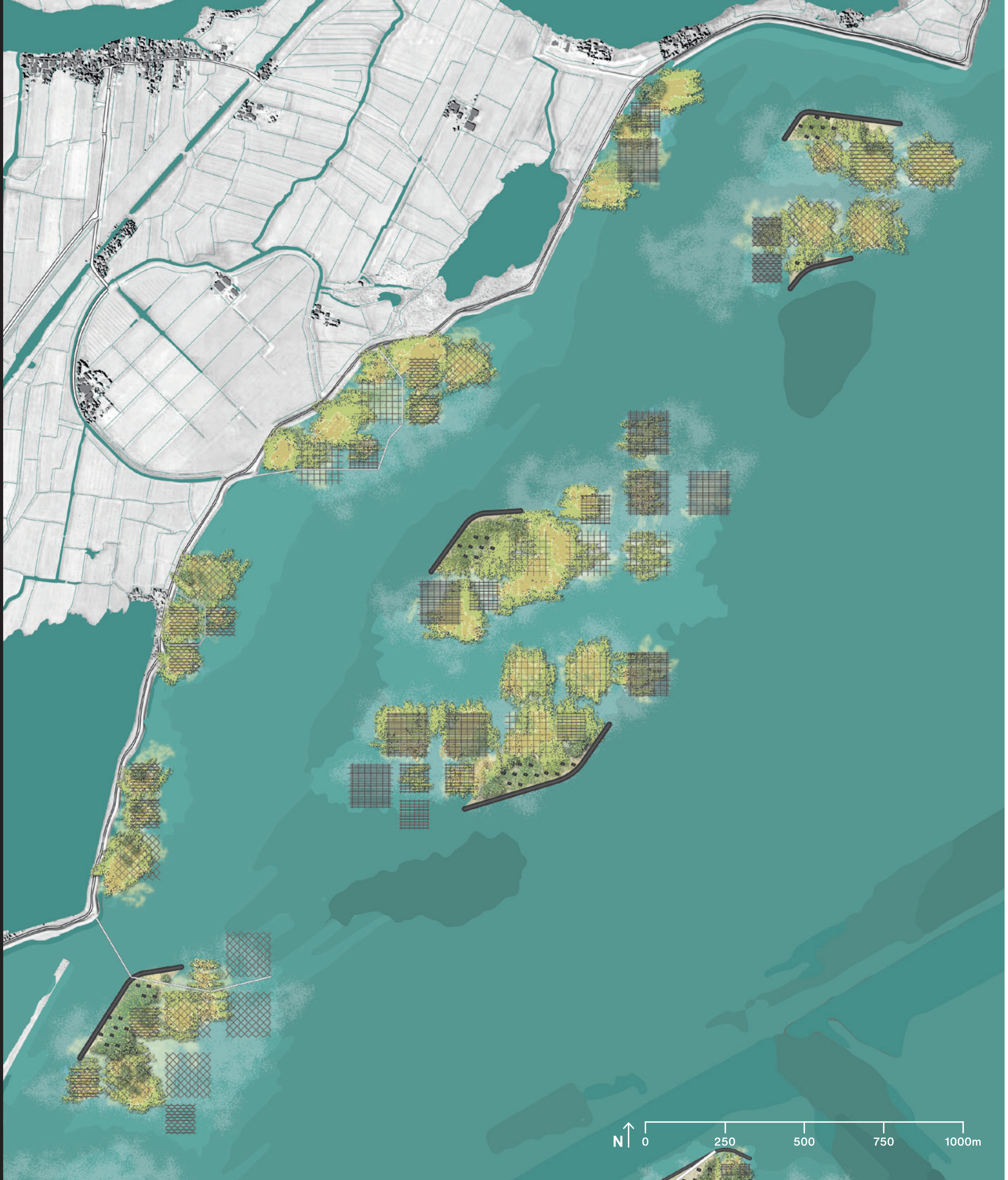
David de Boer | P21-17020 | Archiprix NL brochure | 17-2-2021

MUIDEN COAST

The first string of islands to be developed is along the coast of Diemen and Muiden. This area has over the course of its history been defined by the development of the Vecht region, the creation of the Stelling van Amsterdam. In modern times, major changes have occurred by the creation of large infrastructures, energy production and the necessary nature conservation measures, all squeezed within a green wedge of Amsterdam. The large variety in its coastline allows for a proper site to experiment with the wicker dam grids and the dam modules; making this subregion a place for testing how the modules perform and what effects its variables have. Existing breakwaters and islands are incorporated in the creation of foreshores and islands. The northern orientation of its coast means that the modules will heavily rely on winds coming from the north-northeast. Modules are deployed with a wide array of variables and orientation to breakwater dams in order to measure their effects.

The islands and foreshores are partly formed by already making use of the already existing islands, breakwaters and other nature conservation measures. A variety of different modules provides a set of variables to monitor in how they perform, both for energy production, hydrosere and biodiversity. The results of this monitoring with a conclusion to its effect can be used to have a little more control over creating a diversity in habitats for species in relation to optimal use of the solar arrays. When an advanced hydrosere is reached in the wicker dam grid modules, the modules can be used as small willow plantations to grow the resources for modules in other subareas.

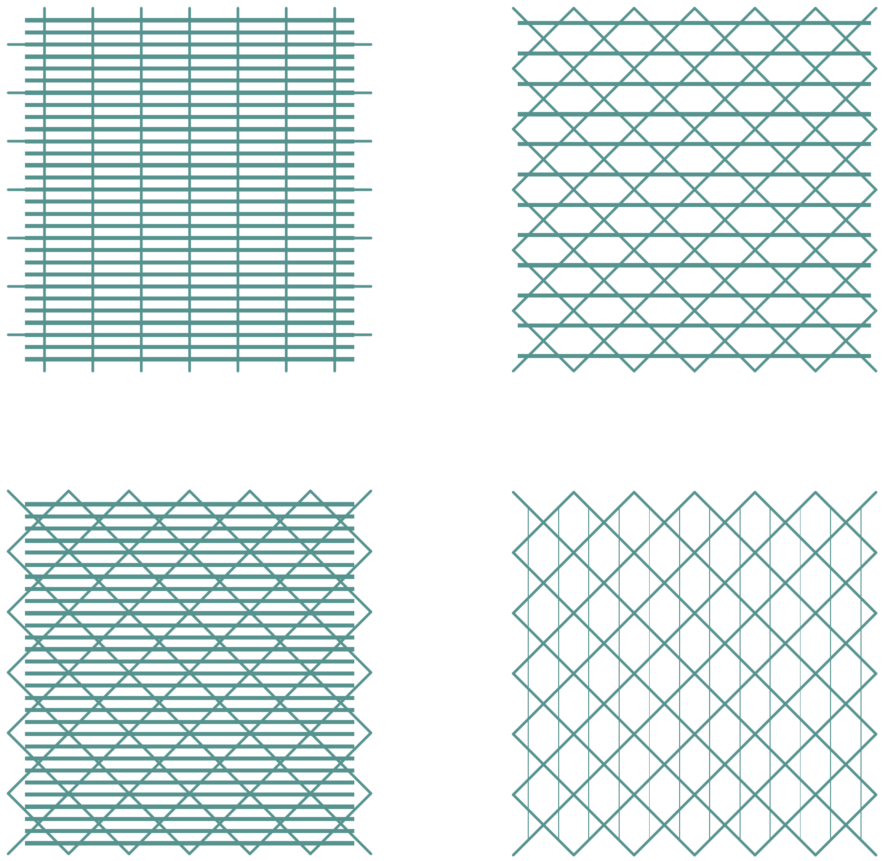




WATERLAND COAST

The Waterland coast is characterised by its ruggedness, the capes and bays which have formed over time because of continuous adaptation of the Waterlandse Zeedijk. Waterland is a historically significant and well-preserved polder area, with far reaching views across meadows, canals and small lakes. The Waterland foreshore is defined by a strand of multiple islands offsetting the outline of the shore, maintaining the experience of bays and quays from the dike. The islands partially protect a foreshore along the coast. The bays will be more sheltered and have more diversity, while the capes provide open views toward the Markermeer. The general size of modules will be bigger and be filled with less primer meant to slow down hydrosere processes and allowing a large area of shallow reed lands to develop over time. Together with greater distances between wicker modules, this can cause succession to occur in a different rate than elsewhere, maintaining a sense of preservation of the openness of this historic area while still increasing its variety.

