A multidisciplinary study on exchange processes in river ecosystems

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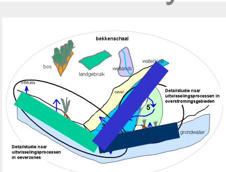
Exchange processes
in river ecosystems



Background

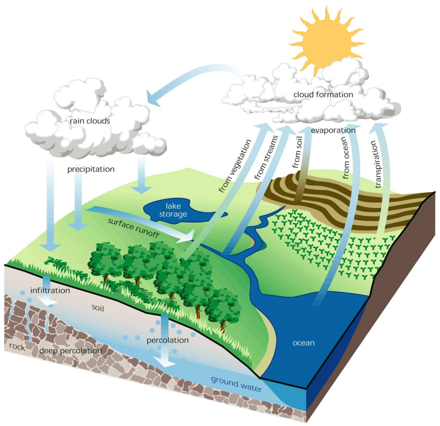


Fig. 2.2 -- The hydrologic cycle. The transfer of water from precipitation to surface water and ground water, to storage and runoff, and eventually back to the atmosphere is an ongoing cycle.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

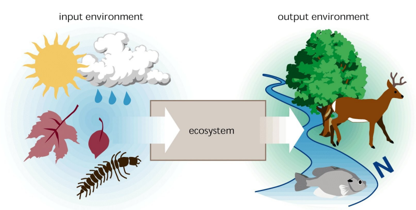
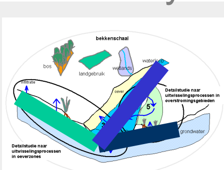


Fig. 1.3 -- A simple ecosystem model. Materials, energy, and organisms move from an external input environment throujgh the ecosystem, and into an external output environment.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

- ✓ **Land-Ocean interaction**
  coastal eutrophication
  Quantity and quality of the input of sediments, organic matter and nutrients in coastal seas are determined by upstream processes in the river basin

- ✓ **Longitudinal connectivity in stream/river ecosystems**
  Output of the upstream system is input for the downstream sytems, and determines its structure and function
  Output or input may be understood as hydraulic, chemical and biological characteristics of the interaction

Exchange processes
in river ecosystems



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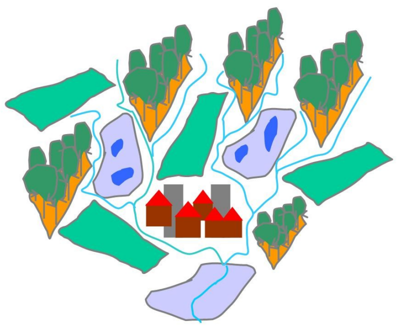
Background

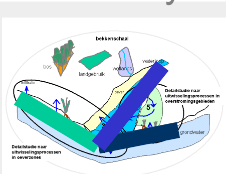


Models have been developed on river basin and subbasin scale

✓ ecosystem interactions are generalized
But especially at the land/water interfaces we find ecotones which in different ways regulate the exchange

✓ experience is that information on smaller spatial and shorter temporal scales are needed
Exchanges and transformations are strongly determined by events and spatial distributions

