DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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D13.1: Quantified ESS for 3 mature sites including recommendations for application

PART 2 - Emscher case

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Introduction

In WP13, the DESSIN ESS Evaluation Framework, developed in WP11, was applied to the three DESSIN mature cases in order to test its applicability. The aim was to quantify ESS, to assess changes in ESS provision, and to conduct a sustainability assessment in order to validate the ESS Evaluation Framework.

The three mature case studies are:
PART 1 – Aarhus case in Denmark
PART 2 – Emscher case in Germany
PART 3 – Llobregat case in Spain

The mature cases represent case studies where innovative solutions were already realized. Therefore, it is possible to compare the status before and after the solution was implemented. The case studies are distributed throughout Europe in order to cover a broad geographical range with diverse environmental conditions and social dimensions. Furthermore, the case studies offer an illustration of a wide variety of ecosystem service types targeted with restoration projects.

Each case was included for specific reasons and has a specific focus:

The innovative solution in the **Aarhus mature case** study is the real-time control of a full urban water cycle with sewers and wastewater treatment plants as well as recipient waters such as lakes, river, and a harbor. All these elements are combined into one model-based real-time decision support system (DSS). The aim of this real-time DSS system was to adapt Aarhus' water system to climate change related challenges and to raise the recreational potential in the city of Aarhus via an improvement of the water quality. Thus, this case has a special emphasis on water quality issues and recreational values.

The **Emscher site** applies the ESS Evaluation Framework to individual sections of the Emscher river network for the status before and after the large-scale Emscher restoration was realized. Subsequently, the results are transferred across the multi-site case study allowing a prognosis for the whole catchment. Service provision is, in the end, related to the costs of the restoration project for the river network as a whole.

The **Llobregat study** has a focus on the economic valuation of changes in ESS provision resulting from the implementation of infiltration ponds. These ponds were created in order to replenish the groundwater reserves and provide drinking and non-drinking water to the Barcelona area. The current and past status and the resulting benefits are assessed for individual beneficiaries.

The application of the analytical evaluation framework consists of the following steps for each case:

- Selection of key ESS affected by the innovative solutions
- Identification of relevant indicators to measure changes in ecosystem status and service provision
- Quantification of the case-relevant ESS
- Valuation of the final ESS
- Assessment of the innovative solution with regard to sustainability aspects

A reflection of the applicability of the ESS methodology was formulated for each mature site throughout the validation process, going along with the development of the Framework. This provided practical recommendations for the improvement of the methodology during the developmental phase.

The recommendations are reported in the combined **Milestones 21 & 26**.

D13.1: Quantified ESS for 3 mature sites including recommendations for application
PART 2 - Emscher case

SUMMARY

This Deliverable reports the results of the application of the ESS Evaluation Framework (D11.2) for the Emscher mature case.

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Table of contents

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List of Acronyms and Abbreviations

C	Carbon
COD	Chemical oxygen demand
CSO	Combined sewer overflow
EG	Water management association Emscher (“Emschergenossenschaft”)
ESS	Ecosystem Service
FEGS	Final Ecosystem Goods and Services
FESS	Final Ecosystem Service
GEP	Good ecological potential
GIS	Geographical Information System
IESS	Intermediate Ecosystem Service
N	Nitrogen
NRW	North-Rhine-Westphalia
P	Phosphorous
SI	Saprobic index
TOC	Total organic carbon
UDE	University of Duisburg-Essen
WFD	Water Framework Directive
WTP	Willingness to pay
WWTP	Wastewater treatment plant

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List of Figures

List of tables

Executive summary

In the **Emscher mature case study** we evaluated the changes in ecosystem services (ESS) resulting from a large-scale restoration project. This restoration project, the Emscher re-conversion, started with the construction of an underground sewer network in the Emscher catchment. Subsequently, it aims at restoring all water bodies which have been open sewage channels for the last 100 years. As part of the restoration is already completed, data are available for comparing ecosystem characteristics before and after the conversion took place. Based on this data, the DESSIN ESS Evaluation was applied to assess resulting changes in several ESS. Where required, data gaps were filled using predictions or estimations.

Following the Steps 0 to 8 of the **DESSIN Cookbook**, we started the assessment with the description of the study area and its characteristics. In this step, we also identified the most important stakeholders in the area. Later on, this step is helpful for the detection of beneficiaries of ESS. Subsequently, the most important Drivers and Pressures were identified. By providing a detailed description of the Response, which is in this case the Emscher re-conversion, it was found that the Response aims at alleviating from the Pressures rather than to affect the Drivers. The reduction in Pressures results in an improved State of the ecosystem under study. Several relevant parameters of State were identified and indicators selected and assessed. Based on these parameters of State affected by the Response, hypothetically existing ESS were listed along with their respective hypothetical beneficiaries. The latter were compared with the list of stakeholders which was developed in the beginning. Those ESS having a beneficiary, were classified into final ESS (FESS) while the remaining ESS were classified as Intermediate ESS (IESS) in case they act as prerequisites for the provision of FESS.

The IESS and FESS identified and assessed in this case study are:

- IESS # 1: *Self-purification: N retention*
- IESS # 2: *Self-purification: P retention*
- IESS # 3: *Self-purification: C retention*
- IESS # 4: *Biodiversity*
- FESS # 1: *Opportunity for placement of infrastructure and reduced risk of flooding*
- FESS # 2: *Opportunity for placement of infrastructure in environment*
- FESS # 3: *Opportunity for biking & recreational boating*
- FESS # 4: *Opportunities to understand, communicate, and educate*
- FESS # 5: *Knowledge that a restored river area exists, with suitable water quality (i.e. Good ecological potential (GEP))*

These IESS and FESS were assessed using indicators. The FESS were further monetized using economic methods. Finally, the resulting benefit was compared to the initial spending for implementation of the solution.

Further ESS were identified as being case-relevant but were not assessed quantitatively in this study:

- ESS: *CO_2 sequestration*
- ESS: *Local climate regulation*
- ESS: *In-stream cooling effect*
- ESS: *Research opportunities*
- ESS: *Drinking water provision in the downstream Rhine catchment*

These ESS were described qualitatively.

Furthermore, **climate change related challenges** were discussed and possible impacts on ESS provision and use were described qualitatively.

As part of the DESSIN Cookbook, we also conducted a **sustainability assessment** of the Emscher re-conversion. This assessment provides information on a number of environmental, social, financial as well as governance and assets related aspects which were not yet covered in the ESS assessment.

Introduction

This document reports on the application of the DESSIN ESS Evaluation Framework in the Emscher mature case study. The DESSIN Cookbook was followed step-by-step in order to identify case-relevant key ESS, quantify them via appropriate indicators, and value the changes in ESS provision resulting from the measure conducted.

In the Emscher case, the Emscher re-conversion project, a large scale restoration project, represents the innovative solution or measure, whose effects on ESS provision are to be evaluated. As the Emscher catchment has sections (streams or sub-catchments) in different restoration stages – some of which are already fully restored – a comparison of before and after the implementation of the solution is possible.

According to DESSIN's Description of Work, the application of the Framework was conducted for individual streams or stream sections of the Emscher River network and the results were transferred or scaled up across the multi-site case study. This allows a prognosis for the whole catchment. Final ecosystem service provision is related and compared to the total costs of the restoration project for the river network as a whole. This comparison takes into consideration the lifetime of the effects of the measure as well as the time for implementation of the measure. A comparison of costs and benefits for individual sections was not appropriate, as for some ESS (e.g. *Opportunity for biking*) a partitioning of the resulting benefit into individual sub-catchments is not possible.

An assessment of service provision for restoration scenarios (like e.g. for an intermediary restoration stage) was not useful, as for instance the evaluation of some biological indicators for different restoration stages was not meaningful.

Predicted climatic changes in the area were considered and effects on ESS were assessed qualitatively in order to demonstrate future trends and shifts in importance of single ESS.

A sustainability assessment was conducted for the Emscher restoration in accordance with Part V of the DESSIN ESS Evaluation Framework as well.

SETTING THE SCENE

Step 0. SETTING THE SCENE

0.1 Administrative details

The present Ecosystem Services Evaluation study is conducted by Emschergenossenschaft (EG) in collaboration with University Duisburg-Essen (UDE) and IWW as part of the EU FP7 project DESSIN. EG's main tasks are wastewater treatment, care and maintenance of water bodies, flood protection, regulation of water flows, groundwater and rainwater management, and two major and outstanding keynote tasks that were agreed upon by the associates: the construction of underground wastewater channels and the re-naturalization of the open wastewater conduits.

0.2 Objectives of the assessment

The assessment is conducted with the aim of (i) testing the ESS Evaluation Framework proposed and (ii) identifying the benefits resulting from the Emscher re-conversion project for subsequently conducting a cost-benefit analysis. The intended audiences are researchers working on the topic of ESS as well as potential practitioners for the application of the ESS Evaluation Framework.

0.3 Overview of the study area

The Emscher catchment is located on the eastern side of the Rhine River in the federal state of North-Rhine Westphalia (NRW; Figure 1). About 2.2 M people live and work in the Emscher catchment, the so called "Ruhrgebiet", which is one of the most densely populated areas in Europe (Table 1).

The Emscher catchment basin covers 865 m² and belongs to two geographical regions in the Northern Lowlands: Westphalian Lowlands and Lower Rhine Plain. The highest and lowest elevation in the catchment is 150 m above sea level at the Emscher source in Holzwickede, south east of Dortmund and 25 m at the Emscher mouth in Dinslaken, where it meets the River Rhine (Figure 2). The Emscher River is 85 km long and the total length of the stream network within the basin is 341 km. Mean discharge at Emscher mouth is approximately 16 m³/s. The basin is exposed to temperate seasonal climate with maritime influence. Average annual temperatures range from 8.5 and 10.5 °C with mean annual precipitation of 800 mm.

Figure 1: Location of the Emscher catchment within North-Rhine Westphalia, Germany, and Europe.

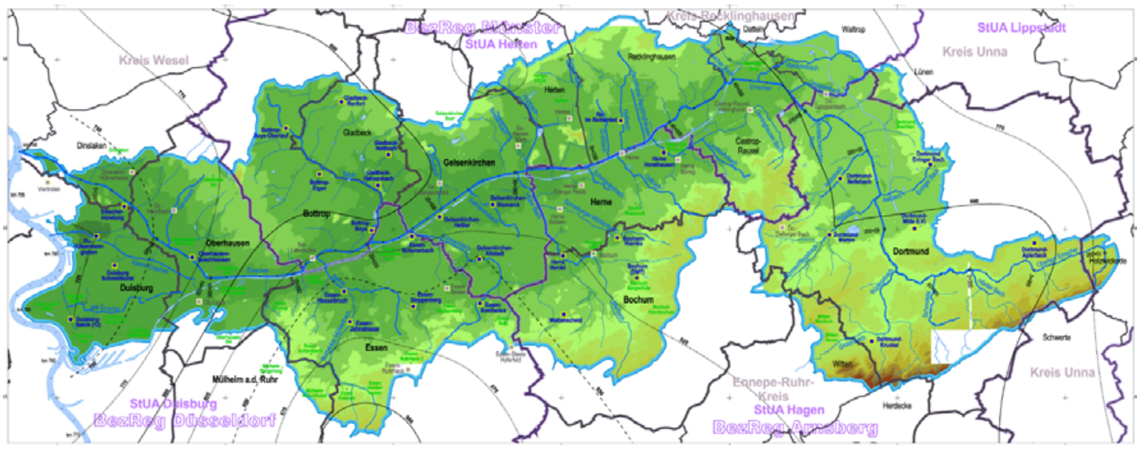


Figure 2: Physical map of the Emscher catchment, colour code for elevation (green: 3-20 m above sea level, brown: 220-257 m above sea level) (source: Hydrotec, Hochwasser-Aktionsplan Emscher, 2004)

Until 1860, the Emscher River was a slow flowing, meandering river (Figure 3) with a length of 109 km from its source in Holzwickede to its discharge into the river Rhine, draining a catchment of approximately 784 km².

The former land use in the Emscher basin was mainly urban settling, coal mining, steel production and steel processing. A shipping channel and a network of roads were built for that purpose.

With the start of industrialization and a rapid urban growth by 1860, the regular inundation of the extensive Emscher floodplains resulted in frequent flooding of the urban and industrial areas close to the river. In addition, the Emscher River received increasing amounts of waste water originating from industry and settlements. Flooding of the contaminated river lead to the spreading of water-borne diseases and epidemics.

Flood defense required coordinated efforts of the municipalities along the Emscher River that founded the Emschergenossenschaft (EG) in 1899, associating individual cities of the Ruhrgebiet, and mining and industrial companies active in the area. The main task of this association was to assure water and waste water discharge and to avoid further flooding, resulting in a straightened and channelized Emscher River. As a result of this first Emscher conversion, the original river length was reduced to 85 km; floodplains were cut off and at the water bodies were lowered by up to 5 m; further actions were channel bed fixation with concrete beds as well as shore embankment.

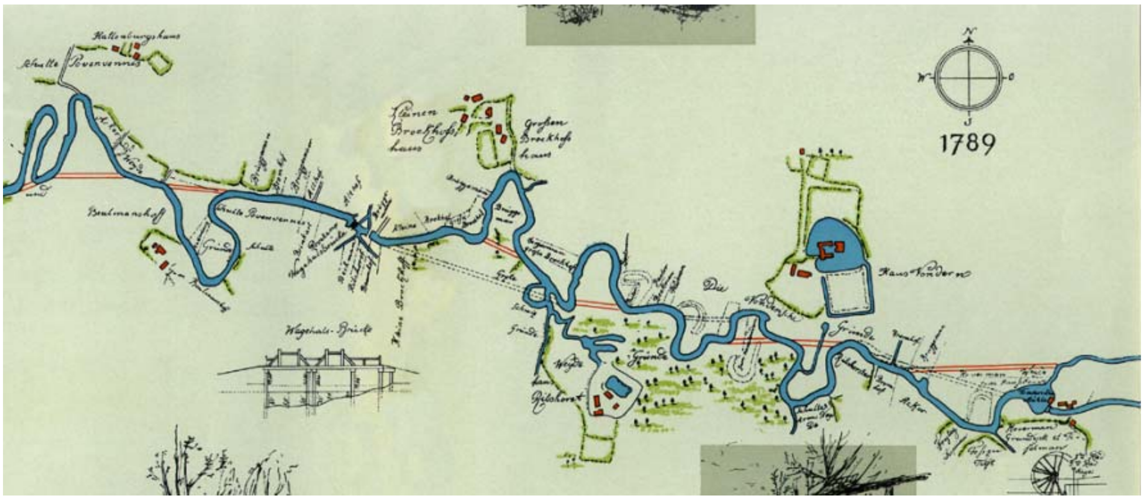


Figure 3: Emscher catchment in 1789

Mining subsidence in the area resulted in depressions of up to 30 m, causing disturbed river discharge and rising groundwater levels. To restore the water flow, pumping stations were built in the entire catchment and the river mouth was relocated northwards to Dinslaken, increasing the catchment size to 865 km². Continuing mining subsidence precluded the use of culverts for wastewater discharge to avoid leakage due to braking pipes. Wastewater was thus discharged in open aboveground channels. Underground discharge, separated from the natural river bed, was not considered possible because subsidence would have caused underground pipes to break.

With ending of the industrial area in the 1960s mining subsidence slowly diminished. By 1990, culverting became feasible again, advancing the planning of the second Emscher conversion or Emscher re-conversion. The aim was to separate the wastewater from the river water, using culverts routing the sewage to wastewater treatment plants (WWTP). Eventually, the original Emscher River and its tributaries should be revitalized.

To date, 40% of the Emscher area is depressed due to mining subsidence. This generates a constant need for controlling the water discharge and groundwater level in the catchment, performed by pumping stations (Figure 4).

Figure 4: Emscher catchment with subsidence areas (yellow) amount to approximately 40% of the catchment area.

Today's land use is a very densely populated area with 17 cities that form one metropole conglomerate. Agriculture is less prominent in this area then in NRW in average; business has shifted towards service companies. A shipping channel in parallel of the Emscher and a network of highways and roads is present. Artificial land cover (incl. urban settlements, industrial areas and transport infrastructure) amounts to ~ %, agricultural land use ~ 18% (incl. pastures and cropland), natural area (incl. 12.5% of forested area) ~ 22% (Emschergenossenschaft 2009). 2.2 M inhabitants live in the Emscher basin with a mean population density of 2,775 inhabitants/km². During industrialization the number of inhabitants in the Ruhr area as increased steeply, however, with high fluctuations. In 2006, 400,000 people less lived in the area compared to 1961. Further decrease in inhabitant number is expected by the Landesamt für Datenverarbeitung und Statistik Nordrhein-Westfalen (LDS NRW) and the Bertelmann-Stiftung (Junkernheinrich et al. 2008). Making up only 2.5% of the area of NRW, the Emscher region achieves 10.5% of NRW's total annual gross value added (MUNLV NRW 2006).

Table 1: Emscher socio-economic data (Source: Emschergenossenschaft 2009)

Area	Data
Catchment area	865 km² (= 2.5% of state NRW)
Population	2.2 M inhabitants
Population per km²	2,775 inhabitants /km²
Artificial land cover	~ 50%
Agricultural land cover	~ 18%
Natural land cover (incl. forested area)	~ 22%

The people in the area are used to avoid the streams in the area since 1900, when the streams turned into a system of open wastewater channels. In a densely populated area, places for local recreation are highly demanded. Therefore, one of the main benefits from the Emscher re-conversion is to re-allow the experiencing of the Emscher River and its tributaries and to bring recreation along waterways back to the people.

Spatial scale of ESS assessment:

The Emscher basin comprises the main Emscher River and its tributaries divided into nine subcatchments. In this study, we selected eleven “focus streams” (Figure 5), i.e. river sections at the Emscher and its tributaries differing in their ecological development potential and in the date of restoration (”age“). The case-relevant key ESS for the Emscher case are evaluated for these focus streams and, in a second step, the results are transferred and scaled up to the entire Emscher catchment.

Upscaling to basin level is conducted via similarity of stream profiles (width, depth, form), based on 5 different profile types.

ESS provision beyond the Emscher catchment area is not assessed (e.g. drinking water provision in the downstream Rhine River).

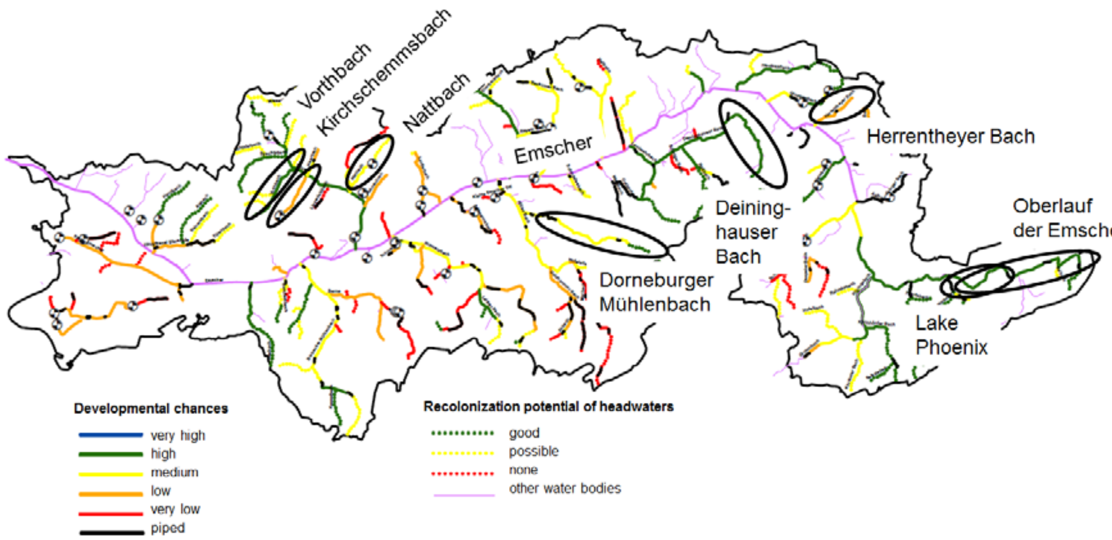


Figure 5: Focus streams within the Emscher basin. Color codes indicate ecological development potential of the streams (Source: Semrau et al. 2007).

Temporal scale of ESS assessment:

The 30-year project Emscher re-conversion started in 1990 and is intended to be completed in 2020. Thus, the Baseline scenario we consider is the scenario “BEFORE” and the scenario after implementation is “AFTER” the Emscher re-conversion.

0.4 Stakeholder list

The following local stakeholders could be identified based on the Description of work of DESSIN. They consist of representatives from governmental and non-governmental organizations, water utilities and water boards, environmental interest groups, business facilitators, water users and others.

- People living in the area
- Recreators (boaters, bikers, walkers)
- Researchers, environmental educators
- Industry (including agro-industry)
- Mining companies
- Industrial forestry
- NGOs
- Water board (= WWTP operator, CSO operator)
- Chambers of commerce
- Industrial memorial tourism

0.5 Terminology

No further additions needed. For abbreviations, see the list of acronyms.

DRIVERS

Step 1. DRIVERS

The challenges in the region are diverse; however, all of them are related to the former mining activities (coal mining, steel production), industrialization, and urbanization. During more than a century, wastewater was transported together with the Emscher surface water in open waste water channels. Both the Emscher and its tributaries were channelized and surrounded by dikes, which turned them into heavily modified water bodies. This is also recognized in the WFD's requirements concerning the Emscher catchment.

1.1 DRIVER: Flood protection

Flood protection – along with the need to discharge wastewater – was the most important driver for the first Emscher conversion, resulting in a manmade open wastewater system. Though the second Emscher conversion aims at renaturalizing the streams, an adequate level of flood protection has to be guaranteed at any time.

1.2 DRIVER: Industry

Industry is an important factor since the 1860s, when coal mining, steel production and steel processing started. Now it has shifted towards service providers.

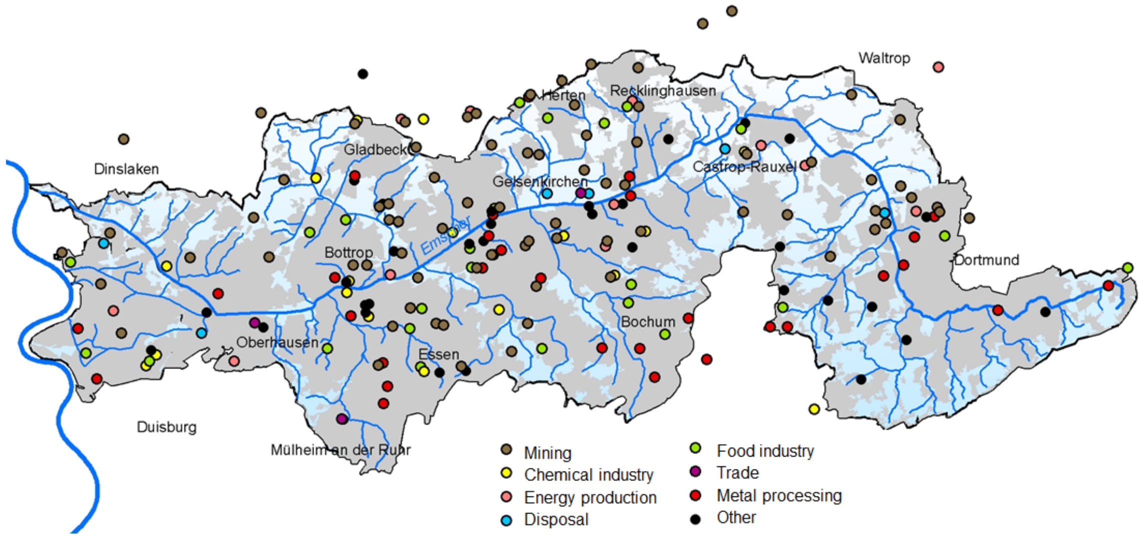


Figure 6: Industry and commerce in the Emscher basin (Source: Emschergenossenschaft 2009)

1.3 DRIVER: Tourism & recreation

Tourism in the Ruhr area is not relevant except for some industrial/cultural heritage sites. Local recreation, however, is very important for the inhabitants of the Emscher cities.

1.4 DRIVER: Transport

A dense network of transport routes through the area shapes the landscape and often run alongside of the Emscher or its tributaries. These include roads, highways, and the most travelled railway route in Germany. Shipping does not take place in the Emscher, however, an artificial shipping channel (the Rhein-Herne-Kanal) was built just alongside the Emscher.

1.5 DRIVER: Urban development

The urban development in the Emscher basin started in the 1860s and the basin is now one of the world's most densely populated areas. About half of the area in the basin is artificial land cover. The respective land use is commonly progressing directly up to the water body environment.

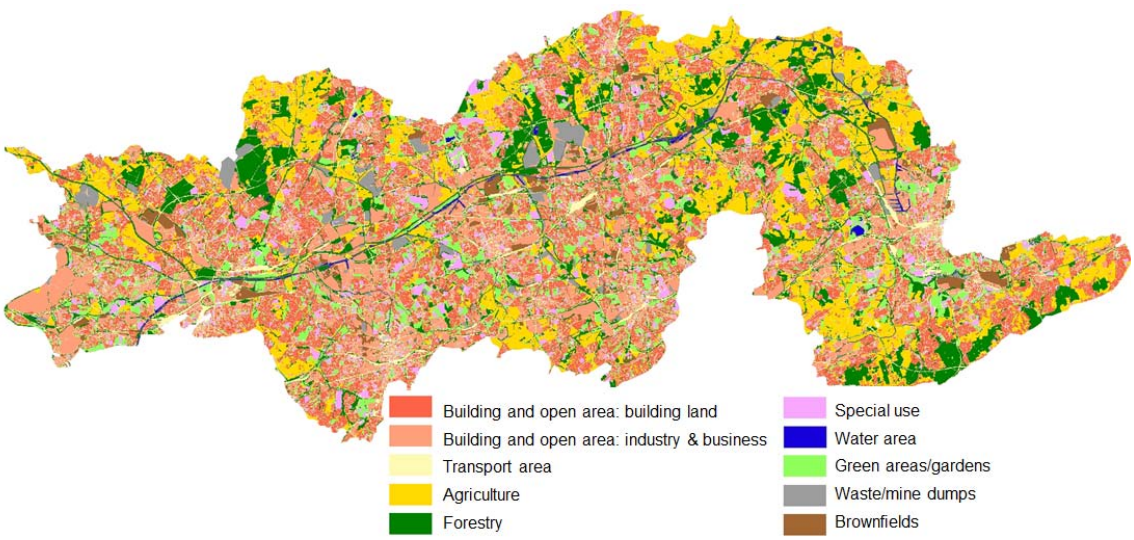


Figure 7: Land use in the Emscher basin. (Source: Landesvermessungsamt NRW 2006)

PRESSURES

Step 2. PRESSURES

The drivers in the Emscher basin as described above, are all strongly linked to and resulting from each other. Subsequently, also the pressures resulting from them are interwoven.

2.1 PRESSURES: Industry, urbanization and transport related pressures

Diffuse sources of industrial pollution can result from run-off following deposition of air emission. Also run-off from roads and sealed surface is to be considered.

However, mainly point sources of pollution are of concern. After completion of the Emscher re-conversion, these point sources will be: 290 CSO facilities and 4 large-scale WWTPs. The volume of waste water disposed in the basin is 0.6 billion m³/a. Due to the dense population and the high variety of industrial branches, the pollution consists of diverse substances. Municipal wastewater consists of mainly an organic carbon load as well as nutrients (nitrogen and phosphorus) but also of pharmaceutical residuals, and pesticides/biocides. Industrial wastewater can contain high loads of hydrocarbons and metals. Mining effluents contain hydrocarbons and metals as well as high chloride loads.

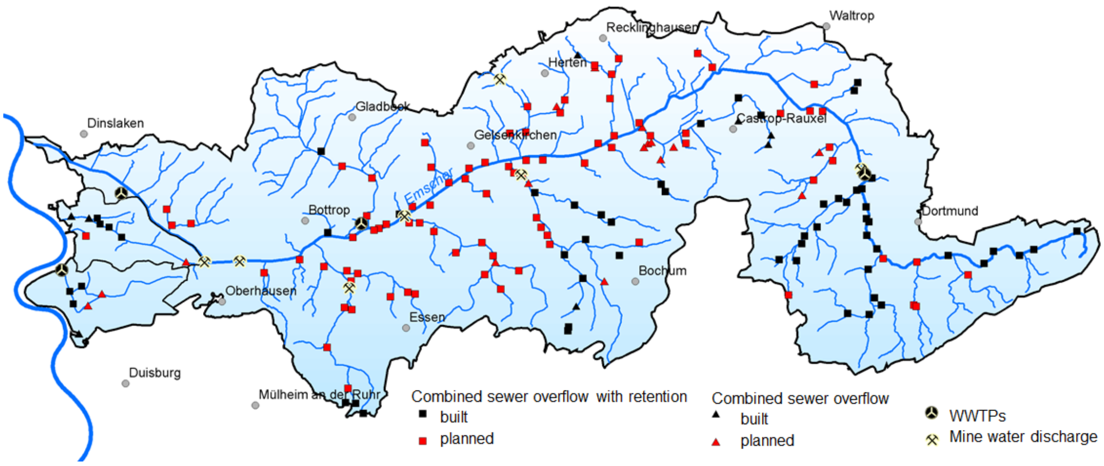


Figure 8: Point sources to the Emscher streams (CSOs and communal WWTPs), status 2008 (Source: Emschergenossenschaft 2009)

Apart from diffuse and point source pollution, the morphology of the landscape was changed in order to create dry area for industry, housing, and transport ways. These drained subsidence areas are assured by a flood protection concept for the entire basin, described in the next paragraph.

2.2 PRESSURES: Flood protection related pressures

The requirement for flood protection in the area led to the decision to channelize the streams and encase them by dikes in the end of the 19th century. This caused an alteration of stream morphology and hydrology. At that time, also pumping stations and other manmade structures were installed to maintain the discharge function of the Emscher and its tributaries, which was disrupted due to subsidence. All these activities resulted in hydromorphological pressures.

PART III – Description of Responses and identification of potential beneficiaries

RESPONSES

Step 3. RESPONSES

3.1 Description of the proposed measure

The re-conversion of the Emscher River and its tributaries is the measure/innovative solution which is being evaluated in this study. It is a restoration project, lasting for 30 years (from 1990 until 2020) and affecting all water bodies in the catchment. The total budget for this multi-site project is 4.5 billion €.

The restoration process consists of two steps:

1st step:

The separation of surface water and wastewater by constructing an underground combined sewer network (with a total of 423 km of sewers) both along the Emscher tributaries and the Emscher River itself. Via this step the water quality is considerably improved.

2nd step:

Subsequently, the Emscher and its tributaries are renaturalized aboveground in their morphology and connectivity. A total of 341 stream km will be restored in the catchment.

As part of this multi-site project, several technologies have been taken up as part of the Emscher re-conversion. These are, e.g.:

- four large-scale energy efficient WWTPs,
- 290 combined sewer storage channels storing large volumes of water during rain events,
- 7 large-scale pumping plants necessary to allow waste water in the future Emscher waste water channel to reach the river Rhine and 121 pumping plants to drain subsidence areas and connect tributaries to the Emscher main stream,
- innovative ideas for flood water retention areas, such as a public lake (Lake Phoenix, Dortmund), a zoo (Zoom, Gelsenkirchen), vegetated basins, secondary floodplains.

A scheme of the Emscher re-conversion process is depicted in Figure 9.

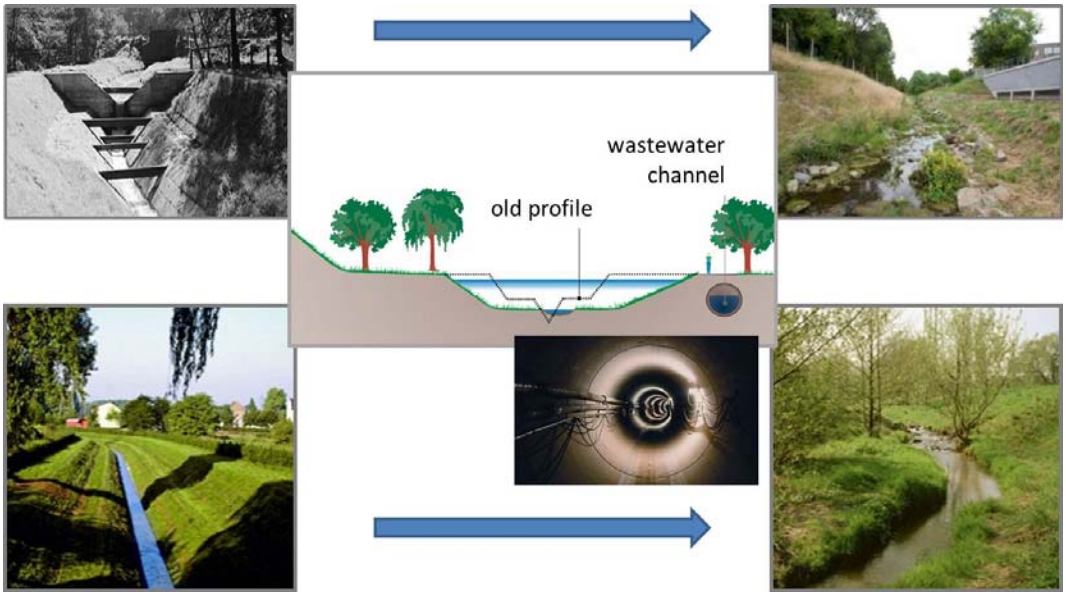


Figure 9: Emscher re-conversion. Left: open wastewater channels in the former river beds before restoration, center: conversion process by building underground wastewater channels and widening the river profile, right: near natural river bed after restoration.

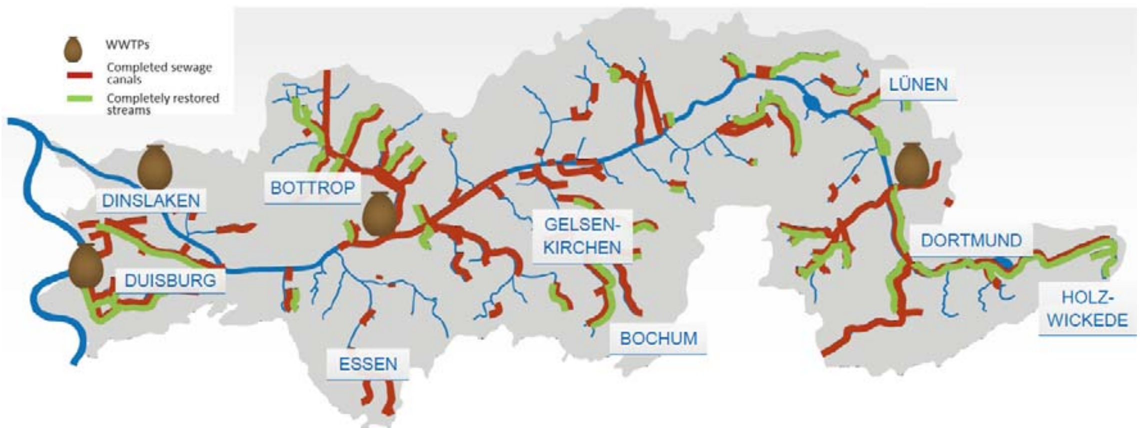


Figure 10: Emscher re-conversion progress, status 2015, showing the two steps: 1st building of sewage system (red) and WWTPs and 2nd restoring streams (green), status 2015.

3.2 Claimed/expected capabilities of the proposed measure

The Emscher re-conversion has the following capabilities:

- Improvement of water quality (tested)
- Reduction in the frequency of overflow events (tested)
    - After the Emscher re-conversion, 290 CSO facilities will exist, able to hold a total volume of combined sewage of 571,826 m³. An area of 200.5 km² (¼ of the catchment) will be drained by the system. Additionally, a volume of 165,000 m³ can be retained inside the sewage channels. This results in a storage capacity of 32 m³/ha.

- Improvement of the physical structure of watercourses (tested)

3.3 Driver, Pressure, and/or State affected by the capabilities

No DRIVERS are affected by the Emscher re-conversion.

