KISTERS

Optimal use of hydroelectric power plant Linne

13 September 2018: 5th symposium on the hydrological modelling of the Meuse basin, Liège, Aquapôle, Campus de l'Université de Liège - Sart Tilman;

Speaker: Stefano Vincenzo De Simone

About KISTERS

Company profile

About KISTERS

Company profile

KISTERS Key facts

15 subsidiaries, > 500 FTEs, Revenue 67 M€ (2015)

KISTERS AG
DACHS & EUS

KISTERS Austria
KISTERS Switzerland
KISTERS Netherlands
KISTERS France
KISTERS Iberica

KISTERS North America

KISTERS China

KISTERS Australia
HyQuest Solutions Australia
HyQuest Solutions New Zealand

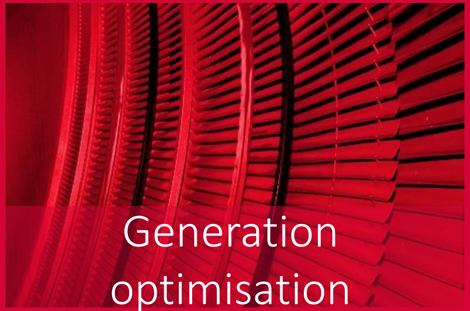
Energy, Water, Air, Logistic & Aviation, Engineering

About KISTERS

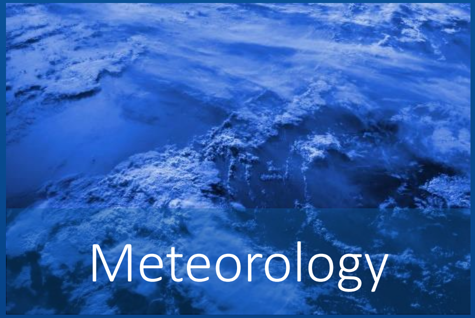
KISTERS

Qualifications and expertise

Energy and Environment



Water and Environment



About KISTERS

KISTERS

Professional, specific and cross cutting HYDROPOWER solutions for a responsible market

Intergovernmental Organisations (IGO)

National, Federal, State, Provincial and Regional Agencies

Cities, Municipalities and Local Government

Water Utilities

Mining Industry

Agriculture

Hydro Power

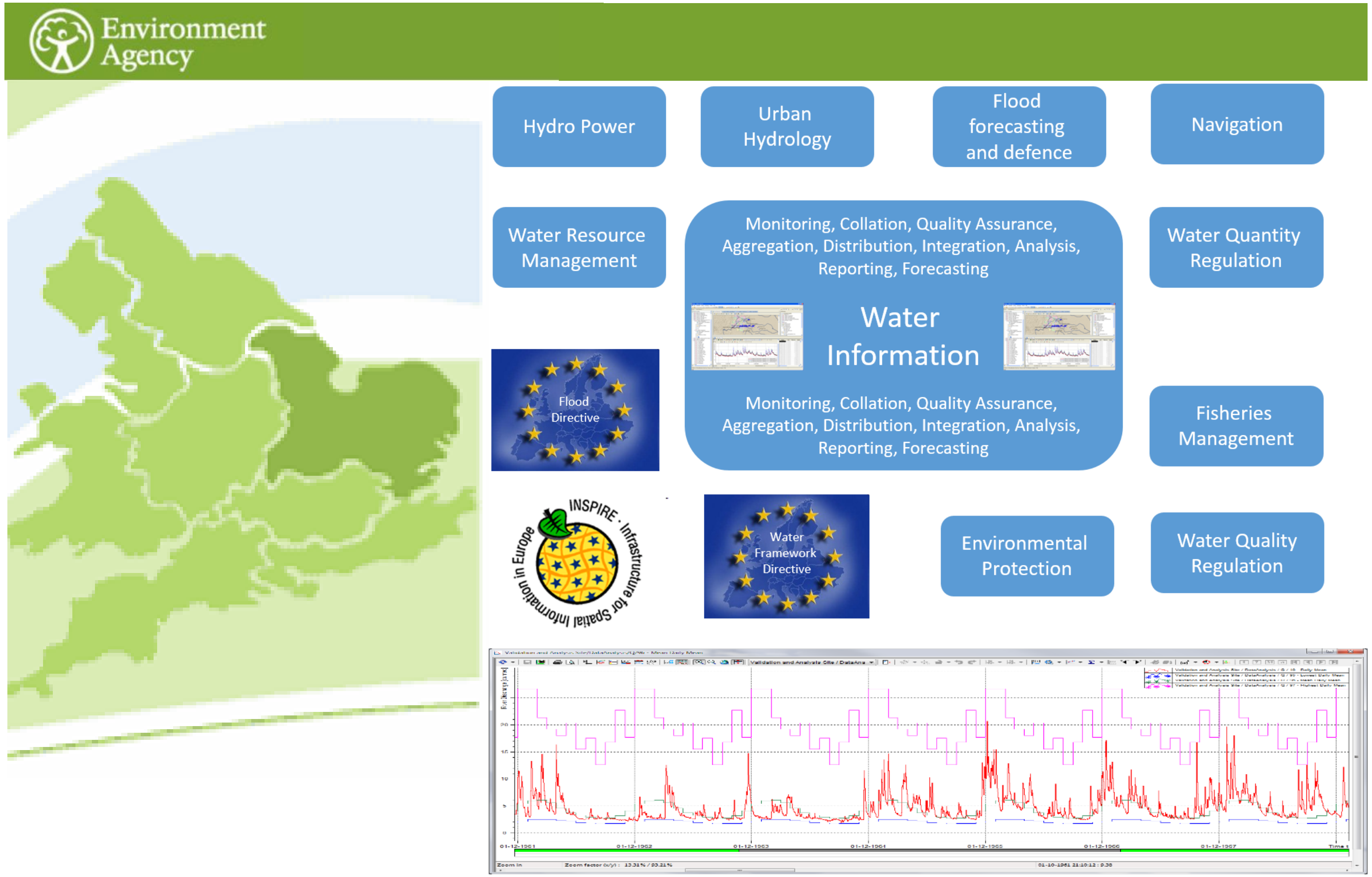
KISTERS Show Cases

Benefit of integrated water data management

KISTERS Show Cases

KISTERS

Response to an integrated Water Resource Management for the Environment Agency of England and Wales