Exchange processes in river ecosystems



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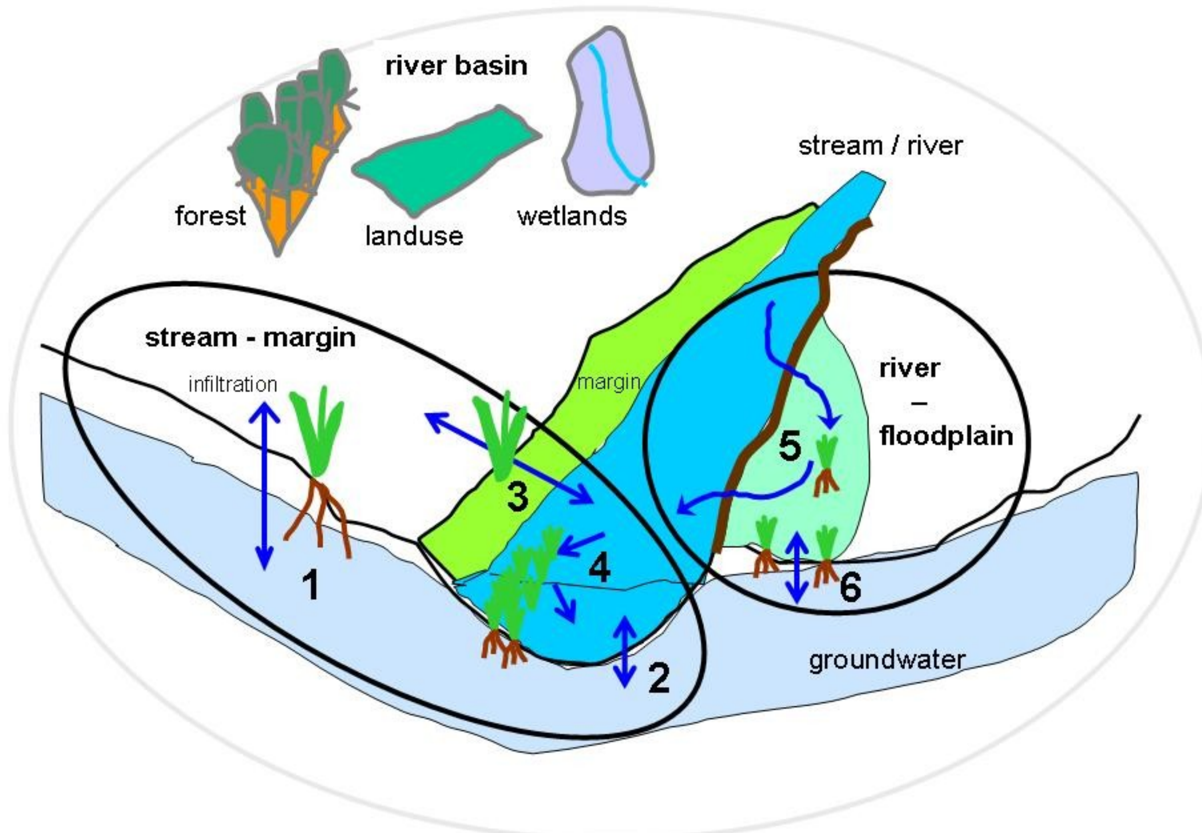
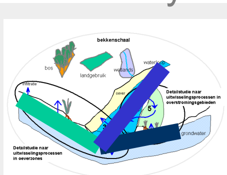
Project

Zones of interaction

1. shallow ground water with wetland or terrestrial systems
2. deep ground water with the water course
3. stream with the margin
4. stream with macrophytes
5. water course with floodplain
6. surface and ground water with the plant-soil system



Exchange processes in river ecosystems



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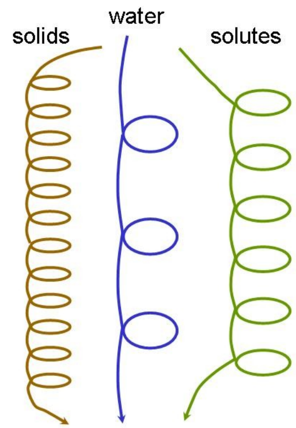
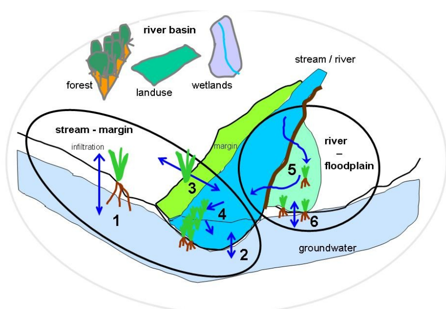
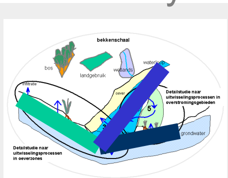
Project aim





Exchange processes
in river ecosystems



To investigate how the diverse physical and biological processes and their interactions determine the exchange of

- *water*,
- *dissolved compounds* and
- *suspended matter*

in margins and floodplains of water courses

Necessary to develop models for land-water interfaces and their integration on the ecosystem level