However, the following PRESSURES are affected by the capabilities:

- Reduction of point and diffuse pressure

  These pressures can be, for instance, organic or chemical pollution reaching the streams via run-off (diffuse) or from CSO facilities during rain events (point). Also oxygen-depleted effluent from WWTPs to streams is a relevant point pressure.

- Reduction in the frequency of overflow events

  Combined sewer overflow events represent point sources at which combined sewage is discharged into recipient waters during rain events.

- Mitigation of morphological alteration

  Drivers such as flood protection and urbanization caused straightening and channelizing of streams, representing morphological alterations.

Each of these reduced pressures results in an improvement of various parameters of STATE.

- A reduction of point and diffuse pressures allows for physicochemical conditions within the recipient water bodies coming closer to natural conditions. These physicochemical parameters are, for instance, transparency, thermal conditions, oxygenation conditions, salinity, and nutrient conditions. Also the concentrations of hazardous substances discharged into the water body are reduced via a reduction of this pressure.

- A reduction in the frequency of overflow events also represents a reduction of a point pressures, in this case, from CSOs. As a result, the same physiochemical parameters as mentioned above are affected.

- A mitigation of morphological alteration affects the hydromorphology of streams, bringing hydrology and morphology closer to the natural state. Hydrology reflects the parameters water quantity, the dynamics of water flow as well as water residence time. Morphology is concerning depth and width variation in a water body, the structure and the substrate of a stream bed as well as the structure of the shoreline.

All capabilities also positively affect biological parameters of STATE, e.g. the occurrence and abundance of macrophytes and phytobenthos, and similarly, aquatic communities of benthic invertebrates and fish.

Furthermore, all capabilities result in improved cultural parameters of STATE. These parameters are, for instance, human appreciation and interest or dislike and concern in relation to water, vegetation, fish and wildlife, odor, noise and infrastructure as well as the presence of other people.

3.4 Case-relevant ESS

Case relevant ESS are expected to be changed as an effect of the Emscher re-conversion's capabilities on Pressures and State. The case-relevant ESS identified for the Emscher case are listed in the Annex (Table Step 3.4). These represent all ESS from the CICES classification (Haines-Young, Potschin 2013) that are hypothetically changed due to the proposed measure.

Step 4: Identification of expected beneficiaries of the changes introduced by the proposed measure

4.1 Comparison of case-relevant ESS with potential beneficiaries and FESS

Following the DESSIN Cookbook, all final ESS (FESS) that correspond to the case-relevant ESS selected in Step 3.4 are selected from Landers, Nahlik (2013) (Annex, Table Step 4.1). Each of the identified FESS is listed together with the respective beneficiaries (Landers, Nahlik 2013).

4.2 List of stakeholders (Part I) compared to list of beneficiaries (US EPA)

Finally, based on list of stakeholders (Part I), we identified those beneficiaries actually present in our study area. These are:

- Residential Property Owners
- People who care
- Boaters
- Experiencers and Viewers
- Researchers
- Educators and Students

There is no Drinking Water Treatment Plant in the Emscher basin which could benefit from water provision for drinking. There are also no industries which use the Emscher water for non-drinking purposes. Thus, there are no direct beneficiaries for provisioning services (water provision) in the Emscher region. As the Emscher River is a tributary of the Rhine River it contributes to drinking water provision in the downstream Rhine catchment area. This ESS provision, however, is beyond the spatial scope of the present assessment.

4.3 Categorization of case-relevant ESS into Intermediate ESS and final ESS

Combining the output of 3.4 and 4.3 results in the list of ESS below. Which *Intermediate ESS* might be preconditions for *final ESS* is shown by arrows.

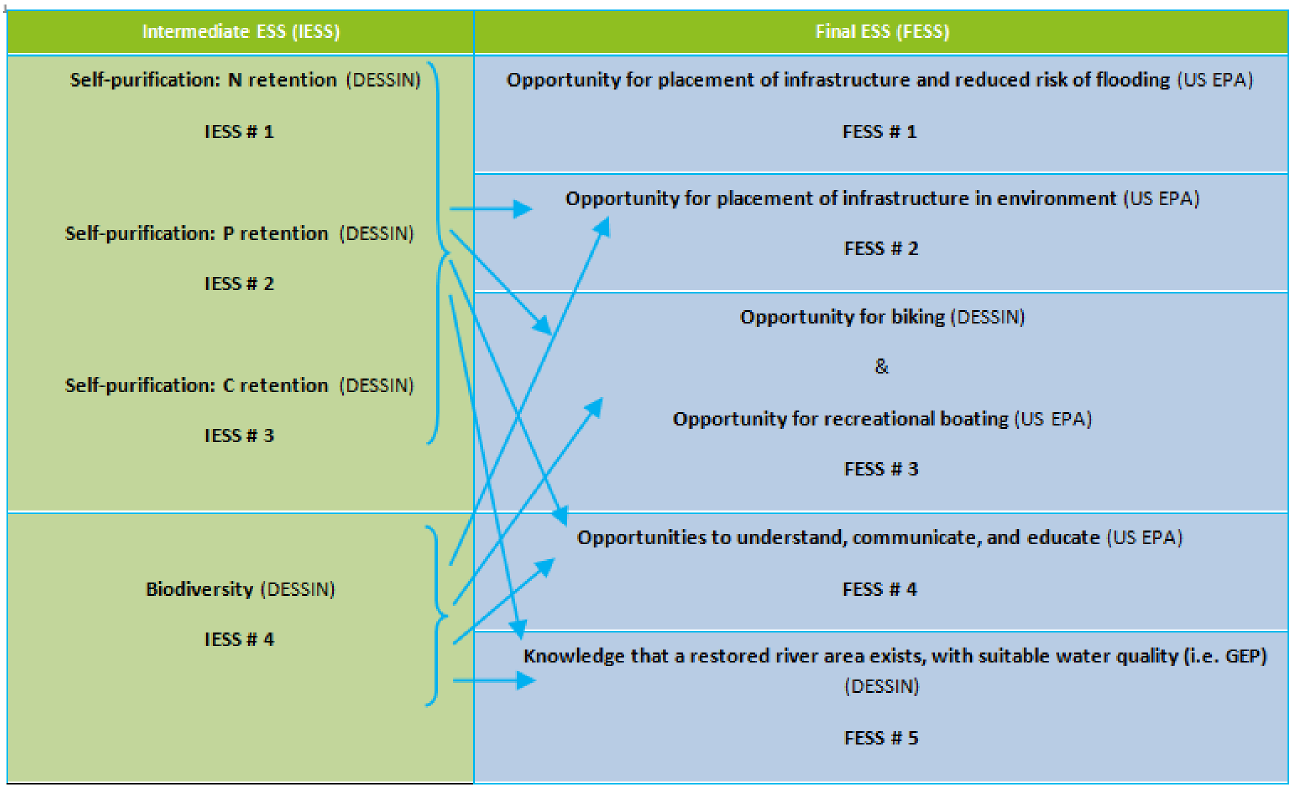


Figure 11: Key Intermediate ESS (Regulating & Maintenance ESS, green) and final ESS (Cultural ESS, blue) relevant for the Emscher mature case that are to be evaluated. Arrows show the links between IESS and FESS.

These *Intermediate ESS* and *final ESS* will be assessed. IESS that are case relevant but are not assessed are CO_2 sequestration (Global climate regulation by reduction of greenhouse gas concentrations) and Local climate (Micro and regional climate regulation). Similarly, a FESS not assessed is: Research opportunities (Educational). These ESS are only discussed qualitatively.

5. STEPs 5, 6, 7 and 8

For each of the case-relevant ESS mentioned above, the STEPS 5, 6, 7 and 8 are conducted one after the other. In STEP 5 parameters hypothetically affected by the proposed measure were identified. In STEP 6 indicators for quantifying Impact I Provision were selected. In STEP 7 appropriate economic methods for assessing Impact II - Use and resulting benefits were chosen. Finally, in STEP 8 a quantification of the expected changes in State, Impact I and Impact II before and after implementation of the measure was conducted. The identified parameters, selected indicators and economic methods, and the respective results are presented and discussed below for each ESS.

Note that for all IESS, the evaluation process stops after the Impact I Provision assessment, because no direct beneficiary within the study area could be identified. Thus, there is no use of this ESS by humans and, therefore, also no change in human well-being (i.e. no resulting benefit).

For FESS, on the other hand, beneficiaries are present in the area and are using the services which are provided by the ecosystem. Therefore, a use and a benefit could be assessed. Note, however, that for FESS we could not assess the Impact I Provision by the ecosystem. Furthermore, FESS are dependent on the provision of IESS but this dependency could not be quantified.

Regarding the results of the quantitative IMPACT II assessments it shall be noted, that no complete aggregation of the different calculated economic figures was pursued. This is due to the fact that the results partly express figures with different “economic meanings”. So by simple means their direct unadjusted aggregation is theoretically incorrect, since different economic evaluation methods have been used for each calculation. The aggregation would need a careful interpretation and adjustment process which was out of scope of this mature case study. For additional information on this topic it shall be referred to the explanations in Step 7 of the DESSIN cookbook and in chapter 5 of the companion document.

5.1 IESS # 1: Self-purification: N retention

The Regulating & Maintenance service “*Nitrogen retention*” is provided by a denitrification capacity of streams (A) and floodplains (B). This denitrification service is conducted by bacterial communities on the surface of and within the sediment/soil. Nitrifying bacteria transform ammonium (NH_4+) to nitrites (NO_2-), and subsequently, the nitrites to nitrates (NO_3-). Denitrifying bacteria then transform nitrates to atmospheric nitrogen (N_2). This process leads to a removal of the nutrient nitrogen from the river water. It takes place at the water-sediment interface in the river itself (A) and at the land-water interface of the floodplain during flooding (B). Thus, the process mainly depends on the wetted or potentially wetted surface. In the floodplain, the soil type is also important, as the second part of the process is occurring under anaerobic conditions only. The initial N concentration in the water is of importance when a final N concentration is to be obtained or a load removal is to be calculated.

As part of the Emscher re-conversion, stream profiles are widened and secondary floodplains are connected (Figure 12). This increases the stream bed area (A) and also provides a larger water-sediment surface where N turnover can place. Furthermore, on the enlarged water-sediment and land-water surface vegetation can grow, holding back P and C from the river water (see 5.2 and 5.3).

Figure 12: Emscher re-conversion at the Borbecker Mühlenbach. left side: technical state, middle: directly after restoration, right side: two years after restoration (Source: Johann, Frings 2016).

In the Emscher basin, this self-purification process does not have a direct beneficiary, as there are no stakeholders in the Emscher catchment directly using the water for drinking or non-drinking purposes. Drinking water provision in the downstream Rhine catchment is beyond the scope of the study.

This Intermediate service, however, is important for providing a number of Cultural services in the catchment, specifically, FESS # 2-5. The reason is that a better water quality promotes the recreational use of the water bodies (FESS # 3) and also the attractiveness of the water environments for housing (FESS # 2), for education and research (FESS # 4), etc. Self-purification is an important ecosystem function which gives a stream the capability to quickly recover from occasional and short term pollution events, e.g. from CSO emissions. Furthermore, it enhances the capability to further improve water quality after discharge points from WWTP. This ecological function needs to be in place in order to achieve the good ecological potential (GEP) in a water body. FESS # 5 covers this aim of achieving the GEP.

5.1.1 STATE (IESS # 1)

Methods

The parameters

- water-sediment surface area (in-stream, i.e. in the river bed) and
- area of land-water interface (in the floodplain without the river bed)

have been derived for A) stream beds, B) floodplains, and C) vegetated basins (see Annex), respectively.

For A, the water-sediment surface has been obtained from stream profiles (Source: EG, planning data) extracted from hydrological models (Jabron, Hydrotec). The profiles' wetted surface area, projected water surface area and volume are calculated based on stream geometry of single sections, the length of these sections as well as their inclination and water level. The profiles of the open wastewater channels (BEFORE) and the restored streams (AFTER restoration) could be compared (Figure 13).

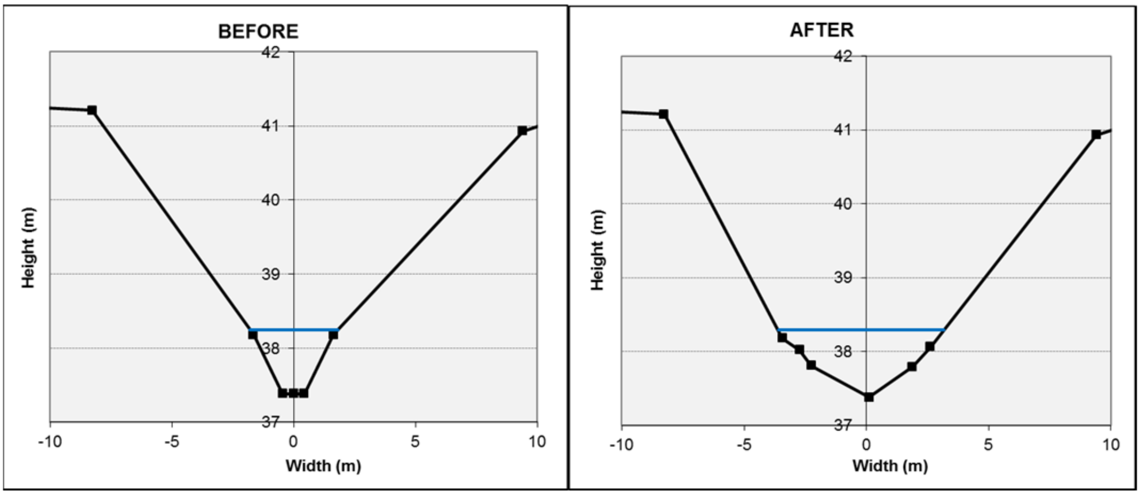


Figure 13: Excerpt from Excel-Tool showing stream profiles and calculating in-stream wetted surface (water-sediment surface), projected surface (water surface area) and volume based on stream bed profiles BEFORE and AFTER the Emscher re-conversion (Source Excel tool: UDE, data source: EG)

For B, the land-water interface is derived from the actual floodplain in the Emscher area, which we defined as the area that is statistically flooded every 50 (or 100) years, mapped in GIS (Geographical Information System) as HQ50 lines (or HQ100, in case no HQ50 line is mapped) (Data source: UDE, EG; Figure 14). Furthermore, land use was identified for these areas, acting as a proxy for soil type.

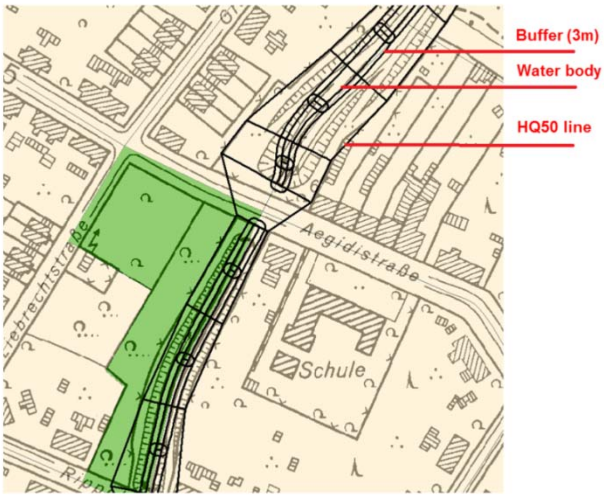


Figure 14: Excerpt from GIS map on stream location, floodplain (HQ50) area, and land use within the floodplain (Data source: EG, UDE).

Furthermore, initial N concentration, specifically NH_4N which represents the ecologically most relevant and predominant part of nitrogen in the water, was obtained from monitoring campaigns (Data source: EG, UDE).

All parameters of State were assessed for the DESSIN focus streams and then scaled up to basin level according to similarity of stream profiles.

Results & discussion

BEFORE the conversion, the total in-stream wetted surface (A) in the Emscher catchment was considerably smaller than AFTER (Figure 15).

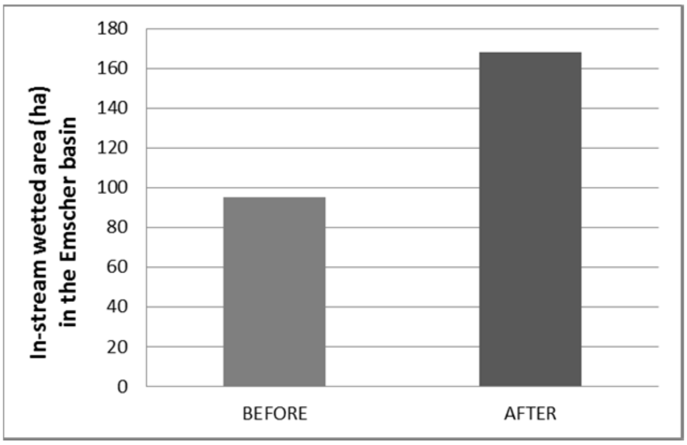


Figure 15: In-stream wetted area in the Emscher basin BEFORE and AFTER the restoration (Data source: EG)

For part of the streams in the Emscher basin, the land-water interface in the floodplain (B) does not change due to the restoration while for another part of the streams it increases. This results in an overall increase of the potentially wetted surface in the floodplains of the Emscher basin (Figure 16). This information was derived from the ecological development potential evaluated for each water body in the Emscher basin (Semrau et al. 2007; Semrau et al., internal documents 2013). Land use within the HQ50 areas changed from 75% grassland, 20% woodland, and 5% concrete bed (EG, expert opinion) to 45% grassland and 55% forested area (derived from land use data for the DESSIN focus streams, UDE). Thus, the overall area increases as does the proportion of forested area due to a decrease of grassland area. Further information can be obtained from the Annex.

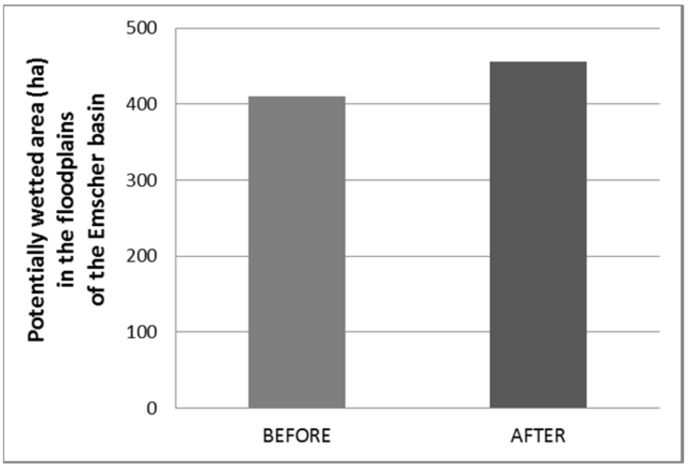


Figure 16: Potentially wetted area in the floodplains of the Emscher basin BEFORE and AFTER the restoration (Data source: EG)

The results show that the potentially wetted area in the floodplain is approx. 4 times larger than the wetted in-stream area and approx. 8 times larger than the projected surface area in-stream (Figure 21). Note, however, that the area in the floodplain is not constantly wetted but only occasionally.

5.1.2 IMPACT I - Provision (IESS # 1)

Based on the State parameters and standard denitrification rates obtained from literature, two indicators for Impact I Provision have been developed:

A) Potential denitrification in-stream

B) Potential denitrification in the floodplains (i.e. without the river bed)

A) Potential denitrification in-stream

Methods

The instream N retention was calculated based on stream bed profiles (Figure 13) and literature values (according to Niemann 2001) on denitrification rates. Calculations were conducted in an Excel-tool (Figure 17) developed by UDE. The Excel-tool is a simplified water quality model. It allows estimating the turnover of carbon and nutrients (N, P) in a given river reach. The results provide a rough estimation of the self-purification capacity for aerobic river systems.

To assess the potential N turnover BEFORE the restoration, we applied a standard concrete bed profile (Figure 13, left side). Upscaling from four DESSIN focus streams to the entire Emscher basin was done according to similarity of stream profiles. Further details can be obtained from the Annex.

In-stream retention of N, P, and C

Time	Geometry	
	wetted surface	volume
[d]	[m²]	[m³]
1	6,321	3,384

(green)	editable
(blue)	calculated
(yellow)	final result
(grey)	headdings

Initial concentration		
COD [mg/l]	N [mg/l]	P [mg/l]
14.02	0.02	0.02
meanCOD	meanNH4	meanPtotal

Initial load		
COD [g]	N [g]	P [g]
47450.50	67.69	81.23

Mass Transfer		
COD [g/(m²*d)]	N [g/(m²*d)]	P [g/(m²*d)]
1.20	0.003	0.01

Retention per day and section		
COD [g/(d)]	N [g/(d)]	P [g/(d)]
7585.59	18.96	4.55

Retention per hour and section		
COD [g/(h)]	N [g/(h)]	P [g/(h)]
316.07	0.79	0.19

Loads after transfer (1h)		
COD [g]	N [g]	P [g]
47134.43	66.90	81.04

Concentration		
COD [mg/l]	N [mg/l]	P [mg/l]
13.93	0.02	0.02

Retention per meter		
COD [g/h*m]	N [g/h*m]	P [g/h*m]
0.1	0.0	0.0
[g/h*km]	[g/h*km]	[g/h*km]
135.77	0.34	0.08

Figure 17: Excerpt from Excel-Tool modeling in-stream retention of N, P, and C based on stream bed profiles, initial concentrations and retention rates obtained from literature (Source Excel tool: UDE, data source: EG).

Results & discussion

Figure 18 shows the in-stream N turnover in one year scaled up to the entire Emscher basin based on the DESSIN focus streams. We detected an increase from 1.04 t to more 1.84 t of NH_4N eliminated from the water body per year.

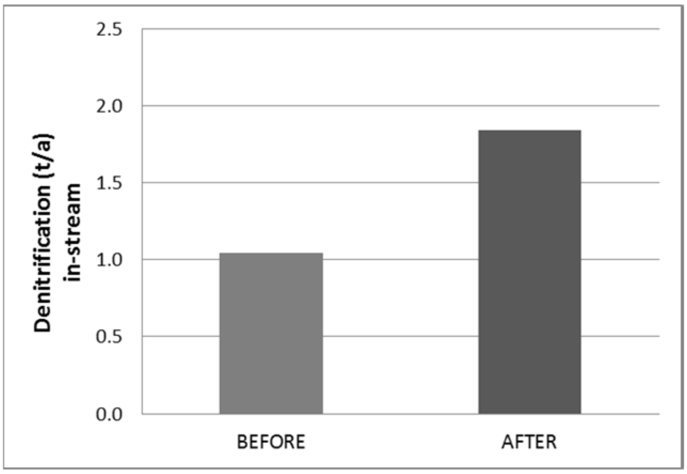


Figure 18: Total in-stream N turnover in the basin BEFORE and AFTER the Emscher re-conversion. The calculation is based on stream bed profiles and literature values on denitrification rates (Source Excel tool: UDE, data source: EG).

B) Potential denitrification in the floodplains

Methods

The calculations of indicator B are based on the land-water interface represented by the HQ50 areas along the streams (Figure 14). Subsequently, we applied a rule of thumb based calculation using literature values on denitrification rates for different soil types according to Scholz et al. (2012). Soil types were derived based on land use types. N turnover was estimated for each of the DESSIN focus streams, based on the area of a certain soil type and the specific denitrification rate for this soil type. Upscaling to the entire Emscher catchment was conducted according to the similarity of stream profiles. For the potential N turnover BEFORE the restoration, we applied an average standard land use within the HQ50 area (EG, personal communication), being: 75% grassland, 20% forest, and 5% concrete surface. Grassland and forest area was conservatively assigned the soil type with the lowest denitrification rate. Further details can be obtained from the Annex.

Results & discussion

The total N turnover in the floodplain increased from BEFORE to AFTER (Figure 19), which is due to the increased land-water-interface area (Figure 16).

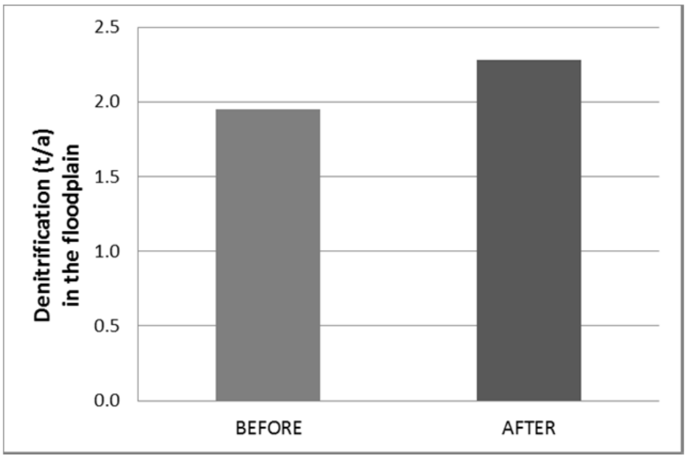


Figure 19: N turnover in the total floodplain of the Emscher basin BEFORE and AFTER the Emscher re-conversion. The calculation is based on the HQ50 areas and literature data on denitrification rates (Source Excel tool: UDE, data source: EG).

We showed that the level of the total in-stream N turnover in the Emscher basin is comparable to the total turnover in the floodplains. The total in-stream wetted surface area (Figure 15) is only about a quarter of the total floodplain area (Figure 16). However, the denitrification rates we applied for in-stream turnover (Niemann 2001) are twice as high as those applied for the floodplains (Scholz et al. 2012). This is reasonable, as denitrification within the stream takes place constantly, while denitrification in the floodplain occurs only under anaerobic soil conditions during flooding. In total, similar N turnover for the in-stream process and the process in the floodplain are obtained. In both cases, turnover AFTER the reconversion is higher than BEFORE.

The combined N turnover in streams and in the floodplains sums up to 2.99 t/a BEFORE and 4.12 t/a AFTER the reconversion.

5.1.3 IMPACT II – Use & resulting benefit (IESS # 1)

There is no direct beneficiary, and thus, no direct use and resulting benefit for this Intermediate Regulating & Maintenance service. It is a prerequisite for final Cultural services. FESS # 2-5 are reflecting the use and the resulting benefits from this service as outlined in the introduction of the present chapter 5.1.

If appropriate beneficiaries were in place, economic methods that could be applied are e.g. opportunity costs (i.e. avoided treatment costs) by drinking water treatment plant operators or comparative treatment costs in WWTPs.

Uncertainty

It has to be pointed out that both methods described above rely on values on retention rate obtained from scientific literature. No field measurements of specific retention rates in the streams investigated were available.

The wetted surface calculation based on stream bed profiles seems to be quite an accurate method. The floodplain area, on the other hand, is derived from the HQ50 lines, which is the area statistically flooded once in 50 years. Parts of this area are flooded more regularly. Information on e.g. the HQ1 area was, however, not available.

Thus, the methods represent only a rough estimate of the complex progresses happening in the ecosystem. A number of simplifications had to be accepted (e.g. the wetted surface area derived from profiles does not consider the additional surface increase due to sediment instead of concrete bed) and estimations to be made (e.g. concerning land use before the re-conversion). Also seasonal differences (i.e. temperature dependency) and the dependency of the turnover rate on the initial concentration were disregarded.

Note also that we did not assess the nutrient retention in the vegetated basins. These act as artificial floodplains in the Emscher catchment and will, thus, have a considerable share in nutrient retention.

Also the methodology for upscaling the results from the focus streams to the entire Emscher basin is related to some uncertainty, as we upscale according to similarity of stream types (5 types, all streams categorized via expert knowledge) weighted by stream length.

To validate our results, we compared them to those obtained by Scholz et al. (2012) who assessed N, P, and C retention for the 25 rivers with the largest floodplains in Germany. Their results reveal e.g. for the floodplains of the Ruhr an N retention of approx. 250 t/a and for the Lahn of approx. 100 t/a. As they have considered the denitrification taking place both in the floodplain and the river, we also need to combine our results on denitrification in stream and in the floodplain. This sums up to 4.12 t/a (AFTER). It has to be considered that the Ruhr basin with 4,485 km^2 is considerably larger than the Emscher catchment and that it has extensive floodplains for drinking water provision by bank filtration. Considering this, the results obtained here are in a similar range as those assessed by Scholz et al. (2012).

5.2 IESS # 2: Self-purification: P retention

The Regulating & Maintenance service "*phosphorous retention"* is a result of the retention of particle-bound phosphorous by macrophytes in streams (A) and of the retention of particle-bound phosphorous by vegetation in floodplains (B). The in-stream process takes place at the area covered by macrophytes (Figure 20), while the process in the floodplain takes place at the land-water interface during flooding. In-stream (A), the projected surface (i.e. the water surface as seen from above) as well as the initial total P concentration in the water are of importance when a final P concentration is to be obtained or a load removal is to be calculated. In the floodplain (B), the land use is applied as a proxy for vegetation types within the potentially wetted area.

Figure 20: In-stream growth of macrophytes in the Oberlauf der Emscher and vegetation in the secondary floodplain.

During the Emscher re-conversion, where stream profiles are widened and secondary floodplains are created, both the water surface area and the land-water interface are enlarged, increasing the P retention capacity.

Similarly as N retention, P retention does not have a direct beneficiary in the Emscher catchment. Therefore, the evaluation does not go beyond the Impact I Provision assessment. P retention, however, is also an important IESS for providing FESS # 2-5.

5.2.2 STATE (IESS # 2)

Methods

Similar as for N retention, the parameters

- projected in-stream surface area and
- area of land-water interface (in the floodplains, without the river bed)

were evaluated for A) stream beds, B) floodplains, and C) vegetated basins (see Annex), respectively, using the same methods as reported in 5.1.2.

Furthermore, initial P concentrations, specifically total P, were obtained from monitoring campaigns.

Results & discussion

BEFORE the conversion, the in-stream projected surface area was considerably smaller than AFTER (Figure 21).

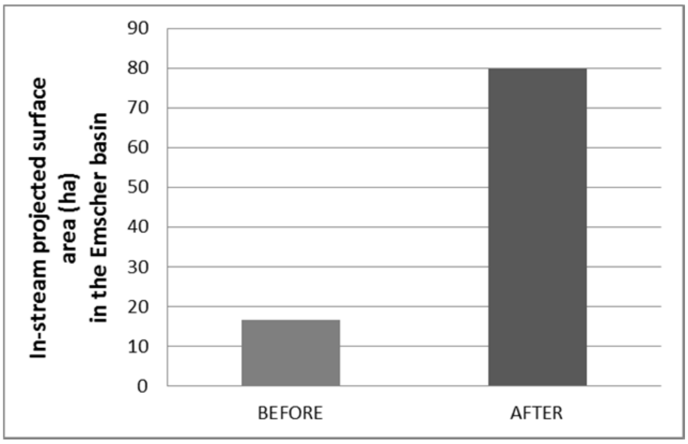


Figure 21: In-stream projected surface area in the Emscher basin BEFORE and AFTER the restoration (Data source: EG)

5.2.2 IMPACT I - Provision (IESS # 2)

Similar as for N retention, two indicators for Impact I Provision have been developed:

A) Potential P retention in-stream

B) Potential P retention in the floodplains (i.e. without the river bed)

All of the indicators are based on the State parameters mentioned above and standard P retention values obtained from scientific literature (for explanations see Annex).

A) Potential P retention in-stream

Methods

Indicator A was calculated based on stream bed profiles and retention rates reported in literature. The calculations were conducted in the Excel-tool as described in 5.1. A macrophyte cover of 80% or 20% was assumed for restored streams (AFTER) with high and low macrophyte growth, respectively. For unrestored streams (BEFORE), we assumed a cover of 5% resembled by growth of algae. Literature data was derived from Scholz et al. (2012).

Upscaling to catchment level and evaluating the retention BEFORE the restoration were also conducted as described in 5.1. Further details can be obtained from the Annex.

Results & discussion

The in-stream P retention increased from 0.88 t per year BEFORE the restoration to 4.23 t per year AFTER (Figure 22). This positive effect is due to a larger stream bed surface as well as a larger surface of macrophytes available for particulate P retention after the reconversion.

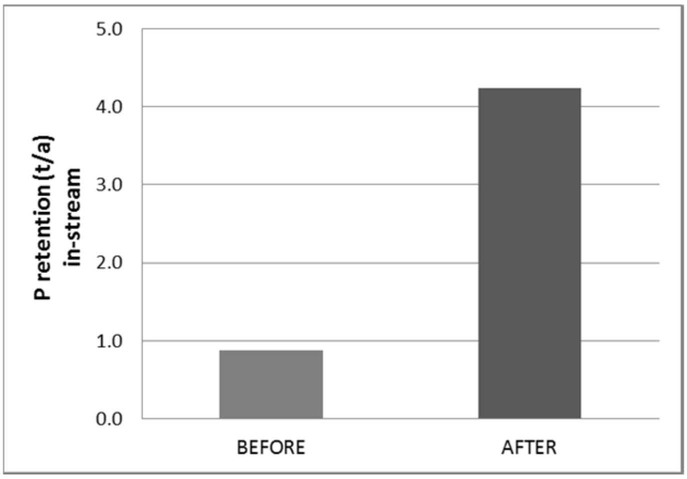


Figure 22: Total in-stream P retention in the Emscher basin BEFORE and AFTER the Emscher re-conversion. Calculation based on stream bed profiles and literature data on P retention rates (Source Excel tool: UDE, data source: EG).

B) Potential P retention in the floodplains

Methods

For the calculation of indicator B, we applied a rule of thumb based calculation using literature data on P retention rates for different land use types according to Scholz et al. (2012). Land use type is applied as a proxy for vegetation type. P retention was estimated for each of the DESSIN focus streams, using the area of a certain vegetation type and the specific P retention for this vegetation type. Upscaling to the entire Emscher catchment was conducted as for N retention. Further details can be obtained from the Annex.

Results & discussion

Total P retention in the floodplain increased from 0.66 to 1.41 t per year (Figure 22), resulting from the increase in the part of forested area within the HQ50 area.

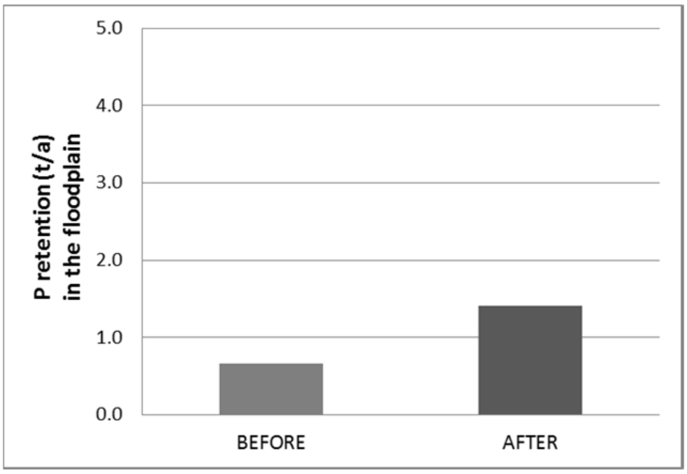


Figure 23: Total P retention in the floodplains of the Emscher basin BEFORE and AFTER the Emscher re-conversion. The calculation is based on the HQ50 areas and literature data on P retention rates (Source Excel tool: UDE, data source: EG).

The results indicate that P retention in the streams happens in a similar range as in the floodplains. Even though in-stream retention rates are reported to be 10 times higher than in floodplains, the projected surface area we identified is 8 times smaller than the floodplain area. In total, a similar retention level can be observed. In both cases, retention AFTER the reconversion is higher than BEFORE.

The combined P retention in streams and in the floodplains sums up to 1.54 t/a BEFORE and 5.64 t/a AFTER the reconversion.

5.2.3 IMPACT II – Use & resulting benefit (IESS # 2)

There is no direct Impact II for this service, as it is an Intermediate service. It is also a prerequisite for the final Cultural services FESS # 2-5.

Uncertainty

The methodological constraints are similar as for N retention. Furthermore, not all relevant processes could be assessed. For instance, in reality P elimination from the water column occurs not only via retention of particulate P but also via uptake of dissolved P into the macrophytes (for biomass). Due to a lack of literature data on uptake rates per area of macrophyte growth, however, the latter process could not be considered in our calculations. Thus, we only consider the particle-bound P held back by macrophytes on the stream bed and by vegetation in the floodplain. Note that even though this leads to a removal of P from the water column, accumulation in and potential resuspension from the sediment will occur.

