Flood risk assessment

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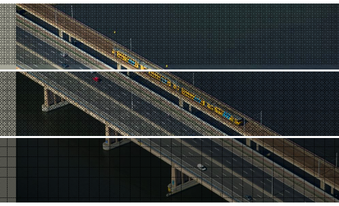
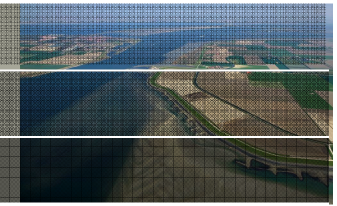
Deltares
(previous name: WL | delft hydraulics)

The problem: river floods





- Most rivers in the Netherlands surrounded by dikes
- Dike breaches are a hazard to be dealt with
- Dikes need to be heigh enough and *strong* enough

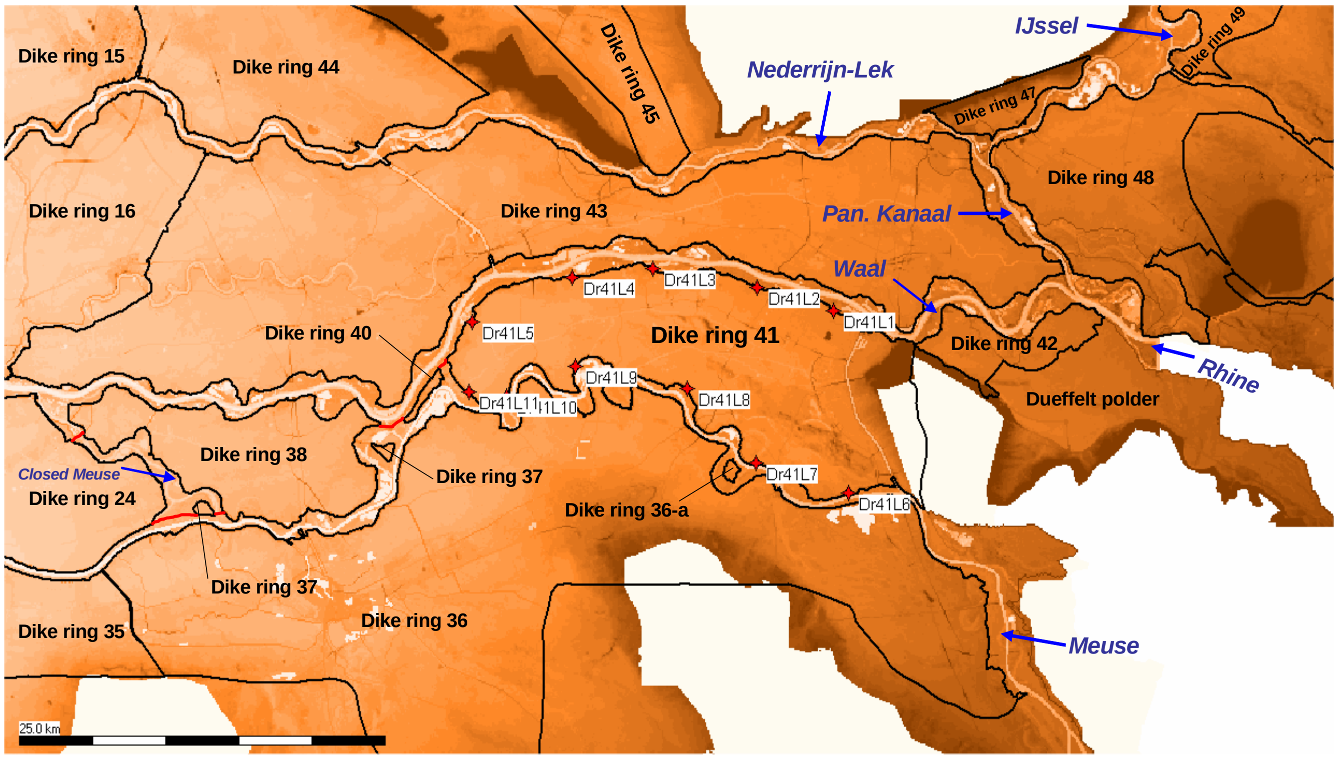
This project: comprehensive approach

Study area (1)

