

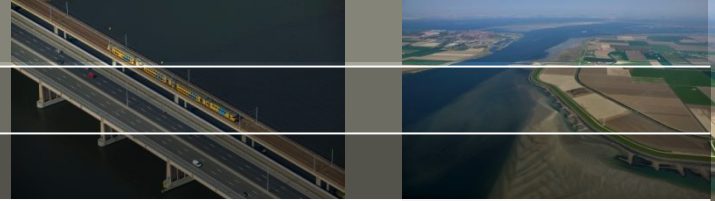


Quick Scan Tool for water allocation in the Netherlands

Peter Gijsbers, Jorn Baayen, Judith ter Maat

15 mei 2017

Overview

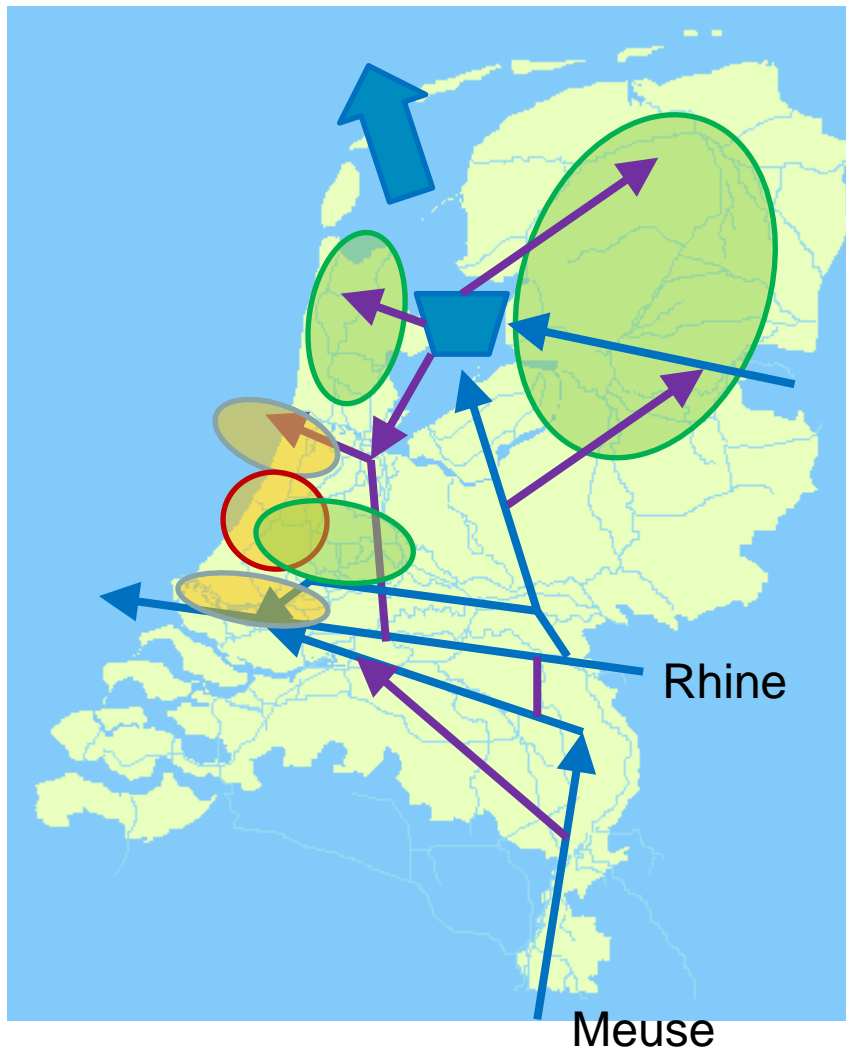


Fresh water issues in the Netherlands
The policy process & policy support models
The water allocation model
The Quick Scan Tool application
Using the Quick Scan Tool

An aerial photograph of a Dutch polder landscape. A large body of water, likely a river or lake, occupies the left side of the frame. A long, straight dike runs diagonally from the bottom center towards the top right, separating the water from a large area of agricultural land. The land is divided into numerous rectangular plots of varying colors, including green, brown, and tan, indicating different crops or land uses. In the background, a small town or village is visible on the left side, nestled between the water and the land. The sky is a clear, pale blue.

Fresh water issues in the Netherlands

Fresh water supply issues in the Netherlands



Current management issues:

- waterlevel control
- **saline intrusion and saline boils**

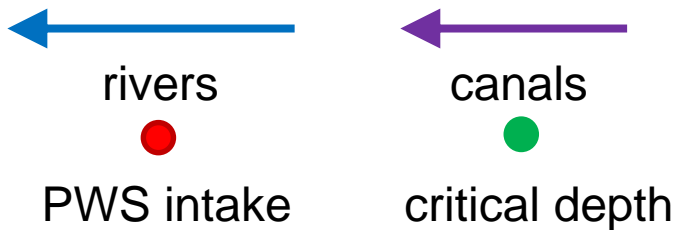
Looking at 2050 and 2085

- warmer climate → **increased evapotranspiration**
- port developments → **increased saline intrusion**
- sea level rise → reduced drainage gradients

rivers

canals

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- reduced navigation depth Rhine
- higher velocities on ARK shipping canal
- more saline intrusion in SW delta

An aerial photograph of a coastal region. On the left, a large body of water (likely a bay or estuary) meets a town with red-roofed buildings. To the right, a long, curved dike separates the land from the water. The land behind the dike is divided into large, rectangular agricultural fields in various shades of green and brown. Several white wind turbines are visible along the dike. The sky is clear and blue.