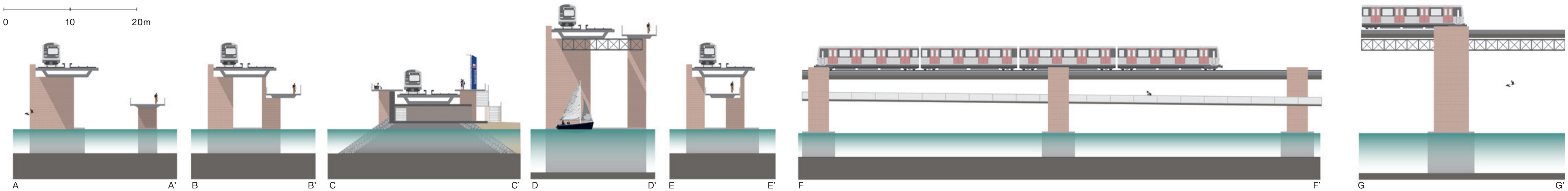
Small floating walkways from the capes can allow visitors to explore the reed lands and its biodiversity, as well as creating the opportunity for small scale boating recreation. The preconditions of the modules, including its variables and initial energy production, are imprinted on steel elements present by some of the islands. These elements, inspired by totem poles, provide a monument to the preconditions over time, listing the variables and initial energy generation of the islands. The form language and colours are inspired by colourful buoys and signs along the water. After the solar panels have been removed and the modules have 'wildernised', the element remains as a witness to its original state.

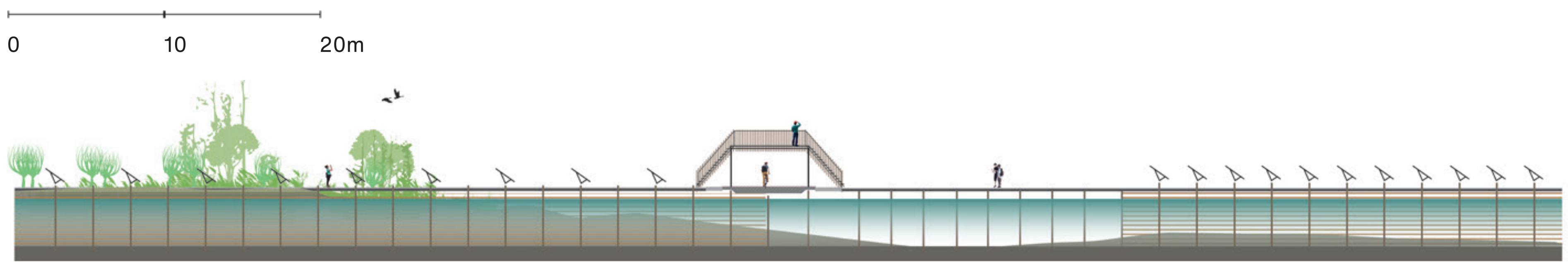


PAMPUS CAUSEWAY

The string of islands in the middle of the IJmeer is not part of a foreshore. It follows the direction of an implied urban connection by being centred around an extension of several reinforced breakwaters that are broader and higher than usual. These breakwaters double act as a causeway for a new above ground metro line and bicycle highway. This metro line extends from the metro station Diemen-Zuid, underneath the Amsterdam Rijnkanaal and IJburg, coming above ground just east of the Buiten-eiland, a part of the urban extension of IJburg II. The metro line follows a bridge from there that is partially supported by the foundation of the breakwaters. The bridge slopes down slightly at these islands and rises to around 14 meters to cross the shipping lane to the Randmeren. At the Pampushaven of the Flevopolder, the elevated metro line turns south onto land and connects to the rail network in the centre of Almere.

The metro connection with Almere can fulfil the cities promise as a proper suburb of Amsterdam, allowing affordable housing for commuters. The elevated metro line is combined with a fast cycling path, so that commuters can cross the IJmeer by bike as well. This cycling path diverts from the elevated metro track multiple times to also offer a more diverse and interesting route along the string of islands. In other places the path converges with the elevated metro, making use of the same foundations of the viaduct and protecting cyclists from wind on the sheltered side of the metro



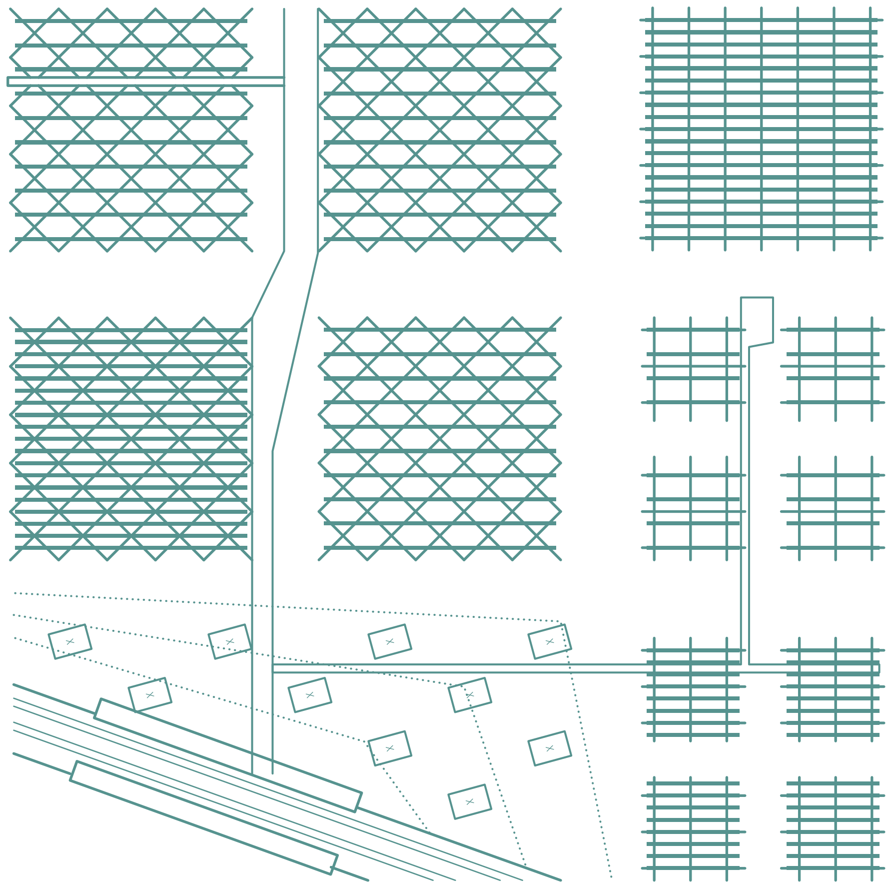


CENTRAL ISLAND

The islands that this causeway is partially based on differ in size and orientation, with a notably large island in the middle. This island is accessible for visitors not only by bike, but also by metro. A metro station that is used outside of commuter peak hours, such as in weekends, can efficiently allow Amsterdam residents to get outside of the city within a couple of minutes (fig. 8,10).

The central island features the bicycle lane, as well as a hierarchy of modular elevated footpaths that allow people to explore the modules on the islands. The footpaths partially rest on the same foundations as the wicker grids, letting the visitors to walk across, alongside and besides them.

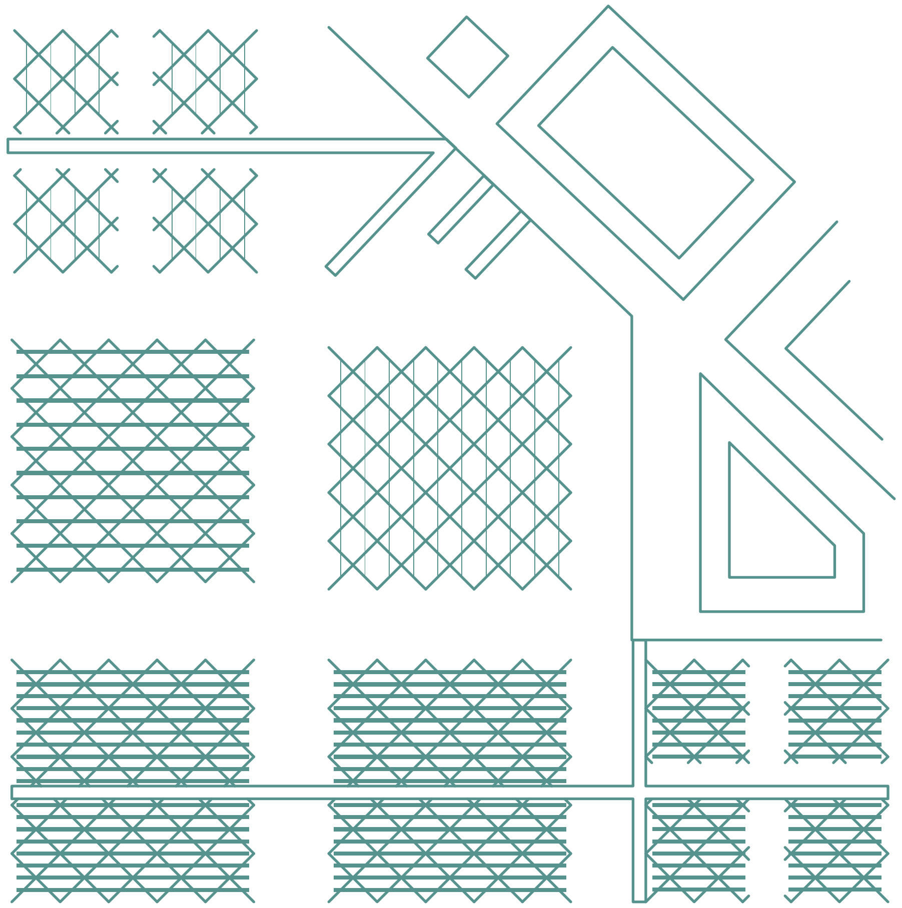
When a somewhat sturdy ground has formed after sludge thickens the soil layer, the footpath can be placed on a newly built module further down the path. In time, the path system grows. By walking along the path system, visitors experience the transition of the ecological system and the energy system that takes place in the modules. The paths end at the breakwaters that partially outline the island, offering wide views towards the Markermeer. The centre island also allows for small scaled recreation such as swimming and canoeing between the modules.