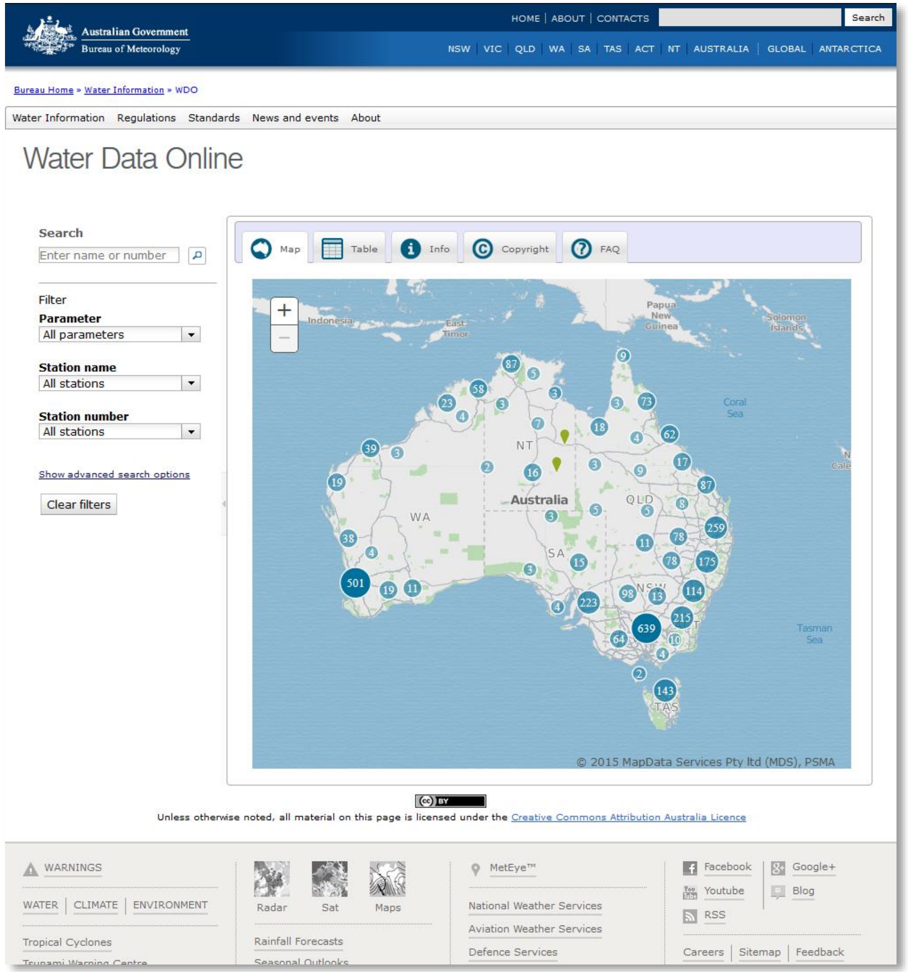


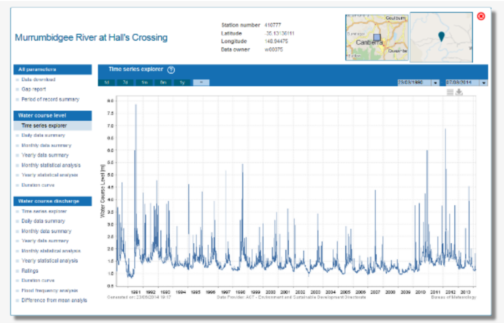
Fact Sheet

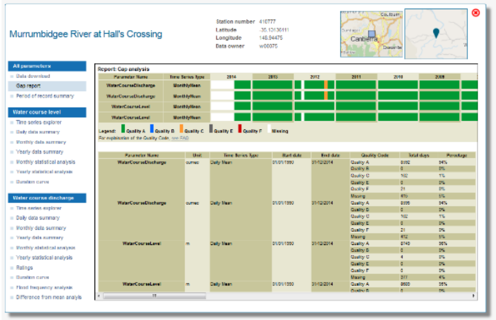
- National archive for a total catchment size of 151,000 km^2
- More than 80,000 parameters
- Single archive for national groundwater, climate and surface water data
- Integration of 140+ decentral databases into one controlled open archive
- Adaption of different workflows and processes to a national solution
- National consistent quality control procedures in place
- Integrated and climate change aware management of the resource water
- 100% compliant to EU directives

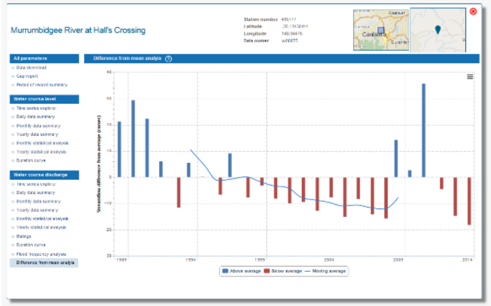
KISTERS Show Cases

Australian Water Resource Information System: Addressing water scarcity for a sensible continent









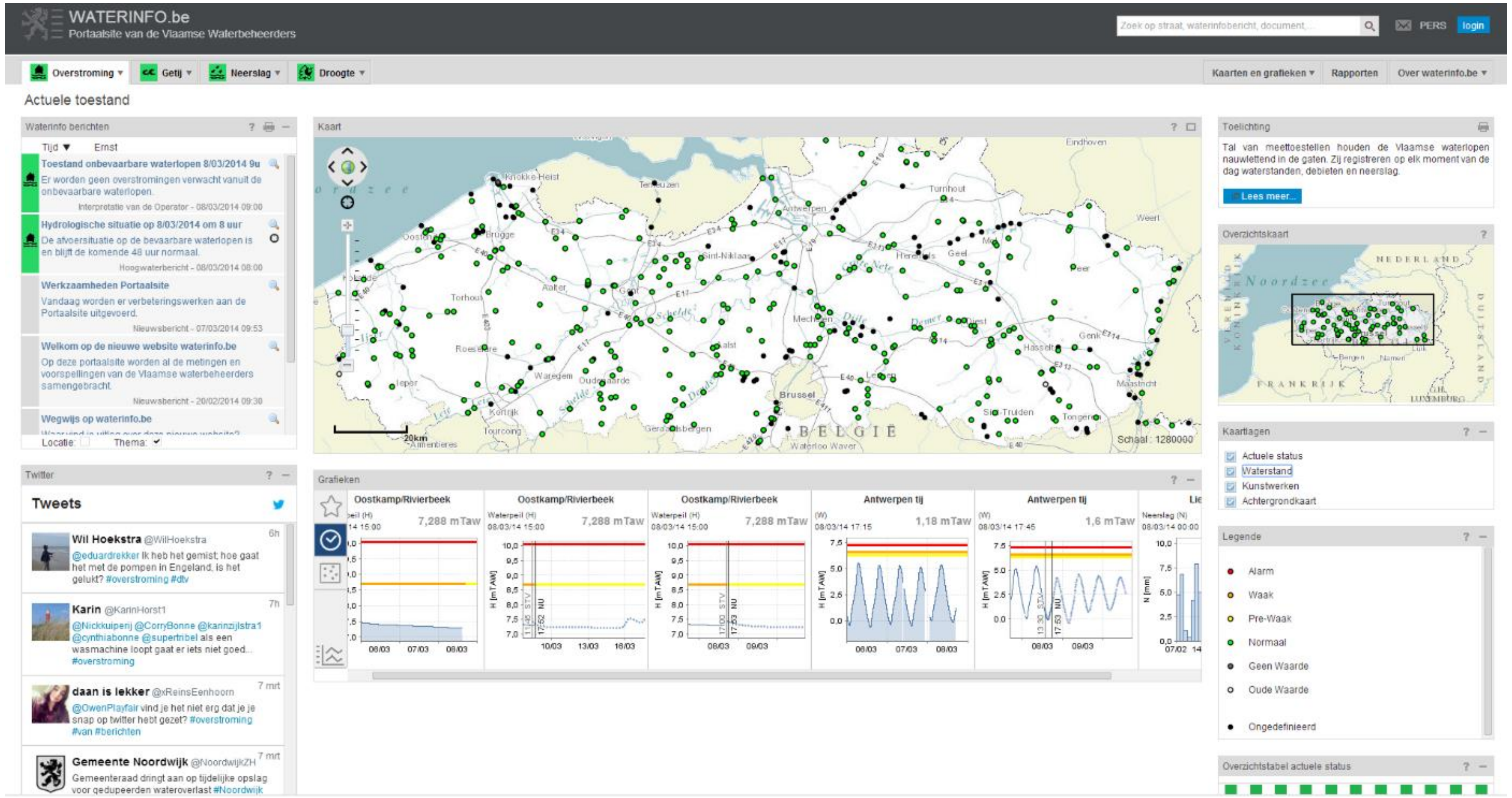
Fact Sheet

- **Water Data Online** is a KISTERS solution to centrally manage Australia's Water Resources in time of climate change
- Central solution to manage demands and expectations for the water consuming industries and related stakeholders
- Data from more than 260 data providers are integrated into a central access point at BOM
- Producing the core data products to inform Australia about the current water conditions
- Enabling the Geo-Fabric integration of in-situ data

KISTERS Show Cases

KISTERS

WaterInfo.be: Central Flood and Drought information portal for 1.6 Million people in Flanders



VLAAMSE MILIEUMAATSCHAPPIJ

sigis

alsic

flanders HYDRAULICS RESEARCH HYDROLOGICAL INFORMATION CENTRE

Fact Sheet

- **WaterInfo.be** is an operational flood and drought portal for Flanders, Belgium
- Connecting two authorities to a common information portal (HIC&VMM)
- 15.000 short term forecasts, 3500 long term forecasts
- About 500,000 Imports per day; 4 Million calculation requests
- Surface Water, Tidal Stations, artificial forecast points @ critical infrastructure nodes
- 1,000 professional users
- 1.6 Million Public users per hour

The research question:

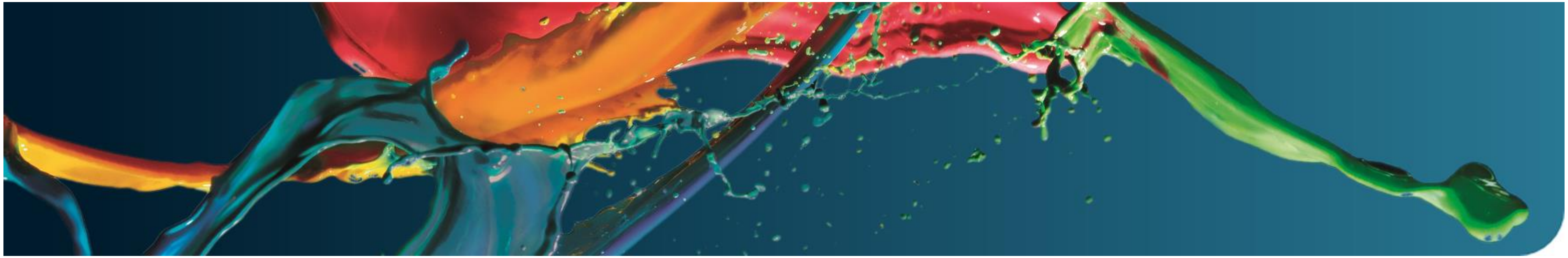
Upstream of weir Linne the water level may vary in a range of 35 cm between the minimum and the maximum level.