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Approach – Measurement and modelling

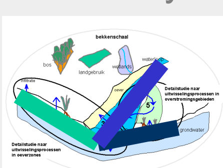
We focus on two systems

2. stream and margin (AA)
3. River and floodplain (Demerbroek)

Measurements

- monitoring for **mass balance** construction
- use available data

Exchange processes in river ecosystems



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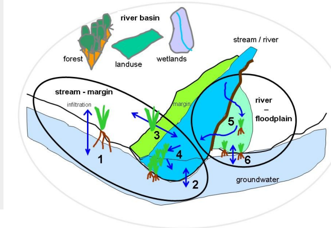
Approach – Measurement and modelling



ecosystem

Data
- mass balance (hydrological data and quality)
- system characteristics (morphology, vegetation)

Model development
-coupling of hydraulic models, i.e. hydraulic and ground water, with
- implementation of transformation processes (biological, chemical)

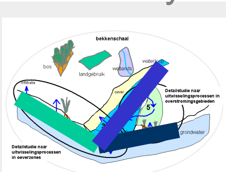
These type of models deliver:
-ecosystem input-output
- spatial connectivity

subsystems

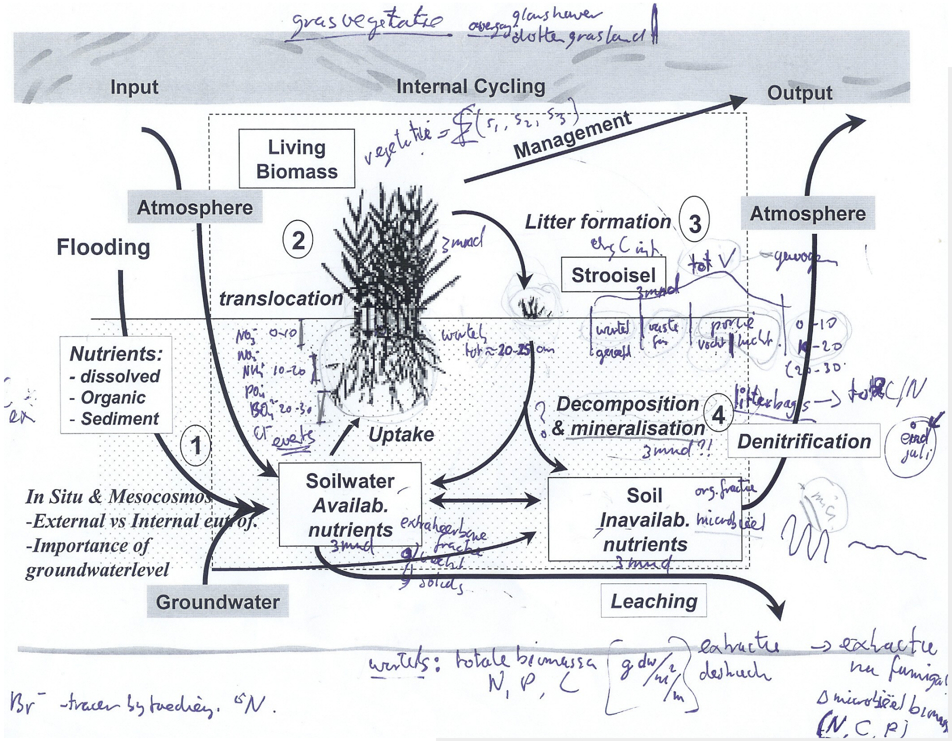
Data (available from other projects)
- nutrient cycling in plant-soil systems
- macrophyte-discharge interaction

Model development
- Plant-soil models
- ground water/sediment/surface water (diagenetic models)

These type of models deliver:
- proces information for ecosystem model
- insight in spatial heterogeneity
- tools for data analysis.



Modelling plant-soil systems



Scheme for model development is directed towards increasing of the model complexity.