To validate the results, we compared them to those obtained by Scholz et al. (2012) for the 25 rivers with the largest floodplains in Germany. P retention in the Ruhr and Lahn basins account for approximately 10 t/a. This includes retention in the floodplain and retention along the shoreline of the rivers. The values obtained are again comparable to the combined P retention in-stream and in the floodplains assessed for the Emscher basin. These add up to 5.64 t/a. These results are also in a similar range.

5.3 IESS # 3: Self-purification: C retention

The service of organic carbon retention investigated in this study is subdivided: The C retention process assessed in streams (A) is provided by biofilms via uptake for biomass (growth) and energy supply (respiration), while the process evaluated in the floodplain (B) resembles carbon stock in the soil (underground) and in vegetation (aboveground). The in-stream process takes place at the water-sediment surface while the process during flooding takes place at the land-water interface. In-stream, the wetted surface as well as the initial C concentration in the water are relevant parameters. In the floodplain, the potentially wetted surface area and its soil type are of importance, as well as land use as a proxy for vegetation types.

Similarly to N and P retention, we expect an increased C retention capacity in sections where stream profiles are widened and secondary floodplains are developed (i.e. where the restoration is completed).

5.3.1 STATE (IESS # 3)

The relevant parameters of State are adopted from 5.1.1 and 5.2.1, being

- water-sediment surface area (in-stream, i.e. in the river bed) and
- area of land-water interface (in the floodplain, without the river bed).

Furthermore, initial C concentrations, specifically mean values of total organic carbon (TOC) transferred by a correlation factor to chemical oxygen demand (COD), were obtained from monitoring campaigns.

5.3.2 IMPACT I - Provision (IESS # 3)

Again, two indicators for Impact I Provision have been developed, one for the in-stream process and one for the process in the floodplain:

A) Potential C retention in-stream

B) Potential C stock in the floodplains (i.e. without the river bed)

A) Potential C retention in-stream

Methods

The in-stream method applied for C retention is similar as for N and P retention with specific carbon retention rates from scientific literature (Niemann 2001).

Results & discussion

The in-stream C retention per year scaled up to the entire Emscher basin (Figure 23) shows an increase in C retention from 416.4 t/a BEFORE restoration to 736.06 t/a AFTER the restoration due to an increase in the wetted surface area.

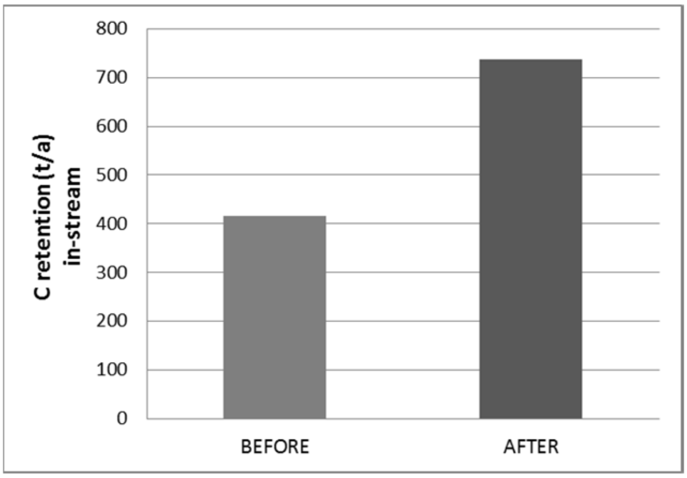


Figure 24: Total in-stream C retention in the Emscher basin BEFORE and AFTER the Emscher re-conversion. The calculation is based on stream bed profiles and C retention rates obtained from literature (Source Excel tool: UDE, data source: EG).

B) Potential C stock in the floodplains

Methods

This indicator is based on organic carbon stock values for different vegetation types according to Cierjacks et al. (2010), defined as "Total C stocks aboveground and belowground". We used the values reported for softwood and meadows (grassland). The specific C stock was determined for each focus stream. Upscaling to catchment level was conducted as for N and P retention.

Results & discussion

Total above and belowground carbon stock in the floodplain increases by 38 megatons (Figure 24), resulting from the larger floodplain area (HQ50 area) and a larger part of forested area within the HQ50 area AFTER re-conversion.

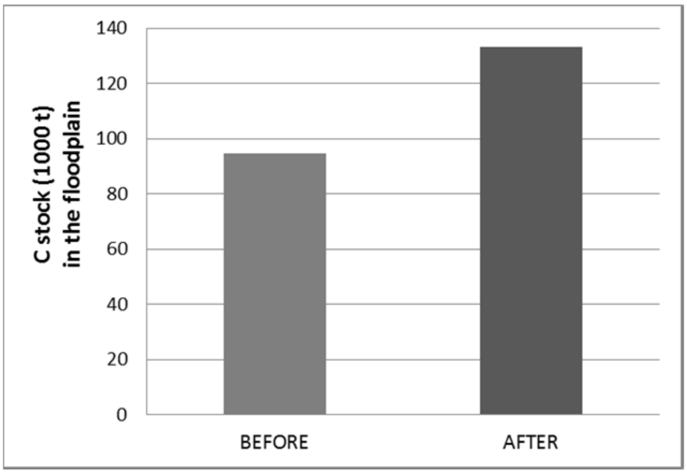


Figure 25: Total C stock in the floodplains of the Emscher basin BEFORE and AFTER the Emscher re-conversion. The calculation is based on the HQ50 areas and literature data on C retention rates (Source Excel tool: UDE, data source: EG).

With regard to carbon, in-stream C retention in the Emscher basin cannot be compared to the C stock in the floodplains. The first process describes a retention rate per year, while the second represents the existing C stock above and below ground. The two processes cannot be summarized.

5.3.3 IMPACT II – Use & resulting benefit (IESS # 3)

As all self-purification services, carbon retention is also an intermediate service and a prerequisite for FESS # 2-5.

Uncertainty

The methodological differences in this case are similar as for N and P retention.

The relatively high C stock of 133,160 t determined for the entire Emscher basin (168 ha, AFTER) is due to high literature values on C stock (Scholz et al. 2012) for the land use/vegetation types grassland and woodland.

5.4 IESS # 4: Biodiversity

Biodiversity is an important IESS for Cultural services but also for other Regulating & Maintenance services. It is based on the availability of habitats and is reflected by biological communities of bacteria, algae, macrophytes, macroinvertebrates, fishes, etc. in rivers. Concrete endpoints for macroinvertebrates are for instance: the number of different taxa, the number of red list taxa, and indicators such as the ecological status of a river. Biodiversity as a Regulating & Maintenance service does not have a direct beneficiary, however, it is part of the provision of final Cultural services – in our case these are FESS # 2-5.

5.4.1 STATE (IESS # 4)

The State of an ecosystem under study can be described by the

- number of different habitats (not assessed).

5.4.2 IMPACT I - Provision (IESS # 4)

For the assessment of Impact I Provision we applied proxies, being standard measures of biodiversity in ecology. We focus on aquatic macroinvertebrate communities, not taking into consideration algae, macrophytes, fishes or terrestrial plants and animals. The indicators we applied were:

A) Taxa richness/ number of species

B) Number of red list species (i.e. endangered aquatic macroinvertebrate species)

C) Saprobic index (i.e. an indicator of the level of organic pollution, based on the composition of the macroinvertebrate community)

D) Assessment of the ecological potential according to the EU Water Framework Directive

The biological indices reported below are derived from monitoring data (Source: EG, UDE). The stage AFTER is derived from monitoring results in restored streams at various stages (1 to 18 years) after restoration. The time after restoration (1-2 years versus 3-9 years versus <10 years), however, did not have a significant influence on taxa richness at the streams sampled. For this reason, only the two stages BEFORE and AFTER are reported. BEFORE values are derived from three monitoring campaigns at the unrestored Emscher main stream.

A) Taxa richness/ number of species

The number of aquatic invertebrate taxa rose from an average of 9 to 18 species per sample between BEFORE and AFTER the re-conversion (Figure 26).

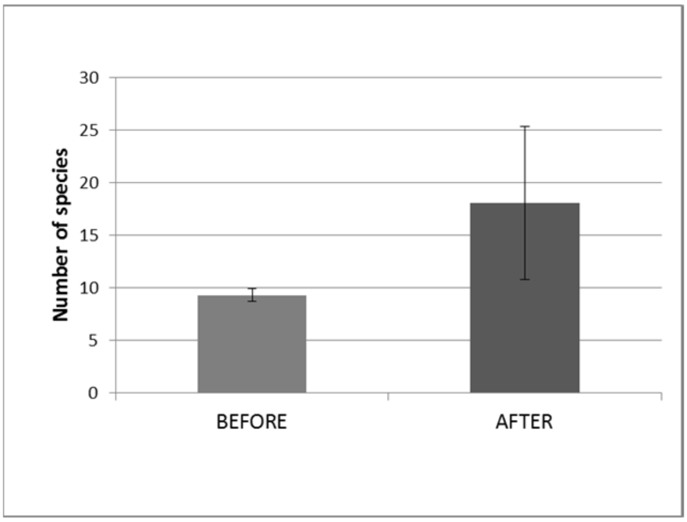


Figure 26: Taxa richness, given as average number (with standard deviation) of aquatic macroinvertebrate species at sampling sites in the DESSIN focus streams BEFORE and AFTER restoration (Data source: EG, UDE).

B) Number of red list taxa

No red list taxa of aquatic invertebrates were found BEFORE the restoration, while a maximum of four red list species were present at the sites sampled AFTER the restoration (Figure 27).

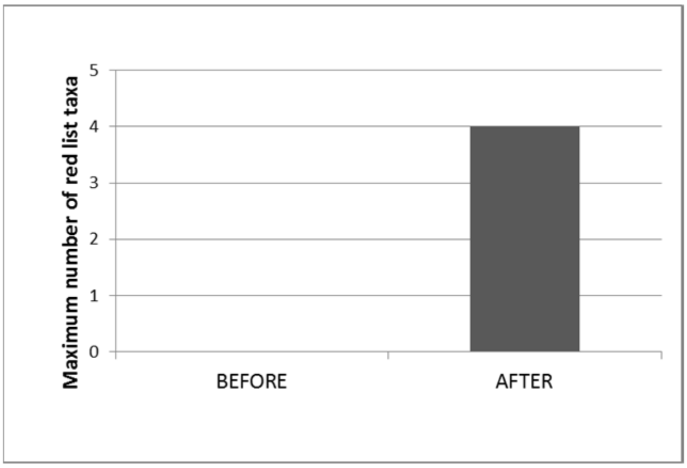


Figure 27: Maximum number of red list taxa occurring at sampling sites in the DESSIN focus streams BEFORE and AFTER restoration (Data source: EG, UDE).

C) Saprobic index

The Saprobic index (SI) is reported as ecological quality ratio (EQR). The EQR standardizes biological quality values (Rolauffs et al. 2002; Birk, Hering 2006). The calculation is conducted according to the formula based on the Saprobic index derived from the composition of the aquatic macroinvertebrate community:

EQR_{SI} =1 – ((observed SI value - reference SI value) – (maximum SI value - reference SI value)) An EQR value of one represents (type-specific) reference conditions and a value close to zero indicates a bad ecological status. The EQR AFTER the restoration is considerably closer to 1 than the EQR BEFORE (Figure 28).

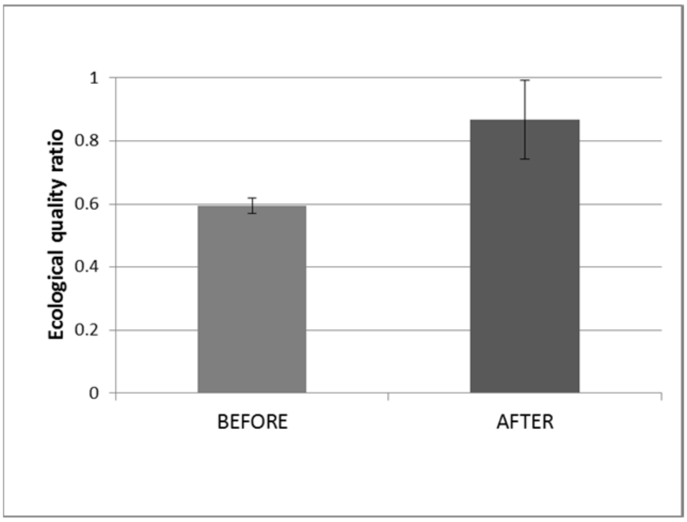


Figure 28: Ecological quality ratio on the Saprobic index based on the composition of the aquatic macroinvertebrate community occurring at sampling sites in the DESSIN focus streams BEFORE and AFTER restoration, with standard deviation (Data source: EG, UDE).

D) Ecological potential

The ecological potential (Döbbelt-Grüne et al. 2015) at the stage BEFORE restoration has not been monitored in tributaries of the Emscher but only in the main stem. Nevertheless, we adopted bad potential for all streams in the Emscher basin for the BEFORE stage, as all unrestored streams were in fact open wastewater channels with a concrete bed and sewage water (except for short upstream sections in a few tributaries) (Figure 29).

We categorized the streams' ecological potential according to the ecological potential determined in the latest monitoring campaign. When several sites were sampled in one stream and did not show the same ecological potential, the most representative site was selected via expert opinion.

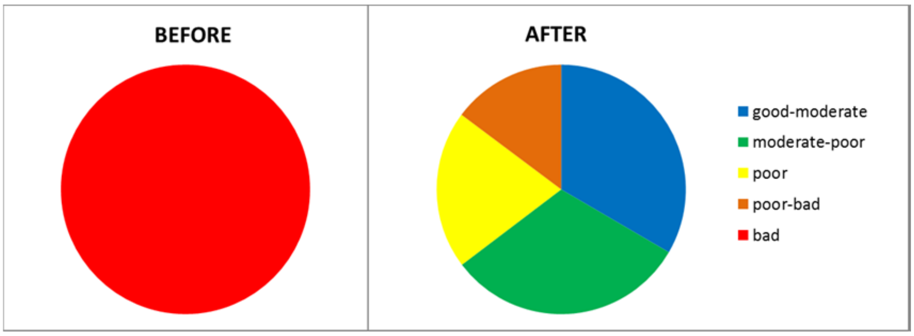


Figure 29: Ecological potential of the Emscher basin BEFORE and AFTER restoration. Fractions are plotted in km of total stream length (297 km) (Data source: EG, UDE).

5.4.3 IMPACT II – Use & resulting benefit (IESS # 4)

Similarly as the Regulating & Maintenance service self-purification, also biodiversity is an intermediate service, however, with high importance for the provision of the final Cultural services FESS # 2-5.

Uncertainty

Few monitoring results were available on the state BEFORE the ecological improvement of the streams. However, a bad potential and a very poor aquatic invertebrate community (as observed in the Emscher main stream before restoration) can be adopted for all streams before restoration.

Upscaling the results from the focus streams to the entire Emscher basin was only done for the ecological status. As taxa richness, number of red list species, etc. are given as average or maximum, it is more challenging to transfer the results to basin level. Especially since these endpoints depend on diverse factors shaping biological communities, which can hardly be approximated with similarity of stream types. The results for the ecological status are scaled up to basin level according to the similarity of stream types weighted by stream length. Note that in reality, also here further factors than only similarity of stream type determine the community.

5.5 FESS # 1: Opportunity for placement of infrastructure and reduced risk of flooding

Flood protection in the basin is achieved via two approaches:

- Natural water retention is realized by restoration of the streams and their floodplains.
- Technical flood protection is assured via the construction of rain and flood retention basins.

Furthermore, the de-coupling of rainwater from the combined sewage system decreases the amount of water reaching the sewers and the streams.

As the Emscher River length was shorted by 30% during the first Emscher conversion, the discharge rate was augmented accordingly. This fact in combination with a growing subsidence area, gave flood protection a high significance.

Nowadays and due to the intensive anthropogenic utilization of the area, the part of sealed surface in the Emscher basin is extremely high (60%). Thus, during rain events large volumes of rainwater are discharged into the sewers. Also in the streams, rainwater input results in high discharge peaks regarding water level and flow rate. Hardly any natural floodplains were present before the Emscher re-conversion, because the artificial land cover reaches close to the streams. Space restriction is still a major limitation of the re-conversion success (Figure 30).

Figure 30: Low water level and restricted space for the development of the Deininghauser Bach in the city of Castrop-Rauxel.

Where the conditions allow, stream profiles are widened as part of the restoration efforts and secondary floodplains are attached (Figure 31). This increased the retention volume inside the stream bed which can delay the flood wave and reduce the water level (Impact I Provision).

Figure 31: Emscher re-conversion at the Berne (left side: technical state, right side: one year after restoration) (Source: Johann & Frings, 2016).

Additionally, 40% of the Emscher basin is polder area which constantly needs to be protected from flooding. Therefore, technical flood protection is provided through dikes (a total of 129 km of dikes along the Emscher and its tributaries). Pumping stations keep the polder areas dry and flood retention basins (Figure 32) buffer discharge peaks. Rain retention basins serve as additional storage volume for combined sewage in order to delay discharge from CSO facilities into water bodies.

Figure 32: Vegetated flood retention basin Dortmund-Mengede (Source: EGLV Blog).

5.5.1 STATE (FESS # 1)

The following information on parameters of State needed to be obtained for the stages BEFORE and AFTER restoration for later on assessing Impact I Provision:

- stream profiles
- water holding volumes in floodplains (not assessed)
- water holding volumes in basins
- the area at risk of flooding

Furthermore, knowledge on the level of flood protection to be provided throughout the basin as a regulatory threshold was required.

Figure 33 shows the level of flood protection throughout the Emscher basin BEFORE the re-conversion. In the source section, the Oberlauf der Emscher, a level of only HQ20 is required, followed by HQ50 and HQ100 sections. The major part of the Emscher River has a protection level of HQ200. This means that only flood events of the intensity which statistically occur once in 200 years can cause flooding beyond their embanked secondary floodplains. AFTER the restoration, and already completed, all HQ50 sections of the Emscher have an increased flood protection level of HQ100. The central and Western section will continue with a level of HQ200, however, with reduced discharge.

The improvements in the flood protection levels result from the construction of the flood retention basins Lake Phoenix, Mengede and Ellinghausen in the upper Emscher section around the city of Dortmund. Furthermore, a culvert in the Emscher channel downstream of Dortmund Dorstfeld helped improve the flood protection. Note that no changes in height or position of the dikes along the Emscher had to be made.

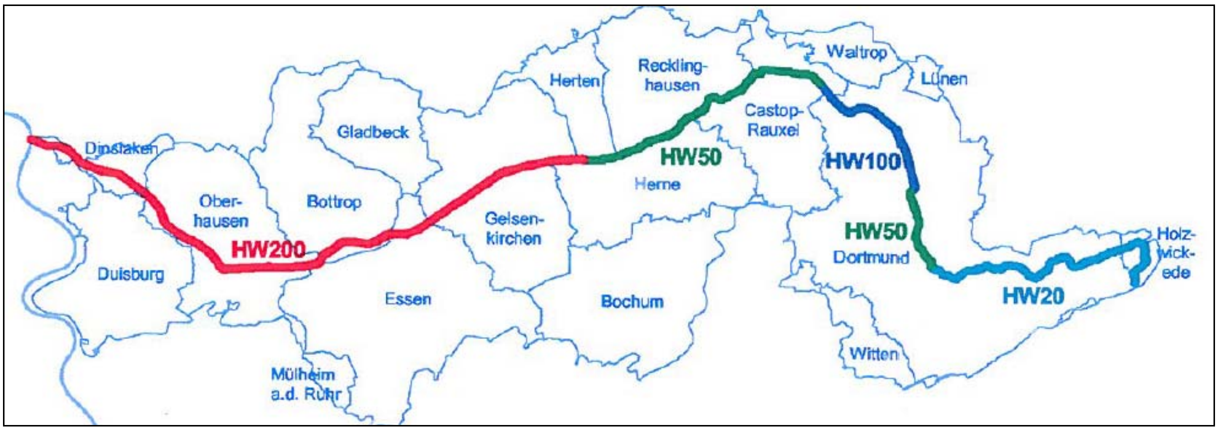


Figure 33: Level of flood protection (HQ) valid BEFORE the re-conversion (Source: Hydrotec 2004).

In case of flood events with an intensity stronger than HQ100 events, the areas along the Emscher marked in turquoise in Figure 34 will be flooded, while the yellow areas will only be flooded in case of dike failure during HQ200 events.

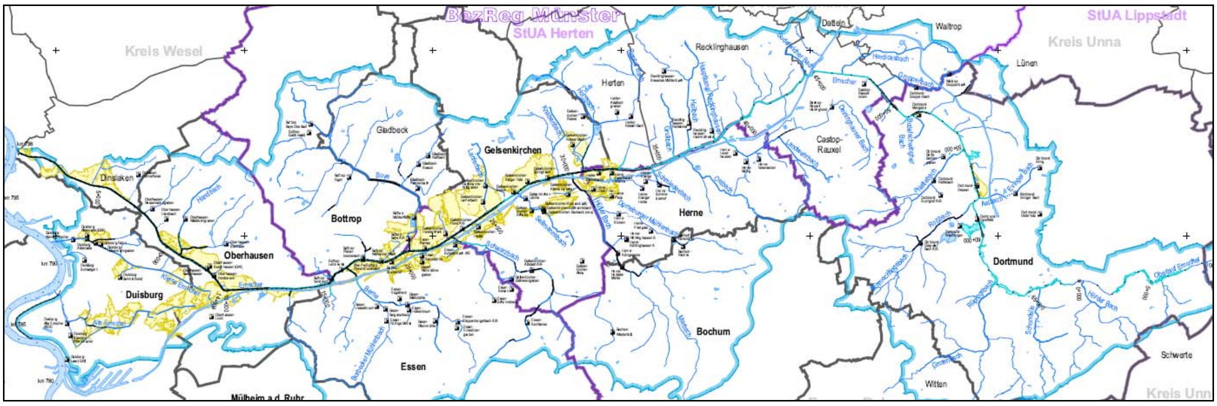


Figure 34: Flooded areas at HQ100 (turquoise) and potentially flooded areas at HQ200 in case of dike failure (yellow) BEFORE the re-conversion (Source: Hydrotec 2004).

5.5.2 IMPACT I - Provision (FESS # 1)

In order to assess the water retaining capacity in the Emscher basin, various indicators were selected:

A) Stream bed's water retaining capacity (not reported)

B) Floodplain's water retaining capacity (not reported)

C) Vegetated basin's water retaining capacity

D) Discharge reduction

C) Vegetated basin's water retaining capacity

One aim of the Emscher re-conversion is also to augment the retention capacity within retention basins in the upper sections of the Emscher in order to lower the flood risk for downstream sections. A total of 23 flood retention basins with a total storage volume of 3.3 M m³ (EG, planning status 2005) are to be in place after the re-conversion (Figure 35). A considerable part of the basins are vegetated and represent nature-based solutions or artificial secondary floodplains with a number of additional benefits. Apart from flood retention, these benefits are: habitat for animals and plants, carbon sequestration via plants, recreational potential for people living in the area, local climate improvement via evaporation and evapotranspiration.

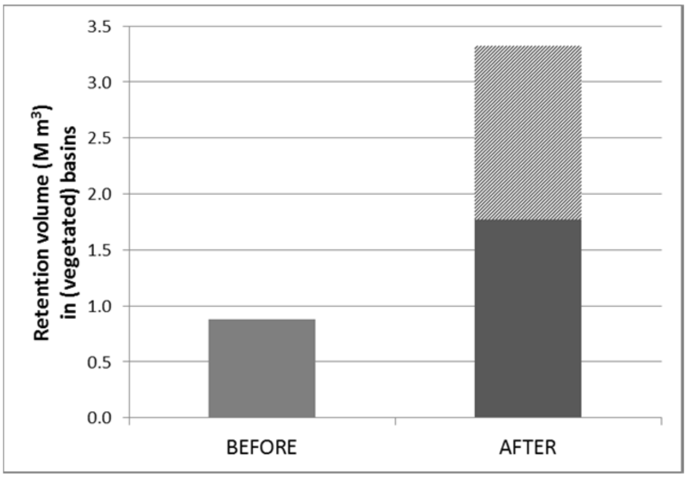


Figure 35: Retention volume inside flood retention basins BEFORE and AFTER the Emscher re-conversion. Fraction of vegetated basins hatched (Data source: Emschergenossenschaft 2014; EG, planning status 2015).

D) Discharge reduction

Method

Empirical discharge data for 60 years (1950-2010) were available from EG. A model for the BEFORE and AFTER status was developed (Beysiegel 2015) for 17 exemplary tributaries and the Oberlauf der Emscher in the program "Timeview 2.5.0". The model was based data records of precipitation, temperature and evapotranspiration, and on two types of stream cross-sections: a near-natural profile and a trapezoidal profile. The near natural profile has a higher retention factor compared to the trapezoidal one due to higher turbulences, higher friction losses, and thus, lower water speed. A number of distribution functions have been calculated (Figure 36) and the distribution which fitted the empirical distribution best was chosen.

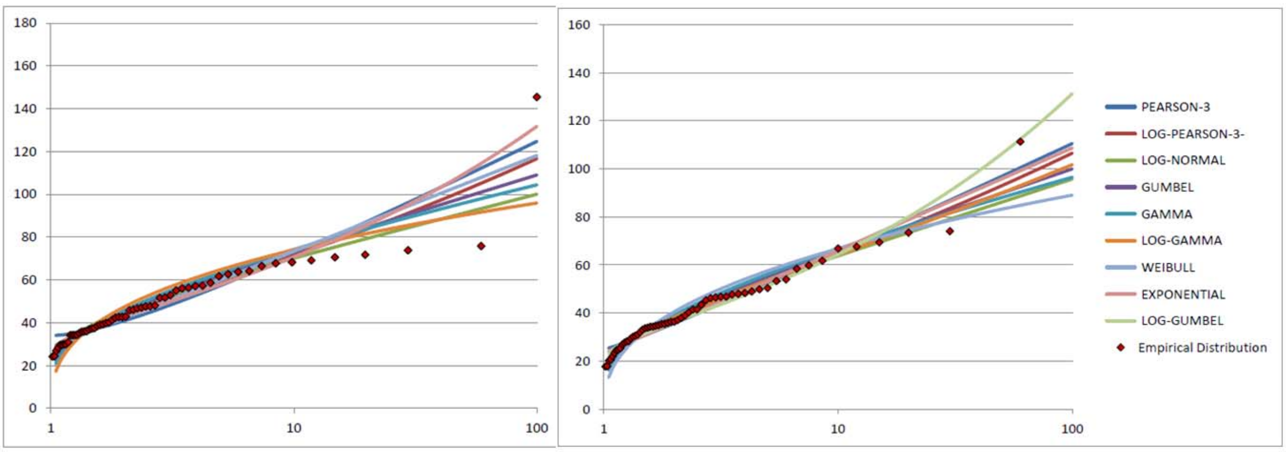


Figure 36: Modelled discharge distribution curves for the Oberlauf der Emscher (Source: Beysiegel 2015).

Results & discussion

The model showed that discharge in the state AFTER restoration was considerably lower for most of the tributaries and the Oberlauf der Emscher (Figure 37). For 100 year events, there was an average decrease of 27% and for 2 year events of 44% from BEFORE to AFTER restoration for the exemplary streams. Note, however, that considering single events, this was not always the case; at times, also higher discharge rates occurred.

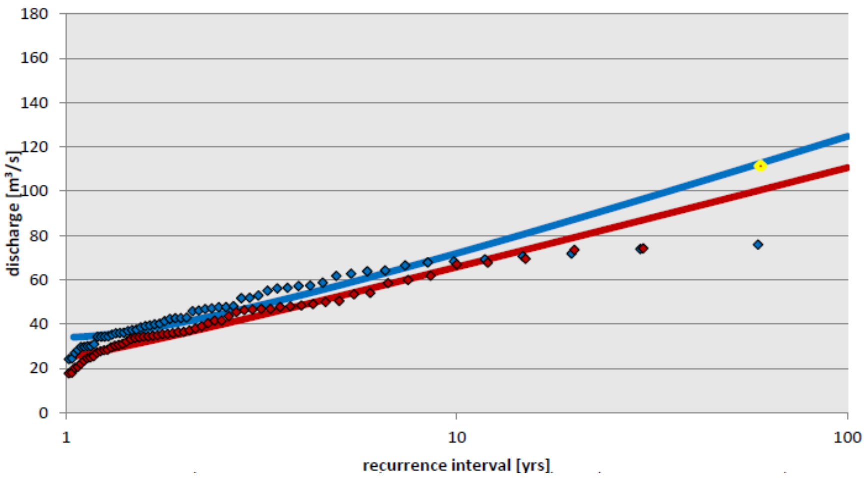


Figure 37: Probability distributions (Pearson-3, solid line) and empirical distribution (dots) for discharges in the Oberlauf der Emscher for the BEFORE (blue) and AFTER (red) for recurrence intervals HQ1 to HQ100 (Source: Beysiegel 2015).

Discharge AFTER the ecological restoration proved to be lower in all exemplary tributaries than BEFORE the restoration for both 100 year and 2 year events (Figure 38).

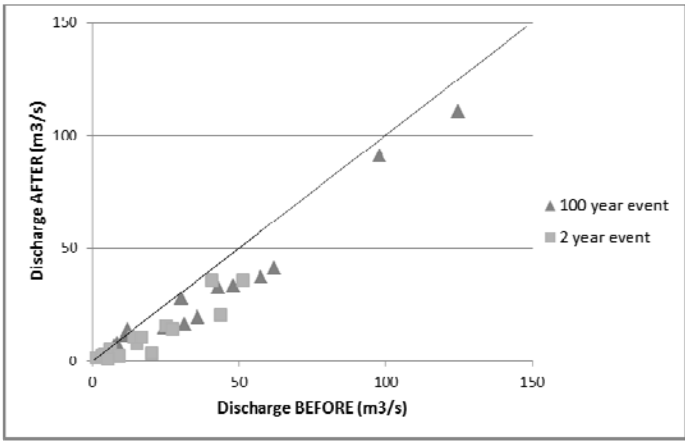


Figure 38: Discharge BEFORE and AFTER during a 100 year and 2 year event for the exemplary tributaries (Source: Beysiegel 2015)

The results for the exemplary tributaries were transferred to the DESSIN focus streams and were scaled up to catchment level by weighting the average discharge with stream kilometers according to similarity of stream profiles. Discharge AFTER was 24% and 43% lower than BEFORE for 100 year and 2 year events, respectively (Figure 39).

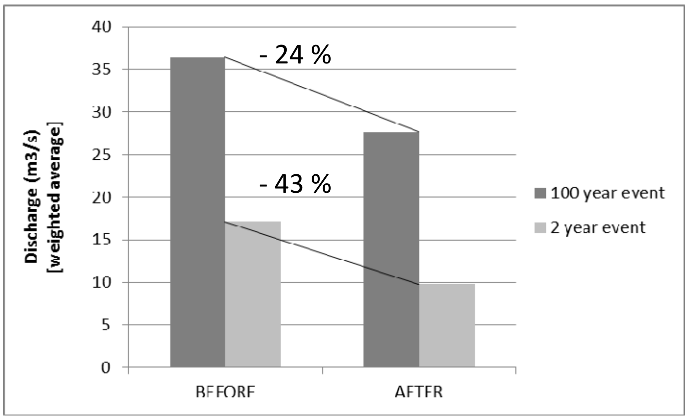


Figure 39: Reduction in average discharge in the basin BEFORE and AFTER for a 100 year and 2 year event, weighted by stream length for the entire basin, based on five focus streams (Data source: Beysiegel 2015).

The model also demonstrated an effect on the Emscher River itself, showing a peak decrease of up to 15% in the Emscher stream AFTER the restoration of the tributaries, i.e. even without the restoration of the Emscher River itself.

5.5.3 IMPACT II – Use & resulting benefit (FESS # 1)

The use of the flood protection service by beneficiaries is equal to its provision, i.e. if a protection level of HQ50 is provided, this provision is also entirely used; similarly with HQ100 or 200.

A monetarization of the benefit is conducted with regard to the avoided costs from flood damage.

Method

In the flood action plan (Hydrotec 2004), the flood damage is assessed concerning flooded areas at HQ100, HQ200, and HQ>500 events. Furthermore, the damage occurring in case of dike failure during flood events stronger than HQ200 and HQ>500 (hence called "potentially flooded areas") was assessed in the flood action plan. Here, flooded areas were identified for different flood scenarios based on the flooding statistics of 1993 and 1995, discharge amounts, water levels for HQ100, HQ200, and HQ>500, and a digital elevation model. Subsequently, damage costs were calculated for objects, cars, land use, and infrastructure by applying damage functions (HOWAS). Also objects especially susceptible to flooding such as industry facilities, power plants, mining sites and underground railways were considered. The damage costs are directly depending on the water level.

A summarization of damage costs of the potentially flooded areas at HQ100 and HQ200 is not possible, because dike failure cannot occur at several spots – or, if it does, there is not enough water to fill several polder areas.

Results & discussion

BEFORE the re-conversion, a HQ100 flood event would have flooded an area of approx. 415 ha. Excluding the area within dikes and the backwater zones of the tributaries, the remaining area accounted for 126 ha, which was almost entirely (123 ha) within the municipality of Dortmund. The estimated damage costs for objects, cars, land use, and infrastructure within this area are about 178 M €. These damage costs were indexed according to the building cost index of the German Federal Statistical Office (Statistisches Bundesamt; category maintenance of residential buildings). The damage costs almost entirely stroke the city of Dortmund with minor costs in Castrop-Rauxel and Recklinghausen and no costs in the remaining basin. For a HQ200 event, the damage costs would have increased by 1.7 M € and at an extreme event (HQ>500) by 7.1 M €. AFTER the re-conversion, these damage costs are avoided due to the measures mentioned above (Figure 40). As by definition the damage costs for a HQ100 event are only expected to occurs once in 100 years statistically, the annual costs avoided are estimated to be about 1.78 M €/a. As discussed in chapter 5.11, climate change effects can result in flood events with a reoccurrence interval of 100 years (i.e. HQ100) to occur more often (e.g. every 80 years). This would, for instance, increase the avoided costs to 2.22 M €/a.

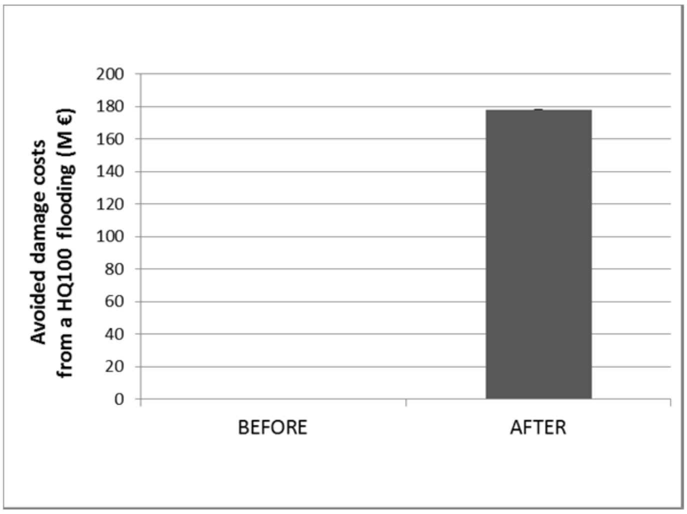


Figure 40: Avoided damage costs from a HQ100 flooding (Data source: Hydrotec 2004).

For the case of dike failure, the damage costs for the time BEFORE the re-conversion for potentially flooded areas at HQ100 and HQ200, can be assessed for single cities. The city districts with the highest estimated damage costs at HQ100 are: Gelsenkirchen Erle (656 M €), Duisburg Alte/Kleine Emscher (489 M €), and Gelsenkirchen Karnap (434 M €). For a HQ200 event, the costs account for 764 M €, 553 M €, and 449 M €, respectively. Also here, the damage costs were indexed. A summarization of the damage costs for various cities is not valid, as outlined above.