"Can this variable level be used to optimize the operational mode of the power plant according the energy market?"

And if so, what are the benefits, in MWh, in €, and CO2 emission reductions?

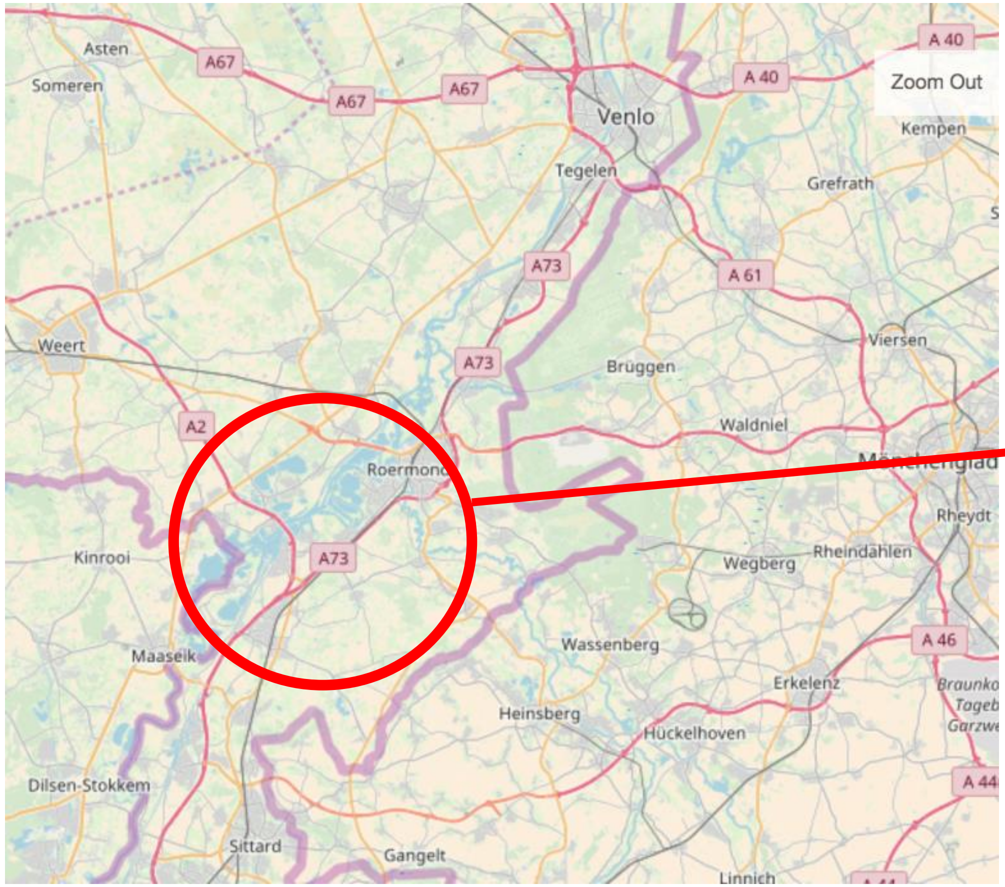
Pilot study

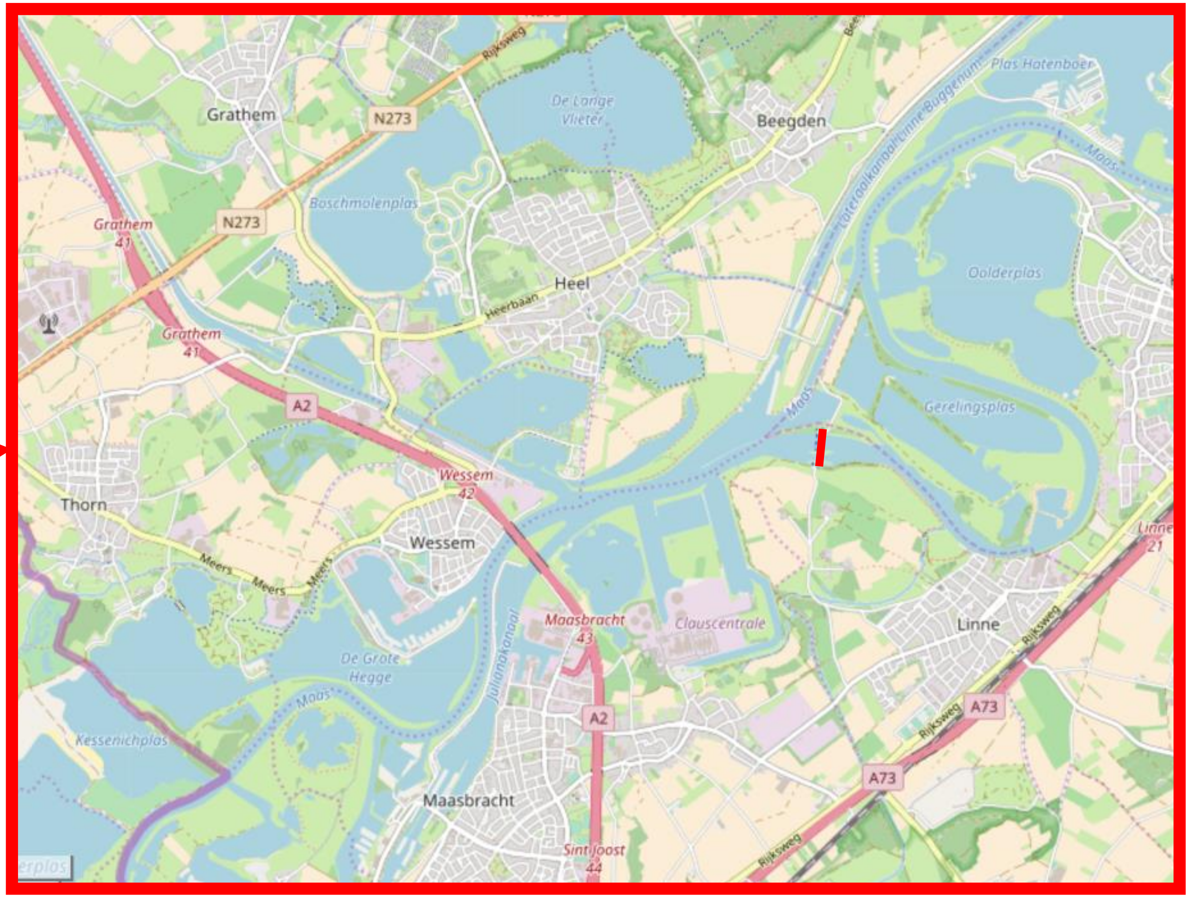
Julia Rauw, Matthijs den Toom, Jesse van der Wees, Jorn Baayen, Bernhard Becker



Linne

Where is it?





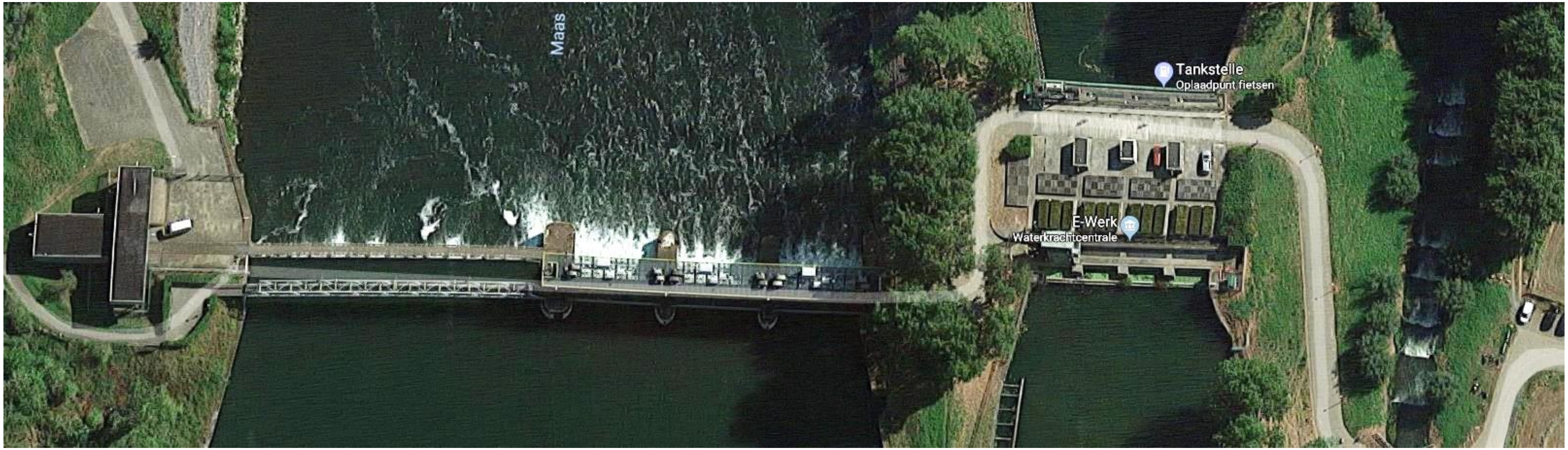
Linne

Where is it?