The Policy Process

Policy process: Delta Program Fresh Water

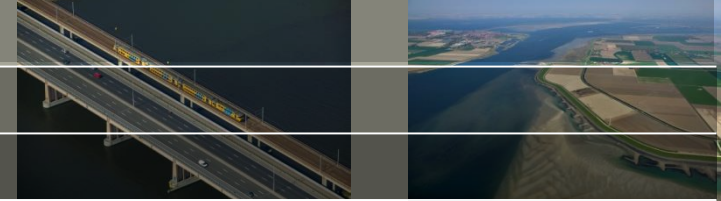
Phase 1 ended 2014 with parliament decision

- national focus, possibly large interventions

Phase 2 underway (parliament decision 2021)

- regional focus on hotspots
- process organized by national government with stakeholders including water boards, agricultural sector, drinking water companies, nature & landscape managers
- regions identify interventions (savings, costs, regional impacts)
- national government manages nationwide consequences
- supporting analysis conducted by institutes and consultants
 - reference year: 2015
 - assessment years (2050, 2085)
 - 4 climate/socio-economic change scenario's (WARM, INTENSE)

Policy support models



PAWN: First national model instrument (1980's);

- surface water allocation, sector models for agriculture, shipping, drinking water, nature

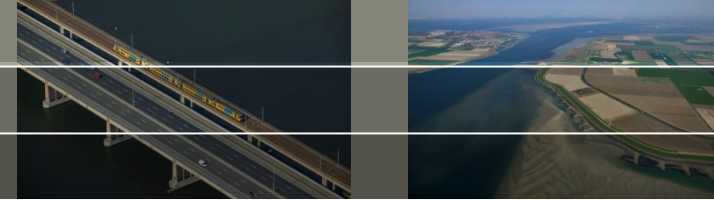
Nowadays:

- National Hydrological Model (coupled surface-groundwater)
- National Hydraulic Model (incl. saline intrusion, temperature)
- National Water Quality model (Water Framework Directive)

Characteristic:

- highly detailed (processes & spatial resolution)
- computation intensive
- useful for detailed evaluation of expected final policy decisions
- **not suitable for screening and support of stakeholder processes**

Need for a Quick Scan Tool

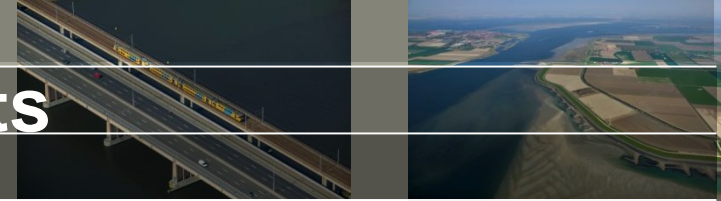


- For operational support of the National Committee on Water Allocation in periods of drought
 - to be used by Committee members
- For support of the policy process
 - to be used by research institutes and consultants

Purpose:

- Allow screen of intervention options:
 - storage control levels
 - water demand (extractions and flushing)
 - adjustment of capacities (policy only)
- Show regional tradeoffs (water demand, allocation, shortages) preferably extended to sector impacts (agriculture, shipping)

Quick Scan Tool Requirements

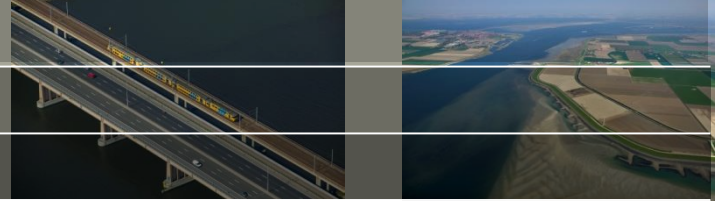


- Accommodate priority based water allocation to support the legally established displacement rules on water requests for extraction, flushing and water level control
- Develop a network model as simple as possible that captures the relevant infrastructure for decisions on the national scale:
 - major intakes and storages
- Use data from the National Hydrological Model
- Show regional tradeoffs (water demand, allocation, shortages) preferably extended to sector impacts (agriculture, shipping)
- Allow easy manipulation of interventions via the GUI
- Provide visual outputs on maps and in graph and table

An aerial photograph showing a coastal water management system. A large body of water is on the left, separated from a series of agricultural fields by a long, green dike. The fields are divided into various colored patches of green, brown, and tan. A small town with red-roofed buildings is visible on the left side of the dike. The sky is clear and blue.