1. Hypothesis testing

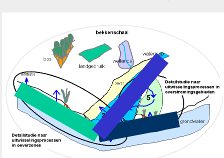
2. inverse analysis directed towards estimation of fluxes between compartments

3. simpel mechanistic compartment model (no spatial resolution)

4. structuurmodel met uitbreiding van het aantal structuurelementen en procesbeschrijvingen

5. Incorporation of transport processes with defining a verticale resolution

Exchange processes in river ecosystems



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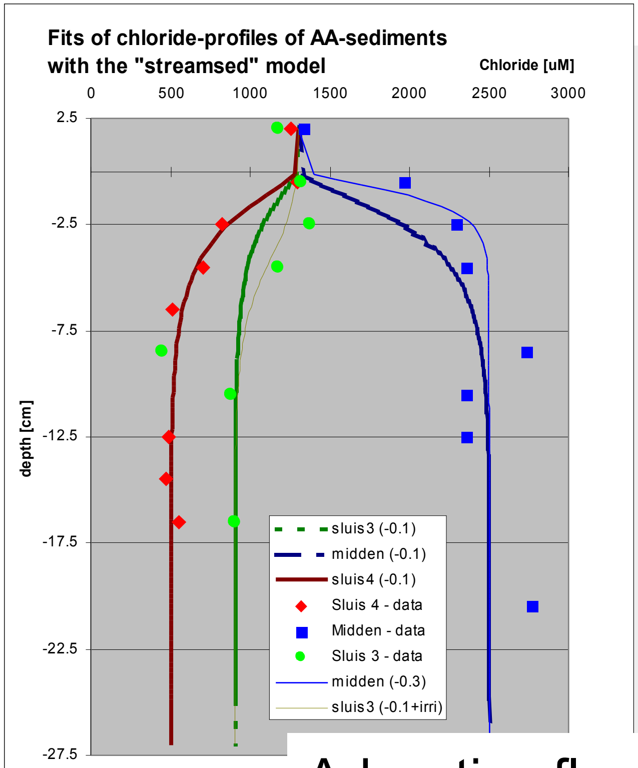
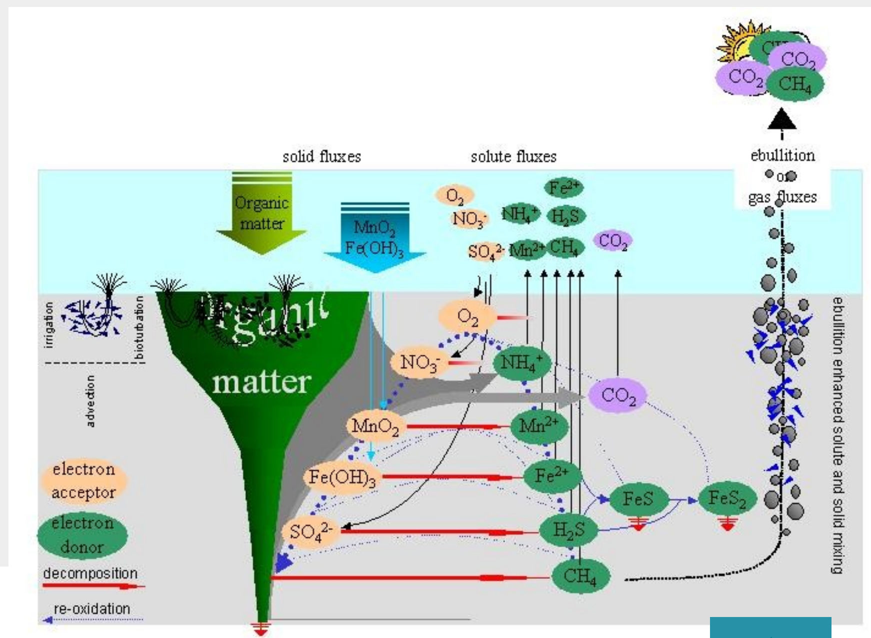
Model development - stream sediment systems



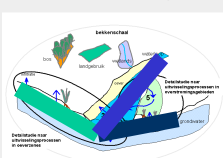
Advective flow

Sediments form the interaction zone between groundwater and stream or river. This zone may be an important transformer (filter) of nutrients.

This may be studied by applying diagenetic models.