Pilot study

River section Linne

Parameter	Value
Surface	12.855.200 m^2
Minimum Level	20,0 m a.s.l.
Maximum Level	21,15 m a.s.l.



Pilot study

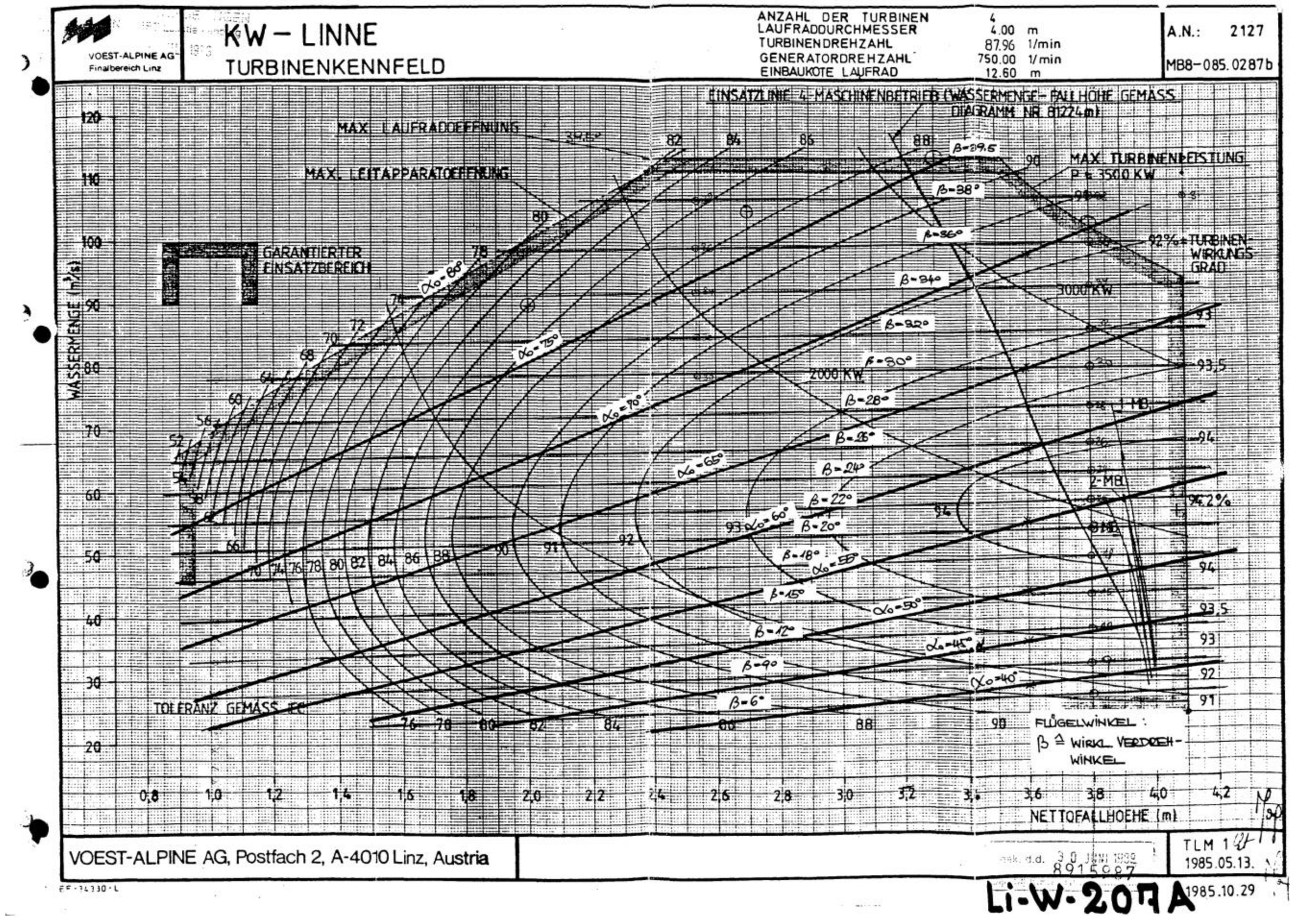
KISTERS

River section Roermond

Parameter	Value
Surface	7.295.800 m^2
Minimum Level	16,70 m a.s.l.
Maximum Level	16,95 m a.s.l.

Pilot study

Kaplan turbines hydroelectric power plant

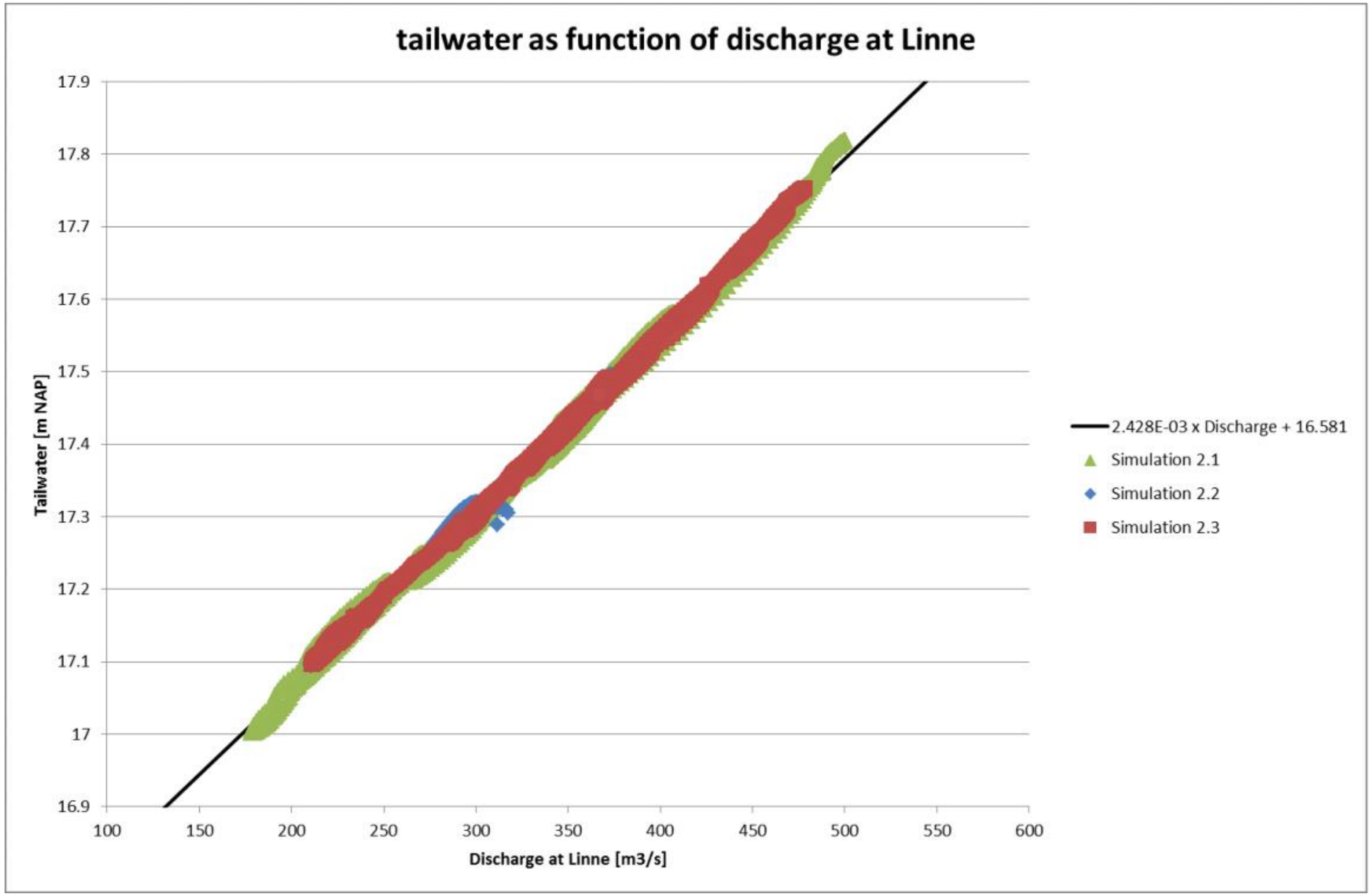


$$P = g * \rho * \eta(Q, \Delta H) * Q * \Delta H$$

Symbol	Meaning
g	Gravity constant
ρ	Density of water
η	Efficiency
Q	Flow
ΔH	Level difference

Pilot study

Water level downstream of weir Linne (tail water)



Relation flow-water level directly downstream.