The Water Allocation Model

Choice of modelling concept



Choice amongst different model codes with different concepts:

- Heuristic decision rule approach
- Mathematical programming approach (multi-objective optimization)

Choice made: Mathematical programming

- using Lexicographic Goal Programming
- → transform the multi-objective problem to a sequence of scalar optimization problems
- → solve each problem while retaining the result from the previous priority

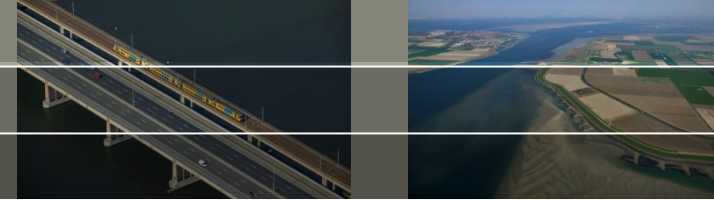
Lexicographic Programming approach



The idea of the algorithm is:

1. Minimize f_1 to yield a minimum objective value of ε_1 .
2. Minimize f_2 to yield ε_2 subject to the additional constraints
 - $f_1(x) = \varepsilon_1$
3. Minimize f_3 subject to the additional constraints
 - $f_1(x) = \varepsilon_1$
 - $f_2(x) = \varepsilon_2$
4. ...

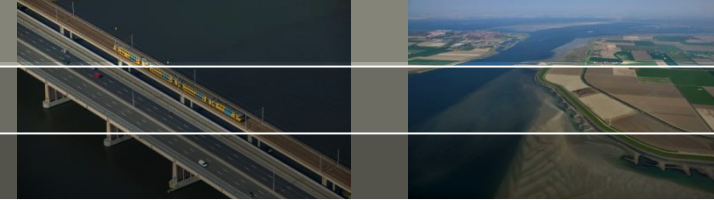
Formulation of goals



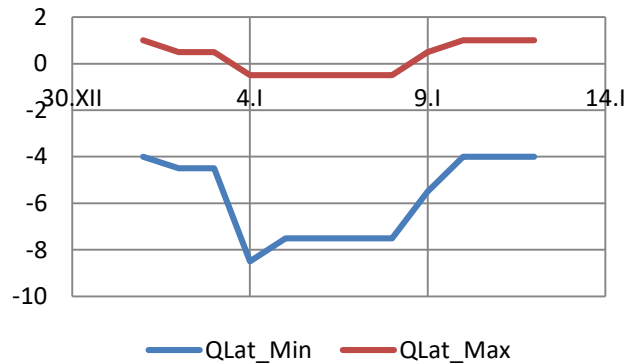
E.g. in our case the ordered list of goals

1. Stay within capacity ranges $H_{\min} \leq H \leq H_{\max}$
 $Q_{\min} \leq Q_{\text{instream}} \leq Q_{\max}$
2. preserve minimal target levels: $H \geq H_{\text{target min}}$
3. provide drinking water: $Q_{\text{extract}} \geq Q_{\text{req.pws}}$
4. preserve medium levels: $H \geq H_{\text{medium}}$
5. provide regional demands $Q_{\text{extract}} \geq Q_{\text{req.pws}} + Q_{\text{req.region}}$
6. preserve medium high levels: $H \geq H_{\text{mediumhigh}}$
7. provide water for flushing: $Q_{\text{instream}} \geq Q_{\text{req.flushing}}$
8. preserve target lake levels $H \leq H_{\text{target max}}$
9. minimize flows on inlets and outlets

Formulation of goals

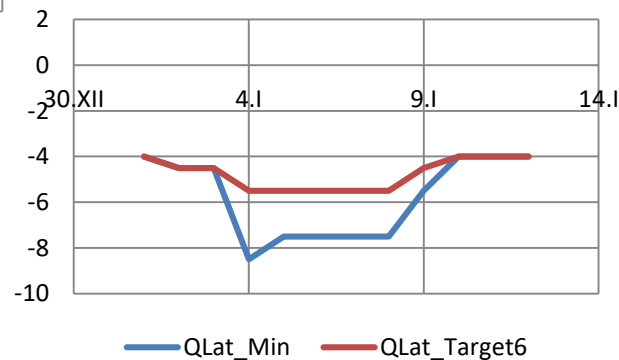


Lateral (priority 1)

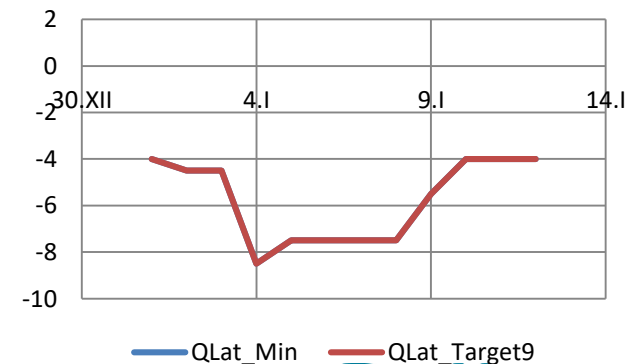


Squeezing the solution space of Lateral fluxes (extractions)

Lateral (priority 6)



Lateral (priority 9)

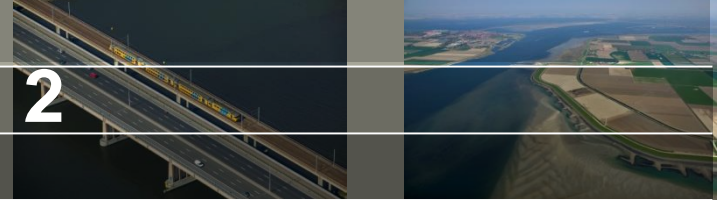


QLat_Max = Natural Contribution
 QLat_Target6 = QLat_Max + Utilities Request
 QLat_Target9 = QLat_Target6 + Rural Request
 QLat_Min = QLat_Target9