Exchange processes
in river ecosystems



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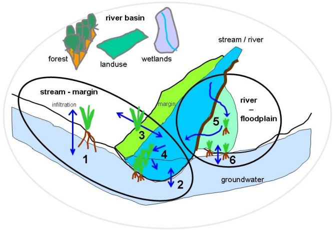
Approach – Measurement and modelling



ecosystem scale

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- system characteristics (morfology, vegetation)

Model development
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These type of models deliver:
- ecosystem input-output
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subsystems

Data (availbable form other projects)
- nutrient cycling in plant-soil systems
- macrophyte-discharge interaction (mowing patterns)

Model development
- Plant-soil models
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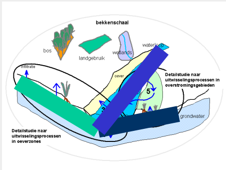
Exchange processes in river ecosystems



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Model integration

Formulations of discharge, flow and mixing of water

- hydraulic formulations

$$\frac{Q}{A} = \overline{u} = \frac{1}{n} R_h^{2/3} S^{1/2}$$

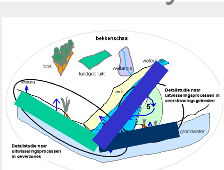
- ground water formulations

$$Q = -kA\frac{h_a - h_b}{L}$$

- box model (transport-reaction)

$$\frac{\partial C}{\partial t} = -v\frac{\partial C}{\partial x} + D_{comp}\frac{\partial^2 C}{\partial x^2} \pm reaction$$

Exchange processes
in river ecosystems



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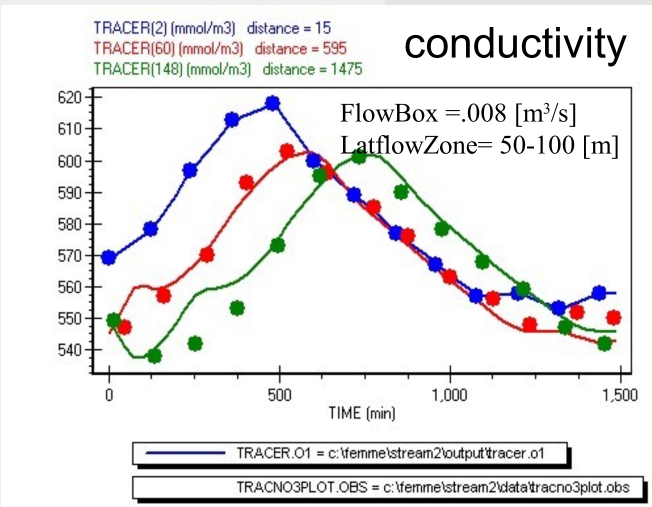
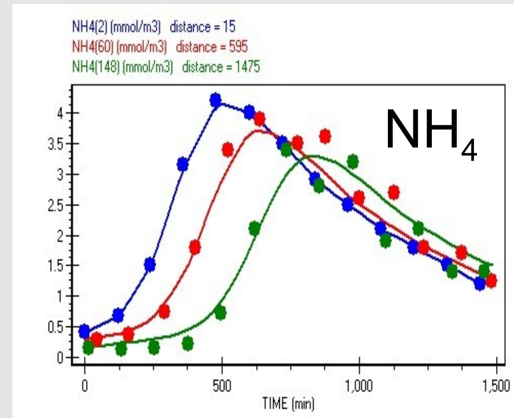
Model integration

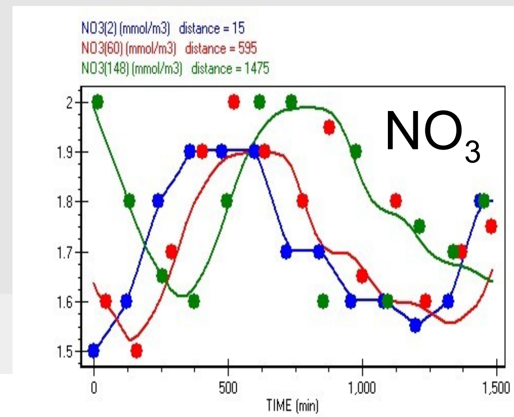
Analysis of data to construct mass-balances