Based on SOBEK simulations by Deltares.

NB.: Weir flow reduces the ΔH

Pilot study

Weir Linne

Source: Pepijn van Aubel, Rijkswaterstaat

- The discharge through the needle weir part is externally specified between 0 and 210 m^3/s
- The discharge through the movable part of the weir can vary between 0 and 215 m^3/s
- Fish ladder with 4 m^3/s fixed discharge

Source: Bernhard Becker, Deltares

Pilot study

Weir Roermond

Source: Pepijn van Aubel, Rijkswaterstaat

- The discharge through the needle weir part is externally specified between 0 and 240 m^3/s
- The discharge through the movable part of the weir can vary between 0 and 200 m^3/s
- Fish ladder with 4 m^3/s fixed discharge

Pilot study

Fish migration

Assumptions:

- During fish migration periods the plant is not used at night. All water goes over the dam during these nights.

- During the day, as much water as possible passes through the turbines.

NB .: Migration periods are determined on with the help of a *MIGROMAT*

Pilot study

Cooling water Claus power plant

When the Claus plant is in use, water of the Maas is used for cooling. This warms up the water.

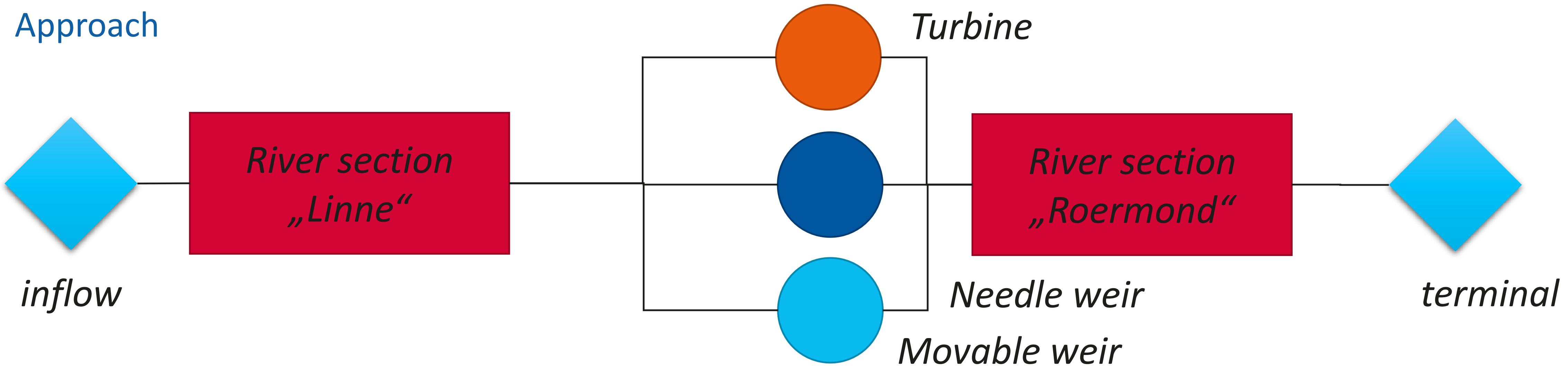
If the Claus power plant is in use, there is a maximum temperature imposed on the water. In practice, this results in a limitation on the buffering capacity of the weir.

Expectation: Maximum level of weir is dominant, so that temperature restriction is not or hardly impacting the weir operations

Pilot study

KISTERS

Approach



Optimization with RTC-Tools:

- Convex optimization problem guarantees global optimum
- Water system is part of the optimization problem, derivatives (Jacobian and Hessian Matrix) are calculated

Optimization goals and constraints:

- Water level range upstream
- Maximize power production
- Fish migration requirements

Pilot study

Boundary conditions

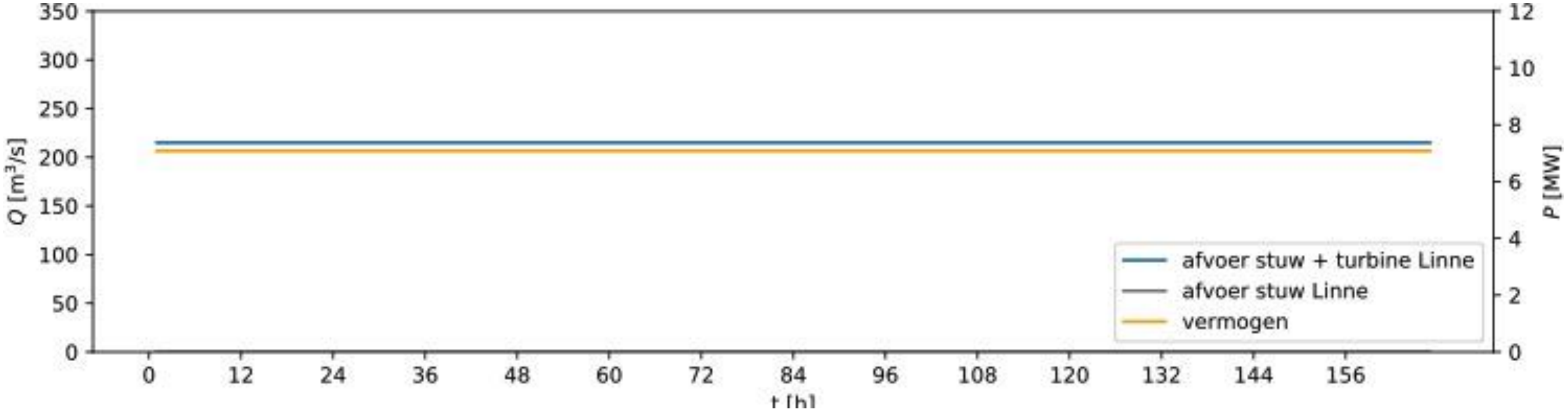
Parameter	Value
Discharge Maas	215 m^3/s
Discharge of needle dam part of the weir Linne	0 m^3/s
Discharge of needle dam part of the weir Roermond	100 m^3/s
Energy price	EPEX SPOT June 2018

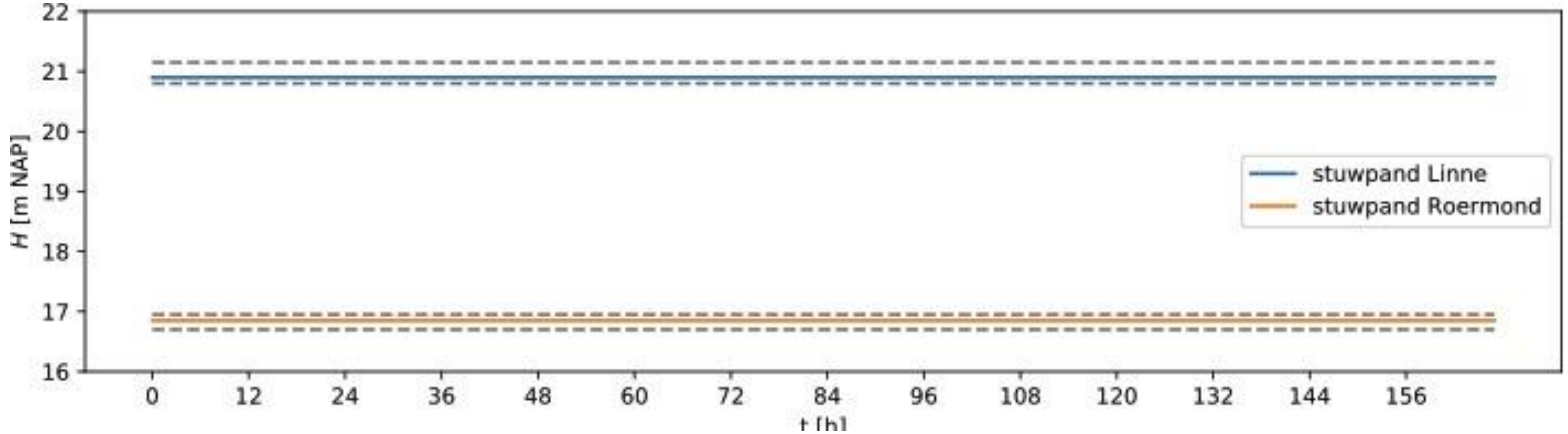
Discharges through the needle dam part of the weirs are not adapted during optimization.
It is only regulated with the movable part of the weir and with the turbines.

NB .: In order to show the effects of optimization, a constant discharge of the Maas is considered.
During operations discharge predictions will used, which represent the dynamics of the river.