Note: extractions are negative

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The model engine: RTC-Tools 2



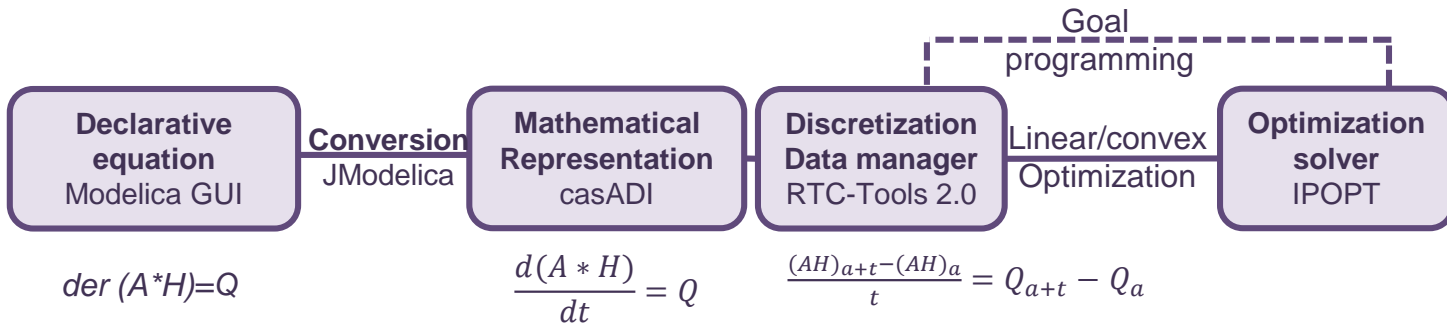
RTC-Tools 2.0 is a open source toolbox for control and optimization of environmental systems.

- Mathematical framework designed for stable operation in environments that require consistent results
 - Convex optimization under uncertainty
 - Multi-objective optimization
 - > weighted programming
 - > lexicographic goal programming
- Interdisciplinary, object-oriented model formulation using Modelica
- Flexibility in control formulation using python scripting
- Integration capability with among others Delft-FEWS

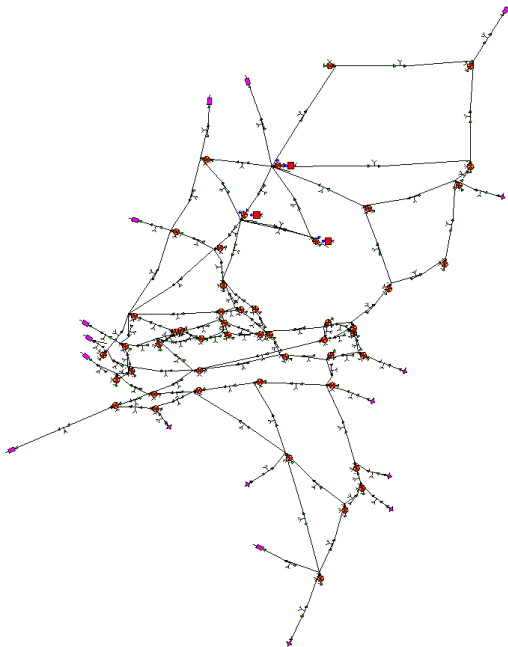


Deltares

RTC-Tools 2 software components



Model schematization



RTC-Tools manages:

- conversion with CasADi
- discretization
- data handling
- calling solver

Quick Scan Tool/RTC-Tools python snippets

Each goal and input data are connected to a variable
Each variable represents a state of a network element

Processing an input file

```
elif "QLat" in max_value_id:
    g.append(MaximumForcingGoal(self.get_timeseries(
        max_value_id, state_id, priority, function_range))
elif "QOut" in min_value_id:
    g.append(MinimumDischargeGoal(
        self.get_timeseries(min_value_id, state_id, priority, function_range))
elif "QOut" in max_value_id:
    g.append(MaximumDischargeGoal(
        self.get_timeseries(max_value_id, state_id, priority, function_range))
elif "HMin" in min_value_id and "HMax" in max_value_id:
    g.append(LevelRangeGoal(self.get_timeseries(min_value_id,
        self.get_timeseries(max_value_id, state_id, priority, function_range))
elif "QOut.Q" in state_id:
    g.append(MinimizeDischargeGoal(state_id, priority, (0,1),1))
```

Assigning goals to RTC-Tools

```
class MaximumForcingGoal(Goal):

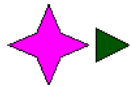
    def __init__(self, QForc_max, QForc_state, priority, function_range, function_nominal=1):
        self.target_max = QForc_max
        self.state = QForc_state
        self.priority = priority
        self.function_range = function_range
        self.function_nominal = function_nominal

    def function(self, optimization_problem, ensemble_member):
        return optimization_problem.state(self.state)

    # The penalty variable is taken to the order'th power.
    order = 1
```

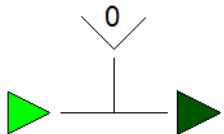

Some network elements in Modelica

Inflow



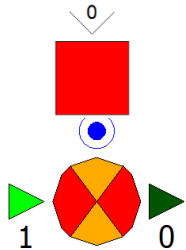
```
within Deltares.ChannelFlow.SimpleRouting.BoundaryConditions;  
  
block Inflow  
  extends Deltares.ChannelFlow.Internal.QSO;  
  // Inputs  
  input Modelica.SIunits.VolumeFlowRate Q;  
equation  
  QOut.Q = Q;  
end Inflow;
```