Currently, no data are available for damage costs in potentially flooded areas at HQ100 and HQ200 for single cities AFTER the re-conversion; they are currently investigated.

Uncertainty

In the assessment of discharge reduction, it has to be noted that the retention effect observed in the models is due to the combination of technical flood protection and natural retention: the construction of rain and flood retention basins and the ecological restoration. The single effects could not be partially assessed.

Note also that in the estimation of avoided damage costs, economic follow-up costs in the consequence of flood events are not taken into account.

5.6 FESS # 2: Opportunity for placement of infrastructure in environment

This final Cultural service describes how the attractiveness/aesthetics of a landscape/environment influences the prices for buildings with a view on these landscapes. The provision (Impact I) of an environment suitable for placement of infrastructure can either be assessed using landscape aesthetics metrics or by considering a number of intermediate services that act as preconditions for such a suitable environment. In our case these are the IESS # 1-4. Landscape aesthetics were not assessed, as not all information was available.

In the Emscher case, we have identified two beneficiaries for service "*Opportunity for placement of infrastructure in environment*":

A) Resources-dependent businesses (cafés and restaurants) and

B) Residential property owners.

Therefore, we will focus on the use (Impact II) of this service in terms of

A) Commercial places with view on restored river and

B) Flats/houses with view on restored river.

Both types of use can be monetized with the willingness to pay (WTP) for commercial places or flats/houses, respectively. For the assessment, we adopted results of the rwi study (Barabas et al. 2013) and the price increases they detected throughout the New Emscher valley.

Figure 41: Creation of Lake Phoenix (left: steel processing plant at the area of Phoenix East, center: Phoenix East area after plant dismantling, right: completed creation of Lake Phoenix) (Source: EGLV, Hans Blossey)

5.6.1 STATE (FESS # 2)

As this FESS relies on the provision of several intermediate ESS, it also depends on the parameters of STATE that were assessed for these IESS. The State parameters to be assessed for the IESS "*Self-purification potential (N, P, C)*" were reported in 5.1.1, 5.2.1, and 5.3.1, and those for the IESS "*Biodiversity*" in 5.4.1. The Landscape aesthetics metrics (not assessed) relies on a number of single parameters of State. For a list of these single parameters see Factsheet FESS # 2 and # 3 in the Annex.

5.6.2 IMPACT I - Provision (FESS # 2)

The FESS "*Opportunity for placement of infrastructure in environment*" relies on the provision of several intermediate ESS:

- *Landscape aesthetics*
- *Self-purification potential (N, P, C)*
- *Biodiversity.*

Note that a quantitative link between Impact I assessed for IESS # 1-4 and Impact II assessed for FESS # 1-5 is not possible. As there is a multitude of factors that influence prices of real estates and the appreciation of an environment, no direct link can be drawn. However, we assume that a river environment which has a high self-purification capacity and can deal well with occasional pollution via CSO events is visually cleaner, shows less turbidity, less smell, less signs of eutrophication such as mass growth of algae or the creation of foam, and accordingly, is more attractive to people.

5.6.3 IMPACT II – Use & resulting benefit (FESS # 2)

The quantification of the use of the service is represented by A) the commercial and B) the housing area and the resulting benefit is analyzed for the two different types of beneficiaries A) Resources-dependent businesses (cafés, restaurants) and B) Residential Property Owners.

The monetization of the "*Opportunity for placement of infrastructure in environment*" was calculated by hedonic pricing via two methods, presented below. The first method focused on the already restored Lake Phoenix area and covers both types of beneficiaries, while the second method focused on residential property owners in the entire New Emscher Valley.

Method 1

The benefit assessment focused on Lake Phoenix with no consideration of the remaining basin. Data were obtained from the City of Dortmund, the Chamber of Commerce and Industry, the Statistical Bureau, and an online real estate portal. In the use assessment, the area of commercial or housing places was applied as indicator for demand for working or living space, respectively. The monetary benefit arising from this is given in € rent/cost per year for the direct Lake Phoenix surroundings.

A transfer of these results to the entire Emscher basin is not appropriate, as similar restoration projects as the creation of Lake Phoenix are currently not planned. If they were to be realized in the future, similarly positive effects on real estate and rental prices as around Lake Phoenix can be expected.

Results & discussion of method 1

A) Resources-dependent businesses (cafés, restaurants)

As this method focusses on Lake Phoenix, which did not exist until its creation and flooding in 2010, the BEFORE values for use and benefit account for 0.

The area of commercial places with view on the created Lake Phoenix and the Oberlauf der Emscher flowing along the lake is presented in Figure 42 and the subsequent assessment via hedonic pricing in Figure 43. Data on the used area was obtained from the City of Dortmund. For the monetary evaluation we obtained the number of restaurants along the lake shore, the rental cost for commercial area, and the yearly turnover per restaurant (Data sources: German Chamber of Commerce and Industry, German Federal Statistical Office).

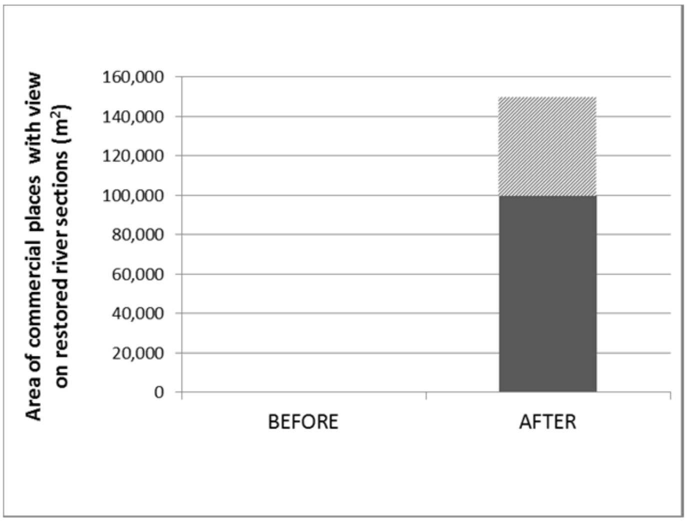


Figure 42: Area of commercial places with view on the created Lake Phoenix and the Oberlauf der Emscher. The range of results based on different assumptions is hatched (Data source: City of Dortmund).

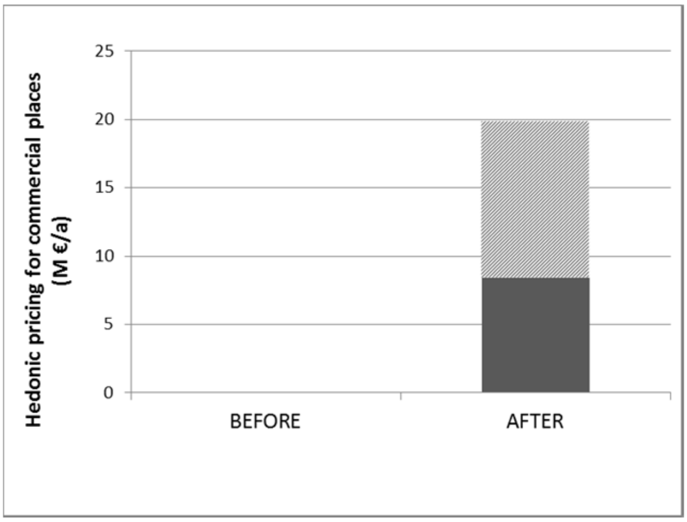


Figure 43: Hedonic pricing method applied to commercial places with view on the created Lake Phoenix and the Oberlauf der Emscher. The range of results based on different assumptions is shown hatched (Data source: German Chamber of Commerce and Industry, German Federal Statistical Office).

B) Residential Property Owners

Similarly as for resources-dependent businesses, also for residential property owners we assume use and benefit at Lake Phoenix BEFORE its creation to be 0.

The area of flats and houses with view on the created Lake Phoenix and the Oberlauf der Emscher flowing along the lake is presented in Figure 44 and the assessment via hedonic pricing in Figure 45. Again, the used area is obtained from the City of Dortmund; the monetization was conducted based on the rental cost for housing area from the online real estate portal "wohnungsboerse.net".

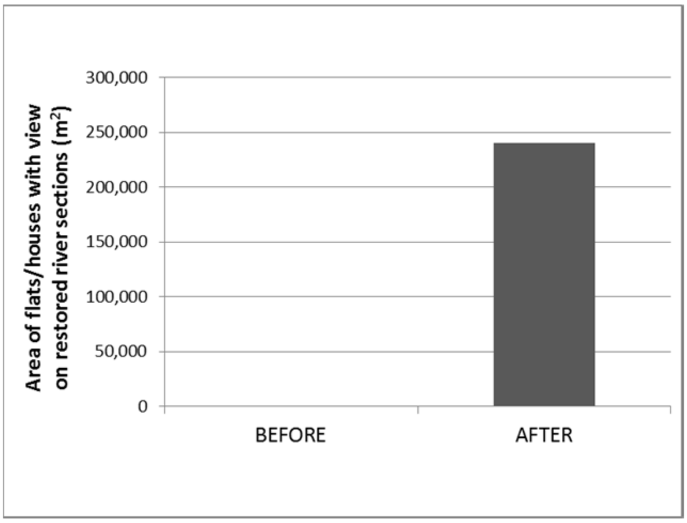


Figure 44: Area of flats/houses with view on the created Lake Phoenix and the Oberlauf der Emscher. The range of results based on different assumptions is shown hatched (Data source: City of Dortmund).

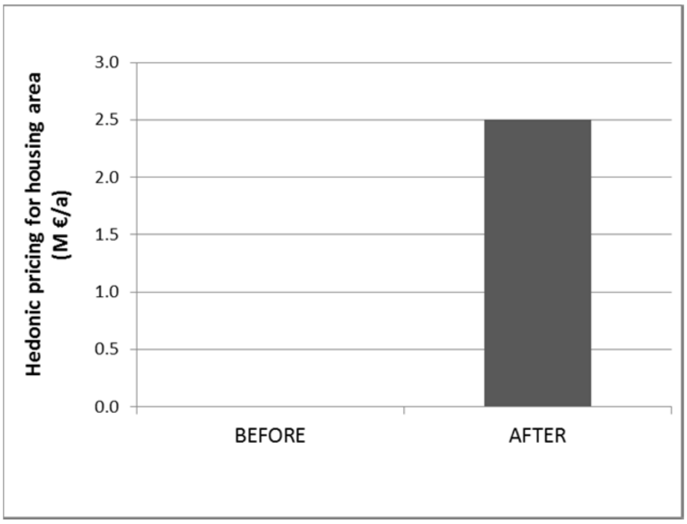


Figure 45: Hedonic pricing method applied to flats/houses with view on the created Lake Phoenix and the Oberlauf der Emscher (Data source: online real estate portal "wohnungsboerse.net").

Method 2

A study on the economic effects of the Emscher conversion in the Emscher region, conducted by the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (Barabas et al. 2013), was the basis for applying this method. The study revealed an increase in certain types of real estate and rental prices in the New Emscher Valley. This can be due to the already progressed conversion to the New Emscher Valley in that area.

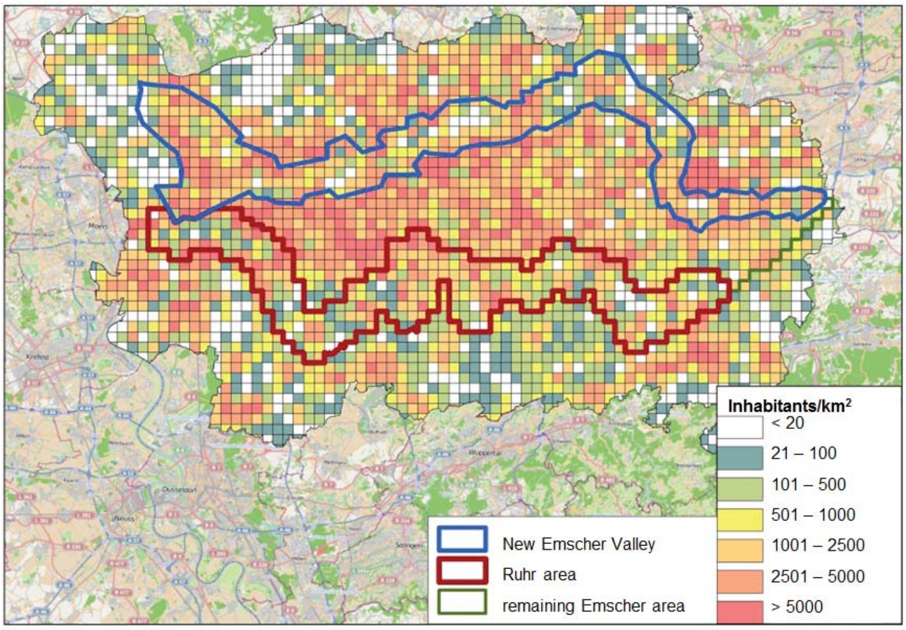


Figure 46: Map of the entire Ruhr area showing the subareas compared within the rwi study: The New Emscher Valley, the Ruhr Valley, and the remaining Emscher area as well as the number of inhabitants per km² , status 2000 (Source: microm in Barabas et al. 2013).

In order to transfer these results to the entire Emscher basin after full restoration, i.e. the entire New Emscher Valley restored, we took the following approach: The change in value for flats for sell and rental flats (€/m²) for those areas where the restoration had already taken place (at Lake Phoenix) was transferred to the total used housing area (m²) of owner-occupied flats (not reported due to data constraints) and total used housing area (m²) of rented flats for the entire New Emscher Valley. The same was done for the remaining Emscher area.

Note that this calculation focusses on the New Emscher Valley, and as such, only on the Emscher main stem without taking into consideration the increase in value along the tributaries as well.

Results & discussion of method 2

By applying method 2, we estimated the changes in residential rents (Figure 47) for the total housing area for the New Emscher Valley (NE) and the remaining Emscher region (Emscher) for BEFORE and AFTER the ecological restoration of the Emscher. For the renting offers, we detected price increases for both the NE (11.81 to 35.97 M €/a) and the remaining Emscher (40.38 to 86.08 M €/a), each for the total housing area. The price increase we detected is a result of two developments: a price change due to the restoration and an increase in the number of rental flat offers. This increase in the number of flats with various sizes was observed both in the NE (from 3,062 to 5,590) and the remaining Emscher (9,434 to 21,896) (Barabas et al. 2013). The reason for the increase in the number of flats is not clear.

For flat purchase offers, we could not make a prediction, as no data on price changes in flat purchase offers resulting for the restoration was available. Furthermore, effects on flat purchase offers are one-time effects only.

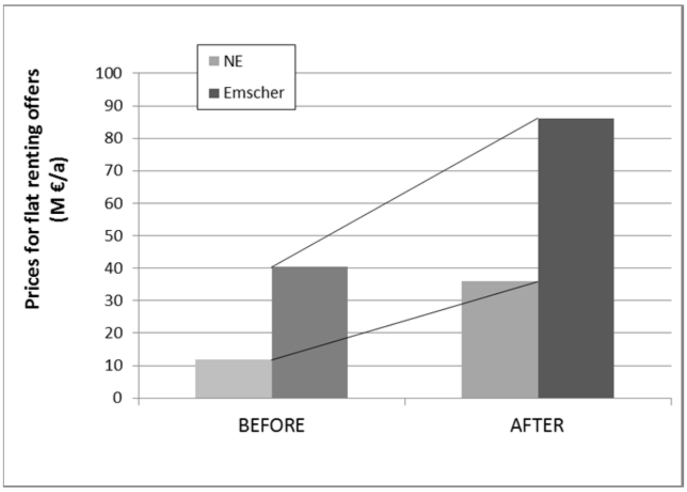


Figure 47: Prices for flat renting offers, BEFORE and AFTER re-conversion in the New Emscher Valley (NE) and the remaining Emscher area (Emscher) in M € per year (Data source: Barabas et al. 2013).

The observed effect was differentiated into price effect and area effect in order to specify the effect caused by the restoration. We see that the price effect is positive for the NE (from 11.81 to 20.44 M €/a) and constant for the remaining Emscher (40.38 to 40.33 M €/a; Figure 47). The area effect is positive in both the NE and the remaining Emscher, as explained above (increase in number of flats).

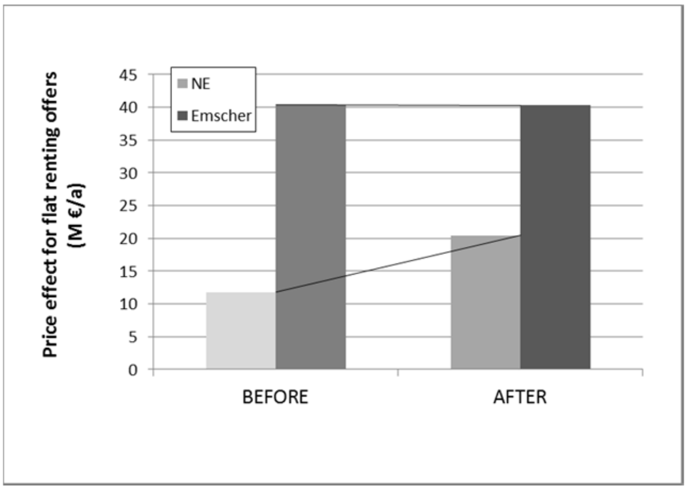


Figure 48: Price effect (i.e. without area effect) for flat renting offers, BEFORE and AFTER re-conversion in the New Emscher Valley (NE) and the remaining Emscher area (Emscher) in M € per year (Data source: Barabas et al. 2013).

Uncertainty

Method 1

Due to the fact that the values for the total area for retail businesses and residential buildings had to be taken from planning reports, there is some uncertainty linked to the final results. But as the leasing prices are real data sets, the calculated economic impact is assumed to be a good estimation of the real economic impact.

Method 2

The calculation of the increase in renting prices needs to be seen as a rough estimation only due to the different data sources for the states BEFORE and AFTER. Furthermore, it is not clear if the observed area effect is a result of the Emscher re-conversion or other factors.

5.7 FESS # 3: Opportunity for biking & recreational boating

This final Cultural service describes how an environment is suitable for recreational activities, in our case biking & recreational boating. The provision (Impact I) of an environment suitable to provide this opportunity can either be assessed using landscape aesthetics metrics and/or the intermediate services IESS # 1-4 which are preconditions for such a suitable environment.

In the Emscher case, we have identified two beneficiaries for this service:

A) Bikers and

B) Boaters.

Therefore, we will focus on the use (Impact II) of this service in terms of

A) Biking activity and

B) Boating activity.

5.7.1 STATE (FESS # 3)

Besides the parameters of State required for providing the intermediate services IESS # 1-4 (See 5.1.1, 5.2.1, 5.3.1., 5.4.1.), further cultural parameters of State are required. In our case, these are

- presence of bike paths (Figure 49)
- presence of lake for sailing/boating.

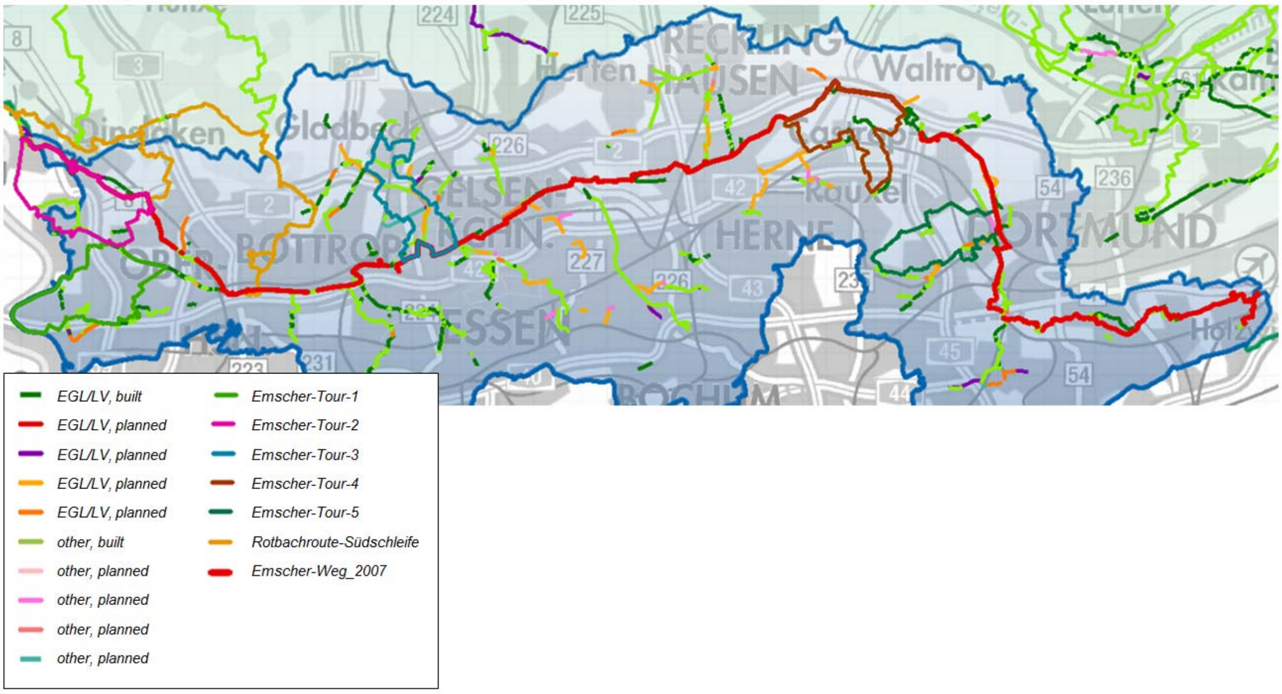


Figure 49: Network of biking paths in the Emscher basin (Source: EG, WebGIS).

The total length of biking paths increases from less than 40 to more than 120 km (Figure 50) from BEFORE to AFTER the Emscher re-conversion.

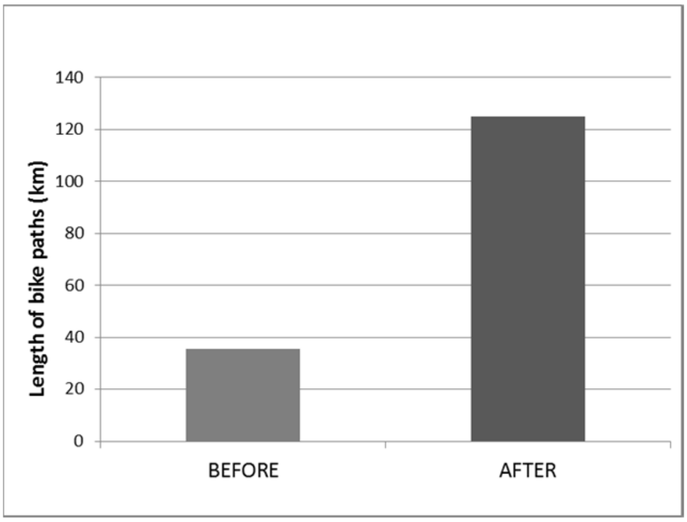


Figure 50: Length of biking paths in the Emscher basin (Source: EG).

Lake Phoenix represents the only lake present in the Emscher region that offers the opportunity for sailing (Figure 53).

5.7.2 IMPACT I - Provision (FESS # 3)

See 5.6.2.

5.7.3 IMPACT II – Use & resulting benefit (FESS # 3)

The FESS "*Opportunity for biking & recreational boating*" was assessed for two types of beneficiaries:

A) Bikers

B) Boaters

A) IMPACT II – Use & benefit: Biking

Method

To evaluate the use and economic value of biking in the Emscher basin, we transferred the results of a study on the economic effects of the Römer-Lippe bike route in the Lippe basin (Radschlag, IGS 2013) to the Emscher area. The basins and the expected number of bikers are comparable. The total spending per biker on a day trip or a several day bike tour was multiplied with the number of bikers per year, representing the WTP of the users of the bike paths.

Results & discussion

BEFORE the Emscher re-conversion, only 28% of the 125 km of bike paths that will be available by 2020 were present. Thus, the number of bikers (Figure 51) and the total economic value originating from biking activities were both approx. 72% lower at that time (Figure 52).

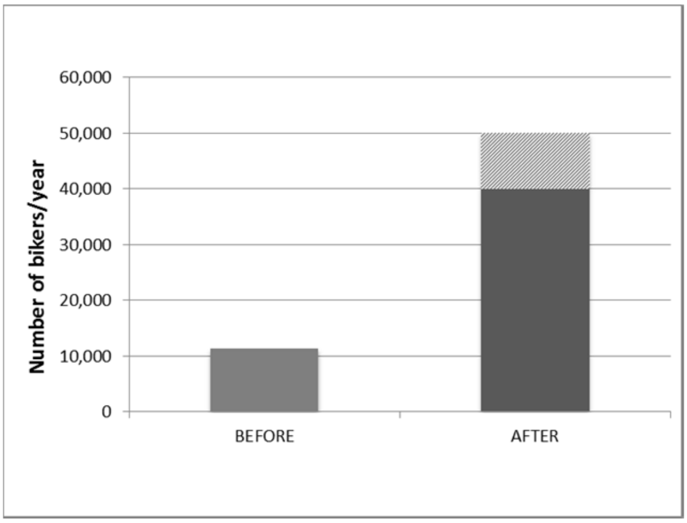


Figure 51: Expected number of bikers per year on the bike paths in the Emscher basin, range hatched (Data source: Radschlag, IGS 2013).

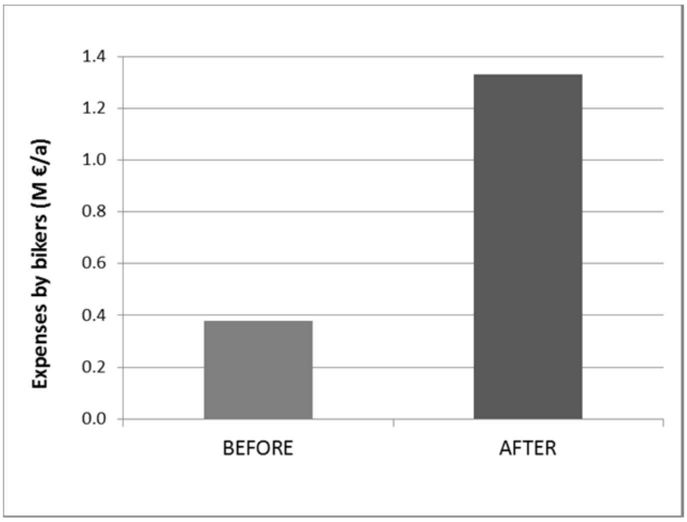


Figure 52: Expected expenses by day-trip and bike route bikers per year in the Emscher basin (Data source: Radschlag, IGS 2013).

A) IMPACT II – Use & benefit: Boating

Figure 53: View of Lake Phoenix as a recreational area (Source: EGLV, Gabi Lyko).

The recreation activity boating is only possible on Lake Phoenix and not on other water bodies within the Emscher basin. Furthermore, this kind of activity is only possible as a result of the creation of Lake Phoenix. As there was no lake before, the use and the recreational benefit accounted to 0 BEFORE the conversion (Figure 54, Figure 55, Figure 56, Figure 57). The total expected expenses by boaters at Lake Phoenix are more than 50,000 €/a.

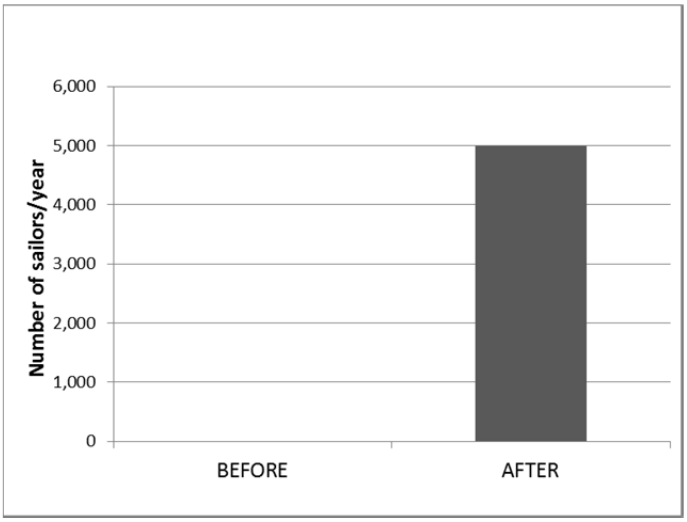


Figure 54: Number of sailors on Lake Phoenix per year (Data source: Lake Phoenix boat rental).

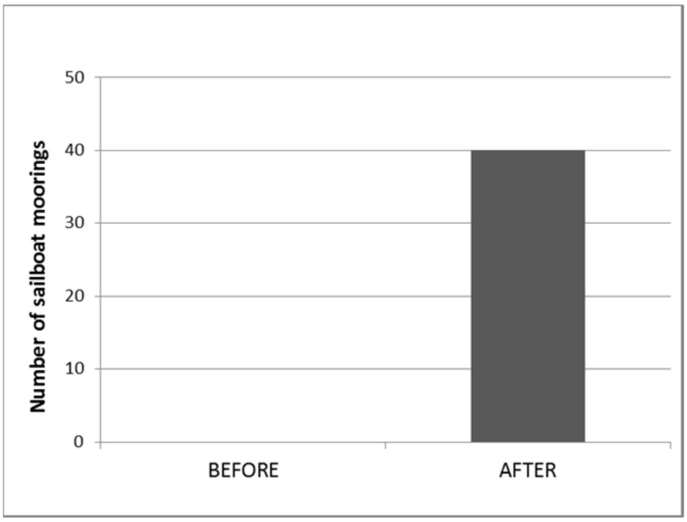


Figure 55: Number of sailboat moorings on Lake Phoenix (Data source: Lake Phoenix boat rental).

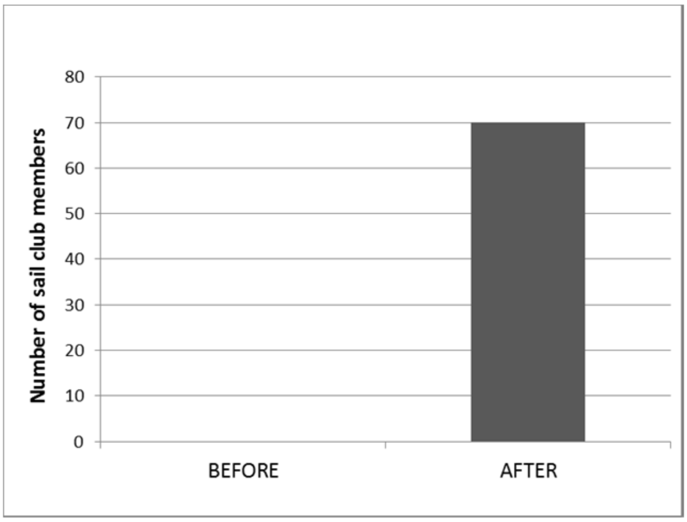


Figure 56: Number of sail club members at Lake Phoenix (Data source: Lake Phoenix boat rental).

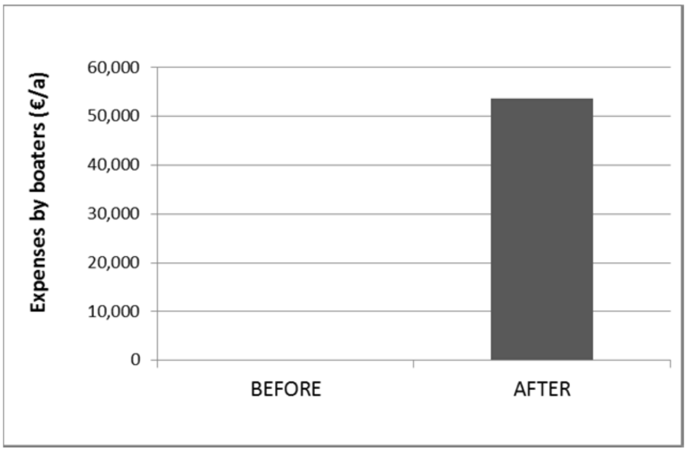


Figure 57: Expected expenses by boaters at Lake Phoenix (Data source: Lake Phoenix boat rental).

Uncertainty

This FESS is present at only one site in the Emscher case and, thus, cannot be scaled up to basin level. However, it is an interesting example of possible effects from innovative restoration measures.

5.8 FESS # 4: Opportunities to understand, communicate, and educate

This final Cultural service describes how an environment is suitable for educational activities. Similarly as for FESS # 2-3, the provision (Impact I) of an environment suitable to provide this opportunity can either be assessed using landscape aesthetics metrics and/or the intermediate services IESS # 1-4 which are preconditions for such a suitable environment.

In the Emscher case, we have identified educators and students as beneficiaries for this FESS.

5.8.1 STATE (FESS # 4)

See 5.1.1, 5.2.1, 5.3.1., 5.4.1.

5.8.2 IMPACT I - Provision (FESS # 4)

The provision of a suitable environment is essential for educational activities. The FESS "*Opportunities to understand, communicate, and educate*" relies on the provision of several intermediate ESS, being e.g. *Landscape aesthetics, Self-purification potential (N, P, C)* and *Biodiversity*.

Note, however, that there is no direct link between Impact I and Impact II.

5.8.3 IMPACT II – Use & resulting benefit (FESS # 4)

For the use of this FESS we have identified three potential indicators:

A) Offer: educational offers linked to the environment
The offer could not be quantified, because no data are available on this metric.

B) Acceptance: participation in excursions

C) Outcome: persistence of knowledge and environmental awareness
The outcome could not be quantified, because no data are available on this metric for success of the educational units.

Figure 58: Educational excursion along Lake Phoenix and the new Oberlauf der Emscher with its new floodplain bypassing the lake.

B) Acceptance: participation in excursions

The number of participants in excursions at Lake Phoenix and in excursions along streams within the Emscher basin are shown in Figure 59 and Figure 60. The price paid by participants in an excursion to Lake Phoenix (during a scientific conference) is depicted in Figure 61.

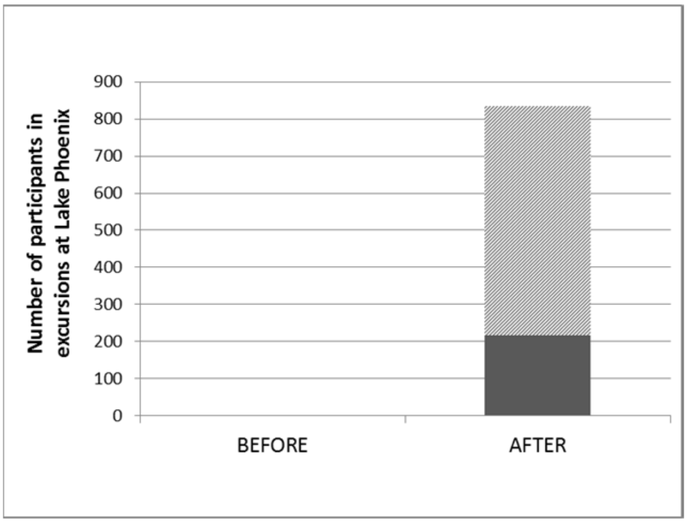


Figure 59: Number of participants in excursions at Lake Phoenix, range hatched (Data source: EG).

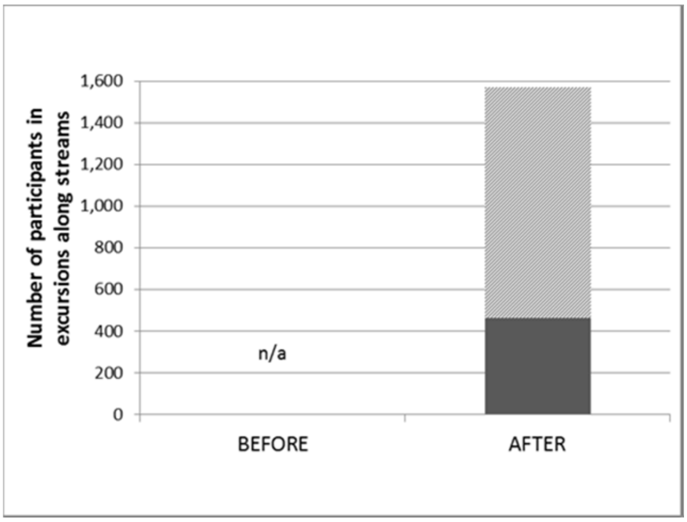


Figure 60: Number of participants in excursions along streams within the Emscher basin, range hatched (Data source: EG).