ALMERE OUTER DIKE

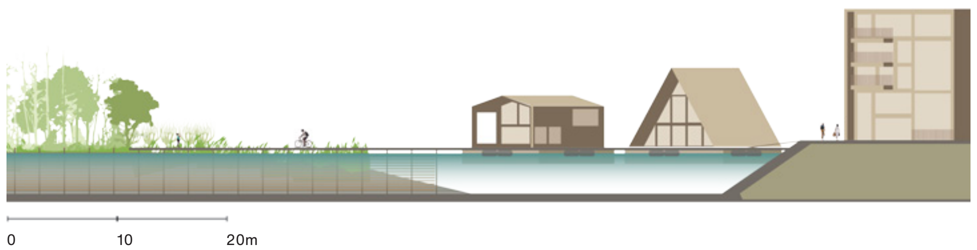
To the east of the centre islands and the shipping lane to the Randmeren, the elevated metro line continuous along the corner of Flevoland before connecting to it. This area is projected to be a possible zone for outer dike expansion of the city of Almere, which will in this project be called 'Almere Outer Dike'. The new metro connects this area to Amsterdam and the centre of Almere, making it very suitable for a mixed residential area with a medium to high densities amidst the waters of the Markermeer.

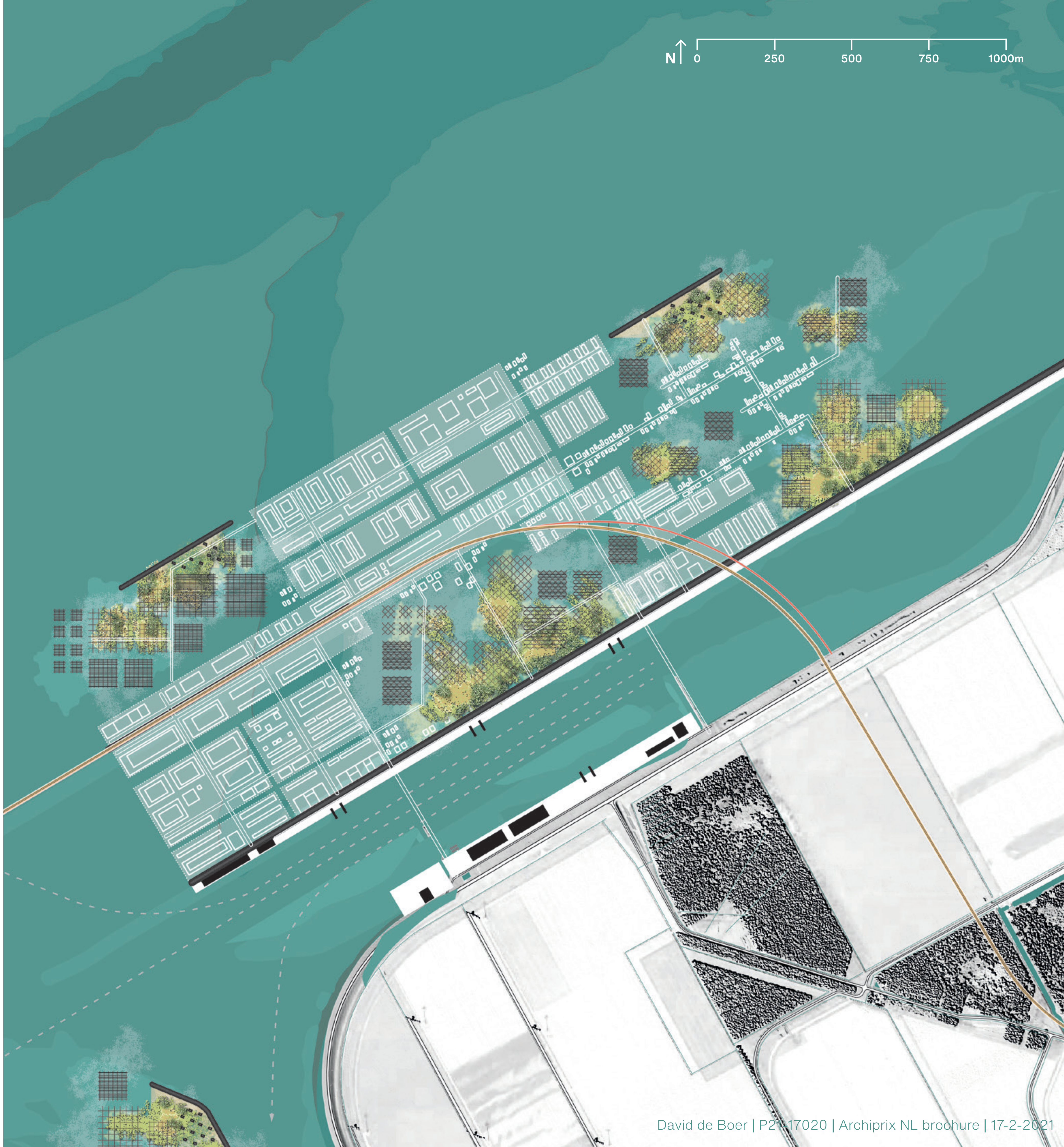
The breakwater dam that is currently present at the Pampushaven can function as the base of this urban expansion towards the northwest. To provide this urban expansion with green areas, wicker modules will be placed alongside the existing breakwater.