Branch



```
within Deltares.ChannelFlow.SimpleRouting.Branches;  
  
block Steady  
  extends Deltares.ChannelFlow.Internal.QSISO;  
  extends Deltares.ChannelFlow.Internal.QForcing;  
  extends Deltares.ChannelFlow.Internal.QLateral;  
equation  
  QOut.Q = QIn.Q + sum(QForcing) + sum(QLateral.Q);  
end Steady;
```

Storage



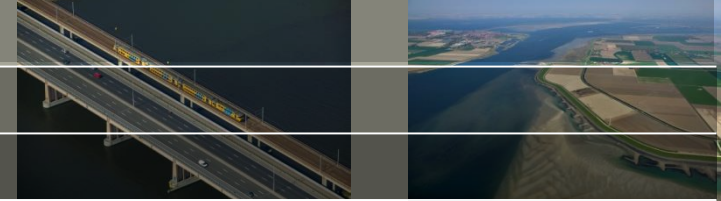
```
within Deltares.ChannelFlow.Hydraulic.Storage;  
  
model Linear "Storage with linear level-storage relation"  
  extends Internal.PartialStorage(HQ.H(min = H_b));  
  // Surface area  
  parameter Modelica.SIunits.Area A;  
  // Bed level  
  parameter Modelica.SIunits.Position H_b;  
equation  
  V = A * (HQ.H - H_b);  
end Linear;
```

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An aerial photograph of a coastal region. On the left, a large body of water (likely a bay or estuary) is visible. To the right of the water, a city with numerous buildings is situated. Further right, a long dike or levee runs parallel to the water, featuring a bridge with several piers. The land behind the dike is divided into various agricultural fields, some green and some brown. The sky is clear and blue.

The Quick Scan Tool application

Development process



- Joint requirements analysis with members National Committee on Water Allocation
- Joint model schematization design sessions with key expert of the Committee
- Joint design to implement intervention options in the model
- Validation by experts of institutes

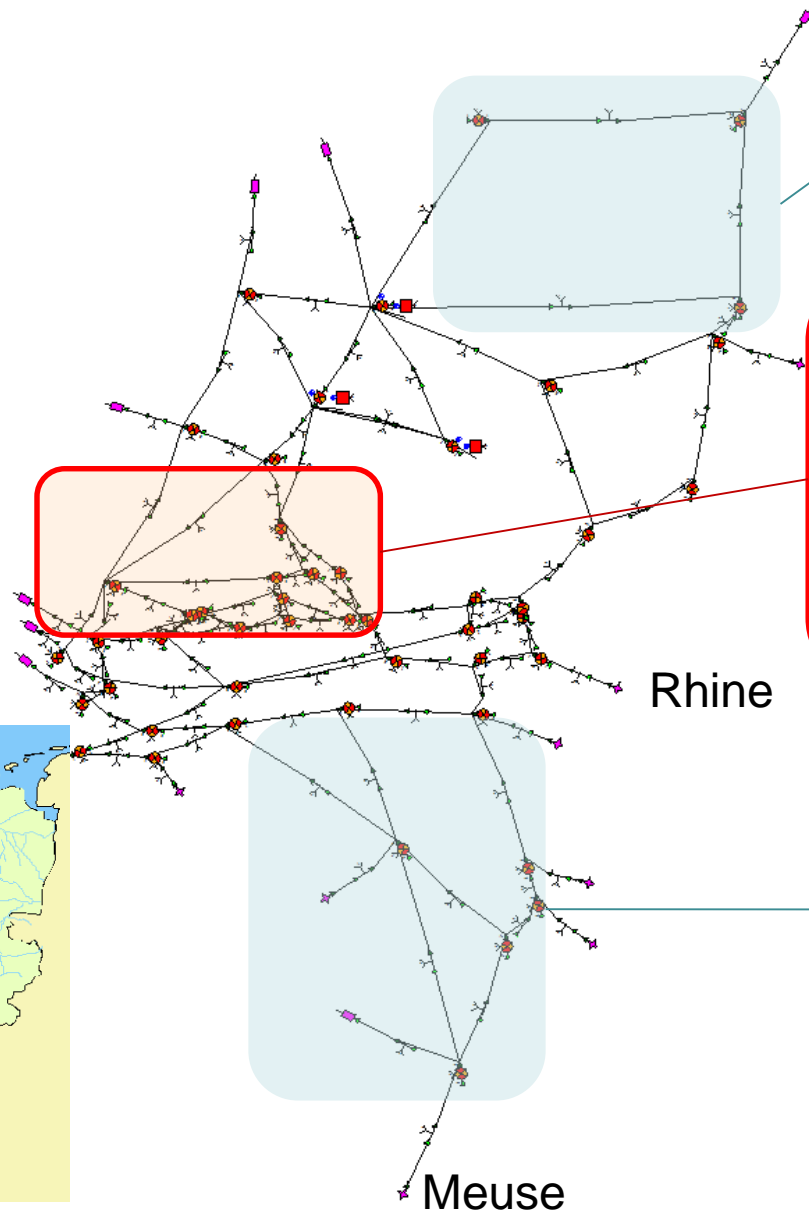
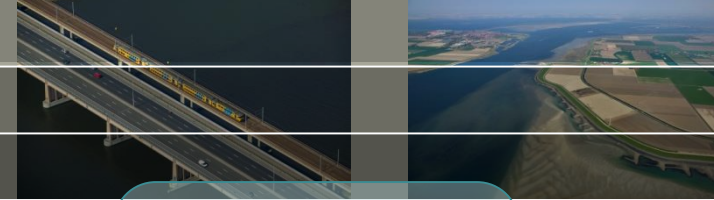
First prototype;