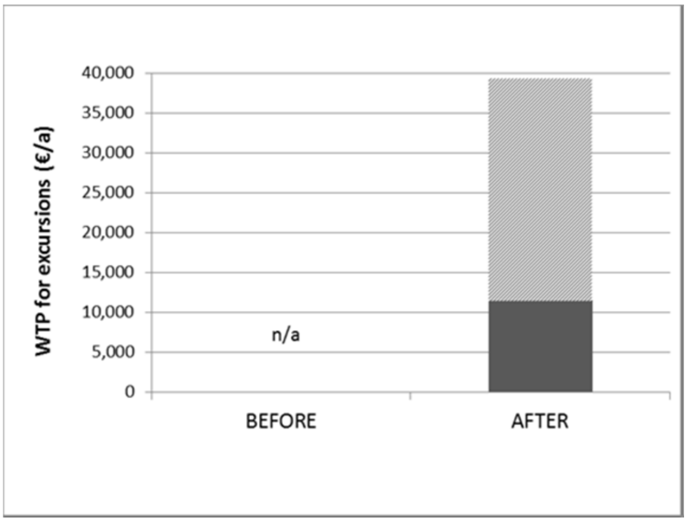


Figure 61: Willingness to pay for excursions within the Emscher basin, range hatched (Data source: UDE, DGL – Deutsche Gesellschaft für Limnologie e.V. conference).

Uncertainty

Also pupils, students, etc. are participants in educational excursions, possibly having a different WTP than guests of conferences. However, due to data constraints, the WTP was transferred from the costs of a conference excursion only.

5.9 FESS # 5: Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)

FESS # 5 describes the "*Knowledge that a restored river area exists, with suitable water quality*". In our case, we define suitable water quality with the goal to reach the good ecological potential (GEP), the regulatory threshold of the WFD. The provision (Impact I) of such a river environment suitable to reach this goal is also reflected by the intermediate services IESS # 1-4 as preconditions.

The beneficiaries for this final service are people who care.

5.9.1 STATE (FESS # 5)

See 5.1.1, 5.2.1, 5.3.1., 5.4.1.

5.9.2 IMPACT I - Provision (FESS # 5)

The FESS "*Knowledge that a restored river area exists, with suitable water quality*" depends on the provision of the IESS *Self-purification potential (N, P, C), Biodiversity* and others.

In this case, a quantifiable link between Impact I and Impact II is possible by comparing the final nutrient concentrations in a given water body with a given self-purification potential with the regulatory thresholds of the WFD concerning maximum nutrient concentrations. Similarly, biodiversity indicators could be compared to biodiversity goals of the WFD. We conducted the latter comparison by means of the ecological potential (see 5.4.2).

5.9.3 IMPACT II – Use & resulting benefit (FESS # 5)

An indicator of use is, in this case, not required and not appropriate.

The indicator for monetizing the value derived from the "*Knowledge that a restored river area with suitable water quality exists*" was taken from literature using the benefit transfer approach.

Benefit transfer was conducted from a WTP study for achieving the good ecological status (GEP) of the River Wupper by Hecht et al. (2015), as primary valuation research was not feasible within the DESSIN project. Wupper and Emscher are comparable in terms of length, area, location, affected beneficiaries, and market construct (see Annex for further information). The total WTP for restoring the Emscher was finally calculated by taking the WTP for reaching the GEP of the River Wupper and transferring it to the population structure in the Emscher catchment (Figure 62).

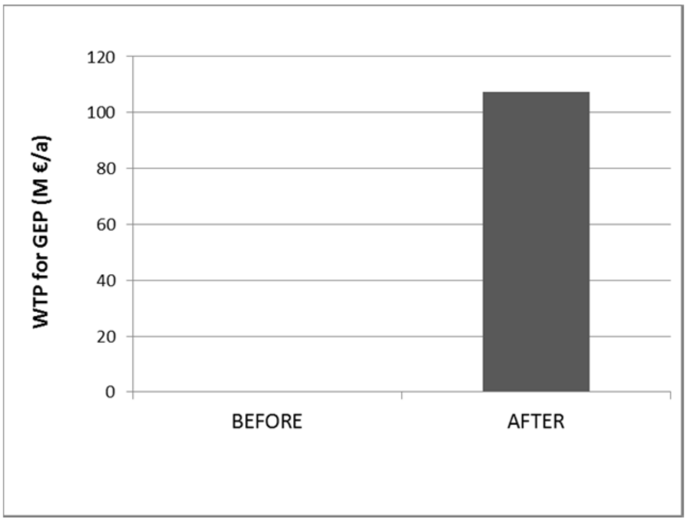


Figure 62: Willingness to pay for river environment to reach the good ecological potential (Data source: Hecht et al. 2015).

Uncertainty

The benefit transfer method is always linked to some uncertainty, as the benefit was not evaluated in the area under study. Nevertheless, a transfer was regarded appropriate, as both the Wupper and Emscher are tributaries to the River Rhine, have nearly the same length and catchment area. Also the affected beneficiaries and market construct are comparable and both rivers were historically used for (industrial) sewage disposal.

5.10 Further ESS not assessed quantitatively

The following ESS could not be assessed quantitatively due to data constraints. In this chapter, they are, therefore, briefly described qualitatively.

5.10.1 ESS: CO_2 sequestration (Global climate regulation by reduction of greenhouse gas concentrations)

Ongoing restoration activities have an effect on greenhouse gas concentration via several processes. These are discussed in the sustainability assessment in Part V (En124 and EG 213). One of these processes is the increased CO_2 sequestration by vegetation which is developing in the newly restored floodplains and river banks. These floodplains are either newly created or re-connected. Within these floodplains, the share of the land use types grassland and forested area shifts towards forested area. As forested area is capable in fixing more CO_2 compared to grassland, an increase in carbon sequestration is to be expected from BEFORE to AFTER restoration.

5.10.2 ESS: Local climate regulation (Micro and regional climate regulation)

Positive effects on local climate have been observed and studied in various cases, where green spaces have been created in urban areas (Elmqvist et al. 2015). For evapotranspiration by plants, energy is abstracted from the air, resulting in a decline in air temperature. Furthermore, the air is humidified via this process. Shading is, of course, also a positive effect of green spaces. These effects are valuable benefits for the inhabitants of cities. Especially during heat periods in summer they reduce temperature in urban heat islands. The effect can, for instance, be monetized as it saves large amounts of energy used in air conditioning. Additionally, pollution removal takes place at the surface of plants/trees. The monetary benefit for people can e.g. be assessed in terms of positive health effects.

5.10.3 ESS: In-stream cooling effect

Vegetated or forested stream shores considerably reduce in-stream water temperature by shading. It has been observed (Refresh project, Piet Verdonschot, personal communication) that shading results in average temperature being 2°C lower with 6°C lower maximum temperatures. From the land use within the HQ50 areas of restored DESSIN focus streams, we derived that on average 54% of the banks are vegetated, and thus, have the potential to contribute to the cooling effect.

5.10.4 ESS: Research opportunities (Educational)

Open wastewater channels are not of interest for conducting research. Natural streams are much more often object of research, investigating ecological functions and processes. Also restored streams offer a wide variety of topics to be investigated, especially concerning the development of newly restored streams and the establishment of communities of plants and animals. Also the self-development of restored stream beds and shores is often object of research studies.

5.10.5 ESS: Drinking water provision in the downstream Rhine catchment

As mentioned in the beginning, the downstream Rhine catchment is beyond the spatial limitation of the present case study, and therefore, not assessed here. However, due the restoration and the re-establishment of ecological functions and services such as the self-purification capacity of the water bodies (IESS # 1-3), positive effects are expected even beyond the study area. One of these effects is the improved water quality of the Emscher discharging into the River Rhine. This will facilitate drinking water provision conducted via river bank filtration of Rhine water and reduce additional water treatment costs. After completion of the Emscher re-conversion, the WWTP at the Emscher mouth in Dinslaken will not anymore treat the entire river like it has before the re-conversion. Thus, CSO discharges into receiving water during rain events will need to be eliminated or retained by the river itself. This elimination/retention is stronger if the self-purification capacity of the streams is high.

5.11 Possible impacts of climate change on ESS provision and use

Climate change scenarios for North Rhine-Westphalia for 2046-2055 predict an increase in temperature in the Emscher region (Figure 63) (MUNLV NRW 2007). At the same time, total precipitation in the summer months will decline while in winter it will increase. The probability for extreme precipitation events is expected to increase throughout the whole year (Figure 64).

The effects of climate change on the weather conditions in the Emscher region have also been analyzed in the research project dynaklim. Mean annual air temperature has already increased and is expected to increase more, especially in the summer months. Concerning extreme temperatures, hot days are expected to increase in frequency and intensity while cold days are expected to decrease. Annual precipitation is forecasted to remain at a level as today. In the far future a decline in precipitation during the summer term is anticipated. Furthermore, dry periods with a longer duration are expected to occur more often with more dry days during the summer term. A higher number of heavy rain events has already been observed and more intensive heavy rain events are expected to occur more often (Quirmbach et al. 2012).

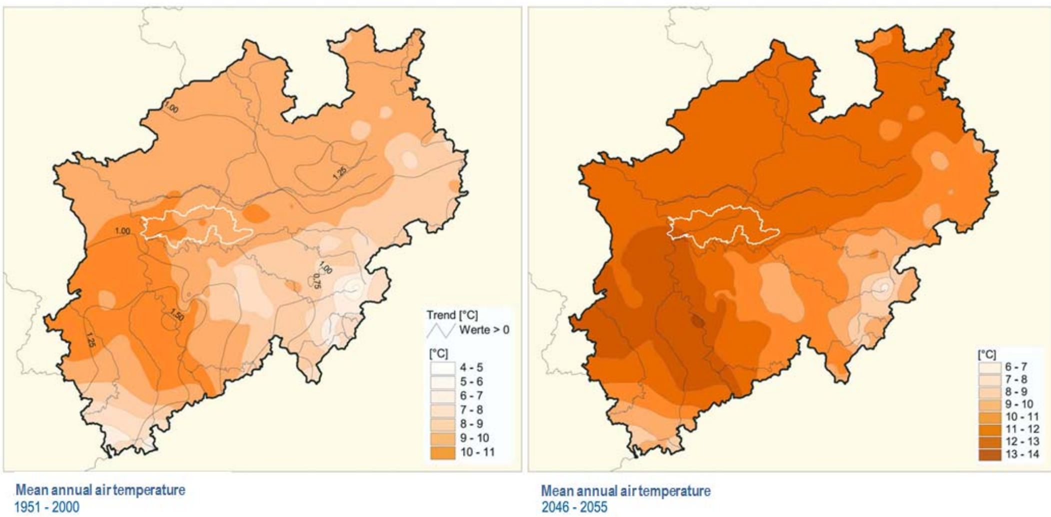


Figure 63: Forecast for temperature increase in North Rhine-Westphalia (left: mean annual air temperature 1951-2000, right: mean annual air temperature 2046-2055 (Source: MUNLV NRW 2007).

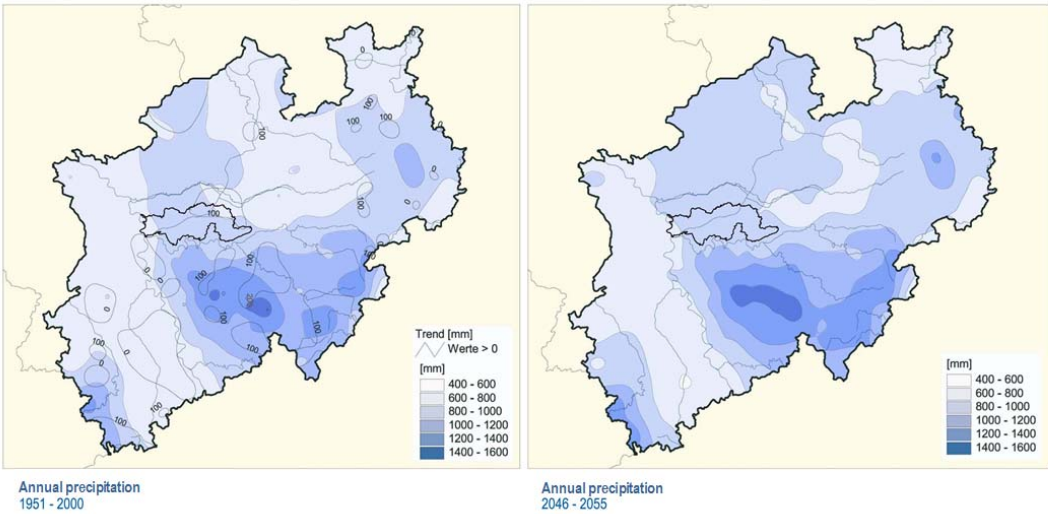


Figure 64: Forecast for precipitation increase in North Rhine-Westphalia (left: annual precipitation 1951-2000, right: annual precipitation 2046-2055 (Source: MUNLV NRW 2007).

These climatic changes have implications for the provision and use of ESS. The following effects on aquatic ecosystems are probable: Increases in air temperature will also lead to higher in-stream water temperatures, especially in shallow, slow flowing water bodies. Higher water temperatures can affect biological communities, both plants and animals. Plant growth could be enhanced with higher temperatures and more sunlight up to a maximum level. Aquatic invertebrates and fishes might, on the other hand, be stressed by high temperatures. Invasive species, however, might be able to better cope with these conditions than local species. Furthermore, conversion processes provided by bacterial communities such as denitrification could be enhanced by a temperature increase – at least up to an optimum (above which a decrease will follow). These potential effects have implications on the IESS "*Self-purification*" and "*Biodiversity*".

Extreme heat days in urban areas will have effects on local climate, rising the importance of the ESS "*Local climate regulation"* as well as of measures (e.g. parks, water bodies) promoting this ESS.

The changes in precipitation can affect several ESS. With less rain in the summer months coinciding with high temperatures, it is more probable that streams periodically fall dry. This, of course, is detrimental for "*Biodiversity*" but also for "*Self-purification*". Furthermore, enhanced precipitation in the winter term and more regular heavy rain events will affect the ESS "*Flood protection*". Natural water retention inside stream beds, floodplains and vegetated basins will gain importance in order to prevent damage by flooding. Flood events of a certain intensity and reoccurrence interval (e.g. HQ100) are expected to occur more often in the future due to climatic changes, e.g. once in 80 years instead of 100 years.

Cultural ESS might also be affected by both climatic developments. The directions of the trends need to be considered distinctively. Flooded areas or streams that fell dry will probably not be a destination for *recreational activities* anymore. Parks and water bodies in the cities will, however, become a location for recreation during hot summer periods. *Research and education* might become more relevant in ecosystems affected by climate change. And the "*Knowledge that ecosystems with a good ecological status*" exist might be valued higher by people who care.

Therefore, climate change can lead to an enhancement of provision and use of several ESS. At the same time, however, a decline in other ESS is anticipated.

5.12 Conclusions & recommendations

5.12.1 Summary

As only final services can be reported in the same unit (€/a) but not intermediate services, only FESS can be shown in one overview graphic. The spider plot below (Figure 65) presents the changes in the monetary benefit for each of the FESS in the same plot. The change in benefit ranges from 53,600 €/a ("*Opportunity for boating*") to 107,335,717 €/a ("*Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)*"). As this range is quite large, the benefits had to be log10 transformed to appear in one plot.

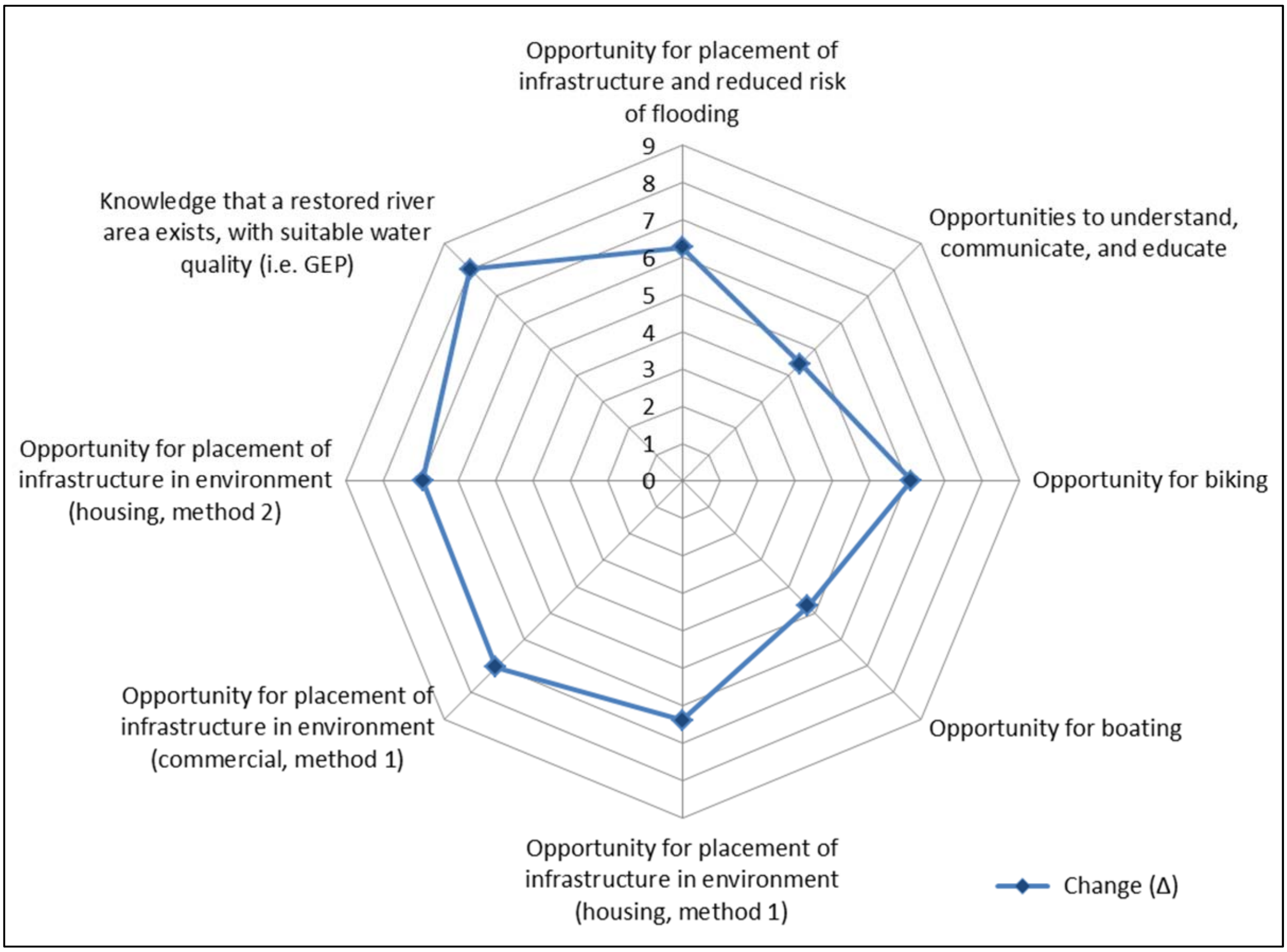


Figure 65: Spider plot showing all FESS evaluated in the Emscher mature case, axis: log10 transformed €/a (red points: BEFORE, blue points: AFTER).

5.12.2 Conclusion

All in all, it can be stated that the Emscher re-conversion has led to an improvement in all of the IESS and FESS assessed.

The fact that these benefits are available to all of the 2.2 million inhabitants in the Emscher catchment as well as to tourists travelling to the area has to be considered in a positive way.

For a comparison of ESS provision and the resulting benefits with the costs of the restoration project (4.5 billion €), some restrictions have to be considered. First of all, not all ESS can be included in this comparison since only FESS are reported in monetary terms (€/a). Thus, the IESS "*Self-purification*" (retention of N, P, and C) as well as "*Biodiversity*" cannot be considered. Also those ESS not assessed quantitatively (*CO_2 sequestration, Local climate regulation, In-stream cooling effect, Research opportunities, Drinking water provision in the downstream Rhine catchment*) cannot be accounted for. Secondly, it has to be noted that those FESS that were quantified and monetized represent only a part of all the ESS relevant in the study area. Thirdly, due to data constraints, several assumptions and estimations had to be made during the assessment process. And finally, not all of the assessed benefits result in a direct economic impact. For example, the WTP for GEP is a theoretical value; this economic impact does not occur in reality. Therefore, only a very roughly calculated cost-benefit comparison can be made.
If the hypothetical value derived from WTP is excluded and benefits from all other FESS are summed up, the annual benefits resulting from the Emscher conversion are estimated to be about 25.73 M €/a. This benefit could be compared to the annualized investment costs of 150 M € per year (4.5 billion € investment costs spent over 30 years). Thus, the benefit for a lifetime of 80 years can be calculated: For those ESS that could be monetized, being *educational and recreational ESS*, *flood protection* and the *opportunities for placement of housing and commercial buildings* the benefit accumulates to 2.06 billion €, excluding, however, the ESS *self-purification*, *biodiversity*, *CO_2 sequestration*, *local climate regulation*, *in-stream cooling effects*, *research opportunities*, and *drinking water provision in the downstream Rhine catchment*, which could not be quantified. Furthermore, it should be highlighted that the benefits are not expected to occur only for 80 years which equals the expected lifetime of the sewage system (see Part V, E.5). The ecological improvement of the streams is supposed to last for eternity, as long as maintenance is assured (see Part V, E.5). With a longer lifetime for the positive effects resulting from the restored streams, the cumulative benefit will be correspondingly higher. Note also that no inflation or price increases are assumed.
Again, it should be highlighted that this cost-benefit-comparison is very rough and incomplete. Further positive and negative effects of the measure which are not included in the ESS evaluation have to be considered in such an assessment as well. Such positive and negative effects are e.g. avoided CO_2 emission costs but also additional pumping costs in the restored system. Some of these aspects are discussed within the sustainability assessment (see Part V).
Concluding, it has to be emphasized that the Emscher re-conversion was a necessity. It was imperative in order to fulfil legal requirements and assure regulated discharge conditions in an area exposed to the consequences of a mining history. In the present study we evaluated extra benefits resulting from the Emscher re-conversion in addition to the fulfillment of the legal responsibilities.

5.12.3 Recommendations

Recommendations by WP13 to WP11 concerning the ESS Evaluation Framework were made throughout the developmental process in order to improve its applicability. In phone conferences and meetings, recommendations were given based on the application and testing of the Framework in the mature cases. These recommendations are reported in the Minutes of Meeting, which are available in the combined Milestones 21 & 26. The main recommendations on the ESS Evaluation Framework include:

- on the components and foundations of the DESSIN ESS Evaluation Framework, i.e. to base it on the DPSIR approach and CICES classification of the EU as well as on the final ESS approach by the US EPA
- to develop a focused cookbook as a stepwise guide while providing detailed background information in a companion document
- to provide future users of the framework with supporting material (annex to the cookbook) as well as reporting templates
- to differentiate between intermediate and final ESS based on the presence of beneficiaries in the study area
- the need to consider spatial and temporal scales
- to suggest indicators for the biophysical assessment of Provisioning, Regulating & Maintenance, and Cultural ESS
- to test economic methods for the monetary valuation.

Recommendations of stakeholders in the Emscher area were gained during a workshop entitled "Which ESS are generated via the Emscher re-conversion?". The Emscher mature case assessment was presented to stakeholders from regional management, landscape ecology in city council, urban forestry, NGO and research and was considered very valuable and important. For future research and further development of the ESS approach, the stakeholders suggested, for instance, that also the connectivity of new habitats should be considered. It was also emphasized that the intrinsic value of biodiversity should be made more explicit. Furthermore, the generation of habitats and areas for ecological development should be considered as a service per se. And it was challenged that also negative changes in ESS need to be investigated and taken into account.

STEP A: Definition of the assessment and decision case

The objective of the SA for the Emscher case was to test the developed SA framework. As the reconstruction process of the Emscher is already at a very advanced stage, this assessment can only be seen as an ex-post evaluation of the Emscher conversion measures highlighting benefits and negative side effects in social, environmental, governance, assets and financial terms. As there was no alternative measure to be considered in the decision making process, once the final decision on renaturalizing the Emscher stream and creating Lake Phoenix was made, there will be no alternative considered in the SA. This means that only two scenarios have been compared by using a set of indicators for different assessment criteria:

- a "**BEFORE**" scenario, dealing as a baseline to the assessment, assuming that no measures have taken place at all and
- a future-oriented "**AFTER**" scenario with all measures of the Emscher conversion finished.

The timeframe of the assessment is set in accordance with the duration of the Emscher restoration of 30 years (from 1990 to 2020). The effects considered refer (if not explicitly stated otherwise) to the local area of the Emscher catchment. Please be aware that this choice of system boundaries implies that positive and/or negative effects occurring outside the focus area are not included in the assessment results. The results presented below have to be interpreted with the system boundaries in mind.

In order to avoid redundancy of previous work and reduce the working effort for the Emscher SA, a comprehensive literature review was done by EG and IWW beforehand in order to gather a detailed overview of assessments and other studies performed in the Emscher region so far. Main contributing studies and documents to the SA were the study on regional economic effects of the Emscher conversion by RWI (Barabas *et al.*, 2013) and measurements/monitoring reports as well as management reports by EG.

STEP B: Selection of indicators

In the second step of the assessment process the DESSIN sustainability indicator list was filtered according to the characteristics of the system and the assessment purpose. Therefore, all indicators relating to a water supply system have been excluded since there is (currently) no water extracted from the Emscher for (drinking) water treatment. The same could have been done for the indicators requiring an alternative technology as reference. But as is the review of recent reports and studies information for some of these indicators had been found without considerable efforts, these indicators will be presented as well. However it must be highlighted that these indicators need to be interpreted differently as no reference value is available. Nonetheless, they can give a valuable impression of the dimensions and characteristics of the system under consideration.

Unfortunately, data availability was a critical (but manageable) issue within this assessment. The rating of appropriate indicators for this case study led to a very condensed list of indicators available for quantitative assessment. Furthermore, due to a lack of data in the environmental dimension, only four of the five dimensions proposed by this framework can be addressed in a quantitative way. Nevertheless, all other indicators, suitable but not quantitatively assessable, are described qualitatively in order to fill this gap.

A detailed list of all indicators selected for assessment can be found in the annex to this chapter (Annex, Part V, Step B).

Step C: Definition of additional indicators

Due to the fact that there was no further data available which had not already been covered by one of the indicators selected in Step B, this step has been skipped within the assessment process of this case study.

Step D: Data collection and assessment

As intended in the DESSIN SA framework, some of the data required for the SA was derived from the ESS Evaluation. In the case of the Emscher restoration, several Impact I and Impact II indicators fit specific criteria of the SA. These parameters and metrics do not require further description as this information can be obtained from Part IV (Table 2).

Table 2: SA data derived from ESS evaluation

FESS/ IESS ID	DESSIN ESS	unit	before	after	SA metric/indicator
FESS # 1	Avoided costs from flooding	[€/a]	0	1.78 M	→ F113
FESS # 2	Economic impact of hedonic pricing	[€/a]	n/a	16,599,840	→ S151
FESS # 3	Economic impact of biking	[€/a]	0	1,330,000	
FESS # 3	Economic impact of boating	[€/a]	0	53,600	
FESS # 4	Economic impact of educational excursions	[€/a]	0	25,400	→ S152
IESS # 1	Potential denitrification rate in total Emscher basin	[t/a]	2.99	4.12	→ A151
IESS # 2	Potential P-retention rate in total Emscher basin	[t/a]	1.54	5.64	
IESS # 3	Potential C-stock in total Emscher basin; Potential C-retention in total Emscher basin	[1000t]; [t/a]	95.53; 416.40	133.16; 736.06	

Further data for the SA of the Emscher case study was obtained by EG and IWW from (Barabas *et al.*, 2013) and the management reports by EG. Whenever possible and suitable, data was expressed in annual values in order to be in accordance with the ESS evaluation and to allow an overall life cycle analysis over the lifetime of the solution – if desired in further research.

All SA indicators that have been assessed quantitatively for this mature case study and which have not been reported in the ESS evaluation part of this document before are summarized in Table 3 below.

Table 3: Overview of additional SA data

SA metric/ indicator	DESSIN ESS	unit	before	after	source
S121	Economic impact derived from initial spending	[-]	0	0.62	RWI study
S131	Employment created by implementation of solution	[1/a]	0	1,400	RWI study
S141	Number of beneficiaries affected	[-]	2,210,557	2,210,557	EG
F111	Investment expenditure	[€]	-	4,500,000,000	RWI study
F112	Operational expenditure (between 1991-2020)	[€]	-	450,000,000	RWI study
F114	Other sources of financing (e. g. subsidies)	[%]	-	100	EG
G111	Compliance improvement w/ relevant EU standards	[%]	0	33	EG
A111	MTTF	[a]	-	80 (sewers) ∞ (other)	EG
A221	lifetime of solution/start up time	[-]	-	2.7	EG

The quantitative assessments summarized in Table 2 and Table 3 as well as further qualitative descriptions to those indicators lacking data for calculation are presented in the following chapter.

Step E: Results and discussion

E.1 Social dimension

Besides the two indicators that deal with data from the ESS Evaluation, four additional indicators have been assessed for the Emscher re-conversion in the social dimension.

Before the Emscher re-conversion was initiated, all Emscher tributaries as well as the Emscher River itself were open wastewater channels. Raw wastewaters from households and industry as well as mining effluent were flowing in these channels together with the original river water (groundwater) and rainwater. Thus, high concentrations of pathogens (*E. coli*, Enterococci) and chemicals were transported in the river network. After the construction of an underground sewer network, the first step of the Emscher re-conversion, all communal and industrial wastewater is conducted underground. Therefore, the concentration of pathogens and pollutants in the streams is considerably lower (**S111, 112, 113**). However, during rain events, discharge of CSO can still lead to occasional input of wastewater into the streams. Also run-off during rain events as well as sewage from brownfields and waste deposits causes input of pollutants.

As the economic impact creation of the measure has already been calculated within the RWI study (Barabas et al. 2013), the resulting production effect of 11 billion euro can easily be transformed to the indicator **S121** proposed in the DESSIN indicator list. As there was neither an initial spending nor a resulting economic impact before the measure had been implemented, there was no economic impact creation to be observed BEFORE. AFTER the construction works are completed, there will be a return on initial spending via economic impact creation of 0.62 (on a scale from 0 to 1). This value might seem to be low with regard to the optimum value of 1 for a "perfect investment". But as there is no comparable measure available, this value can only be taken as an indication that the Emscher restoration works have resulted in a high economic impact creation in the Emscher catchment and beyond.

This becomes evident as well when considering the second indicator metric assessed belonging to the criteria of job creation (**S131**). Barabas et al. (2013) determined the number of jobs that are secured and created by the measures themselves on an annual basis. The final value of 1,400 jobs emphasizes that the Emscher re-conversion is a very large-scale project. Although information on jobs derived from improved Cultural services was not available at the time of assessment, based on the fact that there are several retail stores newly located in the Emscher catchment (especially at Lake Phoenix) after the Emscher re-conversion, a positive effect in this indicator can be assumed.

The annual economic impacts derived from hedonic pricing for commercial places (e. g. cafés, restaurants) (**S151**) and the newly built housing area at Lake Phoenix as well as educational excursions have already been assessed and discussed in the previous chapters on ESS evaluation. As no use of these Cultural ESS existed before the Emscher re-conversion, these can be seen as pure benefits to human well-being resulting from the solution.

All in all, it can be stated that the Emscher re-conversion has led to an improvement in all of the social criteria assessed. The fact that these benefits are available to all of the 2.2 million inhabitants in the Emscher catchment as well as tourists travelling to the area gives further emphasis to this.

E.2 Environmental dimension

As mentioned above, unfortunately, there was no data available on the environmental effects of the Emscher restoration measures besides those affecting ESS provision and use. Thus, the environmental dimension can only be described qualitatively by highlighting tendencies in the indicators' developments.

The Emscher re-conversion is only feasible with intensive excavating, transport, and building activities. These activities go along with a high energy demand (**En125**), and with this, high emissions of CO_2 (**En213**) throughout the 30 year conversion period. The activities are conducted by EG itself as well as by external companies. However, currently no data on CO_2 emissions resulting from these activities is available. The EG management summary states that the main construction works where executed by external contractors (Emschergenossenschaft 2015). But also in the EG statistics, an increase in energy consumption can be observed since the beginning of the Emscher re-conversion (Emschergenossenschaft 2015). Unfortunately, the part which is consumed specifically for the re-conversion measures and not for standard operation tasks cannot be identified.

Energy consumed for WWTP operation is one of the main factors concerning energy demand (Figure 66). Nine WWTPs were in place in the Emscher area BEFORE the re-conversion, while AFTER the re-conversion only four WWTPs remain. Thus, a reduction in energy demand of 10.6% could already be achieved from 2002 to 2015 (Figure 67). Furthermore, the energy recovery rate in the system (**En122**) by EG (mainly from bio gas) has increased by 15.5% over the years. Additionally, a wind power plant has been installed on one of the WWTP sites with an expected annual return of 4,500 – 8,000 MWh/a. Several pumping stations have been newly created during the re-conversion, plus, large-scale underground pumping stations still need to be put in place. The latter are required for transporting wastewater through the newly built sewage system to the WWTPs. The pumping costs cannot be quantified yet because the amount of water reaching these stations cannot yet be exactly forecasted. This forecast is hindered because the future development of the population in the area, the share of rainwater in the combined sewer, and the amount of groundwater infiltrating into the sewers are factors of uncertainty.

Figure 66: WWTP in Bottrop in the Emscher area, one of the largest WWTPs in Germany, with an electricity consumption of 40 M kWh per year.

Another impact concerning CO_2 emissions from the construction works is not caused by energy but by fuel consumption by trucks for moving excavated material.

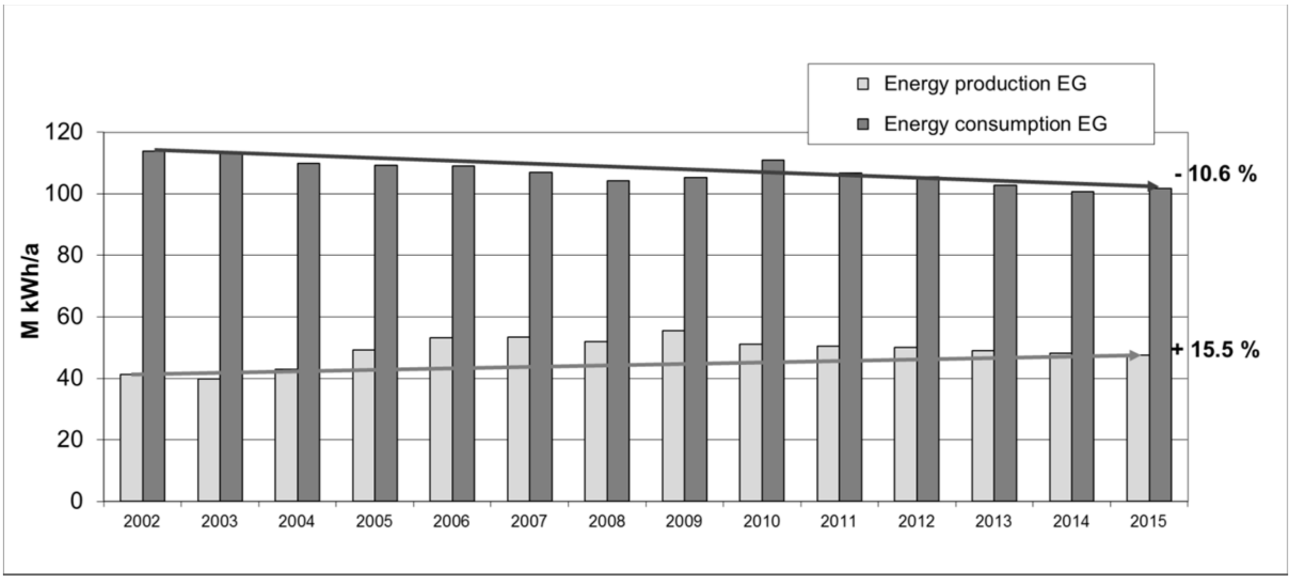


Figure 67: Energy consumption and production at WWTPs in the Emscher area from 2002 to 2015 (Source: Frehmann 2015).