Study area (2)

- Surrounded by Rhine and Meuse
- Approximately 2 million people
- Several major cities
- Agriculture important aspect

Study area (3)

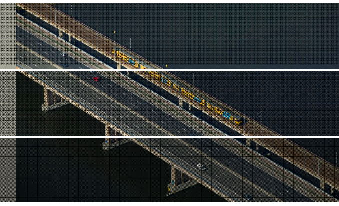


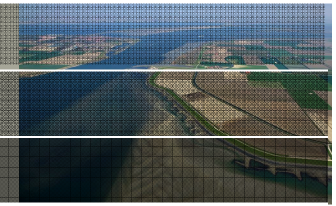
Primary flood protection work, category a (protects so-called dikering ares against flooding)

Primary flood protection work, category b (connects dikering areas)

Considered dike breach location

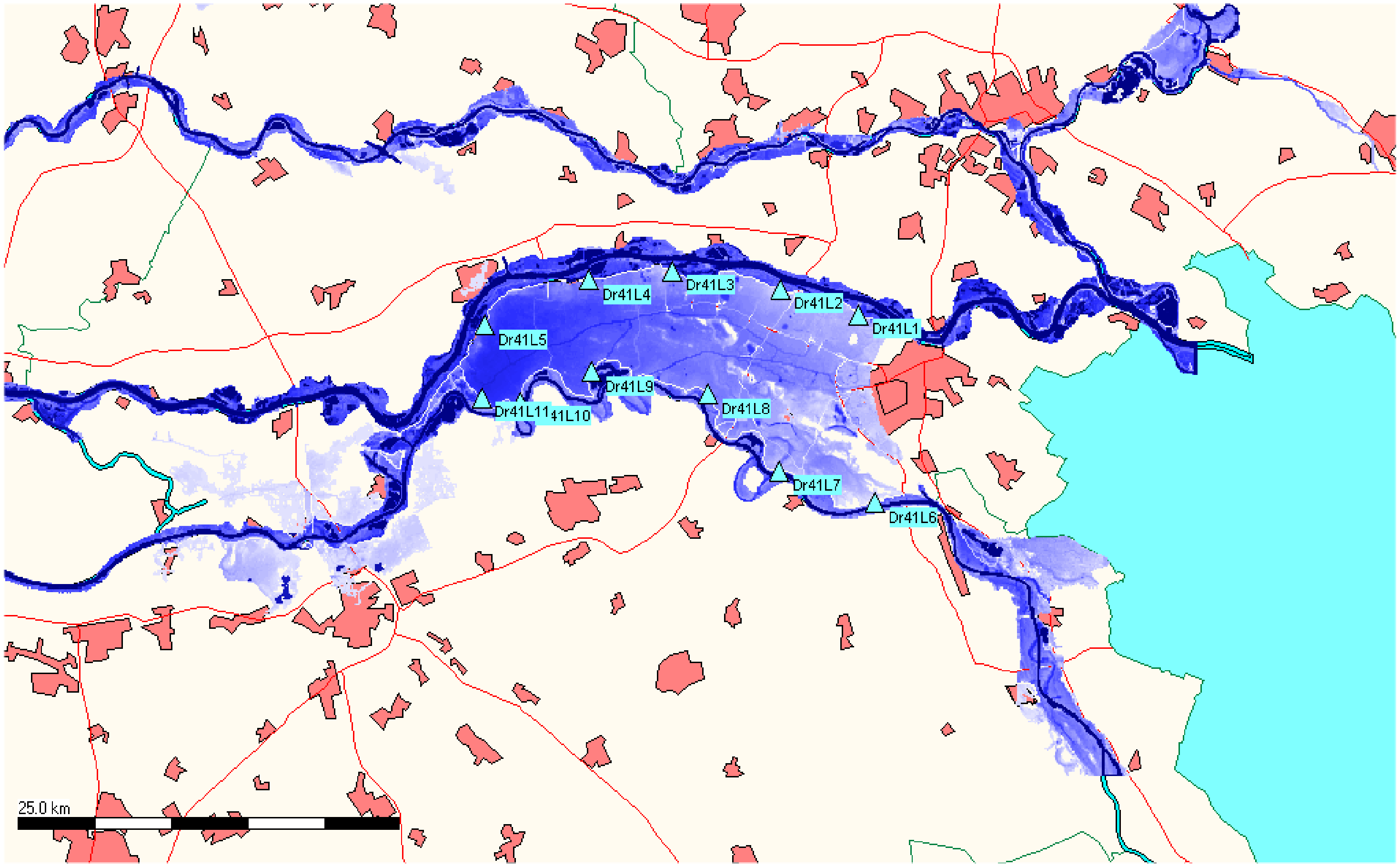
River system behaviour





- Dike breach can mean: lower water levels downstream
- But also: pressure from the land side
- Modelling approach:
  - Select locations for possible breaches
  - Compute the water flow in the rivers and over land
  - Estimate casualties and economic damage

Typical result



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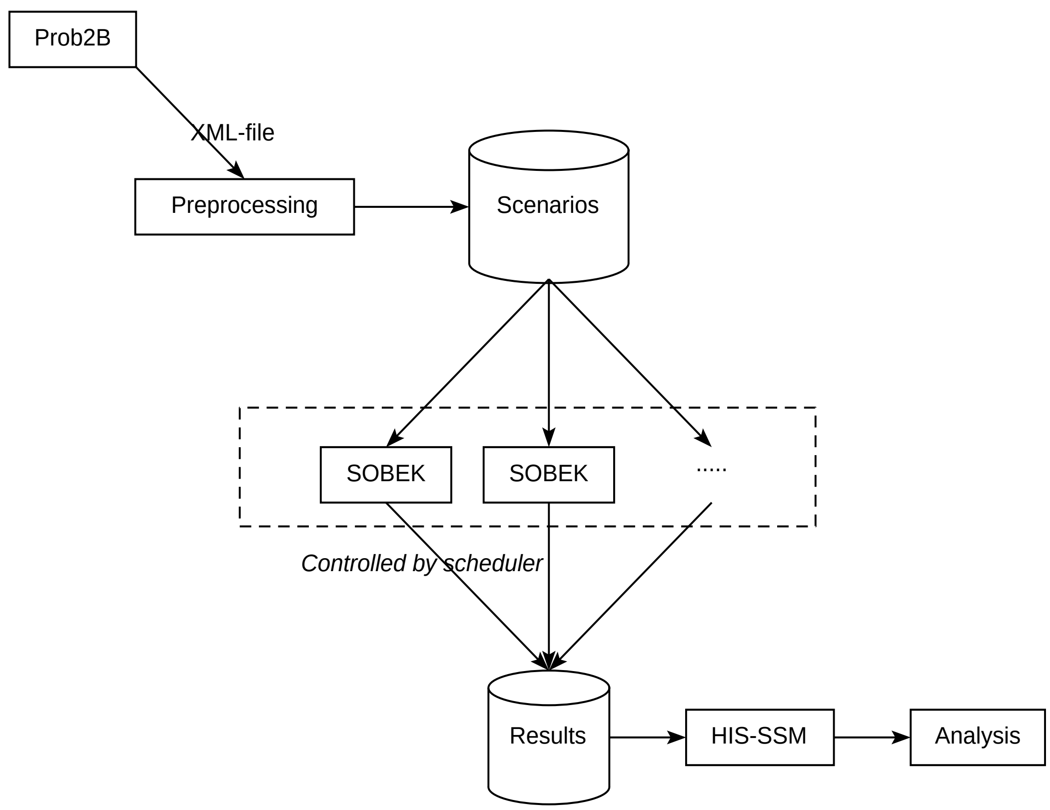
Modelling system