- Excel: dashboard, data handling, pre/postprocessing
- RTC-Tools: water allocation model

Final application:

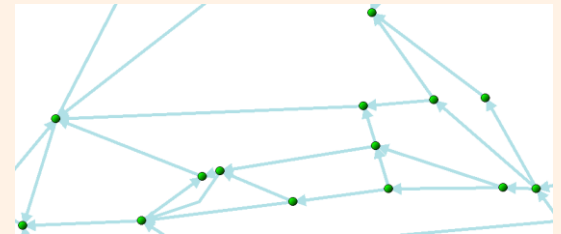
- Delft-FEWS: GUI, data handling, pre/postprocessing
- RTC-Tools: water allocation model

The network schematization



large
simplification
of main water
system

minimal simplification of
main water system



large
simplification of
main water
system



Quick Scan Tool data and workflow

National Hydrological Model

1: Acquire

request by water use

river discharge

lake levels

Delft-FEWS
processing
data management

3: Stack by
priority

2: assign to
coarse
network

5: split by
water use

6: aggregate
by area

7: %delivery
by water use

priority of
each request

parameters

distribution key
Rhine, Meuse

Q_requests
by priority*

H_requests
(min, target)
with priority

river
discharge

initial
conditions

* requests stacked by priority

4: Allocate

RTC-Tools 2

allocate
prio 1

allocete
prio 2

allocate
prio N

QOut, QIn, QLat

final allocation

Legend:

software application

file
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process

end-result

Deltares

Quick Scan Tool workflow navigator

Quick Scan Tool, DPZW Knelpuntenanalyse 2.0 (Stand alone)

Bestand Extra Opties Help

Locale Workflows

5 : Locale Workflows

6 : Data Viewer

REF2015

- Import Data van LHM
- Bereken watervraag (aaf)
- Bereken waterverdeling

WARM2050

WARM2085

DRUK2050

DRUK2085

Warm state selection

T0: 11-01-2003 ...

voorspellingsduur:

Taakuitvoer opties

Logs

workflows segment Bereken waterverdeling

- RunModel_REF2015 (workflow)
 - QST_SeriesEndEstimator_REF2015 (forecast length estimator)
 - RTC_BeginConditioes_REF2015 (transformation)
 - RTC_Randvoorwaarden_REF2015 (transformation)
 - RTC_Verdeelsleutels_REF2015 (transformation)
 - RTC_DoelenPerPrioriteit_REF2015 (transformation)
 - RTC_DoelenPerPrioriteit_REF2015 (transformation)
 - RTC_ModelResultaat_REF2015 (GA)
 - QST_RealisatiePerFunctie_REF2015 (transformation)
 - QST_TekortPerFunctie_REF2015 (transformation)
 - QST_Vaardiepte_REF2015 (transformation)
 - QST2Gebied_RealisatiePerFunctie_REF2015 (transformation)
 - QST2Gebied_TekortPerFunctie_REF2015 (transformation)
 - QST2Gebied_StatistiekRealisatie_REF2015 (transformation)
 - QST2Gebied_StatistiekTekort_REF2015 (transformation)
 - QST2Gebied_LeveringsPercentages_REF2015 (transformation)
 - QST2Gebied_Export_REF2015 (tms export)

Prep: BoundaryConditions

Prep: Goals

Model; AllocateWater

Post: SplitByWaterUse

Post: SpatialAggregation

Post: Statistics

Logs

Kaart Grafieken Ruimtelijke weergave Aanpassing berekening Workflow Navigator

Peter Gijsbers Huidige systeemtijd: 11-01-2003 01:00 (GMT +1) 18:03:54 GMT 20:03:54 CEST Stand alone -190239 , 645687 0.0 MB/s 121 MB

Quick Scan Tool intervention options

Quick Scan Tool, DPZW Knelpuntenanalyse 2.0 (Stand alone)

Bestand Extra Opties Help

Locale Workflows

5 : Locale Workflows

6 : Data Viewer

REF2015

- Import Data van LHM
- Bereken watervraag (a)
- Bereken waterverdeling

WARM2050

WARM2085

DRUK2050

DRUK2085

Modifier ...	Naam	Beschrijving	Locaties	Start tijd	Eind tijd	G...
REF2015 ...	ST1: KWA24,MWK...	max_uitzak_hogeprio_REF2015=10.0	IJsselmeer_Storage	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	Qmax_REF2015=7.9	KWA_Aanvoerder_ARK	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	Qmax_REF2015=9.8	KWA_Doorslag_Lek	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	maxQ_bij_overschrijdinggrenswaarde_REF2015	KWA_Wiericke	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	Qmax_REF2015=12.0	KWN_InlaatPanheel_Maas	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	maxQ_bij_overschrijdinggrenswaarde_REF2015	Lek_Lopikerwaard_KWA	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	Qmin_REF2015=20.0	MaasWaalkanaal	--	--	--	P...	0...	✓	✗	
REF2015 ...	ST1: KWA24,MWK...	max_opzet_REF2015=10.0	Markermeer_Storage	--	--	--	P...	0...	✓	✗	

Aanmaken modifier

Import

Export

Uitvoe...