One more source of climate relevant gas emissions are CH_4 and N_2O emissions from WWTPs, digestion towers, sludge drying sites, and from the Emscher River itself (BEFORE) or the underground sewers (AFTER) (**En213**). These emissions can be transferred and be reported as CO_2 equivalents for the state BEFORE and AFTER the re-conversion (Figure 68). To get an idea of the current monetary value of these avoided carbon emissions in terms of CO_2 certificates, current trading prices were adopted (Source: http://www.finanzen.net/rohstoffe/co2-emissionsrechte/Chart). An amount of 95,47 M kg CO_2 equivalents avoided per year as observed in Figure 68, thus, corresponds to avoided costs of 477,350 to

763,760 €/a (with a price of ~ 5 €/a (Feb-Mar 2016) or ~ 8 €/a (Aug-Dez 2015) per ton of CO_2 equivalents, respectively).

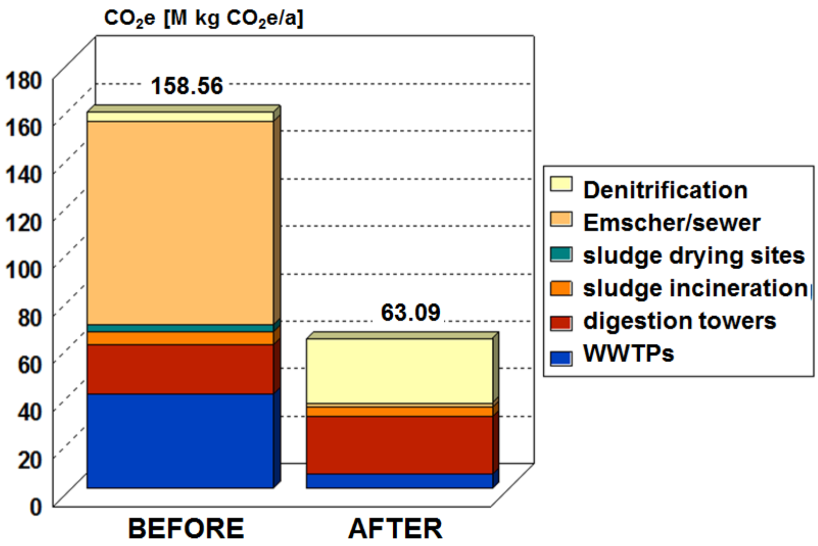


Figure 68: CO_2 equivalent emissions from CH_4 and N_2O emissions from WWTPs, digestion towers, sludge drying sites, from the Emscher River itself (BEFORE) or from the underground sewers (AFTER) (Source: Grün et al. 2013).

Thus, the energy consumption and climate relevant gas emissions during the construction phase may have caused negative environmental effects. These will continue to a smaller extent during operation in the future. EG is aware of these effects and is trying to further reduce energy consumption in the future. Therefore, internal investigations about the effects caused so far and the effects to be expected in the future have started.

On the other hand, the Emscher re-conversion also leads to changes in the CO_2 sequestration in the area (**En213**) resulting from the restoration, re-connection and creation of floodplains along the restored streams. These floodplain areas are relevant for carbon fixation as a result of growing vegetation. The areas have increased in size from approx. 70 to 121 ha in the years 2007 to 2015 (Source: Emschergenossenschaft 2015; EG, unpublished results) and are expected to increase further with ongoing restoration activities. The various aspects mentioned above regarding carbon sequestration (ESS: CO_2 sequestration, 5.10.1) and carbon release (**En213**) can be summarized as follows: Beneficial climate effects are resulting from CO_2 sequestration and avoided CO_2 emissions in the restored system (from greenhouse gas releases from the open wastewater channel) while CO_2 emissions due to digging and construction activities are unfavorable.

The type of energy used is another important factor that has to be taken into account discussing energy consumption. The energy used for construction works done and the additional energy required for sewage pumping in the future was and will be taken from the public electricity system. Therefore, the share of green energy usage (**En123**) will depend on the German energy mix. In 2015, the share of renewable energy was about 33 % which is a major increase compared to the year the reconstruction measures in the Emscher catchment began (1990: 3% renewables; AGEB 2016). Although there is additional energy for pumping required in the future, the share of green energy consumed in the Emscher catchment might be increased due to this positive change in Germany´s energy system.

Of course, restoring a river catchment can generally be seen as a process reducing the usage of artificial and man-made material (**En13**). But the construction process of renaturalizing a river bed might also require bringing back some "natural material" to the Emscher catchment that was used to be in this area but removed long time ago when the concrete channel was build. Besides, building an underground sewage system makes use of further artificial material. The real extent of this material consumption cannot be estimated at the moment, but surely, there is a certain negative impact on the environment linked to this factor as well.

Due to the fact that the sewage will not be discharged into the Emscher streams anymore, the amount of waste recovered should be further increased in the future. The extent of this increase, however, requires further investigations.

E.3 Financial dimension

The Emscher re-conversion was a capital-intensive and costly measure. In total, the investment costs (**F111**) – only those directly related to the measure – were about 4.5 billion €. Furthermore, there was and will be operational expenditure (**F112**) caused in the on-going construction works between 1991 and 2020. These are estimated to be about 0.45 billion € (Barabas et al. 2013). Besides, in the future, additional costs for sewage pumping inside the newly built sewer system are expected to occur but these costs cannot yet be quantified. The reason is that the amount of water that will need to be pumped cannot yet be estimated. In contrast, the expected costs savings in the form of avoided costs of flooding (**F113**) were calculated within the ESS assessment to be about 1.78 M € per year (178 M € per 100 years).

It is clear that it would take a very long time for the investment to amortize just by future cost savings. But in the case study under investigation, cost coverage (**F11**) is not a question since the investment and other expenditure related to the re-construction works are already covered by private-public partnership investments (e.g. subsidy by federal government of NRW). Thus, the only costs that have to be considered for financial sustainability are the additional costs for pumping and whether they are "covered" by the avoided costs from flooding. Since these additional costs cannot be estimated to date, this question cannot be answered exclusively.

E.4 Governance dimension

Regarding sustainability from a governance dimension´s perspective, the Emscher re-conversion supports the compliance with relevant EU standards sustainably (**G111**). The Ecological Potential has come closer to the WFD thresholds. The distance to the GEP has been 100% BEFORE and is expected to be 67% AFTER completion of the restoration efforts. So even though the WFD threshold will not yet be met, there is still an improvement achieved by the measures.

Stakeholder involvement (**G12**) has been given special attention over the whole course of the project. Several relevant actors/stakeholders were involved in planning and implementing the solution from the very beginning. The level of information dissemination aimed to be reached via communicative events can be denoted rather high.

E.5 Assets dimension

The lifetime of the system (**A111**) under investigation can be considered very long. Aside from the sewer system which is planned to last for at least 80 years (after which reinvestment is expected), the ecological improvement at the streams are expected to last for eternity (given maintenance work is conducted). Thus, for the sewer system, the mean time to failure (MTTF) of the solution is 80 years, while the ecological restoration and recreation of near natural stream beds and profiles is not expected to fail at all. With regard to the eternal lifetime of the Emscher conversion measures (except of the sewer system) even the starting (i.e. implementation) time of 30 years which seems to be very high at first glance becomes acceptable (lifetime – start up time ratio: 2.7 for sewer piping / ∞ for the environmental system) (**A221**). In this case it was not considered, that apart from sewage channels, technical facilities might require reinvestment already before 80 years after construction. As the frequency of flooding events and resulting damage costs will be noticeably reduced in the future (see FESS # 1), the capacity of the solution (**A121**) is expected to fit well to projected future needs.

Due to the fact that the sewer network (incl. CSOs) was rebuilt so that the river stream will be waste-water free from now on, the number of complaints (**A211**) due to noise and landscape aesthetics will decline strongly. Future complaints about such unwanted side-effects caused by the solution itself are not expected.

Besides these performance indicators of the solution itself, the Emscher restoration will also increase the potential of nitrogen, phosphor and carbon retention (**A151**) of the River Emscher itself (for detailed information about these indicators: see IESS # 1-3).

As most of the indicators proposed in this assets dimension are dedicated to be used for decision cases to compare two or more technological alternatives, a final evaluation of the sustainability from an assets point of view cannot be made. Nonetheless, these examples show how the stated indicators can be reported and how they could be taken into account in another decision case e.g. for a comparison with alternative technologies.

E.6 Discussion

From the previous explanations for each of the DESSIN sustainability dimensions, it can be concluded that the Emscher re-conversion has many positive effects in social and governance terms. Especially the newly created opportunities for enjoying the Cultural ESS of the Emscher catchment and the improvement of Emscher water quality will bring sustainable benefits for the society. Regarding the environmental dimension, two contradicting effects can be observed: During the Emscher restoration works various negative environmental effects have to be accepted. But once the construction work is completed, there will be mainly positive environmental impacts on ESS and energy demand for operating the system. The financing of the project itself was successfully managed using public-private partnerships. But since the additional costs for pumping in the new system were not available, it cannot be exclusively stated whether the project was financially sustainable for EG. With regard to the assets dimension, a comparable solution is missing, therefore, a final conclusion on the performance of the system cannot be made.

Step F: Decision Support

The objectives of the SA for the Emscher case were to test the developed SA framework, to evaluate the Emscher re-conversion measures ex-post and to highlight benefits and negative side effects. A decision support is not required anymore, as the measure is already implemented. Step F of the Cookbook should be conducted when a decision is not yet taken and support is to be provided. In the Emscher case, it is not needed anymore.

References

AGEB (2016): Struktur der Stromerzeugung in Deutschland 2015. AG Energiebilanzen e.V. Available online at http://www.ag-energiebilanzen.de/21-0-Infografik.html, checked on 3/29/2016.

Barabas, G.; Bauer, T. K.; Budde R.; Janßen-Timmen, R.; Micheli, M.; Neumann, U.; Rappe, H. (2013): Regionalökonomische Effekte des Emscherumbaus. Rheinisch-Westfälisches Institut für Wirtschaftsforschung. Essen.

Beysiegel, W. (2015): The influence of the ecological reconstruction of the Emscher System on the discharge regime. Master thesis. Universität Duisburg-Essen, Essen & Radboud University, Nijmegen.

Birk, S.; Hering, D. (2006): Direct comparison of assessment methods using benthic macroinvertebrates: a contribution to the EU Water Framework Directive intercalibration exercise. In *Hydrobiologia* (566), pp. 401–415. DOI: 10.1007/978-1-4020-5493-8_28.

Cierjacks, A.; Kleinschmit, B.; Babinsky, M.; Kleinschroth, F.; Markert, A.; Menzel, M. et al. (2010): Carbon stocks of soil and vegetation on Danubian floodplains. In *Journal of Plant Nutrition and Soil Science* (173, 5).

Döbbelt-Grüne, S.; Koenzen, U.; Hartmann, C.; Hering, D.; Birk, S. (2015): Handbuch zur Bewertung und planerischen Bearbeitung von erheblich veränderten (HMWB) und künstlichen Wasserkörpern (AWB), Version 3.0. Erstellt im Auftrag der LAWA. Stand Juli 2015, p. 137.

dynaklim. Available online at http://www.dynaklim.de/dynaklim2pub/index.html, checked on 3/30/2016.

EGLV Blog. Available online at www.blog.eglv.de, checked on 3/29/2016.

Elmqvist, T.; Setälä, H.; Handel, S. N.; van der Ploeg, S.; Aronson, J.; Blignaut, J. N. et al. (2015): Benefits of restoring ecosystem services in urban areas. In *Current Opinion in Environmental Sustainability* (14), pp. 101–108. DOI: 10.1016/j.cosust.2015.05.001.

Emschergenossenschaft (2009): Flussgebietsplan Emscher.

Emschergenossenschaft (2014): Fünfjahresübersicht 2014 bis 2018.

Emschergenossenschaft (2015): Geschäftsbericht 2014/2015.

Frehmann, T. (2015): Integral energy recovery strategies for wastewater disposal and treatment in Germany. In *Proceedings of International Conference Water and Energy 2015 - Opportunities for Energy and Resource Recovery in the Changing World, 08.-10.06.2015*.

Grün, E.; Schmelz, K.-G.; Schild, L. (2013): Klimarelevante Emissionen des Emschersystems. In *KA Korrespondenz Abwasser* (3).

Haines-Young, R.; Potschin, M. (2013): CICES V4. 3–Revised report prepared following consultation on CICES Version 4, August-December 2012. In *EEA Framework Contract No EEA. IEA/09/003*.

Hecht, D.; Karl, H.; Werbeck, N. (2015): RUFIS. Beiträge zur Ballungsraumforschung. Umsetzung der Wasserrahmenrichtlinie an der Unteren Wupper. Kosten-Nutzen-Analyse am Beispiel der Wärmebelastung. Bochum (Heft 15).

Hydrotec (2004): Hochwasser-Aktionsplan Emscher. Grundlagen, Überflutungsgebiet, Schaden.

Johann, G.; Frings, H.-G. (2016): Hochwasserrisiko mindern und Ziele des Gewässerschutzes erreichen - geht das? Ein Praxisbeispiel: die ökologische Verbesserung des Gewässersystems der Emscher. In *Technische Universität Dresden - Fakultät Bauingenieurwesen, Insitut für Wasserbau und Technische Hydromechanik, 39. Dresdner Wasserbaukolloquium 2016, "Gewässerentwicklung & Hochwasserrisikomanagment"*.

Junkernheinrich, M.; Jarre, N.; Micosatt, G. (2008): Abwasserwirtschaft und demografischer Wandel - Wirkungen des demografischen Wandels auf die Abwasserwirtschaft und mögliche Konsequenzen für die Emschergenossenschaft. Studie der Forschungsgesellschaft für Raumfinanzpolitik mbH und der Westfälischen Wilhelms-Universität Münster im Auftrag der Emschergenossenschaft, unveröffentlicht. Münster.

Landers, D. H.; Nahlik, A. M. (2013): Final ecosystem goods and services classification system (FEGS-CS). In *EPA United States Environmental Protection Agency. Report number EPA/600/R-13/ORD-004914*.

Landesvermessungsamt NRW (2006): Digitales Landschaftsmodell DLM 25.

MUNLV NRW (2006): Wirtschaftliche Analyse Arbeitsgebiet Emscher. Ministerium für Umwelt, Naturschutz, Landwirtschaft und Verbraucherschutz, Düsseldorf.

MUNLV NRW (2007): Klimawandel in Nordrhein-Westfalen - Wege zu einer Anpassungsstrategie. Ministerium für Umwelt, Naturschutz, Landwirtschaft und Verbraucherschutz, Düsseldorf.

Niemann, A. (2001): Schädigung des hyporheischen Interstitials kleiner Fließgewässer durch Niederschlagswassereinleitungen. Dissertation, Universität Essen.

Quirmbach, M.; Freistühler, E.; Papadakis, I. (2012): Auswirkungen des Klimwandels in der Emscher-Lippe-Region. Analysen zu den Parametern Luftqualität und Niederschlag. In *dynaklim-Publikation* (Nr. 30).

Radschlag; IGS (2013): Bericht zum Projekt Radverkehrsanalyse auf der Römer-Lippe-Route. Radschlag – Büro für Tourismus und Radverkehr; IGS – Ingenieurgesellschaft Stolz mbH Verkehrsplanung und Beratung.

Rolauffs, P.; Hering, D.; Sommerhäuser, M.; Rödiger, S.; Jähnig, S. C. (2002): Leitbildorientierte biologische Fließgewässerbewertung zur Charakterisierung des Sauerstoffhaushaltes. In *Förderkennzeichen (UFOPLAN) 200 24 227. Universität Duisburg-Essen, Essen.*

Scholz, M.; Mehl, D.; Schulz-Zunkel, C.; Kasperidus, H. D.; Born, W.; Henle, K. (2012): Ökosystemfunktionen von Flussauen. Analyse und Bewertung von Hochwasserretention, Nährstoffrückhalt, Kohlenstoffvorrat, Treibhausgasemissionen und Habitatfunktion. In *Naturschutz und Biologische Vielfalt* (124, 2).

Semrau, M.; Reuter, S.; Hurck, R. (2007): Entwicklungschancen der Gewässer im Emschergebiet - Grundlage für einen effizienten Mitteleinsatz. In *Wasser und Abfall* (6).

Statistisches Bundesamt: Baupreisindizes. Available online at https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Konjunkturindikatoren/Preise/bpr210.html, checked on 3/30/2016.

ANNEX: REPORTING TABLES - EMSCHER MATURE CASE

PART I

A.0 Study description

Element of Part I	Instructions	User entries
Administrative details	1. Provide general information about: • the entity/ies involved in carrying out the assessment • the provider/s of information for the assessment • - the provider/s of funding for the assessment	• *Emschergenossenschaft (EG),University of Duisburg-Essen (UDE), IWW Rheinisch-Westfälisches Institut für Wasser (IWW)* • *EG* • *EU FP7 project*
Objectives of the assessment	2. • Define the intended audience of the results (*Who will be the main recipient of the outcome report?*) • Define and explain the specific purpose and the expected outcomes of carrying out the assessment (*What do you want to achieve by assessing changes in ESS in your area?*).	• *Intended audience: Researchers, practitioneers* • *Objectives: The assessment is conducted with the aim of (i) testing the ESS Evaluation Framework proposed and (ii) identifying the benefits resulting from the Emscher re-conversion project for subsequently conducting a cost-benefit analysis.*
Overview of the study area	3. Provide a detailed description of the study area considering: • geographical location (e.g. Mediterranean region, Western Europe, Nordic region) • spatial extent • environmental attributes (e.g. climate type, topography, water quality levels, water availability)	• *Northwest Europe* • *The Emscher catchment basin covers 865 km^2* • *temperate seasonal climate, 150 m above sea level (source) to 25 m (mouth)*

	• economic activities taking place in the area (e.g. land use, land use transitions, comparison of activities by share of GDP) • socioeconomic profile (e.g. population density, average household income, age profile) • sociocultural aspects (e.g. value systems, role of landscape and land use in identity formation).	• *The former land use was mainly urban settling, coal mining, steel production and steel processing. A shipping channel and a network of roads was built for that purpose. Today's land use is a very densely populated area with 17 cities that are apparently merged into one metropole conglomerate. There is hardly any agriculture; business has shifted towards service companies. The total built-up area is ~50%, agricultural land ~18%, natural area (incl. forested area) ~ 22%.* • *2.2 M inhabitants live in the Emscher basin with a mean population density of 2,775 inhab./km^2.* • *The people are used to avoiding the streams in the area since 1900, when creeks and rivers turned into a system of open wastewater channels. In a densely populated area, places for local recreation are highly demanded.*
Stakeholder list	4. Elaborate an exhaustive list of the stakeholders present in the area.	• *People living in the area;* • *Recreators (boaters, bikers, walkers);* • *Researchers, environmental educators;* • *Industry (including agro-industry);* • *Mining companies;* • *Industrial forestry;* • *NGOs;* • *Water board (= WWTP operator, CSO operator);* • *Chambers of commerce;* • *Industrial memorial tourism*
Terminology	5. If necessary after going carefully through the DESSIN Glossary, include the definitions of any additional case-specific terminology here.	*NR*

A.1 Drivers

1. Characterisation Table for Drivers

The list of drivers is based on MARS, 2014.

DRIVER	SPECIFICATION (to be input by the user)
Flood protection	Flood protection – along with the need to discharge wastewater – was the most important driver for the first Emscher conversion, resulting in a manmade open wastewater system. Though the second Emscher conversion aims at renaturalizing the streams, flood protection has to be guaranteed at any time.
Industry	Industry is an important factor since the 1860s, when coal mining, steel production and steel processing started. Now it has shifted towards service providers.
Tourism & recreation	Tourism in the Ruhr area is not relevant except for some industrial/cultural heritage sites. Local recreation, however, is very important for the inhabitants of the Emscher cities.
Transport	A dense network of roads and highways, the most travelled railway route in Germany and a shipping channel are characteristic for the Ruhr area.
Urban development	The urban development in the Emscher basin started in the 1860s and the basin is now one of the world's most densely populated areas.

A.2 Pressures

2. Characterisation Table for Pressures

The relation between the pressure categories and the drivers is based on IMPRESS Guidance No. 3 and MARS, 2014

DRIVER IDENTIFIED IN THE STUDY AREA	PRESSURE CATEGORY	SPECIFICATION
Flood protection	Morphological	The flood protection requirements in the area lead to channelized streams encased by dikes.
Flood protection	Other anthropogenic	Pumping stations and other manmade structures were installed for maintaining the discharge function of the Emscher and its tributaries.
Industry	Diffuse source	Diffuse sources of industrial pollution can result from deposition of air emission.
Industry	Point source	Point sources of pollution (after completion of the Emscher re-conversion) will be CSO facilities and WWTPs (4).
Industry	Activities using specific substances	Due to the dense population and the high variety of industry branches, all kinds of substances can be found in the wastewater.
Industry	Morphological	The morphology of the landscape was changed as a result of the industrialization.
Industry	Other anthropogenic	The industrialization shaped the area in all kinds of aspects.
Tourism & recreation	Morphological	The aim of improving recreational opportunities at the streams will lead to a change in their morphology after completion of the Emscher re-conversion.
Tourism & recreation	Other anthropogenic	
Transport	Diffuse source	Diffuse sources of pollution are run-off from roads and sealed surface (as well as from agricultural areas).
Transport	Point source	As there is a combined sewage system in the Emscher region, point sources of pollution resulting from transportation (after completion of the Emscher re-conversion) will also be CSO facilities and WWTPs (4).
Transport	Morphological	The dense network of transport routes through the area shaped the

		landscape and often runs alongside of the Emscher or its tributaries.
Transport	Other anthropogenic	
Urban development	Diffuse source	Diffuse sources of pollution are run-off from roads and sealed surface (as well as from agricultural areas).
Urban development	Point source	Point sources of pollution (after completion of the Emscher re-conversion) will be CSO facilities and WWTPs (4).
Urban development	Morphological	The intensive urban development shaped the Emscher region in all kinds of aspects.
Urban development	Other anthropogenic	

A.3.1 Description of the proposed measure

The Emscher re-conversion is a project stated in 1990 and expected to be completed in 2020. Its main aims are the creation of sewer net-work incl. CSOs, resulting in waste-water free streams. This first step is followed by the ecological restoration of the waste-water free streams by recreation of near natural stream beds/profiles.

A.3.2 Claimed/expected capabilities of the Proposed Measures

Proposed Measure	Claimed/expected capability	Qualitative description	Quantitative description
Emscher re-conversion: *- creation of sewer net-work incl. CSOs* *- waste-water free streams* *- ecological restoration* *- recreation of near natural stream beds/profiles (technical measure)*	*- reduction of point and diffuse pressure (tested)* *- reduction in the frequency of overflow events (tested)* *- reduction of morphological constraints (tested)*	*- reduction* *- reduction* *- reduction*	*n/a*

A.3.3 Driver, Pressure, and/or State affected by the capabilities

Proposed Measure	**Capability**		
	Effect on DRIVER *(from D catalogue)*	**Effect on PRESSURE** *(from P catalogue)*	**Effect on STATE** *(from S catalogue)*
Emscher re-conversion: *- creation of sewer net-work incl. CSOs* *- waste-water free streams* *- ecological restoration* *- recreation of near natural stream beds/profiles (technical measure)*	*n/a*	*- reduction of point and diffuse pressure (tested)* *- reduction in the frequency of overflow events (tested)* *- reduction of morphological constraints (tested)*	*1. Biological* *- Macrophytes + Phytobenthos* *- Benthic invertebrates* *- Fish fauna* *2. Hydromorphology* *2.1 Hydrology* *- Quantity + dynamics of water flow* *- Water residence time* *2.2 Morphology* *- Depth and width variation* *- Structure and substrate of the water body bed* *- Structure of the water body shoreline* *3. Physiochemical* *3.1 General* *- Transparency* *- Thermal conditions* *- Oxygenation conditions* *- Salinity* *- Nutrient conditions*

			3.2 Priority hazardous substances *- Pollution by all priority substances identified as being discharged into the body of water* *3.3 Other pollutants* *- Pollution by other substances identified as being discharged in significant quantities into the body of water* *4. Cultural* *all*

A.3.4 Case-relevant ESS

STATE Parameter influenced by measure	CICES Class *(restricted to ecosystem type)*	CICES Group	CICES Division	CICES Section
Biological	*Bio-remediation by micro-organisms, algae, plants, and animals*	*Mediation by biota*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	*Mediation by biota*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Maintaining nursery populations and habitats	*Lifecycle maintenance, habitat and gene pool protection*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
Hydrology	*Hydrological cycle and water flow maintenance*	*Liquid flows*	*Mediation of flows*	*Regulation & Maintenance*
Morphology	*Flood protection*	*Liquid flows*	*Mediation of flows*	*Regulation & Maintenance*
	Maintaining nursery populations and habitats	*Lifecycle maintenance, habitat and gene pool protection*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
	Filtration/ sequestration/ storage/ accumulation by ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*

	Dilution by atmosphere, freshwater and marine ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Decomposition and fixing processes	*Soil formation and composition*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
	Mass stabilization and control of erosion rates	*Mass flows*	*Mediation of flows*	*Regulation & Maintenance*
Physiochemical	*Surface water for drinking*	*Water*	*Nutrition*	*Provisioning*
	Surface water for non-drinking purposes	*Water*	*Materials*	*Provisioning*
	Bio-remediation by micro-organisms, algae, plants, and animals	*Mediation by biota*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	*Mediation by biota*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Filtration/ sequestration/ storage/ accumulation by ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*

	Dilution by atmosphere, freshwater and marine ecosystems	*Mediation by ecosystems*	*Mediation of waste, toxics and other nuisances*	*Regulation & Maintenance*
	Decomposition and fixing processes	*Soil formation and composition*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
	Chemical condition of freshwaters	*Water conditions*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
	Maintaining nursery populations and habitats	*Lifecycle maintenance, habitat and gene pool protection*	*Maintenance of physical, chemical, biological conditions*	*Regulation & Maintenance*
all	*all cultural*	…	…	*Cultural*

A.4.1 Comparison of case-relevant ESS with potential beneficiaries and FEGS

CICES Class *(restricted to ecosystem type)* *(from Step 3)*	**Beneficiary** *(Categories and Sub-Categories)*	**FEGS** *(Importance of FEGS to the Beneficiary)*
Surface water for drinking	*Water Subsisters*	*• water suitable for drinking (i.e., human consumption)*
Surface water for non-drinking purposes	*Agricultural,* *Commercial / Industrial,* *Municipal Drinking Water Plant Operators*	*• e.g. water for growing and maintaining crops* *• e.g. water suitable for cooling or processing industrial products* *• e.g. water suitable for processing by a municipal drinking water plant*
Flood protection	*Resource-Dependent Businesses, Residential Property Owners*	*• opportunity for placement of infrastructure and reduced/increased risk of flooding, erosion, and pest infestation on the property*
Hydrological cycle and water flow maintenance	*none*	*none*
Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	*Industrial Dischargers,* *Waste Water Treatment Plant Operators*	*• Opportunity to discharge into the environment* *• Medium for discharging [treated municipal wastewater] into the environment*

Filtration/ sequestration/ storage/ accumulation by ecosystems	*Industrial Dischargers,* *Waste Water Treatment Plant Operators*	• *Opportunity to discharge into the environment* • *Medium for discharging [treated municipal wastewater] into the environment*
Bio-remediation by micro-organisms, algae, plants, and animals	*Industrial Dischargers,* *Waste Water Treatment Plant Operators*	• *Opportunity to discharge into the environment* • *Medium for discharging [treated municipal wastewater] into the environment*
Decomposition and fixing processes	*Industrial Dischargers,* *Waste Water Treatment Plant Operators*	• *Opportunity to discharge into the environment* • *Medium for discharging [treated municipal wastewater] into the environment*
Dilution by atmosphere, freshwater and marine ecosystems	*Industrial Dischargers,* *Waste Water Treatment Plant Operators*	• *Opportunity to discharge into the environment* • *Medium for discharging [treated municipal wastewater] into the environment*
Mass stabilization and control of erosion rates	*Resource-Dependent Businesses, Residential Property Owners*	• *opportunity for placement of infrastructure and reduced/increased risk of flooding, erosion, and pest infestation on the property*
Chemical condition of freshwaters	*Water Subsisters,* *Agricultural,* *Commercial / Industrial,* *Municipal Drinking Water Plant*	• *water suitable for drinking (i.e., human consumption)* • *e.g. water for growing and maintaining crops* • *e.g. water suitable for cooling or processing*

	Operators	*industrial products* *• e.g. water suitable for processing by a municipal drinking water plant*
Maintaining nursery populations and habitats	*Food Extractors* *Pharmaceutical and Food Supplement Suppliers*	*• edible organisms (i.e., flowers, plants, etc.) or associated products (i.e., fruit, greens, tubers, berries, sap) for commercial use or sale• edible organisms (i.e., birds, mammals, reptiles, etc.) for commercial use or sale* *• organisms (i.e., flowers, plants, etc.) or associated products (i.e., fruit, greens, tubers, berries, sap) used in medicines or sold for medicinal purposes* *• organisms (i.e., birds, mammals, reptiles, etc.) or products associated with organisms (i.e., oils, fats, keratin, etc.) used in medicines or sold for medicinal purposes*
all cultural	*Recreational (e.g. Experiencers and Viewers; Boaters)* *Inspirational* *Learning (e.g. Researchers; Educators and Students)* *Non-Use (e.g. People who care)*	

A.4.2 List of stakeholders (Part I) compared to list of beneficiaries (US EPA)

List of stakeholders *(from Part I, Step 0)*	**List of beneficiaries** *(from Step 4.1)*	**FEGS appropriate?**
People living in the area	*Residential Property Owners* *People who care*	*yes*
Recreators (boaters, bikers, walkers)	*Experiencers and Viewers* *Boaters*	*yes*
Industrial memorial tourism	*Experiencers and Viewers*	*yes*
Researchers, environmental educators	*Researchers* *Educators and Students*	*yes*
NGOs	*People who care*	*no*
Industry	*none*	*no*
Mining companies	*none*	*no*
Industrial forestry	*none*	*no*
Water board (= WWTP operator, CSO operator)	*none*	*no*
Chambers of commerce	*none*	*no*

A.4.3 Intermediate and final ESS table

Measure	Capability	ESS affected (use CICES and US EPA catalogue!)					Beneficiaries (use US EPA categorization!)[1]
		CICES section	CICES division	CICES group	CICES class	DESSIN ESS *(use US EPA nomenclature where applicable)*[2]	*(no beneficiary = only intermediate service)*
Emscher re-conversion: - creation of sewer network incl. CSOs - waste-water free streams - ecological restoration - recreation of near natural stream beds/profiles	- improvement of water quality - reduction in the frequency of overflow events - improvement of the physical structure of watercourses	**Regulation & Maintenance services**	Mediation of waste, toxics and other nuisances	Mediation by ecosystems	Filtration/sequestration/storage/ accumulation by ecosystems	**Self-purification: N retention** (DESSIN) **IESS** **Fact sheet # 1** **Self-purification: P retention** (DESSIN) **IESS** **Fact sheet # 2** **Self-purification: C retention** (DESSIN) **IESS** **Fact sheet # 3** **→ ISS for FESS # 2-5**	*No direct beneficiary,* *but potential savings to the **water board** that must meet water quality standards for measures against CSO discharge*
			Mediation of waste, toxics and other nuisances	Mediation by ecosystems	Dilution by atmosphere, freshwater and marine ecosystems		
			Mediation of flows	Liquid flows	Hydrol. cycle + water flow maintenance		
			Maintenance of physical, chemical, biological conditions	Soil formation and composition	Decomposition and fixing processes		
			Mediation of flows	Liquid flows	**Flood protection**	**Opportunity for placement of infrastructure and reduced risk of flooding**	**Residential Property Owners**

							(US EPA/DESSIN) **FESS** **Fact sheet # 1**	
			Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	**Maintaining nursery populations and habitats**	**Biodiversity** (DESSIN) **IESS** **Fact sheet # 4** **→ ISS for FESS # 2-5**	*No direct beneficiary*
			Maintenance of physical, chemical, biological conditions	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*only intermediate ESS:* CO_2 sequestration	*no beneficiary (US EPA)/* Humanity?
			Maintenance of physical, chemical, biological conditions	Atmospheric composition and climate regulation	Micro and regional climate regulation	*only intermediate ESS:* Local climate	*no beneficiary (US EPA)/* Residential Property Owners?; Experiencers and Viewers? (Health effect on citizens)
		Cultural services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	**Experiential use of plants, animals and landscapes in different environmental settings**	**Opportunity for placement of infrastructure in environment** **FESS** **Fact sheet # 2**	**Resources-dependent businesses (operators of cafés and restaurants along the restored riverfront);** **Residential Property Owners**

					Physical use of landscapes in different environmental settings	**Opportunity for biking** (DESSIN) & **Opportunity for recreational boating** (US EPA) **FESS Fact sheet # 3**	**Bikers** & **Boaters**
			Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Intellectual and representative interactions	Educational	Research opportunities (US EPA)	Researchers
						Opportunities to understand, communicate, and educate (US EPA) **FESS Fact sheet # 4**	**Educators and Students**
			Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Other cultural outputs	Existence	**Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)** (DESSIN) **FESS Fact sheet # 5**	**People who care;** **Residential Property Owners**

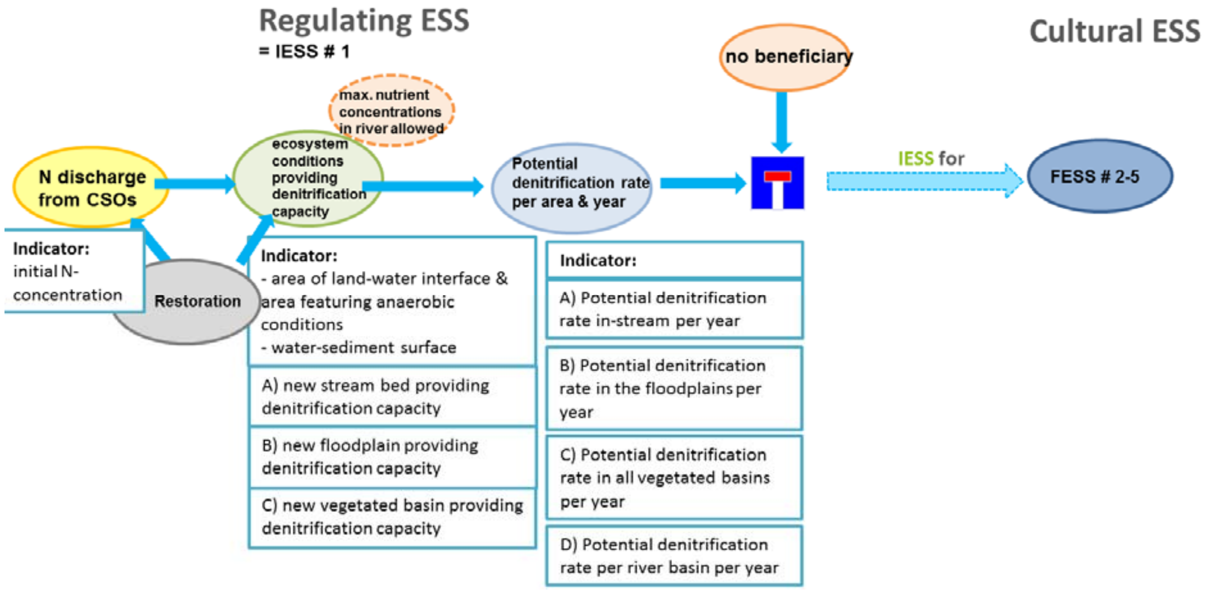
A.4.3 Categorization of case-relevant ESS into intermediate ESS and final ESS

Intermediate ESS (IESS)	Final ESS (FESS)
Self-purification: N retention (DESSIN) **IESS # 1**	**Opportunity for placement of infrastructure and reduced risk of flooding** (US EPA) **FESS # 1**
Self-purification: P retention (DESSIN) **IESS # 2**	**Opportunity for placement of infrastructure in environment** (US EPA) **FESS # 2**
Self-purification: C retention (DESSIN) **IESS # 3**	**Opportunity for biking** (DESSIN) & **Opportunity for recreational boating** (US EPA) **FESS # 3**
Biodiversity (DESSIN) **IESS # 4**	**Opportunities to understand, communicate, and educate** (US EPA) **FESS # 4**
	Knowledge that a restored river area exists, with suitable water quality (i.e. GEP) (DESSIN) **FESS # 5**

STEPs 5, 6, 7 and 8

The overview graphics below are structured according to the Cookbook and Companion document. Color codes: yellow = Pressure, grey = Response, green = STATE, light blue = Impact I, dark blue = Impact II, orange = Beneficiaries, orange with dotted line = Regulatory thresholds. Indicators required for assessing the single elements are given below the elements.