Step 1. Calibration of transport parameters

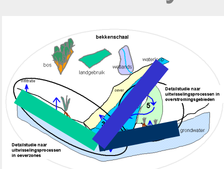


Step 2. Calibration of reaction parameters
- NH_4-consumption
- NO_3-production





Exchange processes in river ecosystems



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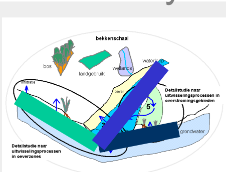
Model integration – Feedback mechanisms

Between disciplines we can distinct different types of information exchange

- model boundaries
- functions
- feedback

in-stream macrophyte-sediment system, affecting

- stream discharge
(presence of macrophytes increase resistance against flow)
- nutrient cycling by uptake of release
- sedimentation within the macrophyte patches that generally show smaller flow velocities



Modelling – macrophytes

Describing discharge, flow distribution and mixing of water

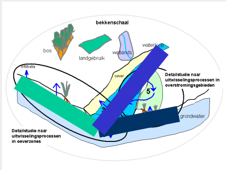
- hydraulic model

Formulation of Manning coefficient as a function of macrophyte biomass

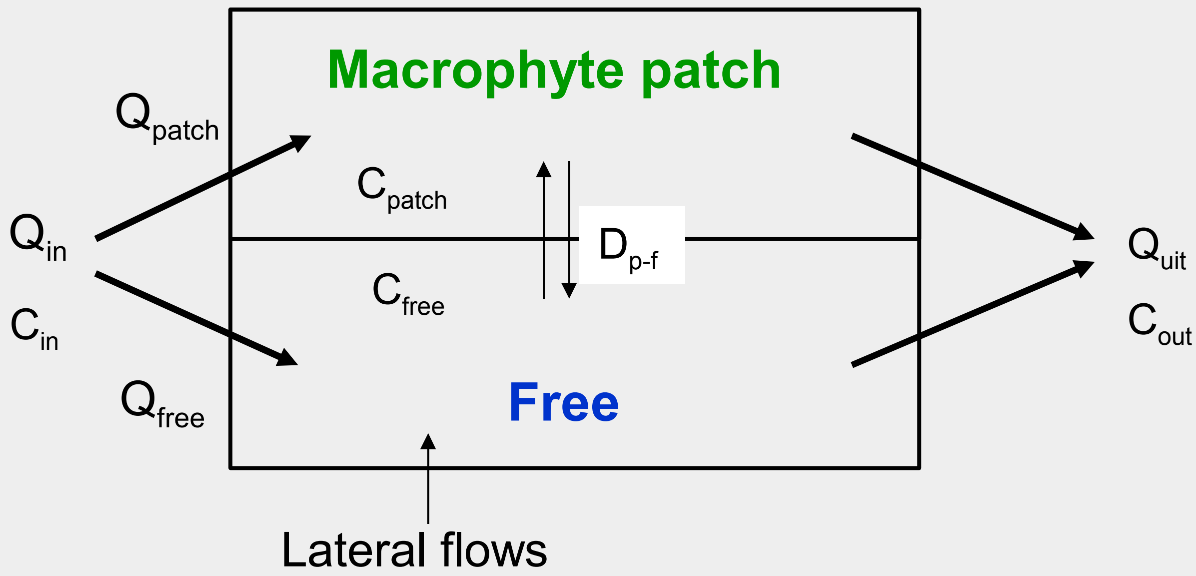
- biogeochemical model

Artificial partitioning of stream in flow zone with and without macrophytes

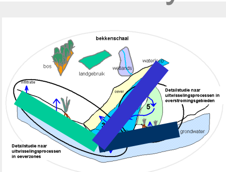
=> linking the effect of plants on transport and transformation



Modelling – Quasi 2D macrophytes



$$Q_{patch} = Vol_{patch} / (Vol_{patch} + Vol_{free}) \times F_{res} \times Q_{in}$$