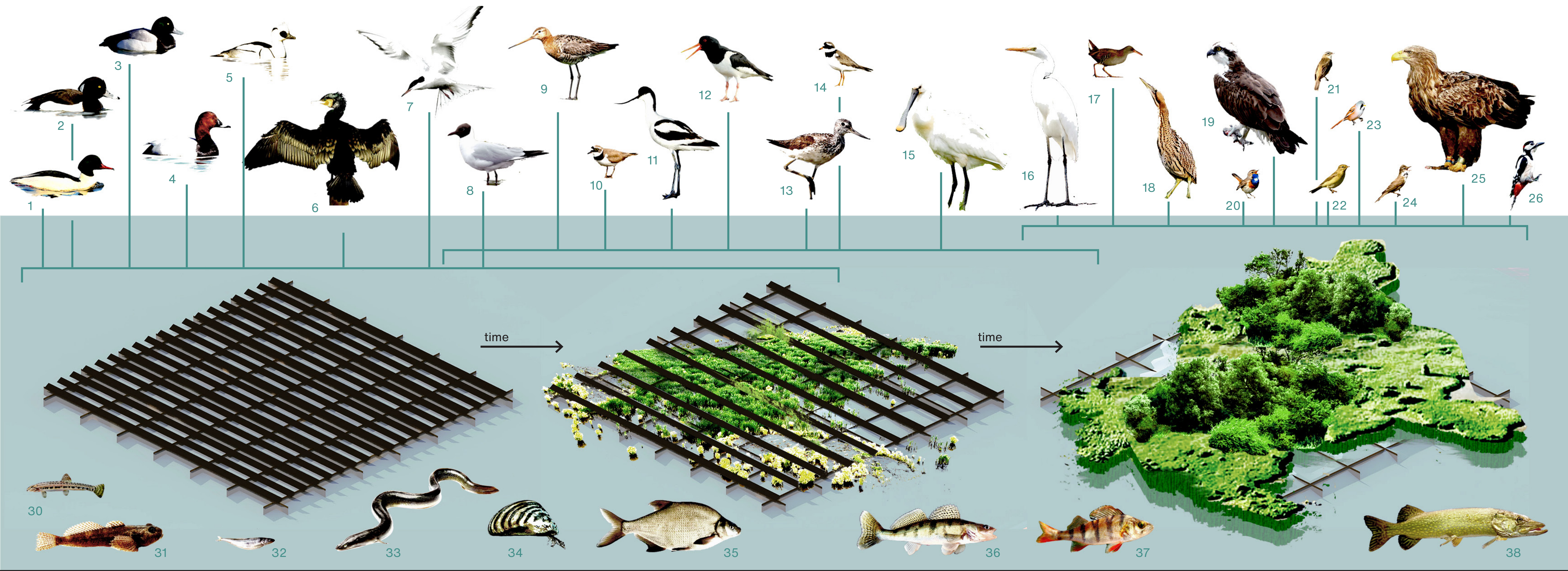


The locations of these modules lay in the extension of the Almere green structure and ecological connection on land. The modules will multiply outward onto the Markermeer to the Northwest. The conditional multiplication of the wicker modules, which extends somewhat randomly, can form the green framework of the new urban area, providing a large, porous green wedge in this urban extension that can dual act as an urban park and a nature area. When this structure has roughly developed, it lays out the structure of the urban areas as well, together with the 'spine' of the metro connection in the centre of this development. When Almere Outer Dike is constructed, the sludge that has to be dug out to create stability for the sand base can be used to fill modules elsewhere. Gabions removed from breakwaters elsewhere in the IJmeer can in turn be used for the edge of Almere Outer Dike. The character of Almere Outer Dike will be highly mixed, with wood-constructed high density housing along the spine and waterfronts, and lower density housing boats and smaller structures on the edges of the newly created green structure.

The Pampushaven, just south of the breakwater in the corner, is currently not in use as a harbour. However, to supply the materials for all the modules, organise construction of the grids and the equipment to place them, a specialised harbour is needed for the entire IJmeer. In the Pampushaven, dredging barges can move in and out of the area and solar panels, willow branches and armour rock can be stored in these areas. The Pampushaven is perfectly situated as a 'base of operations', with good access to the IJmeer by boat and access to regional infrastructure by land. When the production of modules slows down, or when no space in the IJmeer for new modules can be found, the layout of the harbour can be used as a commercial and cultural centre for the urban expansions of Almere, providing a waterfront as a bonus.







KICKSTARTING ENERGY TRANSITION AND ECOSYSTEM CHANGE

The modules can, because of their materials and simplicity of its working principles, be implemented in many different contexts. These contexts can be rivers where banks and floodplains can guide the flow of the river. The modules can also be used as a coastal protecion measure while creating interesting intertidal zones near coastal cities.

However, the IJmeer archipelago is not so much an engeneering novelty as it is a proposition to think differently about both sustainable energy transition and ecosystem restoration in densely populated metropolitan areas. An energy transition must, as this thesis shows, be absorbed into other processes that are happening in the landscape. These processes are partly self-organising, but urbanisation and building infrastructures in these dense environments are important as well. Whether the goals of Amsterdam and Almere for 2040 considering energy and urbanisation can be reached by this approach is highly uncertain. However, the key lesson for an energy transition in this region is to use a modular approach and a vision for large scale implementation, while staying flexible and open for changes in its implementation. Designers being the node of other areas of expertise is key here. Designing, a unique research practice, can as test, evaluate and play with many different features of other sciences such as ecology. This research proved that the discipline of ecology is very important for landscape architecture. Landscape architecture should first not only concern itself with engineering approaches to ecological problems. As in all ecological systems, this design is just a small part of a larger whole. To determine our place in the world that has already been highly influenced by our presence, moving with the pulse of ecosystems in landscape design is a necessity.

By differentiating between human sysems and self-organising ecosystems but building paralell structures, coexisting developments can take place, approaching both cities and habitats and cities as never stagnant but always moving in unpredictable cycles.

1. Mergus merganser
2. Aythya fuligula
3. Aythya marila
4. Aythya ferina
5. Mergellus albellus
6. Phalacrocorax carbo
7. Sterna hirundo
8. Chroicocephalus ridibundus
9. Limosa limosa
10. Charadrius dubius
11. Recurvirostra avosetta
12. Haematopus ostralegus
13. Tringa nebularia
14. Charadrius hiaticula
15. Platalea leucorodia
16. Ardea alba
17. Rallus aquaticus
18. Botaurus stellaris
19. Pandion haliaetus
20. Luscinia svecica
21. Acrocephalus schoenobaenus
22. Phylloscopus trochilus
23. Panurus biarmicus
24. Acrocephalus arundinaceus
25. Haliaeetus albicilla
26. Dendrocopos major
27. Calidris alba
28. Charadrius alexandrinus
29. Larus fuscus
30. Cobitis taenia
31. Cottus perifretum
32. Osmerus eperlanus
33. Anguilla anguilla)
34. Dreissena polymorpha
35. Abramis brama
36. Sander lucioperca
37. Perca fluviatilis
38. Esox lucius

ESSAY

Positioning design in ecosystem change

by David de Boer

Introduction

The relation of living beings to their environment is a broad topic to study; yet it is the fundamental topic of ecology (Townsend et al., 2008), a relatively young field of study that has impacted many disciplines including landscape architecture. The study of the ecosystem, one of the most important concepts in the spatial sense of ecology, includes a large variety of topics relevant for this research due to its complexity of the landscape system and a transition of that landscape into more sustainable performance. But also, the conversion of energy in a system, flora and fauna and dealing with uncertainty are relevant links between ecology and the context of this research. Ecosystems have evolved over millions of years to create highly complex but highly efficiently and sustainably functioning systems (Stremke & Koh, 2010). The study of living systems has resulted in useful methods in studying these topics but have also provided insights to solve environmental problems. Especially landscape architecture, a field which includes ecological knowledge but also shares the study of the living landscape can benefit from certain ecological principles (Lister, 2015).

However, analysing landscape systems and using ecological insights in relation to succession, development and transition in landscape design does not speak for itself. The purpose of this chapter is to produce a useful set of principles for respectively landscape analysis for the purpose of design and principles for design itself. This chapter will gradually move from more contextual, ecological substantive theory to more procedural theory of principles (Ndubisi, 2002), while addressing several themes of interest.

We first have to acknowledge that and landscape architecture are practically two very different fields of study (Koh, 2008). Concepts such as energy, succession and methods like analysing ecosystems have to be made useful for landscape architects. This means that a clear understanding of the fundamental knowledge and development of ecological knowledge concerning development and succession is needed first. This base of understanding is followed by an overview of transdisciplinary applications of ecological theory, among which the tradition of ecological thinking in landscape architecture and relating them back to ecological science.

Secondly, we need to acknowledge the broader change of context of ecology in studying ‘the natural world’ to the fact that anthropogenic activities are omnipresent nowadays. Ecological approaches have evolved into holistic notions of everything being connected, blurring traditional boundaries like natural and anthropogenic (Morton, 2010). While analysing ecology and transdisciplinary applications all the way to landscape architecture, a standpoint needs to develop how to deal with human nature relationships in the context of this research.

Lastly, we need to acknowledge that the relation of living beings to the environment is inherently complex. The notion that everything in that sense in some way connected to everything is overwhelming, but there are different ways of dealing with it which will be adressed in this chapter.

Concepts of succession and ecosystem change in ecology

The field of ecology concerns itself with the distribution and abundance of organisms and the interactions that determine distribution and abundance. These interactions also include the transformation and flux of energy and matter (Townsend et al., 2008; Likens, 1992).

Ecology can be studied across multiple scales in the biological hierarchy, ranging from individual organisms to populations (organisms of the same species) and communities (a multitude of populations). These levels of organisations mostly deal with their internal structure or in the case of the individual organism, their relationship to the environment. A spatial environment with different organisms interacting within it can be the object of study in ecology and is called an ecosystem. An ecosystem is a defined area that contains interacting biotic and abiotic components that have both interactions within the system and interactions outside the system (Tansley, 1935). The focus of ecosystem studies can vary from more biotic elements (species, populations, hierarchy) or abiotic elements (biochemical cycles, the effects of hydrology and geology) (Likens, 1992).

Figure 1: Succession occuring at Nature Park Schöneberger-Südgelände in Berlin. A former railway yard has been taken over by succession processes. Among the current vegetation of birches, beech saplings are coming up as the next stage in the process.