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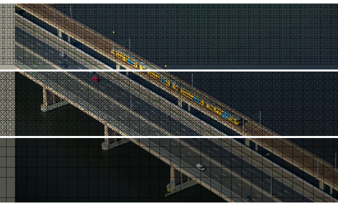
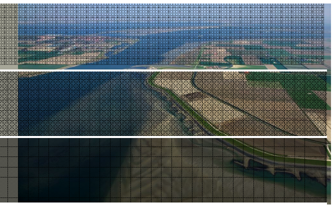
Modelling system: Scenarios





- Monte Carlo simulation: Setting up the scenario
- Floods have stochastic properties: maximum flow rate
- Dikes vary in strength – parameters known approximately only
- Selection:
  - Draw parameters for each location
  - Relation flow rate – water levels known
  - Estimate: dike breach?

Result: 3 x 100 scenarios (for different sets of potential breach locations)

Modelling system: Hydrodynamics

- Fine-grained terrain model (100 x 100 m)
- Flood simulated using “standard” curves – known for a range of maximum flood rates
- Period to simulate: roughly two weeks to three months
- Each simulation takes several days or even weeks to complete

Modelling system: Estimating victims, damage

- Maps of population density and land use
- Maps of water levels and flow velocities from hydrodynamic model
- GIS-based analysis
- Result for each indicated area:
  - the number of victims
  - Amount of economic damage

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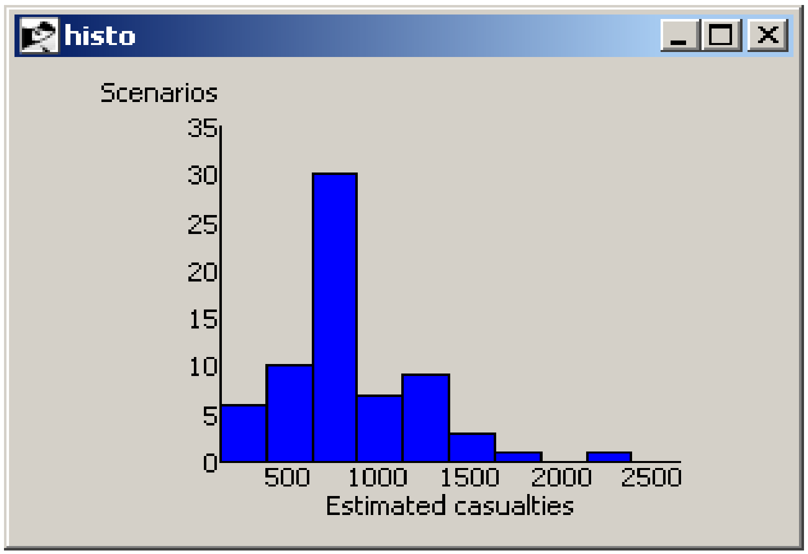
Modelling system: Estimate the risk

- Combine the results for all scenarios
- Risk is expected number of victims or amount of damage – so multiply with probability of occurrence
- Histogram: what is the most likely number of casualties?



Managing the computations

- Different programs run on different sites or computers
- Setting up, starting and checking the computations has to be automated:
    - A set of 300 scenarios
    - Computations take too long

Tcl turns out to be almost perfect for the job

Preparing the hydrodynamic computation

- Copying the (fixed) input files for each computation to a separate directory
- Reading the XML file with flood parameters and dike strength parameters
- Setting up the timeseries for the flood wave and adjusting various input files

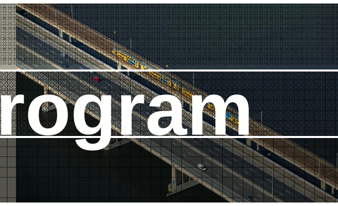
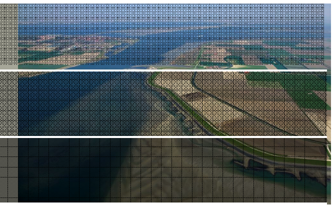
[clock], [string map], [file copy] are the tools here