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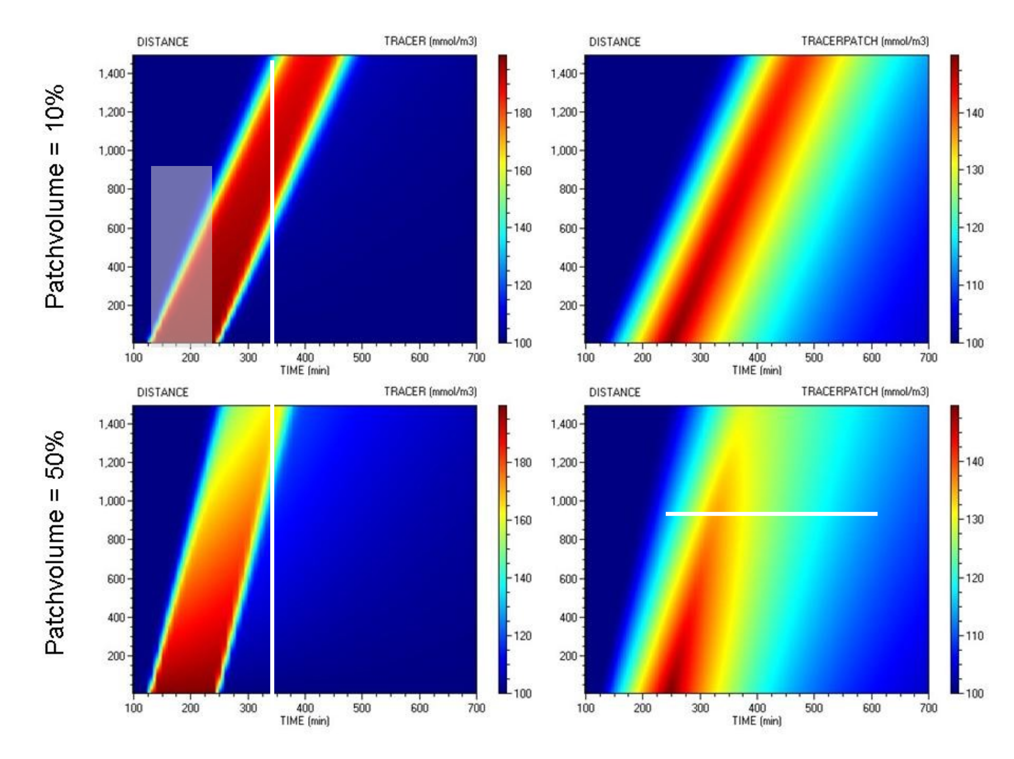
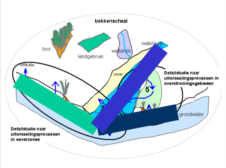
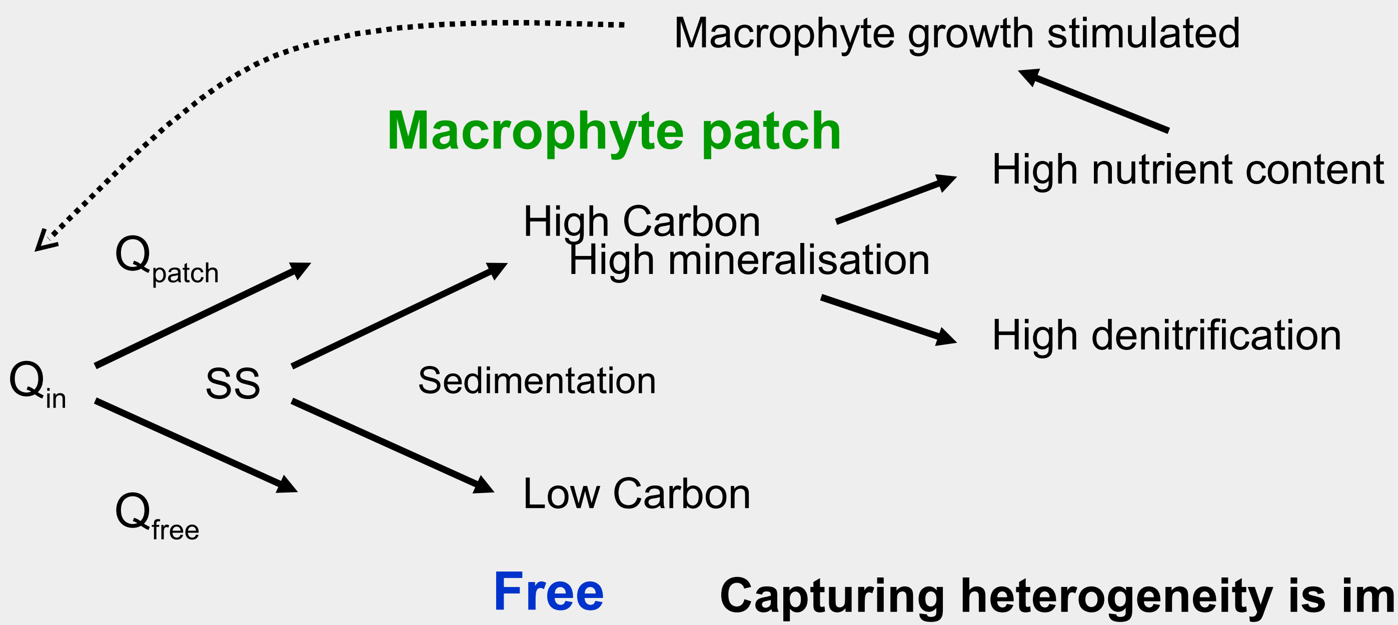
Modelling - Quasi 2D macrophytes