Eigenschappen modifier: REF2015 aanpassingen

Naam

ST1: KWA24,MWK20,ARKnv20,NZK20,KWN12,TKprio

Opslaan

Vraag multiplier (%)

Aanvoer capaciteiten

Criteria inlaten Hollandse IJssel

Peilen

locatie	Streef peil winter (m+ NAP)	Streef peil zomer (m+ NAP)	Max. opzet streefpeil (cm)	Max. uitzak zomerstreefpeil (t.b.v. doorspoeling netwerk)
IJsselmeer_Storage	-0.4	-0.2	10.0	
Markermeer_Storage	-0.4	-0.2	10.0	
Randmeren_Storage	-0.3	-0.05	0.0	

Warm state selection

T0: 11-01-2003 ...

voorspellingduur:

Taakuitvoer opties

Kaart

Grafieken

Ruimtelijke weergave

Aanpassing berekening

Workflow Navigator

Logs

Peter Gijsbers

Huidige systeemtijd: 11-01-2003 01:00 (GMT+1)

18:09:29 GMT

20:09:29 CEST

Stand alone

-190239 , 645687

0.0 MB/s

116 MB

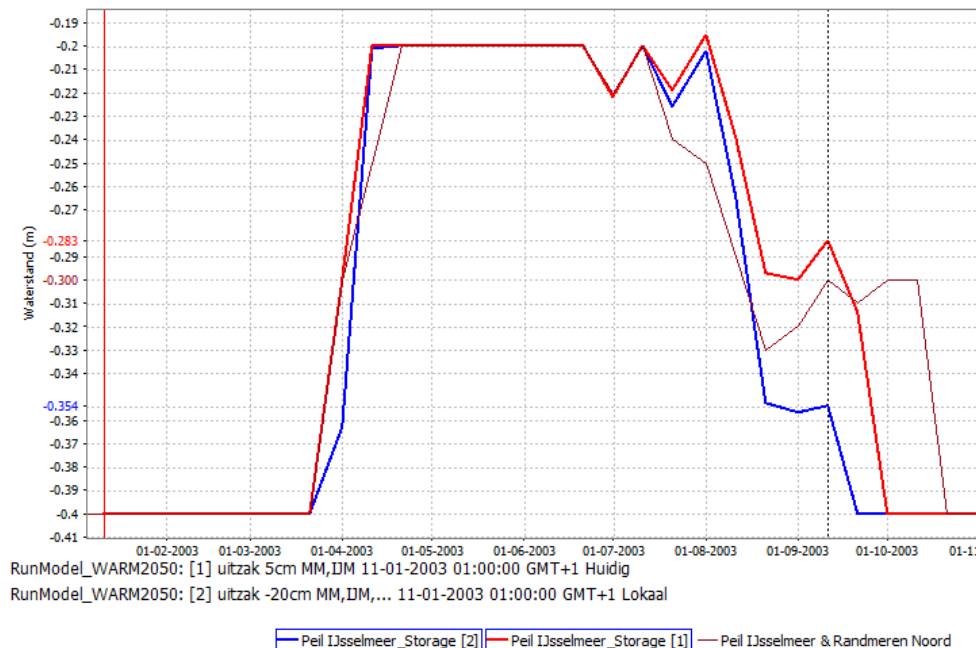
An aerial photograph showing a coastal landscape. On the left, a large body of water (likely a river or estuary) flows towards the bottom left. To the right of the water, a long, curved dike or levee runs along the coastline. Several white wind turbines are visible along the dike. Behind the dike, there is a patchwork of agricultural fields in various shades of green and brown. In the upper left, a small town or city is visible, situated near the water. The sky is clear and blue.