Ecosystems and the communities within them can change over time. Plant succession, the development of vegetational patterns was already studied at the turn of the 20th century. It is a community process, occurring among populations of different species, and a very observable one. Flowers, grasses and herbs will pop up in bare soil, which will subsequently be replaced by other (often larger) species when those grow, die, spread or be outcompeted (fig. 1,2). Therefore, succession can generally be defined as the sequential replacement of species over time, which is the basic definition as stated by Frederic Clements in 1916. The study of succession is therefore mostly concerned with the patterns of this change in vegetation. Clements lists five chronological causes in which succession occurs: a disturbance opening the site, migration of propagules to the site, establishment of species, biotic interactions and adaptation of the site by organisms

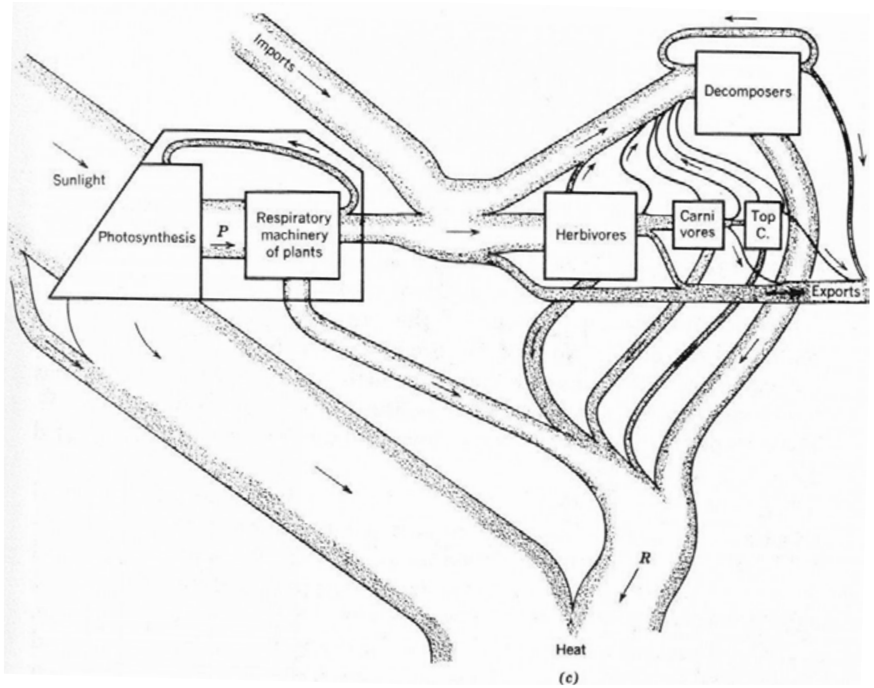
Figure 2: Profile of a succession pathway of a pine forest, with the 'early'stages on the left and the 'mature' stages on the right

(Clements, 1916). First is the concept of a disturbance, which is according to Clements a relatively abrupt loss of biomass. This can be an extreme weather event, like floods, storms or forest fires. This disturbance 'opens the site', or in other words, makes it available for propagules, like seeds, to grow and establish a set of species. These species undergo interactions and will eventually alter the site; like enriching the soil with nutrients, cover open waters or prevent erosion of sediment by root systems. The causes of succession by Clements were refined by Pickett at al. (1987) in which causes were reframed as conditions for succession to occur, and to distinguish the functional components of succession. Generally, the conditions for succession to occur is the availability of open sites (usually following a disturbance, but the death of an induvial can also open the site in a small scale), differential availability of species (the ability for different species to move into the site) and differential performance of species at the site (interactions and different behaviours of species at the site itself). Important concepts to then study succession are pathways, which it the temporal patterns of change. The order in which certain species appear and disappear is part of a pattern. Another concept is the cause of this order of replacement; a cause is an agent of change like the amount of light, or nutrients can all be causes in this sense. The mechanisms of succession are the interactions of these causes; these can be competition for sunlight for example. The last important concept Pickett notes is that of the model. Models are the relations among causes and mechanisms that explain certain pathways. Pathways can give an idea of the change that occurs in ecosystems and can to some extent predict the change in ecosystems with similar conditions. Landscape architects should consider the causes and mechanisms of the replacement of species in succession, and the way the site and species relate to one another. However, it is important to not rely to much on predictability and ideas of control when addressing succession.

The ‘clementian’ theory of succession assumes that succession is directed development towards a ‘climax’ state, in which there is a definable endpoint of the replacement of species. This endpoint can be illustrated by a forest with fully grown trees like beeches or oaks which will not be replaced by new species unless a disturbance occurs. This caused notions of ‘young’ and ‘mature’ ecosystems to come into being in the years after; ecosystems were compared to organisms that will ‘grow’ in biomass and complexity over the course of their ‘lifespan’. The idea of a climax, a final stage in the process and patterns of communities following a disturbance, became heavily embedded in ecological thinking. Mature ecosystems were also described in terms of stability and control, the idea that they came to a point where they are less susceptible to change and disturbance. In the second half of the 20th century, these ideas became more and more contested and eventually proven partly wrong.

In the sixties and seventies, the field of ecology broadened in ways which also influenced the concept of succession and ecosystem change, specifically from an ecosystem perspective rather than mostly vegetation communities. Connections were made between ecology and thermodynamics. Ecologists like Robert MacArthur placed emphasis on the balance of resources like matter and energy in ecosystems, which constantly move towards ‘equilibrium’ in which all resources in a system are used optimally (Pulliam and Johnson, 2002). A balance approach based on systems with inputs and outputs was also explored by the brothers Eugene and Howard T. Odum. Rather than focussing on individual species or communities in their research, energy and matter was quantified and the system was analysed in terms of its biochemical cycles (fig. 3).
H.T. Odum described ecology as the study of the structure and function of nature (Odum & Barrett, 1971). This is also illustrated by the approach that everything could be perceived as transformations of initial solar energy into biomass and continuing further along the hierarchy through species interactions (Odum (H.T.), 1988). This approach to ecosystems could also be used in terms of its development over time, in which Euguene Odum lists many different trends related to systematic or community properties. There is an assumption of increased homeostasis as a final stage in its development as the net production (the ratio of production and respiration) approaches a balance. This is the direction in which all processes eventually move to, or as it is called by Odum, ‘mature’ stages in ecosystems. Production slows down and systems become more complex, there is a peak in biomass (stored energy) and diversity and symbiosis increases. Nutrient cycles close and niche specialisation becomes narrower. Ecosystems become more stable and resilient. This is all opposed to ‘developmental’ stages where the opposite of these trends occurs. Odum, similarly to Clements, also made the analogy between an ecosystem and an organism to illustrate this ‘maturing’ of ecosystems (Odum (E.), 1969).

Figure 3: Flow diagram of energy within an ecosystem in the Silver Springs study by Odum (1971)



Throughout the course of the decades thereafter, several arguments for equilibria were abandoned leading to a new paradigm of succession in ecosystems. To think there is a single equilibrium and a climax state that can be reached that ecosystems approach is misleading in the context of succession. The environment in which ecosystems behave is too susceptible to change in relation to the complex nature of ecosystems for a single equilibrium that changes over time. This is different from organisms where one equilibrium remains the same throughout its development, like body temperature (Holling & Goldberg, 1971). In organisms, many components such as organisms stay the same whereas in ecosystems, they change over time. Instead of one constant equilibrium, an equilibrium in ecosystems may change over time and can composed of multiple equilibria at the same point in time that effect each other as well. Pulliam and Johnson (2002) summarise three misconceptions about equilibria that were assumed before the new paradigm; the idea that ecosystems are always found at or close to equilibrium in relation to their resources, the idea that ecological patches (an area with certain homogeneous environmental features) are relatively autonomous in terms of resources and equilibrium, and the underestimation of the importance of disturbances.

The new paradigm however considers multiple stable states in ecosystems and communities that dynamically and continuously respond to a large variety of disturbances and have done so over the past. Ecosystems exist and change over larger scale in time than we can observe in a lifetime, but also endure smaller changes over shorter lifespans. Rather than linear developments, ecosystems constantly move through recurring cycles based on four processes: exploitation, conservation, release and reorganisation (fig. 4) (Holling, 2001). This process is known as the four-box model or the 'Holling figure eight'. Important to note is that no two cycles are the same; reorganisation means a shift to a new ecosystem state. Ecosystems, being self-organising systems, constantly shift states and are under change, challenging traditional views of resilience. Resilience, which can be defined as the ability to bounce back to former state, was split in the 'engineering resilience' and 'ecological resilience'. (Holling et al., 1973). Engineering resilience is illustrated by a body temperature; it is measured by the return time to a former state after a disturbance, such as the severity of fever or a disease. There are also thresholds to body temperature; above or below means death. Ecological resilience however is, due to its multiple stable states, the severity of disturbance being enough to surpass a threshold and move from one ecosystem state into a different state (Holling et al., 1973; Gunderson, 2003). The new paradigm also considers ecosystems to be not fully autonomous systems but to be very heavily influenced by incoming or outgoing fluxes across system borders (Pulliam & Johnson, 2002). Ecosystems are never devoid of disturbances and external factors and ecosystems are often not in equilibrium in practice, nor do they regularly reach the ideal of a climax state (Gibson, 1996). The enormous complexity of ecosystems and the fact that we cannot fully analyse and know all its details makes us unable to fully understand in which way ecosystems react to disturbances (Jørgensen & Miller, 2000) This means that the predictability of the development of ecosystems is incredibly limited and understanding specific structures and processes is very uncertain.