Pilot study

Reference scenario I: EPEX SPOT + Target level Rijkswaterstaat



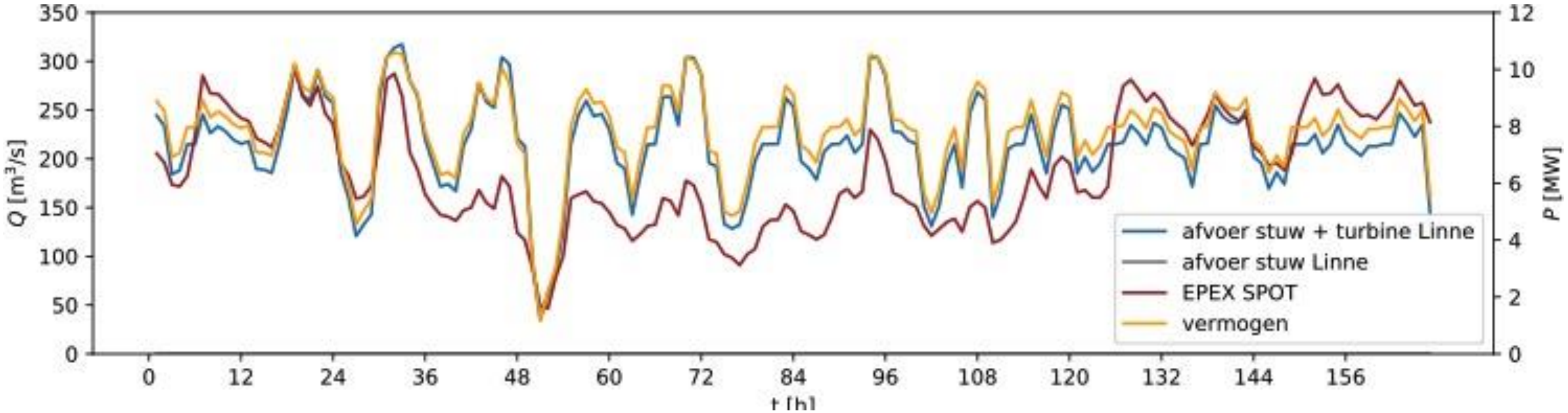


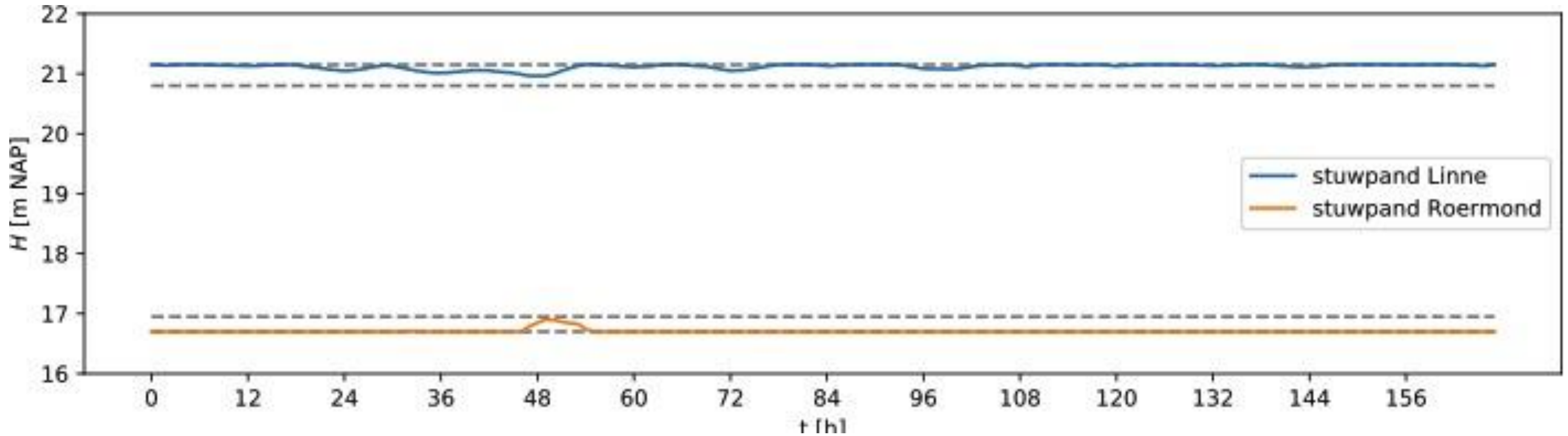
Turnover 1 week:

1182 MWh
€ 44044

Pilot study

Results optimization I: EPEX SPOT + Flexible level





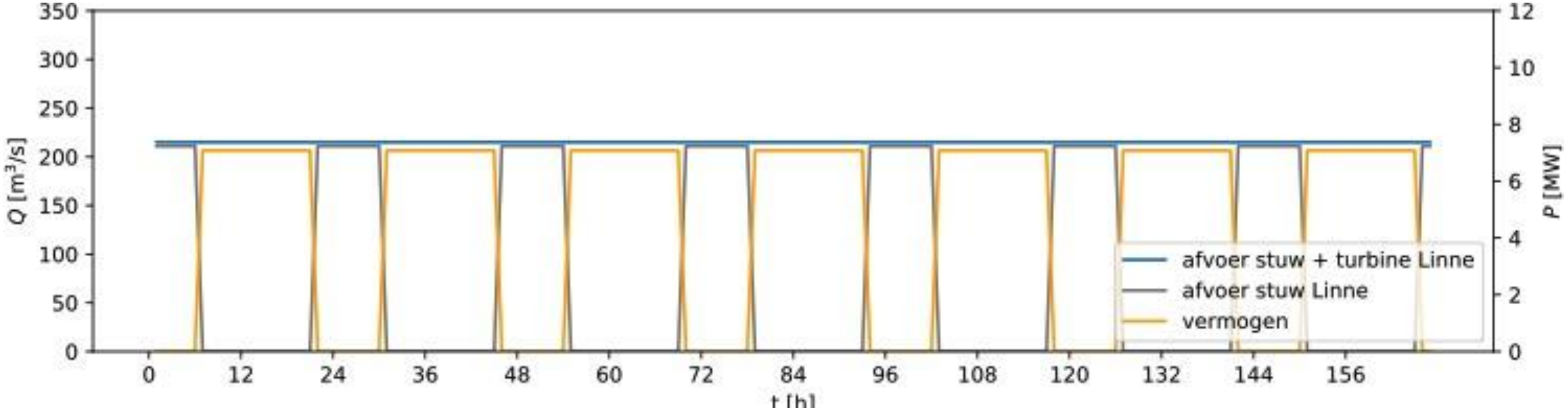
Turnover 1 week:

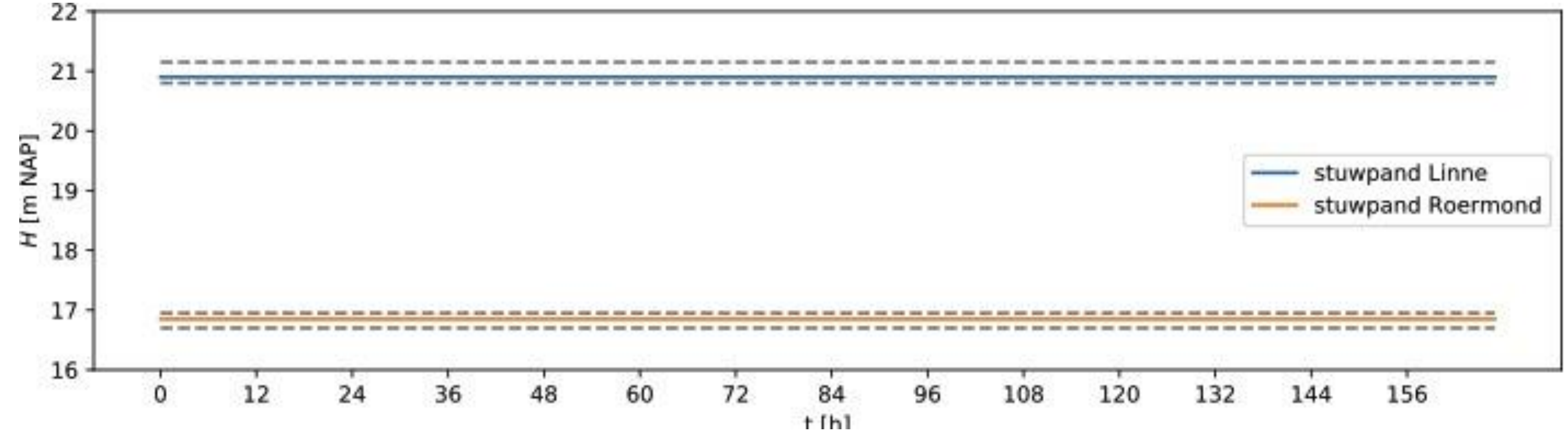
1305 MWh **(+10%)**
€ 50507 **(+15%)**

Pilot study

KISTERS

Reference scenario II: EPEX SPOT + Target level Rijkswaterstaat + Fish migration



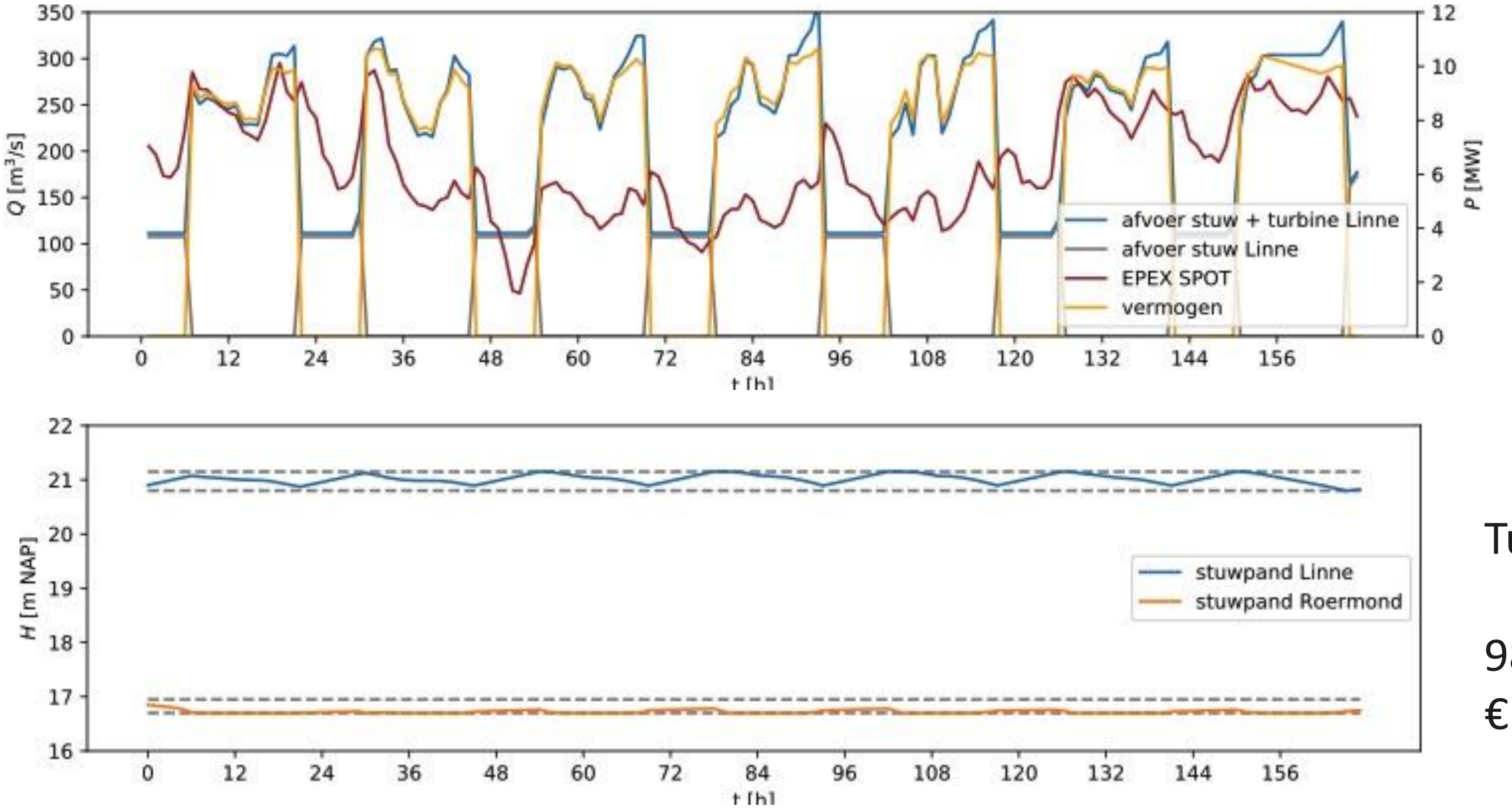


Turnover 1 week:

743 MWh
€ 27692

Pilot study

Optimization results II: EPEX SPOT + Flexible level + Fish migration



Turnover 1 week:

987 MWh **(+33%)**
€ 39036 **(+41%)**

Conclusions

- Pilot study: 10-33% more energy and 15-41% more turnover from Linne hydro power plant through:
  a) flexible deployment in the energy market
  b) maximization of head difference (upstream water level minus downstream water level).
     Expectation after restrictions on flow variation from Rijkswaterstaat:
     5-10% more energy and turnover.

- Higher value for net stabilization in combination with sun & wind.
- Fish migration requirements maintained
- Next step: Continuation of discussion of flow variation with Rijkswaterstaat.

Thanks and Questions?

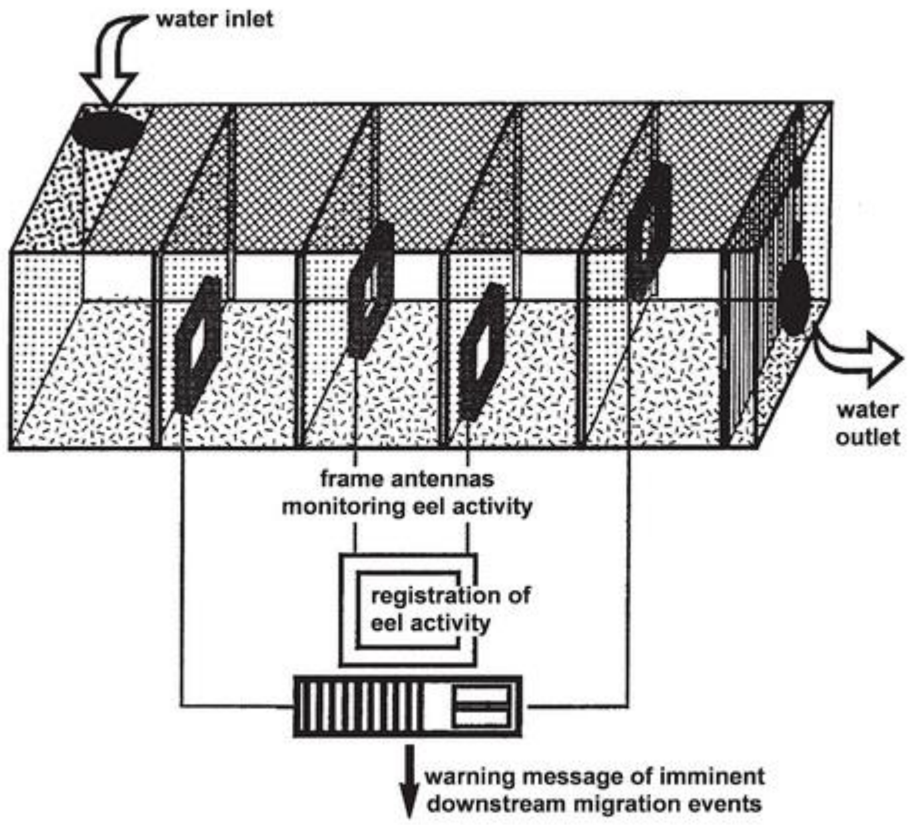
KISTERS Nederland B.V.
Piet Mondriaanplein 13-31
NL-3812 GZ Amersfoort

Phone +31 6 33881175
jorn.baayen@kisters-bv.nl
http://water.kisters.eu

File name:	Optimal use of hydroelectric power plant Linne
Creation date:	2018-09
Presentation date:	2018-09-13
Author:	Jorn Baayen
Speaker:	Stefano Vincenzo De Simone

MIGROMAT

A tool to assess the distinct periods with eel peak migration

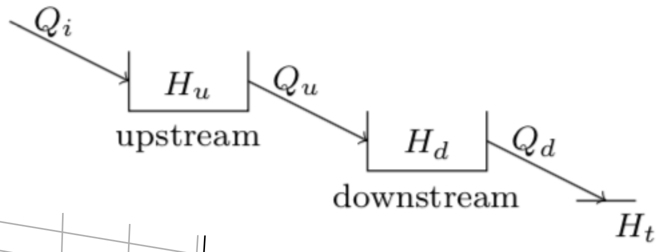


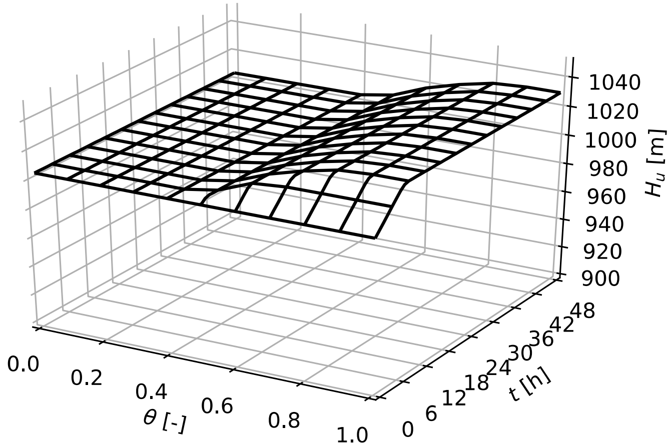
Source: Spawning Migration of the European, Guido van den Thillart, Sylvie Dufour, J. Cliff Rankin