Using the Quick Scan Tool

Validation results vs. Nat. Hydrological Model

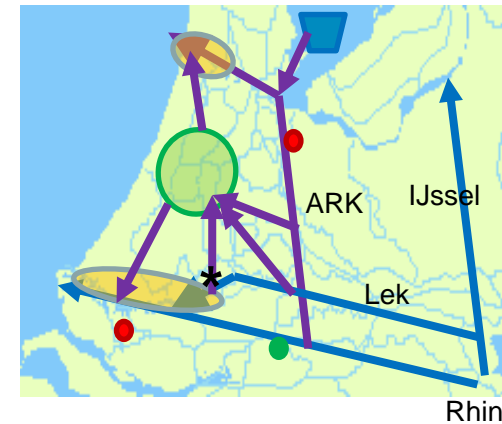
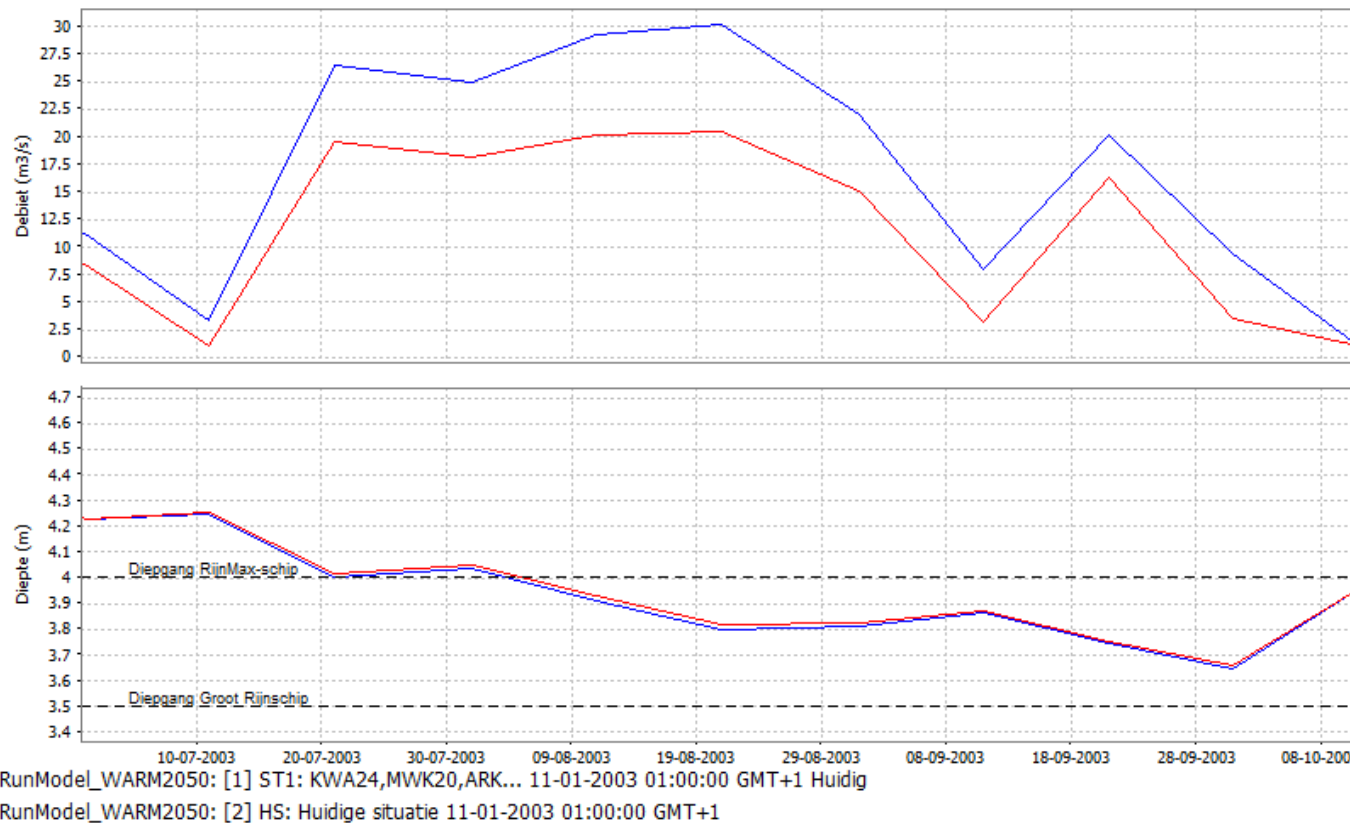
Purpose:

- prevent surprise outcomes when an intervention is chosen for evaluation in National Hydrological Model (NHM)
- → observation of similar behavior/system responses between NHM and Quick Scan Tool



Prel. analysis: Stress test WARM2050 scenario

(top) More water going North for flushing purposes and water supply
(bottom) Hardly any impact on navigation depth at most critical river location



current situation

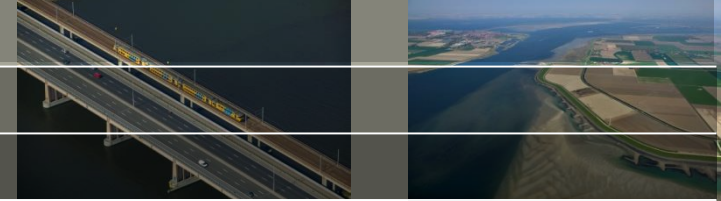
WARM scenario in 2050

Deltares

An aerial photograph of a coastal region. On the left, a large body of water (likely a bay or estuary) is visible. A city with a dense cluster of buildings is situated on a peninsula in the upper left. A long, winding dike system runs along the coast, separating the land from the water. The dike features a series of small, rectangular structures, possibly locks or weirs. To the right of the dike, there is a large area of agricultural land, divided into various colored fields (green, brown, and tan). A road or path runs along the dike. In the foreground, a large, light-colored area of sand or sediment is visible, possibly a beach or a dry riverbed. The sky is clear and blue.

Conclusions

Conclusions



- The validation study shows that the Quick Scan Tool can:
 - support priority based water allocation
 - provides useful answers to assist the policy process with regional trade-offs while screening of intervention options
- The software frameworks made development more a configuration and composition task than a programming task, requiring relative limited development time was limited
 - RTC-Tools software framework provides an easy entry point for development of mathematical programming based water allocation model without much programming/scripting
 - Delft-FEWS provides an useful framework for decision support system development providing good insight in data streams of the application