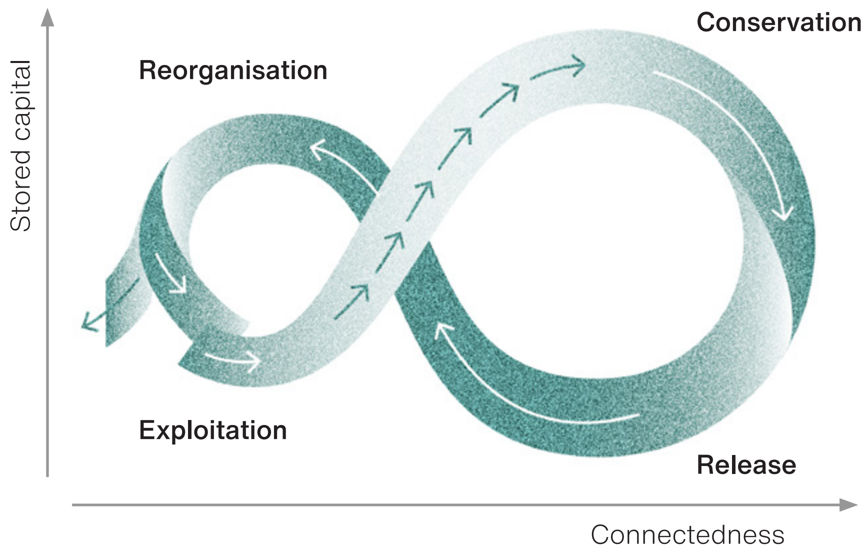


Figure 4: Hollings 'Figure 8' model of cyclical ecosystem dynamics

Humans and ecosystems

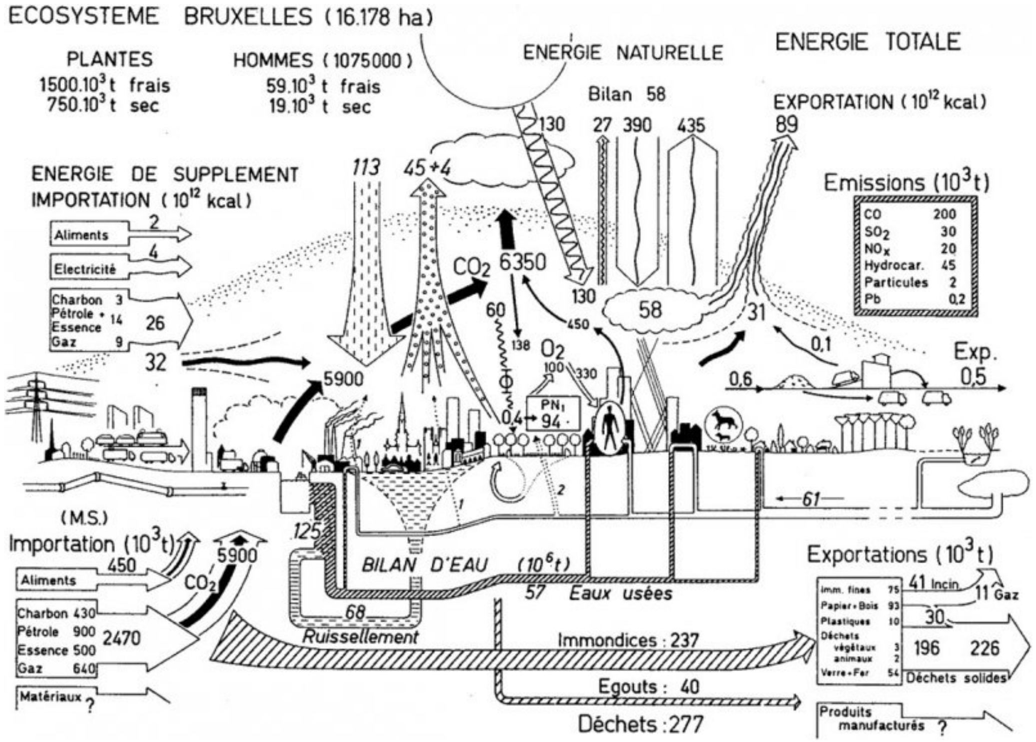


Figure 5: Diagram of the 'urban metabolism of Brussels by Duvigneaud & De Smet, 1977

The new ecological paradigm is further complexified by human influence. The growing impact of humans on ecosystems and the growth of environmentalism made ecology to become a more normative science over the last fifty years (Lister, 2015). Environmental problems made it clear that ecological knowledge eventually had to be used in sustainably managing, planning and designing landscapes (Likens, 1992; Holling & Goldberg, 1971). The increasing effect of humans on ecosystems also questioned the role of human activity in ecosystems, and how to manage them. The idea that human influence on the environment is separate from 'natural' functioning of ecosystem has become obsolete, even though many ecologists before having included human activities in ecosystems. Even the original ecosystem definition by Tansley supports the inclusion of humans and their influences (Pickett & Grove, 2009). Humans are both agents in ecosystem impact and creation, but also participants in those same ecosystems depending on its processes. In fact, humans have become the primary influence on the earths processes, of which they will become the victims as well (Crutzen, 2006). Climate change and species extinction made it clear that ecosystems from this age onward cannot be left alone to develop into resilient systems, as was the incorrect idea of ecosystem management under the Clementian succession theory (Pulliam & Johnson, 2022); we instead have to actively focus on species preservation and their habitats. Not only have the role of anthropogenic effects in ecosystems research grown over the years, they have also led to new classifications of ecosystems, being 'impacted', 'novel' or 'designed'. Impacted ecosystems are ecosystems that endure unintended human alterations to its structure and function, but not to an extend that it reaches a threshold and alters its state. Novel ecosystems have reached that threshold however and exist entirely because of human agency, while being self-sustaining (Morse et al., 2014). A third category is the designed ecosystems. Here, intentional human intervention and maintenance is the driving force. In its development, impacted and novel ecosystems start out from their previous ecosystem functioning, reacting to altering conditions. Designed ecosystems are in its functioning determined by human intention (Higgs, 2017). Especially the last category sets humans apart from other organisms in ecosystems; they can, with the knowledge of systems, intentionally alter system components according to their needs and plan ahead according to those needs. Humans as both the agents and participants of ecosystems blurs boundaries between what is natural and what is cultural or technological from this perspective, especially considering concepts like 'nature-based solutions'. Humans having an overwhelmingly large effect on ecosystems simultaneously questions our involvement. Human intervention cannot only be seen as an organism's involvement in the system, but also as a disturbance. This disturbance can range across many scales; from climate change to land clearing (Zipperer, 2010).

The overwhelming impact of humans on ecosystems made ecological thinking and system thinking popular in other applications than those for natural ecosystems. First, typically 'human' systems could also be described by ecological concepts in a metaphorical or analogous sense. Later, ecosystems that relied heavily on human influence and human systems that relied on natural resources could be studied by ecological modules and concepts (Pickett & Cadenasso, 2002; Wachsmuth, 2012). These approaches could be interpreted from going from 'biomimicry' or learning from nature to a more integrated approach. The idea of 'urban ecosystems' or the 'city as an ecosystems' are popular applications of ecological theory. Cities can be analysed as ecosystems to increase their efficiency and resilience. Transdisciplinary applications of ecological theory on ecosystem change and succession have also become popular in this application as a degree of ecosystem efficiency. This application often goes together with analysing 'urban metabolism', the analysis of cities in terms of biochemical cycles, emerging in the sixties and seventies (fig. 5) (Wolman, 1965; Pincetl at al., 2012; Zhang, 2013). Many researchers of urban ecosystems consider cities as being in a very undeveloped ecosystems, with little closed material and energy cycles (Decker et al., 2000). Ecological concepts can also be used as analogous to human systems in this sense. Human energy systems can also be seen in this sense as systems that are in their 'early' stages high in entropy and in mature stages high in exergy. Fossil fuels are in this sense an early stage where there is also little self-sufficiency with resource scarcity being a self-induced disturbance (Stremke & Koh, 2010; Stremke et al. 2011).