IESS # 1: Self-purification: N retention



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses
CICES Section	Regulation & Maintenance services
CICES Division	Mediation of waste, toxics and other nuisances
CICES Group	Mediation by ecosystems/ Liquid flows/ Soil formation and composition
CICES Class	**Filtration/sequestration/storage/accumulation by ecosystems/ Dilution by atmosphere, freshwater and marine ecosystems/ Hydrol. cycle + water flow maintenance/ Decomposition and fixing processes**
ESS *(use US EPA nomenclature!)*[2]	**Opportunity to discharge into the environment/ Medium for discharging [treated municipal wastewater] into the environment** (US EPA)**/** **Self-purification: N retention** (DESSIN)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** A) Rivers and streams
	B) Wetlands
	C) Lakes and ponds
Temporal scope	A) per year

	B) per year
	C) per year
Spatial scope	A) per river basin B) per river basin C) per river basin
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	Intermediate Service
For FESS: Intermediate ESS required *(use CICES catalogue!)*	no
For Intermediate services: FESS affected & other IESS required	FESS # 2-5
Regulatory Threshold	Water quality standards (WFD) ?
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	no

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Box XX!)*	**Data quality** *(see catalogue in Box XX!)*
DRIVER *(From*	1) Industry: CSO discharge 2) Transport: run-off, CSO	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

IMPRESS/WISE) (only those addressed by the capability??)	discharge 3) Urban development: CSO discharge					
PRESSURE *(From IMPRESS/WISE) (only those addressed by the capability??)*	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions **3) Point source: pollution through CSO discharge of municipal waste water + rainwater** 4) Activities using specific substances??	1) Stream profile 2) Concentration of N in the water 3) Concentration of N in the water 4) -	1) ? 2) mg/L 3) mg/L 4) -	?	direct indicator	
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) construction of a piped sewer network (2) newly created physical structure of watercourses, floodplains, and basins				
STATE *(only those relevant for the assessment of Impact I)*	A) stream bed conditions providing denitrification capacity	(1) water-sediment surface (2) initial N-concentration	(1) m², (2) kg/m³	(1) EGLV planning data/measurement data: stream profiles, water-sediment surface, (2) EGLV monitoring data: N conc	proxy	planning data/ measurement data, monitoring data → "B data"
	B) new floodplain providing denitrification capacity	(1) area of land-water	(1) ha,	(1) ?, EGLV planning	proxy	planning data/

		interface (i.e. HQ50 area), (2) stream length (3) soil types,	(2) km, (3) – ,	data/measurement data: stream profiles, water-sediment surface, (2) GIS (3) GIS		measurement data, GIS data → "B data"
	C) new vegetated basin providing denitrification capacity	(1) water-sediment surface (2) frequency of flooding	(1) m² (2) 1/a	(1) EGLV planning data: basin profiles, water-sediment surface	proxy	planning data/ measurement data, monitoring data → "B data"
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	A) Potential denitrification rate in-stream per year	potential denitrification rate	kg/a N removed in total stream length in the Emscher basin	see State parameters, literature data	proxy	modelled data, literature data → "B data"
	B) Potential denitrification rate in the floodplains per year	potential denitrification rate	kg/a of total floodplain area in the Emscher basin	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	C) Potential denitrification rate in all vegetated basins per year	potential denitrification rate	kg/a in all vegetated basins per year	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	D) Potential denitrification rate per river basin per year	=A+B+C	kg/a in total Emscher basin			
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

INDICATOR TABLE - Further explanation

Further information on IMPACT I – PROVISION indicator "*Potential denitrification rate in-stream per year*":

The developed tool is a simple Excel-based calculation to estimate the turnover of carbon and nutrients (N, P) in a given river reach. It calculates carbon and nutrient loads that are retained/eliminated over in a given time in a given river reach. The results provide a rough estimation of the self-purification capacity for aerobic river systems. The tool does not claim correctness; e.g. the tool does not consider changing turnover rates due to temperature changes or changes related to sunlight exposure or other dynamic variables. Furthermore, it is assumed that there is no further input or output within the time period.

Central information is stream geometry (wetted surface, cross section area). Information about the profile shape, location as well as the water level (e.g. dry weather flow which is reached 50% of the year) was entered. For each profile the overall wetted surface, the projected surface area as well as the total water volume are calculated. Subsequently, literature turnover rates for in-stream retention are applied (COD and N retention rates were taken from Niemann (2001); P retention rates were taken from Scholz et al. (2012)).

	N-retention (kg/ha/a)	P-retention (kg/ha/a)	C-retention (t/ha/a)
In-stream	10.95	53	4.38

The turnover of COD and N is assumed to be performed by the biomass on the wetted surface of the river stretch. For P, we assume that particulate P is held back by macrophytes determined via an estimated percentage of the projected surface area.

The tool was applied to four rivers stretches within the Emscher catchment and, subsequently, scaled up to basin level based on similarity of profiles. Water levels for each profile section were derived using an existing 1D-model and based on median discharge and water level of one year (source: EG). The initial concentrations used were mean values of TOC (transferred by a correlation factor to COD), NH_4-N and Total P (monitoring data source: EG). For the status BEFORE the re-conversion, a standard concrete profile was used, while for the status AFTER, profile geometry was taken from restoration plans; both were implemented into the 1-D model. As river profiles BEFORE restoration were made out of concrete, there were no macrophytes. Nevertheless, we assume a retention of P in algae and biofilms that equals a macrophyte density of 5%. High macrophyte density (80%) of the projected river surface/cross section area is assumed for half of the focus streams and low density (20%) for the other half for the stage AFTER re-conversion.

Further information on IMPACT I – PROVISION indicator "*Potential denitrification rate in the floodplains per year*":

This indicator applies a rule of thumb based calculation using the denitrification rates for different soil types according to Scholz et al. (2012). Various soil types are assigned denitrification rates, given as levels, each corresponding to a range of nitrogen retention rates. Literature values for denitrification rates are adopted from Scholz et al. (2012)(based on Gäth et al., 1997; modified by Höper, 2000; NLfB working group " Bodenkundliche Beratung" and modified by Scholz et al. (2012).

	Denitrification (kg/ha/a)	P-retention (kg/ha/a)	C-stock (t/ha)
Grassland	5	0.75	212
Woodland	5	5	357
Artificial land cover	0	0.75	0

The product of the area [ha] having a certain soil type with its respective nitrogen retention level [kg/ha/a] results in the nutrient retention [kg/a] in the area of a floodplain having this certain soil type. The sum of the retention rates of the areas with individual soil types within a floodplain gives the total potential retention in the entire floodplain of the examined water body/ stream section. The actual floodplain in the Emscher area is defined as the area that is statistically flooded every 50 or 100 years (HQ50 or HQ100). This potential retention is extrapolated to the entire Emscher catchment.
The size of the HQ50 areas was obtained from maintenance and development plans for each stream in GIS (Atkis; EG, Pflege- und Entwicklungspläne) for the state AFTER restoration. The respective area sizes BEFORE restoration were derived from the sizes AFTER restoration with consideration of information from the ecological development potential evaluated for each water body in the Emscher basin (Semrau et al. 2007; Semrau et al., internal documents 2013). The ecological development potential categorizes each stream according to the availability of space for development into (i) a group of streams with no space available, and thus, an area BEFORE restoration similar in size as AFTER. One group (ii) has space for development along 10-40% of its stream

length, and thus, the BEFORE area is assumed to be 85% of the AFTER area. The last group of streams (iii) has space for development along > 40% of its stream length, from which we derive that the BEFORE area was only 70% of the AFTER area.
Furthermore, we assume a land use within the HQ50 areas BEFORE reconversion of 75% grassland, 20% woodland, and 5% concrete bed (EG, expert opinion). For the state AFTER reconversion we derived a partitioning of 45% grassland and 55% woodland from land use data (Atkis, UDE) evaluated for the DESSIN focus streams.
Upscaling to basin level was done according to stream length and the category of availability of space for development.
According to Scholz et al. (2012), the potential denitrification was calculated only for the land use types of woodland and grassland; arable land and sealed surfaces were not considered. A problem in applying this indicator was that during the restoration the channelized streams' concrete beds were removed down to the ground rock. As soil formation has not yet taken place, currently there is no proper soil type. Thus, we chose the soil type with the lowest denitrification rate (i.e. brown earth, regosols, rendzinas) (Scholz, personal communication). The soil that is newly developing along the restored water bodies is most likely rendzinas/ cambisol. Furthermore, the groundwater level in the Emscher area is very low. Since dry, and thus, aerobic soils have low denitrification rates, all other soil types could be ruled out.

RESULTS TABLE

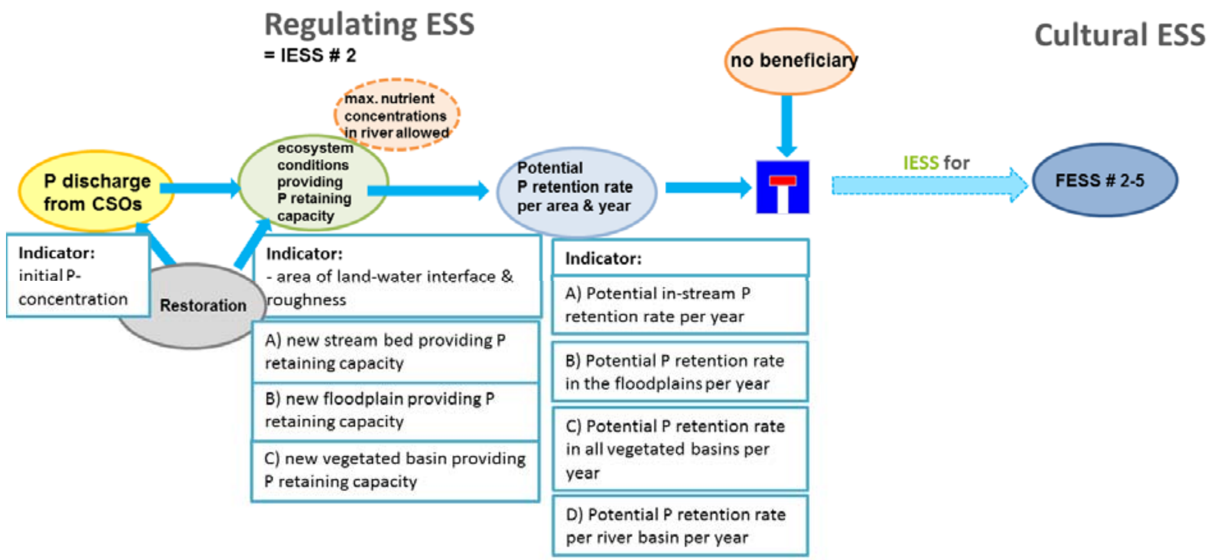
	Case-relevant Element	Output	Output unit	Comments
PRESSURE	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions 3) Point source: pollution through CSO discharge of municipal waste water + rainwater 4) Activities using specific	no results yet	(1) ? (2) mg/L (3) mg/L -	

	substances??			
STATE	A) new stream bed providing denitrification capacity	(1) water-sediment surface: BEFORE: 95 ha (entire Emscher basin) AFTER: 168 ha (entire Emscher basin) (2) initial nutrient concentrations (for 5 focus streams):	(1) m² or ha, (2) kg/m³ or mg/l	
	B) new floodplain providing denitrification capacity	(1) area of land-water interface (i.e. HQ50 area): BEFORE: 410 ha (entire Emscher basin) AFTER: 456 ha (entire Emscher basin) (2) stream length (entire Emscher basin): 252 km (3) soil types: brown earth, regosols, rendzinas	(1) m² or ha, (2) km, (3) –	
	C) new vegetated basin providing denitrification capacity	(1) water-sediment surface (m²): BEFORE: 28 ha AFTER: 66 ha (2) frequency of flooding: not available	m² 1/a	
IMPACT I - PROVISION	A) Potential denitrification rate in-stream per year	BEFORE: 1.04 t/a AFTER: 1.84 t/a	kg/a of total stream length in the Emscher basin	

	COD [mg/l]	N [mg/l]	P [mg/l]
	COD	NH4N	PO4 solute
Kirchschemmsbach	14.02	0.02	0.024
Deininghauser Bach naturnah	20.58	2.16	0.057
Deininghauser Bach uh naturn	20.58	2.16	0.057
Emscher_OL	14.69	0.3	0.093
Vorthbach	15.68	0.07	0.034

	B) Potential denitrification rate in the floodplains per year	BEFORE: 1.95 t/a AFTER: 2.28 t/a	kg/a of total floodplain area in the Emscher basin	BEFORE: concrete bed, no denitrification AFTER: Method according to Scholz et al., 2012
	C) Potential denitrification rate in all vegetated basins per year	not assessed	kg/a in all vegetated basins per year	
	D) Potential denitrification rate in total Emscher basin per year	= A+B+C not assessed	kg/a in total Emscher basin	
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
RESULTS TABLE - Description				

IESS # 2: Self-purification: P retention



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses
CICES Section	Regulation & Maintenance services

CICES Division	Mediation of waste, toxics and other nuisances
CICES Group	Mediation by ecosystems/ Liquid flows/ Soil formation and composition
CICES Class	**Filtration/sequestration/storage/accumulation by ecosystems/ Dilution by atmosphere, freshwater and marine ecosystems/ Hydrol. cycle + water flow maintenance/ Decomposition and fixing processes**
ESS *(use US EPA nomenclature!)*[2]	**Opportunity to discharge into the environment/ Medium for discharging [treated municipal wastewater] into the environment** (US EPA)**/** **Self-purification: P retention** (DESSIN)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** A) Wetlands
	B) Lakes and ponds
Temporal scope	A) per year
	B) per year
Spatial scope	A) per river basin
	B) per river basin
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	Intermediate Service
For FESS: Intermediate ESS required *(use CICES catalogue!)*	no
For Intermediate services: FESS affected & other IESS required	FESS # 2-5
Regulatory Threshold	Water quality standards (WFD) ?

Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	no

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	1) Industry: CSO discharge 2) Transport: run-off, CSO discharge 3) Urban development: CSO discharge	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions **3) Point source: pollution through CSO discharge of municipal waste water + rainwater** 4) Activities using specific substances??	1) Stream profile 2) Concentration of P in the water 3) Concentration of P in the water 4) -	1) ? 2) mg/L 3) mg/L 4) -	?	direct indicator	
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) construction of a piped sewer network				

		(2) newly created physical structure of watercourses, floodplains, and basins				
STATE *(only those relevant for the assessment of Impact I)*	A) stream bed conditions providing P retention capacity	(1) water-sediment surface (2) initial P-concentration	(1) m², (2) kg/m³	(1) EGLV planning data/measurement data: stream profiles, water-sediment surface, (2) EGLV monitoring data: P conc	proxy	planning data/ measurement data, monitoring data → “B data”
	B) new floodplain providing P retention capacity	(1) area of land-water interface (i.e. HQ50 area), (2) stream length (3) landuse and vegetation types,	(1) ha, (2) km, (3) –	(1) ?, EGLV planning data/measurement data: stream profiles, water-sediment surface, (2) GIS (3) GIS	proxy	planning data/ measurement data, GIS data → “B data”
	C) new vegetated basin providing P retention capacity	water-sediment surface	m²	EGLV planning data/measurement data: basin profiles, water-sediment surface,	proxy	planning data/ measurement data, monitoring data → “B data”
IMPACT I - PROVISION *(quantify if necessary for the assessment of*	A) Potential P retention rate in-stream per year	potential P retention rate	kg/a P removed of total stream length in the Emscher basin	see State parameters, literature data	proxy	modelled data, literature data → “B data”

Impact II, otherwise describe qualitatively)	B) Potential P retention rate in the floodplains per year	potential P retention rate	kg/a of total floodplain area in the Emscher basin	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	C) Potential P retention rate in all vegetated basins per year	potential P retention rate	kg/a in all vegetated basins per year	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	D) Potential P retention rate per river basin per year	=A+B+C	kg/a in total Emscher basin			
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

INDICATOR TABLE - Further explanation

Further information on IMPACT I – PROVISION indicator "*Potential P retention rate in-stream per year*":

See explanation for "*Potential denitrification rate in-stream per year*".

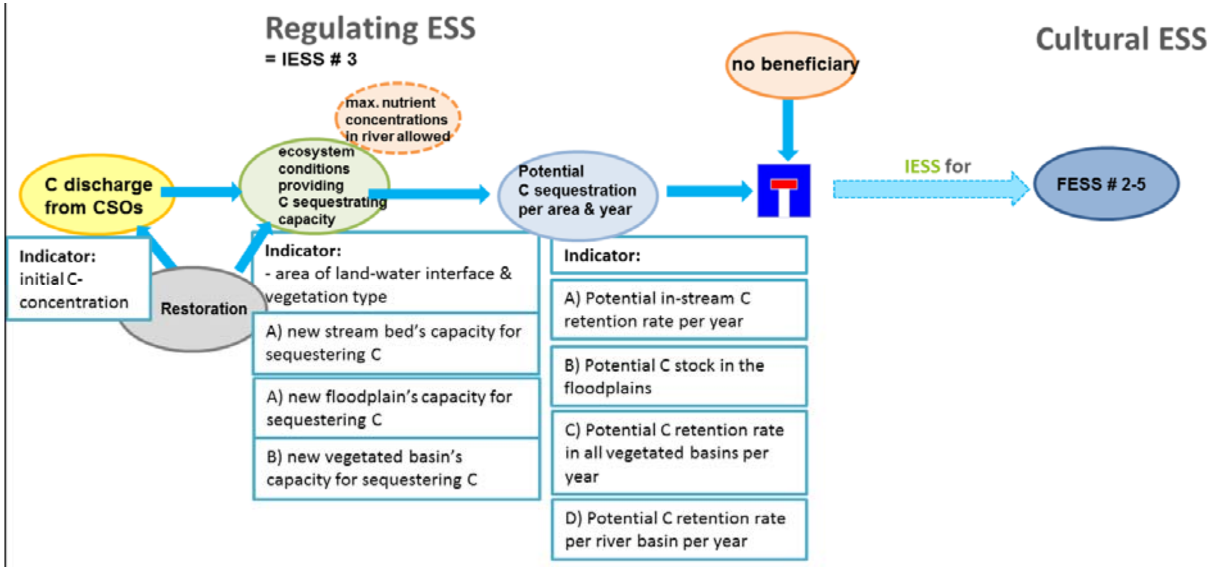
Further information on IMPACT I – PROVISION indicator "*Potential P retention rate in the floodplains per year*":

This indicator applies a rule of thumb based calculation using the phosphorous retention rates for different **roughness values** according to Scholz et al. (2012). Literature values for phosphorous retention rates are adopted from Scholz et al. (2012)(based on Brunotte et al. 2009, Koenzen et al. 2005 and modified by Scholz et al. (2012)). Various **land use and vegetation types** are assigned *Kst* values, each corresponding to a range of potential phosphorous retention rates [kg/ha/a]. The product of the area [ha] having a certain land use and vegetation type with its respective phosphorous retention level [kg/ha/a] results in the nutrient retention [kg/a] in the area of a floodplain having this certain land use and vegetation types.
The potentially wetted area (HQ50) BEFORE and AFTER restoration as well as the respective land use in these areas were derived as described for N retention. Also upscaling of the respective land use areas from stream to basin level was done according to the method described in the Annex section "*Potential denitrification rate in the floodplains per year*".

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
PRESSURE	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions 3) Point source: pollution through CSO discharge of municipal waste water + rainwater 4) Activities using specific substances??	no results yet	(4) ? (5) mg/L (6) mg/L -	
STATE	A) stream bed conditions providing P retention capacity	See results table of IESS # 1		
	B) new floodplain providing P retention capacity	See results table of IESS # 1		
	C) new vegetated basin providing P retention capacity	See results table of IESS # 1		
IMPACT I - PROVISION	A) Potential P retention rate in-stream per year	BEFORE: 0.88 t/a AFTER: 4.23 t/a		
	B) Potential P retention rate in the floodplains per year	BEFORE: 0.66 t/a AFTER: 1.4 t/a		

	C) Potential P retention rate in all vegetated basins per year	not assessed		
	D) Potential P retention rate per river basin per year	= A+B+C not assessed		
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
RESULTS TABLE - Description				

IESS # 3: Self-purification: C retention



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses

DESSIN

CICES Section	Regulation & Maintenance services
CICES Division	Mediation of waste, toxics and other nuisances
CICES Group	Mediation by ecosystems/ Liquid flows/ Soil formation and composition
CICES Class	**Filtration/sequestration/storage/accumulation by ecosystems/ Dilution by atmosphere, freshwater and marine ecosystems/ Hydrol. cycle + water flow maintenance/ Decomposition and fixing processes**
ESS *(use US EPA nomenclature!)*[2]	**Opportunity to discharge into the environment/ Medium for discharging [treated municipal wastewater] into the environment** (US EPA)**/** **Self-purification: C sequestration** (DESSIN)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** A) Rivers and streams
	B) Wetlands
	C) Lakes and ponds
Temporal scope	A) per year
	B) per year
	C) per year
Spatial scope	A) per river basin
	B) per river basin
	C) per river basin
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	Intermediate service

For FESS: Intermediate ESS required *(use CICES catalogue!)*	no
For Intermediate services: FESS affected & other IESS required	FESS # 2-5
Regulatory Threshold	Water quality standards (WFD) ?
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	no

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	1) Industry: CSO discharge 2) Transport: run-off, CSO discharge 3) Urban development: CSO discharge	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	1) Morphological: stream profile 2) Diffuse source: pollution with organic substances through run-off **3) Point source: pollution through CSO**	1) Stream profile 2) COD/BOD/SI 3) COD/BOD/SI 4) -	1) ? 2) mg/L 3) mg/L 4) -	?	direct indicator	

	discharge of municipal waste water + rainwater 4) Activities using specific substances??					
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) construction of a piped sewer network (2) newly created physical structure of watercourses, floodplains, and basins				
STATE *(only those relevant for the assessment of Impact I)*	A) stream bed conditions providing C retention capacity	(1) water-sediment surface (2) initial C-concentration	(1) m², (2) kg/m³	(1) EGLV planning data/measurement data: stream profiles, water-sediment surface, (2) EGLV monitoring data: C conc	proxy	planning data/ measurement data, monitoring data → "B data"
	B) new floodplain providing C retention capacity	(1) area of land-water interface (i.e. HQ50 area), (2) stream length (3) vegetation types	(1) ha, (2) km, (3) –	(1) ?, EGLV planning data/measurement data: stream profiles, water-sediment surface, (2) GIS (3) GIS	proxy	planning data/ measurement data, GIS data → "B data"
	C) new vegetated basin providing C retention capacity	water-sediment surface	m²	EGLV planning data/measurement data: basin profiles, water-sediment surface	proxy	planning data/ measurement data, monitoring data → "B data"

IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	A) Potential C retention rate in-stream per year	potential C retention rate	kg/a C removed of total stream length in the Emscher basin	see State parameters, literature data	proxy	modelled data, literature data → "B data"
	B) Potential C stock in the floodplains per year	potential C stock	kg/a of total floodplain area in the Emscher basin	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	C) Potential C retention rate in all vegetated basins per year	potential P retention rate	kg/a in all vegetated basins per year	see State parameters, literature data	proxy	GIS data, literature data → "B data"
	D) Potential C retention rate per river basin per year	=A+B+C	kg/a in total Emscher basin			
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

INDICATOR TABLE - Further explanation

Further information on IMPACT I – PROVISION indicator "*Potential C retention rate in-stream per year*":

See explanation for "*Potential denitrification rate in-stream per year*".

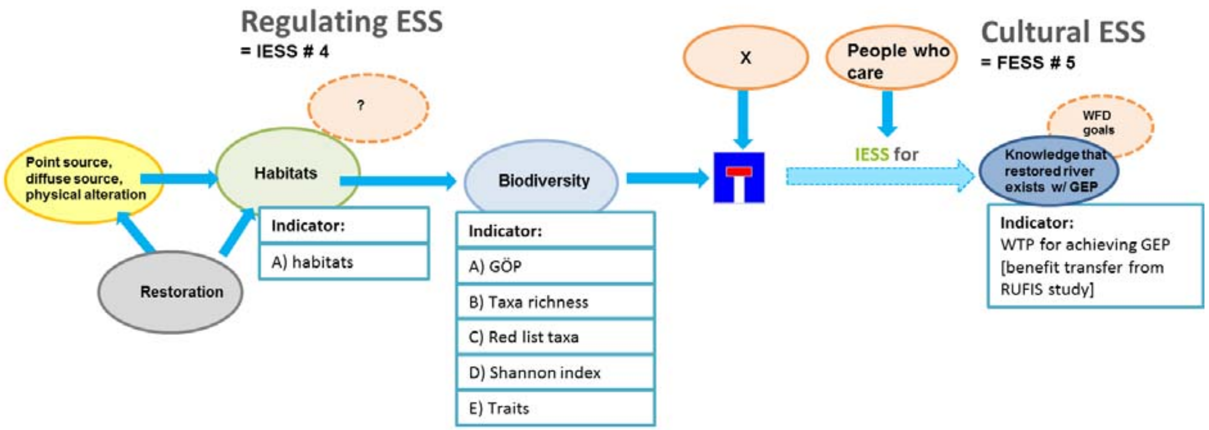
Further information on IMPACT I – PROVISION indicator "*Potential C stock in the floodplains per year*":

This indicator applies a rule of thumb based calculation using the organic carbon stock values for different **vegetation types** according to Cierjacks et al. (2010) in Scholz et al. (2012), defined as "*Total C stocks aboveground and belowground*". We used those values for softwood and meadows (grassland). The product of the area [ha] having a certain vegetation type with its respective C stock value [t/ha] results in the C stock [kg/a] in the area of a floodplain having this certain vegetation types. The potentially wetted area (HQ50) BEFORE and AFTER restoration as well as the respective land use in these areas were derived as described for N retention. Also upscaling of the respective land use areas from stream to basin level was done according to the method described in the Annex section "*Potential denitrification rate in the floodplains per year*".

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
PRESSURE	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions 3) Point source: pollution through CSO discharge of municipal waste water + rainwater 4) Activities using specific substances??	no results yet	(7) ? (8) mg/L (9) mg/L -	
STATE	A) stream bed conditions providing C retention capacity	See results table of IESS # 1		
	B) new floodplain providing C retention capacity	See results table of IESS # 1		
	C) new vegetated basin providing C retention capacity	not assessed		
IMPACT I -	A) Potential C retention rate in-	BEFORE: 416.40 t/a		

PROVISION	stream per year	AFTER: 736.06 t/a		
	B) Potential C stock in the floodplains per year	BEFORE: 94.53 megatons AFTER: 133.16 megatons		
	C) Potential C retention rate in all vegetated basins per year	not assessed		
	D) Potential C retention rate per river basin per year	= A+B+C not assessed		
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
RESULTS TABLE - Description				

IESS # 4: Biodiversity



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses
CICES Section	Regulation & Maintenance services
CICES Division	Maintenance of physical, chemical, biological conditions
CICES Group	Lifecycle maintenance, habitat and gene pool protection
CICES Class	**Maintaining nursery populations and habitats**

ESS *(use US EPA nomenclature!)*[2]	**Biodiversity & habitats** (DESSIN)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** Rivers and streams
Temporal scope	point in time
Spatial scope	per river basin
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	Intermediate service
For FESS: Intermediate ESS required *(use CICES catalogue!)*	no
For Intermediate services: FESS affected & other IESS required	FESS # 2-5
Regulatory Threshold	Water quality standards (WFD) ?
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	no

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box*	**Data quality** *(see catalogue in Framework p.XX!)*

					XX!)	
DRIVER *(From IMPRESS/WISE) (only those addressed by the capability??)*	1) Industry: CSO discharge 2) Transport: run-off, CSO discharge 3) Urban development: CSO discharge	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE) (only those addressed by the capability??)*	1) Morphological: stream profile 2) Diffuse source: pollution through run-off from fertilizer application/ transport emissions **3) Point source: pollution through CSO discharge of municipal waste water + rainwater** 4) Activities using specific substances??	1) Stream profile 2) Concentration of N in the water 3) Concentration of N in the water 4) -	1) ? 2) mg/L 3) mg/L 4) -	?	direct indicator	
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) construction of a piped sewer network (2) newly created physical structure of watercourses, floodplains, and basins				
STATE *(only those relevant for the assessment of Impact I)*	Habitats	1) Ecological potential 2) Taxa richness 3) Red list taxa				

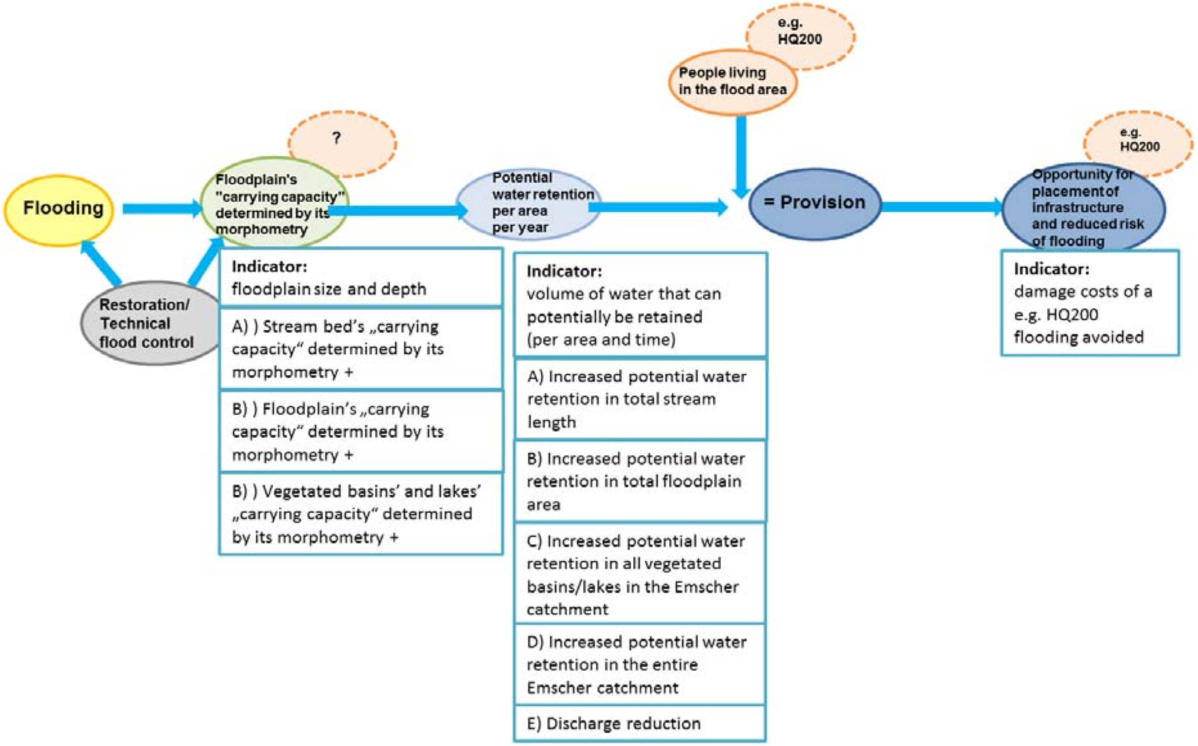
		4) Saprobic index 5) Traits				
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	Biodiversity	A) Taxa richness B) Red list taxa C) EQR (Saprobic index) D) Ecological potential	A) mean number of taxa B) max. number of taxa C) - D) km	monitoring data	direct indicator	→ "A data"
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
INDICATOR TABLE - Further explanation						

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	1) Morphological: stream profile 2) Diffuse source: pollution	not yet quantified		

	through run-off from fertilizer application/ transport emissions **3) Point source: pollution through CSO discharge of municipal waste water + rainwater** 4) Activities using specific substances??			
STATE	Habitats	not assessed		
IMPACT I - PROVISION	Biodiversity	A) Taxa richness BEFORE: 9.33 AFTER: 18.10 B) Red list taxa BEFORE: 0 AFTER: 4 C) EQR (Saprobic index) BEFORE: 0.59 AFTER: 0.87 D) Ecological potential: km | good-moderate | moderate-poor | poor | poor-bad | bad BEFORE | 0.00 | 0.00 | 0.00 | 0.00 | 297.11 AFTER | 99.23 | 92.93 | 61.04 | 43.90 | 0.00	A) mean number of taxa B) max. number of taxa C) - D) - E) km	
IMPACT II - USE	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*

IMPACT II – resulting benefit	IESS → see FESS # 2-5	*not to be quantified*	*not to be quantified*	*not to be quantified*
RESULTS TABLE - Description				

FESS # 1: Opportunity for placement of infrastructure and reduced risk of flooding



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events

	(3) improvement of the physical structure of watercourses
CICES Section	Regulation & Maintenance Services
CICES Division	Mediation of flows
CICES Group	Liquid flows
CICES Class	Flood Protection
ESS *(use US EPA nomenclature!)*[2]	**Opportunity for placement of infrastructure and reduced risk of flooding** (US EPA/DESSIN)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** A) Rivers and streams
	B) Wetlands
	C) Lakes and ponds
Temporal scope	A) Per year
	B) Per year
	C) Per year
Spatial scope	A) per river basin
	B) per river basin
	C) per river basin
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	FESS

For FESS: Intermediate ESS required *(use CICES catalogue!)*	none
For Intermediate services: FESS affected & other IESS required	NR
Regulatory Threshold	e.g. HQ200
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	Residential Property Owners: People living in the flood area

INDICATOR TABLE

	Case-relevant Element	Indicator	Output unit	Data sources & data availability	Indicator quality *(see explanation in Framework Box XX!)*	Data quality *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	(1) Flood protection (2) Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)* *(only those addressed by the*	(1) Other anthropogenic: Flooding	Volume of stormwater during flood event HQ50/HQ100	m^3	?	direct indicator	

capability??)						
RESPONSE *(describe in detail)*	Emscher re-conversion: Natural flood control through near natural stream beds/profiles	1) Estimation of the reduction in the frequency of overflow events?? 2) Estimation of the substitution of technical flood protection infrastructure by green infrastructure?	?			
STATE *(only those relevant for the assessment of Impact I)*	A) Stream bed's "carrying capacity" determined by its morphometry	Stream bed's profile	m³	EGLV planning data/measured data	direct indicator	planning data/measured data → "B data"
	B) Floodplain's "carrying capacity" determined by its morphometry	Floodplain size and depth	m³	EGLV planning data/measured data; GIS	direct indicator	planning data/measured data → "B data"
	C) Vegetated basins'/lakes' "carrying capacity" determined by its morphometry	Vegetated basins'/lakes' profile	m³	EGLV planning data/measured data	direct indicator	planning data/measured data → "B data"
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	A) Increased potential water retention in total stream length (per year?)	Volume of water that can potentially be retained	m³ (/a?) in total stream length	EGLV planning data/measured data	proxy: status-related indicator	planning data/measured data → "B data"
	B) Increased potential water retention in total floodplain area (per year?)	Volume of water that can potentially be retained	m³ (/a?) in total floodplain area	EGLV planning data/measured data; GIS	proxy: status-related indicator	planning data/measured data → "B data"
	C) Increased potential water retention in all vegetated	Volume of water that can	m³ (/a?) in all	EGLV planning	proxy: status-related	planning