Interlude: some code

```
proc constructTimeseries {begin series} {
    set sobekseries {}
    set begintime [clock scan $begin]
    set offset    [lindex $series 0]
    foreach {time rate} $series {
        set seconds [expr {int(86400*($time-$offset))}]
        set datetime [expr {$begintime+$seconds}]
        set sobektime [clock format $datetime -format \
            "'%Y/%m/%d;%H:%M:%S'"]
        lappend sobekseries "$sobektime $rate <"
    }
    # Trick: using a list suppresses an end-of-line at the end!
    return [join $sobekseries \n]
}
```

Running the hydrodynamic program

- Scheduling the jobs on the Linux cluster
- Not too many at a time though (I am not the only user)
- Registering the status:
  - Has the job started yet?
  - Is it finished? If so, successfully?
  - Has it been analysed yet?
- Small files with specific names flag that status (“running”, “done”, “analysed”)
- Script runs via the *cron* utility – so I keep the system busy

Running the risk estimation program

- Copying the result files from the various directories
- Adapting the input files for the program
- Running it in batch mode (it was originally a GUI only)
- Extracting the relevant information:

```
set outfile [open "hisssm-samenvatting.txt" w]
set areas {}
foreach file [glob -nocomplain "*-agg.txt"] {
    if { $areas == {} } {
        set areas [extractAreaDescription $file]
        ... write header ...
    }
    set scenid  [extractScenarioId  $file]
    set numbers [extractInformation $file]
    puts $outfile "$scenid\t[join $numbers \t]"
}
```

Lessons learned

- Traceability and monitoring: being able to analyse what went wrong
- Automate as much as possible: you may need to repeat the exercise
- Can you run the programs in batchmode?

Formal view: tuplespace

- Fill a database with scenarios (here: the file system)
- Each record (scenario) goes through various stages
  – steps in the chain of individual computations
- Ordering *between* scenarios is irrelevant
- Scenarios contain status information

Formal view: tuplespaces (2)

Each record (scenario) has the following information:

- Scenario ID (directory name containing all the files)
- Status (not started yet, running, finished, analysed)

The scheduler program selects a scenario with the right status and starts the computational program that belongs to that status.

In terms of tuplespaces: a *read* operation – the record is taken out of the database.

When the computational program finishes, a new record is written: an *out* operation.

Formal view: tuplespaces (3)

In this case the stages of the computation are:

- Preparation: from the XML file to a set of input files
- Computation: flood wave and dike breaches
- Analysis: has the computation succeeded?
- If success, estimate casualties and damage
- If not: identify why not?

The tuplespace apprach means the scheduler program needs to know nothing of the stage of each scenario. It simply scans the directories.

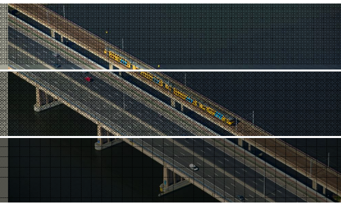
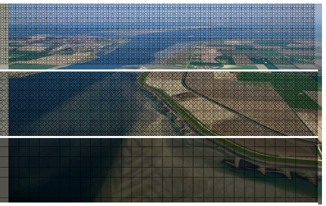
Formal view: tuplespaces (4)

Compare this to approaches found in literature:

- Formal specification of the computational steps (often via XML)
- The description of the complete computation needs to be analysed and transformed.
- Loops (iterations) are expanded
- The scheduler program keeps track of the stages of the computation.

A loop in this set-up:

Simply write a record with the same status, until the stop criterium is fulfilled.

Spin-off

- Setting up a series of computations is useful (to me) in other projects too.
- For instance: optimising the location of a waste water discharge in a coastal area

Work in progress:

- Various ways of dealing with a series of computations
- Possibility of calibration, not just selecting an alternative
- Flexibility in defining the variations?