The view of succession in urban metabolism theory is heavily based on a thermodynamic approach of ecosystem change. Urban metabolism addresses system change as a change of a non-efficient state to a more efficient state, with energy and material flows becoming accounting figures in one and the other. The solution and proposed development are also based on the contested idea that cities increase their resilience by being more like a 'climax ecosystem', including making urban ecosystems analogous to superorganisms. Analogous referencing to ecosystems or organisms in general can conflict with holistic ecological thinking, especially when both are used at the same time. Cities are not just analogous to ecosystems, they are ecosystems under a large human influence (Golubiewski, 2012). The blurring of human systems and natural systems and increasing human influences in ecosystems have complicated the application of ecological theory to other fields, and can also lead to misanthropic and Malthusian assumptions when viewing the city and humans as 'parasites' on the resources around them (Rees, 1997).

Using principles of systems thinking and ecology for sustainable development is a strategy to approach complex ecosystems, which can be called an 'ecosystem approach'. Sustainable developments in this sense can mean sustainable energy systems. The ecosystem approach utilises the contemporary principle of succession and ecosystem development, and approaches ecosystems in a holistic way rather than analogous. Addressing sustainable development of ecosystems requires dealing with complexity and uncertainty. Linear, reductionist approaches focused on a single type of stability fall short when addressing sustainable development; sustainable development means the ability to be flexible and adaptive (Kay, 2008a). Ideas of control, prediction and right answers in complex systems do not apply, as the full functioning of self-organising systems cannot be controlled or predicted. Rather, a mindset of accepting complexity, adaptability and resilience is needed (Kay, 2008b). Humans can impact ecological systems in structure and context; both have a consequence for societal systems themselves as ecological systems provide the context in which they can exist. Being aware of making structural impacts (removing or adding ecological components) or changing the context (changing the context through which components interact), while staying open for feedback loops by the system is important in an ecosystem approach (Kay & Boyle, 2008). An ecosystem approach also means allowing multiple perspectives on problems and human-nature relationships in ecosystems. There is not a 'right' way an ecosystem should be or can be described as (Kay, 2008a).

Ecological thinking in landscape architecture

Landscape architects can often act as the bridge between multiple perspectives and disciplines in projecting possible futures for landscapes and presenting themselves as ecological thinkers. Ecological thinking has had large impacts on the field of landscape architecture. A significant work in this sense is Ian McHarg's 'Design with nature' (1969), approaching ecology as 'not only an explanation, but also a command' for landscape design. Understanding geology, hydrology and ecology of the site became the base for design, a conventional practice today but revolutionary at the time. Designing with the knowledge that natural processes permeate every context for design has grown in the years thereafter. Landscape architects have come to recognise cities as natural environments as well, most notably by Anne Whiston Spirn's essay 'The granite garden' (1984). Both these works are important works in what could be called 'ecological design' as an approach in landscape architecture (Crewe & Forsyth, 2003). This approach draws heavily on using ecological knowledge for habitat maintenance and is mainly concerned with conservation through engineering approaches to ecological problems, but rarely through ecosystem change or succession. The use of ecological knowledge has been fairly narrowminded in landscape architecture and has mostly been instrumental and objectivist in nature (Corner, 1997; Koh, 2008). Examples of this approach are the use of native species in plans and designing shallow banks and meandering courses for rivers and waterbodies.

Some landscape architects however have come to acknowledge the larger characteristics of ecosystems. Barnett (2013) lists several conditions of landscapes to be acknowledged by landscape architects. Disturbance, difference, uncertainty and heterogeneity are in that sense not only conditions to recon with, but also opportunities which can be used in design. Designing encounters in ecosystems between humans and non-humans means that every encounter is different, specific encounters cannot be predicted and each encounter forms the base for further information to occur. Barnett keeps the ecological theory rather substantive and close to its original meaning, implying its use for design to be implicit as procedural theory. His approach is more of an understanding rather than usable principles. More explicit are principles by Lister (2015), who lists several principles of ecosystem change for designing for resilience. The first one being that system change can happen both slow and fasts, with several processes occurring at different speeds. Second being connectedness and modularity within systems, with ability to keep feedback loops to a certain extent controlled. Third, acknowledging that there is no correct state for the ecosystem to exist in and to anticipate change. Fourth, embracing diversity and uncertainty, monitoring change and response, and acting accordingly. Both authors differ to the more instrumental use of ecological knowledge in that they address non-linearity, open-endedness and adaptability in landscape architecture. Design can mean control, but it can also mean a light touch, flexibility and anticipating change.

Figure 3.6: Design visualisation for Freshkills park, USA by James Corner/Field Operations. It's large scale approach in space and time makes it a prime example of Landscape Urbanism

Several paradigms of landscape architecture and landscape architects have approached these principles relating to ecosystems more indirectly. One of these schools of thought is landscape urbanism. The idea of the post-industrial blurring of nature and human society, in the context of the urban and the rural is an important factor in its emergence (Waldheim, 2006). Landscape urbanism takes a systems approach in perceiving sites as open systems and acknowledges a large timespan in which things change (fig 6). Ecological and urban processes are considered to be important forces to recon with. The landscape becomes the field and infrastructure in which processes and fluxes perform. In urban environments, spatial relationships are deemed less important than larger processes of economy, regulation and environment (Corner, 2006; Thompson, 2012). We can see similarities between dealing with uncertainty, complexity, and interestingly processes as a recurring theme in landscape urbanism. Landscape urbanism has been a large influence on, or has in other words 'evolved' into 'Ecological urbanism' (Thompson, 2012). Ecological urbanism also uses a systems approach and view urban systems and landscape as a complex network, putting not only an emphasis on the blurring of boundaries between 'natural' and 'human' systems, but also the blurring of the boundaries of disciplines. Ecological urbanism is concerned with the plurality of relationships in contemporary society: relationships between the individual, groups and the environment, of our thoughts and actions and of our responsibilities and respective disciplines. Ecological urbanism proposes intensive collaboration between spatial experts, especially various kinds of designers and ecologists (Mostavi & Doherty, 2016).

However, landscape architects do not necessarily have to take systematic approaches and directly use ecological theory to deal with uncertainty, complexity and change over time. These approaches have been incentives for landscape architects to take a more creative and poetic approach in relation to ecology (Corner, 1997; Koh, 2008). James Corner proposes that ecologists and landscape architects work together, but also that landscape architects should also approach ecology as a way to create imaginative relationships and a culture of 'systematic bewilderment'. These newly found connections can lie within the pulse, change and movement of nature. Corner states that landscape architects should not pursue finished works, but rather design frameworks, strategies, agencies and scaffoldings to respond to the complexity of nature and its continuous change (Corner, 1997). Designing a framework on which processes perform is also related to the concept of 'landscape infrastructure', being an 'indeterminate interface of hard technological systems and soft biophysical processes by design'. In this sense, the landscape intervention provides an artificial base for natural fluxes (Bélanger, 2013).

Figure 7: The ecocathedral in Mildam by Louis Le Roy. Nature and human interventions are in continuous interplay with one another

Moving with the continuum of nature can also be observed in the works of Louis Le Roy. Le Roy takes in his eco-cathedral an ecological approach of processes and flux rather than an ecology of specific components (Dagenais, 2008). Le Roy employs a continuous interplay between nature and human intervention; he is constantly building and influencing succession pathways along his constructions, which affect his building vice versa (fig. 7). Another approach can be seen in de works of Michel Desvigne. Desvigne does not so much interfere with the process itself but concerns himself with creating the preconditions for successive states. A minimal touch can enhance the beauty of early stages of design, placing an emphasis on the change over time (fig. 8) (Desvigne, 2009).

Building frameworks, interplays and preconditions for the processes of nature also questions the meaning of human interventions and their technologies. Especially for this project, sustainable energy technologies function through natural processes, but are nonetheless human systems. Kees Lokman proposes a hybridisation between human and non-human systems to create dynamic relationships of ecosystem processes, called cyborg landscapes. The term cyborg is used to illustrate technology as an extension of natural processes, forming hybrids. Cyborg landscapes also develop as hybrids, meaning that these responsive landscapes cannot be fully controlled and are open-ended in its development (fig. 9) (Lokman, 2017). Similar to cyborg landscapes, performative landscapes can keep performing and producing, even during change and development. They are machines not in their 'hard-cast' sense, but in productivity. 'Landscape machines' can have inputs and outputs, yet the natural processes are constantly affecting one another (Roncken et al., 2011).