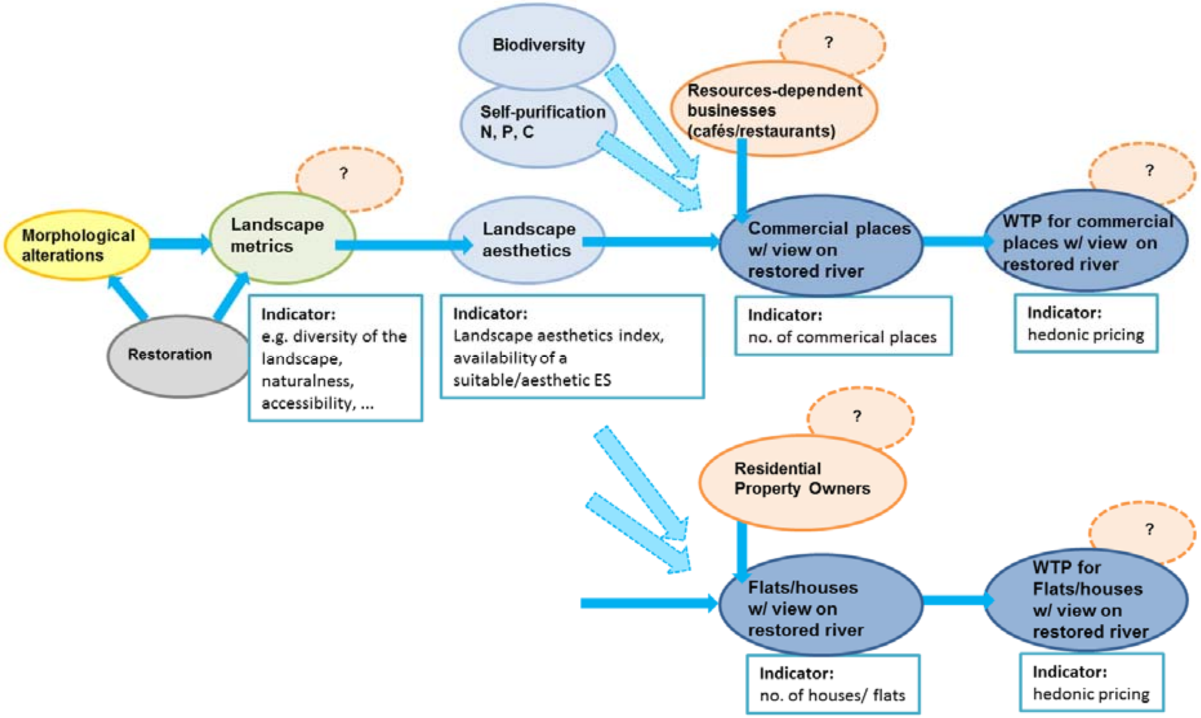
	basins/lakes in the Emscher catchment (per year?)	potentially be retained	vegetated basins/lakes	data/measured data	indicator	data/measured data → "B data"
	D) Increased potential water retention in the entire Emscher catchment (per year?)	= A+B+C	m^3 /a in the entire Emscher basin			
	E) Discharge reduction	Discharge inside streams	m^3/s → %	Master thesis Wiebke Beysiegel (Beysiegel 2015)	direct indicator	modelled data → "B data"
IMPACT II - USE	Equal to Provision	see Impact I Provision				
IMPACT II - resulting benefit	Avoided costs of flood damage		€	Hochwasser-Aktionsplan Emscher (Hydrotec 2004)		
Further explanation						

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	(1) Other anthropogenic: Flooding	no results yet	m^3	
STATE	A) Stream bed's "carrying capacity" determined by its morphometry		m^3	

	B) Floodplain's "carrying capacity" determined by its morphometry		m³	
	C) Vegetated basins'/lakes' "carrying capacity" determined by its morphometry		m³	
	A) Increased potential water retention in total stream length (per year?)	not assessed	m³ (/a?) in total stream length	
	B) Increased potential water retention in total floodplain area (per year?)	not assessed	m³ (/a?) in total floodplain area	
	C) Increased potential water retention in all vegetated basins/lakes in the Emscher catchment (per year?)	BEFORE: 881,500 m³ (0 m³ vegetated) AFTER: 3.3 M m³ (1.55 M m³ vegetated)	m³ (/a?) in all vegetated basins/lakes	
	D) Increased potential water retention in the entire Emscher catchment (per year?)	= A+B+C	m³ /a in the entire Emscher basin	
IMPACT I - PROVISION	E) Discharge reduction	weighted average [m³/s] | BEFORE | AFTER **100 year event** | 36.41 | 27.66 **2 year event** | 17.16 | 9.80 CHANGE: - The discharge for a two-year-event is on average reduced by 44%. - The average percentage of improvement for a flood event with a recurrence interval of 100 years is 27%.	m³/s → %	
IMPACT II - USE	Equal to Provision	see Impact I Provision	m³/km/a	

IMPACT II - resulting benefit	Avoided costs of flood damage	BEFORE: 178,550 €/100 years AFTER: 0 €/100 years	€/100 years	
RESULTS TABLE - Description				

FESS # 2: Opportunity for placement of infrastructure in environment



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events

	(3) improvement of the physical structure of watercourses
CICES Section	Cultural Services
CICES Division	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]
CICES Group	Physical and experiential interactions
CICES Class	**Experiential use of plants, animals and landscapes in different environmental settings**
ESS *(use US EPA nomenclature!)*[2]	**Opportunity for placement of infrastructure in environment**
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** Rivers and streams + Wetlands
Temporal scope	per year
Spatial scope	along water body
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	FESS
For FESS: Intermediate ESS required *(use CICES catalogue!)*	(1) Hydrological cycle and water flow maintenance **(2) Filtration/sequestration/storage/ accumulation by ecosystems ← Intermediate ESS # 1-3** **(3) Maintaining nursery populations and habitats ← Intermediate ESS # 4** (4) Chemical condition of freshwaters (5) Mediation of smell impacts Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds
For Intermediate services: FESS affected & other IESS	NR

required	
Regulatory Threshold	?
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	A) Resources-dependent businesses (operators of cafés and restaurants along the restored riverfront)
	B) Residential Property Owners

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE) (only those addressed by the capability??)*	(1) Flood protection (2) Industry (3) Tourism & recreation (4) Transport (5) Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE) (only those addressed by the capability??)*	(1) Morphological (2) Other anthropogenic (3) Diffuse source (4) Point source (5) Activities using specific substances	no results yet				
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) improvement of water quality (2) reduction in the				

		frequency of overflow events (3) improvement of the physical structure of watercourses				
STATE *(only those relevant for the assessment of Impact I)*	Landscape aesthetics: 1. Presence of surface water 2. Water clarity status 3. Extent to which sound of flowing water can be heard 4. Algae status 5. Odor status 6. Extent of experiential facilities 7. Number of experiential users	1. Percentage of analysis period that surface waters are visible 2. Water clarity metric 3. Percentage of analysis period during which flow rate is sufficient for sound of flowing water to be heard 4. Frequency of algal blooms 5. Odor metric 6. Experiential facilities metric 7. Persons likely to make close-to-home visits	1. Percentage (dimensionless) 2. Water clarity metric 3. Percentage (dimensionless 4. Number of blooms during analysis period 5. Odor metric 6. Experiential facilities metric 7. Number of people living with 8 km of restored reach	1. Monitoring data 2. Monitoring data 3. Discharge monitoring 4. Monitoring data 5. ? 6. ? 7. Population density data, road network maps (from publications on urban density distribution in Ruhrgebiet)	direct indicator: status-related indicator	1. Monitoring data 2. Monitoring data 3. Monitoring data 4. Monitoring data 5. ? 6. ? 7. Literature
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds *Note: no direct link between I1 and I2*	Beauty of the landscape (Composite indicator that aggregates indicators 1-6 in the list above); IESS # 1-4	Dimensionless index		proxy: status-related indicator	see State

IMPACT II - USE	A) commercial places with view on restored river sections	commercial area (at Lake Phoenix)	m²	City of Dortmund		
	B) flats/houses with view on restored river sections	housing area (houses/flats) (at Lake Phoenix)	m²	City of Dortmund		
IMPACT II - resulting benefit	A) Hedonic pricing for commercial place (cafés, restaurants, …)	(1) Rental cost for commercial area per m² (2) (exemplary) business turnover for commercial place	(1) €/m²/a (2) €/a	BEFORE: 0 AFTER: (1) German Chamber of Commerce and Industry (2) German Federal Statistical Office		→ "B data"
	B) Hedonic pricing for housing area	Rental cost for housing area per m² (at Lake Phoenix, in New Emscher Valley)	€/m²/a	BEFORE: 0 (1) AFTER: online real estate portal "wohnungsboerse.net",		→ "B data"

INDICATOR TABLE - Further explanation

Further information on IMPACT II – resulting benefit indicator "Hedonic pricing for housing area":

Method 1:

The area for commercial or flat/housing use and the rental cost for commercial/ housing area per m² resulted in the total rental costs at Lake Phoenix. No upscaling to basin level was conducted.

Method 2:

Total prices for buying and rental flats were available for 2007 and 2011. Buying offers for flats have in averaged decreased in price between 2007 and 2011 by -8% both for the New Emscher Valley and the remaining Emscher area. Renting offers for flats have, however, increased by +3.5% in the New Emscher

Valley while they stayed constant in the remaining Emscher area.

In order to forecast prices per m^2 for the restored Emscher valley, we assumed constant prices for the Emscher area but increased prices for the New Emscher Valley. These were derived from the price increases observed at Lake Phoenix. Price change from BEFORE (0 €/m^2) to AFTER (8.68 €) was used but an average rental price (mean price in the New Emscher valley and remaining Emscher basin in 2011 = 5.22 €/m^2) was distracted, resulting in an increase by 3.46 €/m^2 for rental flats. The area for apartments/flats AFTER re-conversion was assumed to be the same as in 2011. Price estimates were conducted based on total area of flats (calculated from the number of flats of various sizes) and price per m^2. Note that this is only valid for rental flats.

Price effect was differentiated from area effect by assuming a constant number of flats, and thus, total housing area from 2007 through 2020 when calculating the price change.

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
PRESSURE	(1) Morphological (2) Other anthropogenic (3) Diffuse source (4) Point source (5) Activities using specific substances	No results yet		
STATE	Landscape aesthetics	No results yet		
IMPACT I - PROVISION	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	No results yet	Dimensionless index	
IMPACT II - USE	A) commercial places with view on	Method 1:	m^2	

<table>
<tr><td rowspan="2"></td><td>restored river sections</td><td>BEFORE: 0 m²
AFTER: 100,000 – 150,000 m²</td><td></td><td></td></tr>
<tr><td>B) flats/houses with view on restored river sections</td><td>Method 1:
BEFORE: 0 m²
AFTER: 240,000 m²

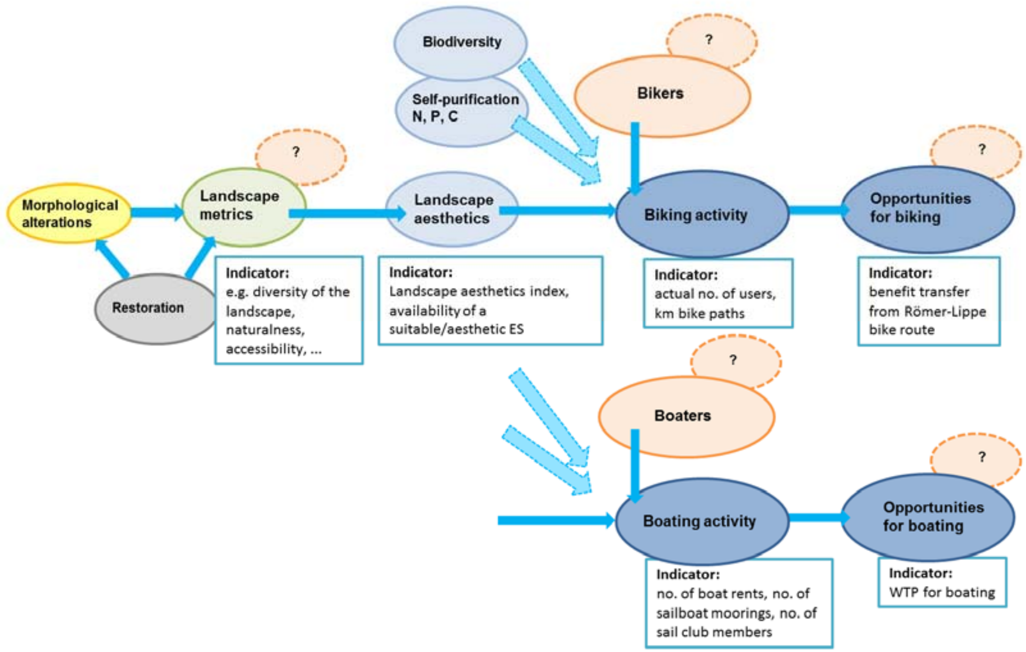
Method 2:
<table><tr><td colspan="3">Number of rental flat offers</td></tr><tr><td></td><td>BEFORE</td><td>AFTER</td></tr><tr><td>NE</td><td>3,062</td><td>5,590</td></tr><tr><td>Emscher</td><td>9,434</td><td>21,896</td></tr></table></td><td>Method 1: m²

Method 2: count</td><td></td></tr>
<tr><td rowspan="2">IMPACT II – resulting benefit</td><td>A) Hedonic pricing for commercial place (cafés, restaurants, …)</td><td>Method 1:
BEFORE: 0 €/a (only Lake Phoenix!)
AFTER: 8,4 - 19,8 M €/a (only Lake Phoenix!)

Method 2: not assessed</td><td>€/a</td><td>Economic impact</td></tr>
<tr><td>B) Hedonic pricing for housing area</td><td>Method 1:
BEFORE: 0 €/a (only Lake Phoenix!)
AFTER: 2,5 M €/a (only Lake Phoenix!)

Method 2:
<table><tr><td colspan="3">Price effect for rental flat offers (M €/a)</td></tr><tr><td></td><td>BEFORE</td><td>AFTER</td></tr><tr><td>NE</td><td>11.81</td><td>20.44</td></tr><tr><td>Emscher</td><td>40.38</td><td>40.33</td></tr></table></td><td>€/a</td><td>Economic impact</td></tr>
<tr><td colspan="5">RESULTS TABLE - Description</td></tr>
<tr><td colspan="5"></td></tr>
</table>

FESS # 3: Opportunity for biking & recreational boating



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events

	(3) improvement of the physical structure of watercourses
CICES Section	Cultural Services
CICES Division	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]
CICES Group	Physical and experiential interactions
CICES Class	**Physical use of landscapes in different environmental settings**
ESS *(use US EPA nomenclature!)*[2]	**(A) Opportunities for biking** (DESSIN)
	(B) Opportunity for recreational boating (US EPA)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** Rivers and streams + Wetlands
Temporal scope	per year
Spatial scope	along water body
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	FESS
For FESS: Intermediate ESS required *(use CICES catalogue!)*	(1) Hydrological cycle and water flow maintenance **(2) Filtration/sequestration/storage/ accumulation by ecosystems ← Intermediate ESS # 1-3** **(3) Maintaining nursery populations and habitats ← Intermediate ESS # 4** (4) Chemical condition of freshwaters (5) Mediation of smell impacts
For Intermediate services: FESS affected & other IESS required	NR

Regulatory Threshold	?
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	A) Bikers (leisure time bikers/ everyday & workday bikers) (FESS not applicable) B) Boaters

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	(6) Flood protection (7) Industry (8) Tourism & recreation (9) Transport (10) Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE)* *(only those addressed by the capability??)*	(6) Morphological (7) Other anthropogenic (8) Diffuse source (9) Point source (10) Activities using specific substances	no results yet				
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) improvement of water quality (2) reduction in the frequency of overflow				

		events (3) improvement of the physical structure of watercourses				
STATE *(only those relevant for the assessment of Impact I)*	Landscape aesthetics: 8. Presence of surface water 9. Water clarity status 10. Extent to which sound of flowing water can be heard 11. Algae status 12. Odor status 13. Extent of experiential facilities 14. Number of experiential users	8. Percentage of analysis period that surface waters are visible 9. Water clarity metric 10. Percentage of analysis period during which flow rate is sufficient for sound of flowing water to be heard 11. Frequency of algal blooms 12. Odor metric 13. Experiential facilities metric 14. Persons likely to make close-to-home visits	8. Percentage (dimensionless) 9. Water clarity metric 10. Percentage (dimensionless 11. Number of blooms during analysis period 12. Odor metric 13. Experiential facilities metric 14. Number of people living with 8 km of restored reach	8. Monitoring data 9. Monitoring data 10. Discharge monitoring 11. Monitoring data 12. ? 13. ? 14. Population density data, road network maps (from publications on urban density distribution in Ruhrgebiet)	direct indicator: status-related indicator	8. Monitoring data 9. Monitoring data 10. Monitoring data 11. Monitoring data 12. ? 13. ? 14. Literature
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds *Note: no direct link between I1 and I2*	Beauty of the landscape (Composite indicator that aggregates indicators 1-6 in the list above) ; IESS # 1-4	Dimensionless index		proxy: status-related indicator	see State
IMPACT II - USE	A) Recreational use by bikers	(1) actual no. of bikers, (2) km of bike paths	(1) no. per year (2) km	(1) Römer-Lippe-bike route study	(1) direct indicator; (2) proxy	→ "B data"

				(Radschlag, IGS 2013); (2) bike paths built		
	B) Recreational use by boaters	(1) no. of sailors (2) no. of sailboat moorings (3) no. of sail club members	(1) count sailors (2) count sailboat moorings (3) count sail club members	(1) Lake Phoenix boat rental (2) Lake Phoenix boat rental (3) Lake Phoenix boat rental	(1) proxy (2) proxy (3) proxy	→ "B data"
IMPACT II - resulting benefit	A) Recreational benefits for bikers	economic impact for this type of recreation	€	Römer-Lippe-bike route study (Radschlag, IGS 2013)		→ "B data"
	B) Recreational benefits for boaters	economic impact for this type of recreation	€			→ "B data"
INDICATOR TABLE - Further explanation						

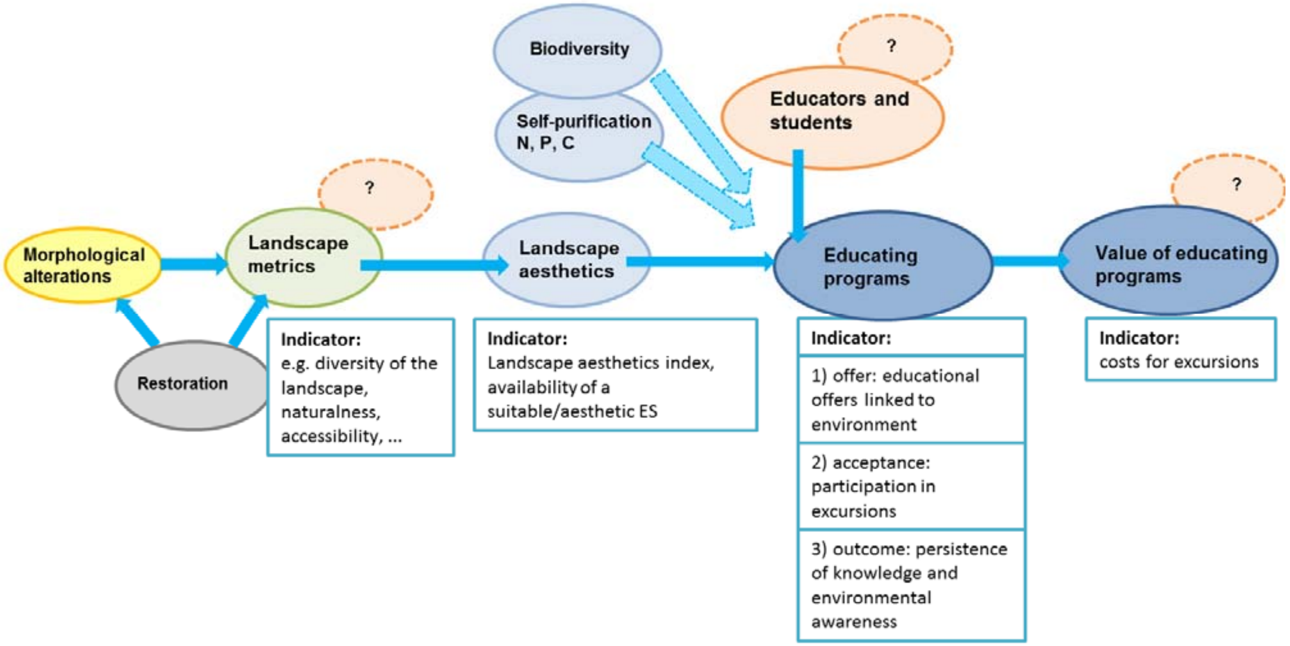
RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE	(6) Morphological (7) Other anthropogenic (8) Diffuse source	No results yet		

	(9) Point source (10) Activities using specific substances			
STATE	Landscape aesthetics	No data available		
IMPACT I - PROVISION	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	No data available	Dimensionless index	
IMPACT II - USE	A) Recreational use by bikers	(1) BEFORE: 11,392 bikers/year AFTER: 40,000 – 50,000 bikers/year (2) BEFORE: ca. 35 km of bike paths AFTER: 123 km of bike paths	(1) count bikers/year (2) km of bike paths	estimation of the number of bikers based on the length (km) of bike paths present BEFORE in relation to AFTER
	B) Recreational use by boaters	(1) BEFORE: 0 sailors/year AFTER: 5,000 sailors/year (2) BEFORE: 0 sailboat moorings AFTER: 40 sailboat moorings (3) BEFORE: 0 sail club members AFTER: 70 sail club members	(1) count sailors (2) count sailboat moorings (3) count sail club members	
IMPACT II – resulting benefit	A) Recreational benefits of bikers	BEFORE: 378,784 €/year AFTER: 40,000 – 50,000 bikers per year - day trippers: 80 % - touring cyclist: 20 % - day trippers: 14.50 € p.P./day - touring cyclist: 75 € p.P./day = 1,330,000 €/year	€/year	benefit transfer from Radschlag, IGS (2013)
	B) Recreational benefits of boaters	BEFORE: 0	€	

		AFTER: 5,000 sailors per year * 5 € p. P./day + 40 moorings * 5 € p. M./year + 70 sail club members * 180 € p.M./year = 53,600 €/year		

RESULTS TABLE - Description

FESS # 4: Opportunities to understand, communicate, and educate



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses

CICES Section	Cultural Services
CICES Division	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]
CICES Group	Intellectual and representative interactions
CICES Class	Educational
ESS *(use US EPA nomenclature!)*[2]	**Opportunities to understand, communicate, and educate** (US EPA)
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** Rivers and streams + Wetlands
Temporal scope	per year
Spatial scope	per catchment
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	FESS
For FESS: Intermediate ESS required *(use CICES catalogue!)*	(1) Hydrological cycle and water flow maintenance **(2) Filtration/sequestration/storage/ accumulation by ecosystems ← Intermediate ESS # 1-3** **(3) Maintaining nursery populations and habitats ← Intermediate ESS # 4** (4) Chemical condition of freshwaters (5) Mediation of smell impacts Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds
For Intermediate services: FESS affected & other IESS required	NR
Regulatory Threshold	NR

Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	Educators and students

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE) (only those addressed by the capability??)*	(11) Flood protection (12) Industry (13) Tourism & recreation (14) Transport (15) Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE) (only those addressed by the capability??)*	(11) Morphological (12) Other anthropogenic (13) Diffuse source (14) Point source (15) Activities using specific substances	no results yet				
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses				

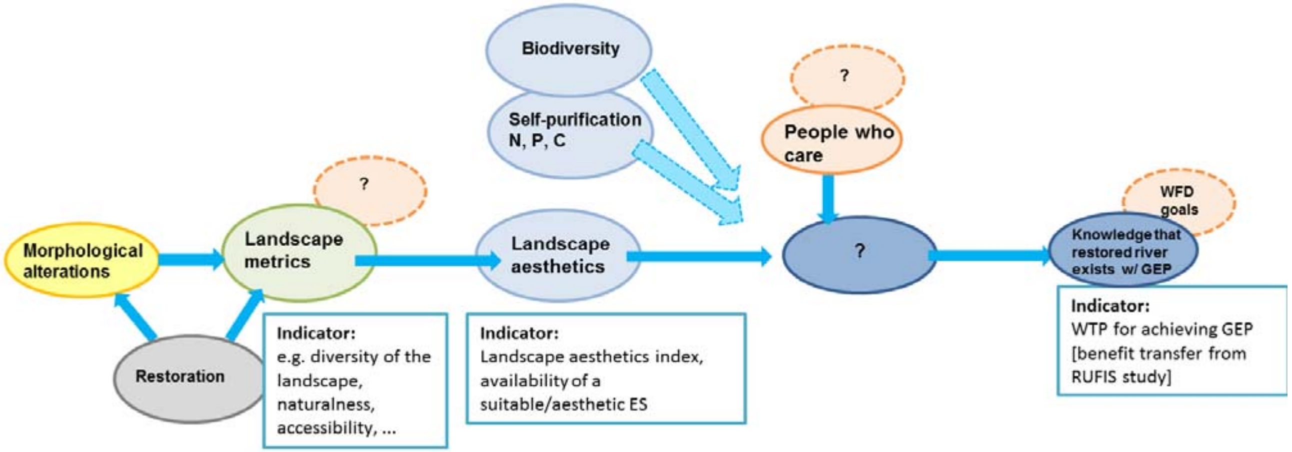
STATE *(only those relevant for the assessment of Impact I)*	← Intermediate ESS # 1- 4	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	← Intermediate ESS # 1-4 Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - USE	1) offer: educational offers linked to environment	number of educational offers linked to environment	count			
	2) acceptance: participation in excursions	number of participants in excursion (to Lake Phoenix and to streams)	count	EG, Marc Franke	direct	→ “B data”
	3) outcome: persistence of knowledge and environmental awareness	metric for success of educational unit	dimensionless			
IMPACT II - resulting benefit	costs for excursions	cost for participating in excursion	€	DGL excursion (UDE, personal communication) as proxy for WTP	proxy	→ “B data”
INDICATOR TABLE - Further explanation						

RESULTS TABLE				
	Case-relevant Element	Output	Output unit	Comments
PRESSURE				
STATE	← Intermediate ESS # 1-4	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT I - PROVISION	← Intermediate ESS # 1-4	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - USE	1) offer: educational offers linked to environment	No data available		
	2) acceptance: participation in excursions	BEFORE: a) Lake Phoenix: 0 b) Course of the stream: n/a AFTER: a) Lake Phoenix: 218-834 b) Course of the stream: 465-1549	count	
	3) outcome: persistence of knowledge and environmental awareness	No data available		
IMPACT II – resulting benefit	costs for excursions	BEFORE: n/a AFTER: a) 218-834 visitors per year * 10 € p. P. + b) 465-1,549 visitors per year * 20 € p. P.	€/a	

		= 11,480-39,320 €/year		

RESULTS TABLE - Description

FESS # 5: Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)



ESS HEAD	
Measure influencing the ESS	(1) creation of sewer net-work incl. CSOs (2) waste-water free streams (3) ecological restoration
Capability influencing the ESS	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses
CICES Section	Cultural Services
CICES Division	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]

CICES Group	Other cultural outputs
CICES Class	**Existence**
ESS *(use US EPA nomenclature!)*[2]	Knowing that the environment exists (US EPA) / **Knowledge that a restored river area exists, with suitable water quality (i.e. GEP) (DESSIN)**
Ecosystem *(use US EPA classification!)*[3]	***Class:*** Aquatic. ***Sub-class:*** Rivers and streams + Wetlands
Temporal scope	per year
Spatial scope	per catchment
FESS or Intermediate Service? *(for Intermed. Service stop after Impact I)*	FESS
For FESS: Intermediate ESS required *(use CICES catalogue!)*	(1) Hydrological cycle and water flow maintenance **(2) Filtration/sequestration/storage/ accumulation by ecosystems ← Intermediate ESS # 1-3** **(3) Maintaining nursery populations and habitats ← Intermediate ESS # 4** (4) Chemical condition of freshwaters (5) Mediation of smell impacts Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds
For Intermediate services: FESS affected & other IESS required	NR
Regulatory Threshold	Water Framework Directive
Beneficiary *(From USEPA[1]/NACE)* *(continue after Impact I only if beneficiary is present)*	People who care/ Residential Property Owners

INDICATOR TABLE						
	Case-relevant Element	**Indicator**	**Output unit**	**Data sources & data availability**	**Indicator quality** *(see explanation in Framework Box XX!)*	**Data quality** *(see catalogue in Framework p.XX!)*
DRIVER *(From IMPRESS/WISE) (only those addressed by the capability??)*	(16) Flood protection (17) Industry (18) Tourism & recreation (19) Transport (20) Urban development	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
PRESSURE *(From IMPRESS/WISE) (only those addressed by the capability??)*	(16) Morphological (17) Other anthropogenic (18) Diffuse source (19) Point source (20) Activities using specific substances	no results yet				
RESPONSE *(describe in detail)*	Emscher re-conversion	(1) improvement of water quality (2) reduction in the frequency of overflow events (3) improvement of the physical structure of watercourses				
STATE *(only those relevant for the*	← Intermediate ESS # 1-4	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*

assessment of Impact I)						
IMPACT I - PROVISION *(quantify if necessary for the assessment of Impact II, otherwise describe qualitatively)*	← Intermediate ESS # 1-4	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - USE	???					
IMPACT II - resulting benefit	Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)	WTP by people in the area for achieving GEP	€/year	benefit transfer from Hecht et al. (2015)	proxy	→ "B data"

INDICATOR TABLE - Further explanation

Further information on IMPACT II – resulting benefit indicator "*WTP by people in the area for achieving GEP*":

As primary valuation research was not feasible within the DESSIN project, the indicator for monetizing the value derived from the "*knowledge that a restored river area with suitable water quality exists*" had to be taken from literature using the benefit transfer approach. The study chosen for that purpose is the WTP study for achieving a GEP of River Wupper by Hecht et al. (2015) which can be at least used for an adjusted unit value transfer for the Emscher case since it fulfills the following criteria: The ESS studied in the Wupper case is the same as in the Emscher case. Wupper and Emscher are both tributaries to the River Rhine of nearly the same length and catchment area so that location, affected beneficiaries and market construct are comparable. As both rivers were historically used for (industrial) sewage disposal it can be assumed that the change in ESS required to achieve a GEP is similar in both cases. Although the study is not published in a peer-review journal it is the best available source for benefit transfer.

The total WTP for restoring the Emscher was calculated by taking the WTP for reaching GEP of the River Wupper and transferring it to the population structure in the Emscher catchment. WTP was transferred based on average WTP with regard to gender, with regard to the total number of inhabitants, and with regard to the age structure of the inhabitants. As in Hecht et al. (2015), only inhabitants > 18 years were considered. The results of the three scenarios (gender, total, age) range from 104 to 108 M € per year.

RESULTS TABLE				
	Case-relevant Element	**Output**	**Output unit**	**Comments**
PRESSURE				
STATE	← Intermediate ESS # 1-4	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT I - PROVISION	← Intermediate ESS # 1-4 Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	*not to be quantified*	*not to be quantified*	*not to be quantified*
IMPACT II - USE	???			
IMPACT II – resulting benefit	Knowledge that a restored river area exists, with suitable water quality (i.e. GEP)	BEFORE: 0 €/a AFTER: 2,686,079 inhabitants (> 18 years old) WTP = 39.96 € per person and year = 107,335,717 € per year	€/a	benefit transfer from RUFIS study
RESULTS TABLE - Description				

A.B Selection of indicators

F	G	H	J	K	N	O	P	Q
							Data Availability	
ID	Metric	Indicator	Unit	System	Alternati		yes	no
S111	Presence of microbial pathogens			WW/WS	no			x
S112	Presence of cyanobacteria and cyanotoxins			WW/WS	no			x
S113	Presence of toxic chemicals			WW/WS	no		x	
S121	Economic impact (incl. Indirect and induced	(Economic impact - initial spending) / economic	[/] or [-]	WW/WS	no		x	
S131	Number of jobs, amount of employment created by implementation of technology/solution		[1/a]	WW/WS	yes		x	
S132	Number of jobs, amount of employment derived from improved cultural services		[1/a]	WW/WS	yes			x
S141	Number of beneficiaries affected		[-]	WW/WS	yes		x	
S142	Categories of beneficiaries affected			WW/WS	yes			x
S151	Experiential and physical use of landscapes in		l/a	WW/WS	yes		x	
S152	Intellectual and representative interactions (Educational)		l/a	WW/WS	yes		x	
En121		Efficient use of energy	[%]	WW/WS	no			x
En12		Energy recovery rate	[%]	WW/WS	no			x
En12		Green energy usage	[%]	WW/WS	no			x
En12	Energy consumed		[kWh/m³]	WW/WS	yes			x
En131	Materials, chemicals and other consumables		[kg/m³] or [kg/a]	WW/WS	yes			x
En13		Recovery of wastes	[%]	WW/WS	no			x
En211	Cumulative energy demand of fossil resources		[MJ]	WW/WS	yes			x
En21	Cumulative energy demand of nuclear resources		[MJ]	WW/WS	yes			x
En21	Global warming potential (100a)		[kg CO_2-eq]	WW/WS	yes			x
En21	Terrestrial acidification potential (100 a)		[kg SO_2-eq]	WW/WS	yes			x
En21	Freshwater eutrophication potential		[kg P-eq]	WW/WS	yes			x
En21	Marine eutrophication potential		[kg N-eq]	WW/WS	yes			x
En21	Particulate matter formation		[kg PM_{10}-eq]	WW/WS	yes			x
En21	Human toxicity (non-cancer)		[CTU_h]	WW/WS	yes			x
En21	Human toxicity (cancer)		[CTU_h]	WW/WS	yes			x
En22	Freshwater ecotoxicity		[CTU_e]	WW/WS	yes			x
F111	Investment expenditure		[/]	WW/WS	yes		x	
F112	Annual operational expenditure		[/]	WW/WS	yes		x	
F113	Avoided costs and/or additional monetary benefits from: - Opportunity to discharge into the environment - Opportunity for placement of infrastructure and		[/]	WW/WS	yes		x	
F114	Other sources of financing (e. g. subsidies) aligned to the solution		[%]	WW/WS	yes		x	
G111	Compliance improvement w/ relevant EU standards (WFD, BWD)	water status reached / water status level required		WW/WS	no		x	
G112	Compliance with relevant national, local standards			WW/WS	no			x
G121	Number of actors/stakeholders involved in planning, implementation, operations, and			WW/WS	yes			x
G122	Communicative events			WW/WS	yes			x
G131	Monitoring			WW/WS	yes			x
G132	Information dissemination			WW/WS	yes			x
A111		MTTF	[year/1 failure]	WW/WS	yes		x	
A112		MTBF	[years/1 failure]	WW/WS	no			x
A121		Sufficient capacity of the technology/solution to the expected use	[%]	WW/WS	no			x
A131		Adaptive capacity as: The probability that the item is able to function at time t (availability at time t) for any given loads	[0-1]	WW/WS	no			x
A141		[Hours of exposed or "dirty work"[1] on the site/total hours of work per year]*100	[number/reference time]	WW/WS	no			x
A142		Risk episodes, injuries on the site/total hours of work in test period	[number/reference time]	WW/WS	no			x
A151		percentage of load removed	[kg N/a]	WW	no		x	
A211		Number of complaints about the technology (due to for instance Noise, Dust, Estetics,	[number/reference time]	WW/WS	no			x
A221		lifetime of solution/start up time		WW/WS	no		x	
A231	training hours for staff operating the solution			WW/WS	yes			x

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