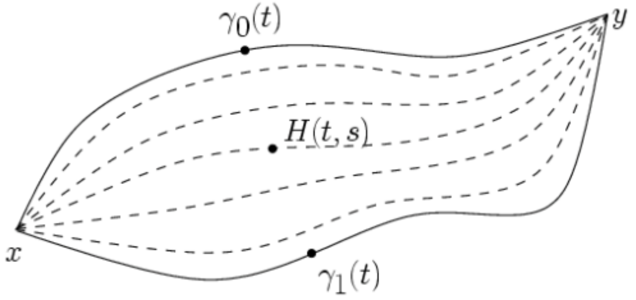
Opimization Method: Homotopy

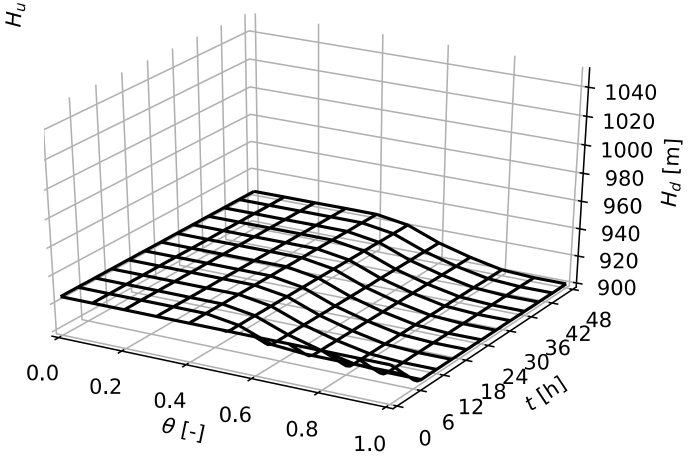
KISTERS

Simple test case: 3% increase in generation

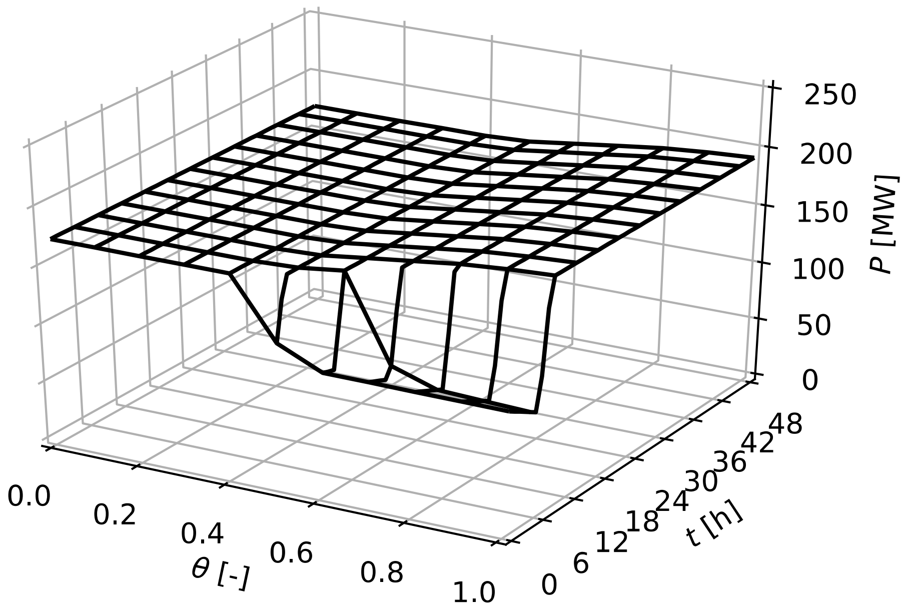








- Take global optimum of „ignore the dynamics“ approach
- Morph/deform „ignore the dynamics“ model into dynamic model, and morph solution along the way.
- Deterministic physics represented result



Track record homotopy approach

Thus far (more are being built by Deltares and KISTERS):

- *Zuid Willemsvaart* (Brabant; Rijkswaterstaat part)
- *Wilhelminakanaal* (Brabant)
- *Twentekanaal* (Twente)
- *Kanaal Gent-Terneuzen* (Zeeuws Vlaanderen)
- *Volkerak-Zoommeer* (Zeeland)
- *Quick Water Allocatie Scan Tool* (QWAST); distribution of Rhine water during drought periods (National)
- *Waterschap Noorderzijlvest* (Friesland)
- *Hoogheemraadschap van Rijnland* (Zuid-Holland)
- *Meuse*: Borgharen – Linne – Roermond, optimization of hydro power plant at Linne (Limburg, in progress)

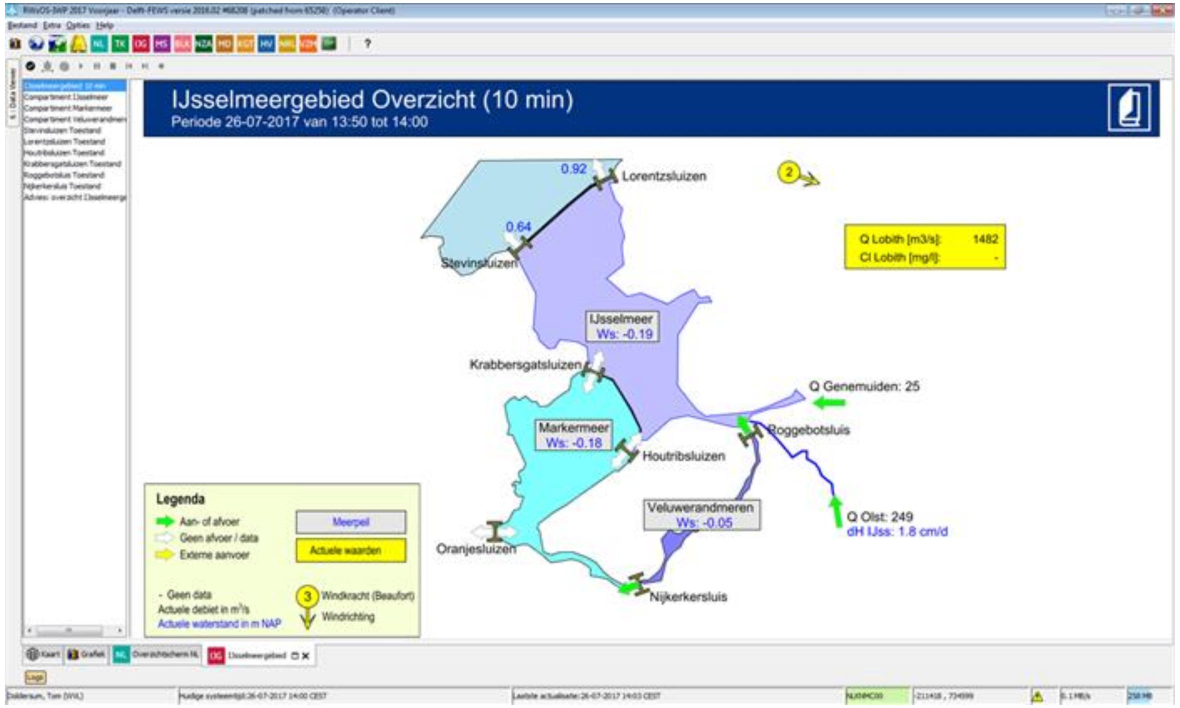
Track record homotopy approach

KISTERS

The standard at Rijkswaterstaat

RTC-Tools 2.0 is the optimization tool used by Rijkswaterstaat IWP, *instrument voor het waterpeilbeheer*, the software suite used to optimize the operations of the waterways and bodies operated by Rijkswaterstaat.

Rijkswaterstaat
Ministry of Infrastructure and the Environment



Multi-objective optimization

KISTERS

Assigning priorities to every operational objective

We use a technique known as lexicographic goal programming, originally popularized by CADSWES‘ RiverWare product since the late 1990s:

- Optimize first priority
- Add priority attainment level as additional constraint
- Optimize second priority
- Add priority attainment level as additional constraint
- … and so forth …

Available in RTC-Tools 2.0 and used in all projects listed earlier.