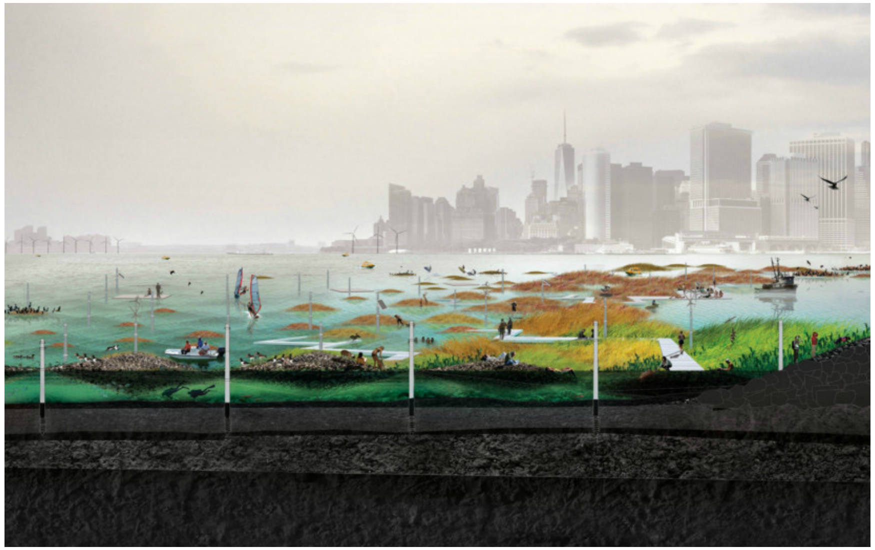


Figure 9: Visualisation of the project 'Oyster tecture' by SCAPE, shown as an example of cyborg landscapes by Lokman (2017). Oysters settle in human-made frameworks

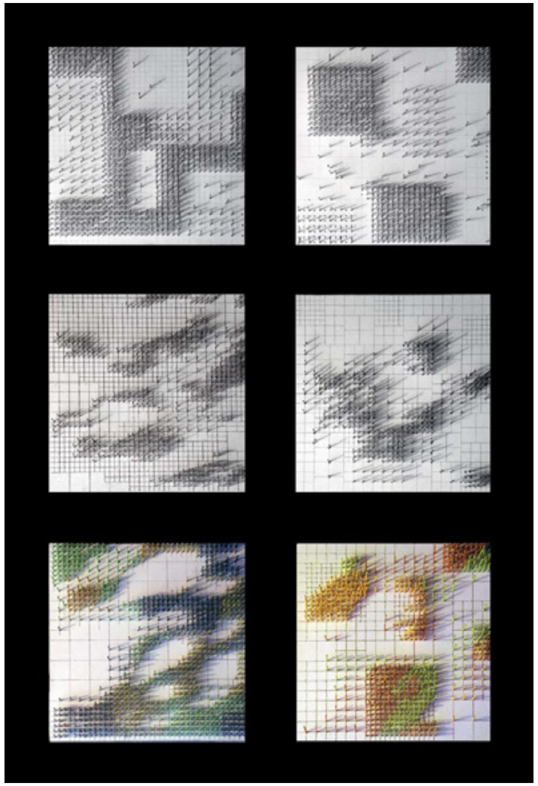


Figure 8: Model for the Walker Art Centre by Michel Desvigne. A grid of trees as a precondition will change its composition in the years after implementation

Technologies for sustainable energy production, like wind turbines and PV panels, are of course actual machines, fixed in place with its internal processes staying the same over time. However, different renewable energy technologies have very different characteristics that can be of use considering change in landscape. For example, an individual PV panel is easier to install than a single 3 MW wind turbine. The grain size is therefore important to consider when using sustainable energy technologies in ecosystem change. And even though the mechanics of renewable energy production itself is not necessarily directly available for 'hybrid' opportunities, the aspects of their implementation in the landscape can be. Sustainable energy technologies need to be fixed somewhere where they can make use of wind and sun. They need an infrastructure to transfer energy to substations. Al these aspects can be opportunities for sustainable energy technologies to situate themselves and function 'ecologically'.

The process-oriented and open-ended approaches of the landscape architects above are not solely technical in nature. In their processes and change lies a poetic beauty of observing change but can also possess a sense of sublime as it moves into the unknown (Roncken et al., 2011). At the same time, imagining its change and possible futures can instigate a sense of bewilderment (Corner, 1997). We prefer to have a combination of the known and the unknown, a sense of control and letting go. We prefer messy ecosystems in orderly frames (Nassauer, 1997). The way in which apply control to our design within ecosystems can therefore vary. A new ecosystem approach for landscape architecture synthesised from the above will be proposed.

An ecosystem approach for landscape architecture

Ecosystems are not separate from human systems; humans exist in them and depend on them for their existence. However, humans have unique and dominant impacts on ecosystems compared to other species. Humans are also able to plan and predict and work goal-oriented to a certain extent; they are not fully self-organising, so neither are ecosystems in the Anthropocene. Therefore, concepts like succession and knowledge of ecosystem change have emerged through the study of natural systems. Taking direclty analogous approaches to these concepts, especially succession, for human intervention can lead to misinterpretation. Respecting ecology as a specific, independent science that is adopted but not necessarily adapted by landscape architects is important when trying to understand and work with ecosystems. Ecosystems have to be understood on a larger scale while acknowledging its unpredictability and complexity. Instrumental use of ecological measures are important as well, but have to be applied within the knowledge of ecosystem characteristics.

The role of the designer is to therefore to organise the landscape in parallel with ecosystem development, equipped with an understanding of it's components, processes and location. The goal should not be to change a self-organising system, but rather letting the intervention be changed by the system processes, and in turn affecting the ecosystem as a whole. These 'frameworks' can be directed to respond to certain flows but allows its development and outcomes to be uncertain. These frameworks can also act as disturbances, opening the site for new development and allow different pathways of succession. This means that a predetermined end state of the development should not be pursued. There is no single correct state of both the human system and the ecosystem. Design with an acknowledgement of unpredictability, complexity and open-endedness in ecosystems. Since pathways for sustainable development of energy systems are unclear as well; adapt according to ecosystem responses and related goals. For energy systems to integrate with ecosystems, maximizing efficiency or output is not so much the goal, but rather adaptability and hybridisation of the system over time. Consider the cycles through which ecosystems change, with every cycle being a bit different than the last one, provided by the base of the previous one.

To illustrate designing with open-endedness and parallel to unpredictable self-organising processes and systems, compare this design attitude to building a dam out of rocks and pebbles in a small stream. Even though you start goal oriented to block the stream, you also start with the knowledge you can never fully block the stream or control the flow of water. We can only build, see how the course of the water changes and react to it accordingly. The dam is never finished, as the water constantly finds new ways to move around the constructions, or the water destroys the dam.

This does not mean that an intervention is pointless; it can very much so provide a base for an unpredictable, but positive ecoystem response for ecosystems stuck in a rut. The intervention itself can directly related to, in this case, providing renewable energy. By staying flexible and a good comprehension of basic processes in the system, the intervention can also be adapted to fit other uses. In this way, human interventions can run parallel with self-organsing processes of ecosystems (fig. 10), providing the instigation for change and interchanging processes throughout both their development.

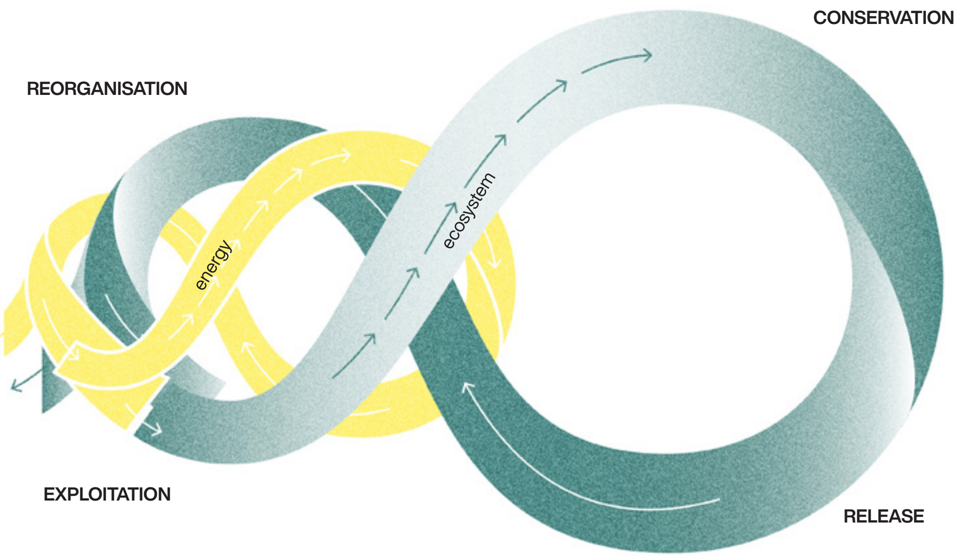


Figure 10: a proposition for an adapted 'holling figure 8', where a cycle of energy transition builds the exploitative phase of the ecosystem. Further on, it develops parallel to the ecosystem while interchanging effects with it.

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