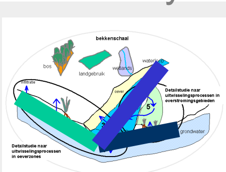
Exchange processes
in river ecosystems



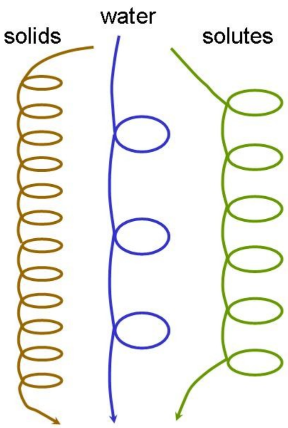
Modelling – cascade effects / feedback



Capturing heterogeneity is important !



Model integration

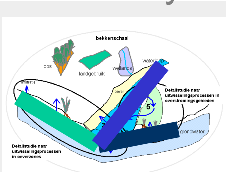


What is a good way to describe integrated transport features of water, solutes and and solids for stream and floodplain system, which also alows implementation of transformation processes and (biological) structures?

Demands

1) Which capture feedback mechanisms (and give developmental characteristics of the model)

2) Spatial heterogeneity in transport and reaction determines the functioning of the ecosystem and requires 2D-modelling



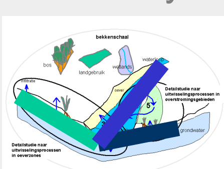
Differences in modelling software

What software packages allow development of integrated models for small scale and ecosystem models?

1) Modflow-Daflow
Hydrology based
What are the possibilities for incorporation of transformation processes and feedback relations

2) Femme-Fortran
very flexible, open source, 2D/3D calculations and visualizations need to be invorporated

Exchange processes
in river ecosystems



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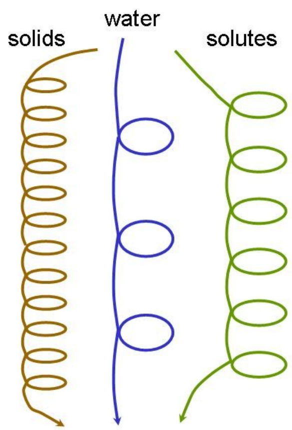
Concluding remarks

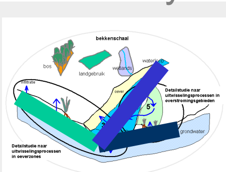


sketch of our project - wide range of activities

Development of integrated stream-margin and river-floodplain models to describe exchange processes.
- transport
- transformation
- ecosystem configuration

Based on small scale models of the system interfaces
=> data analysis tools of measurements and experiments

Present focus on model formulations to describe the transport of water, solutes and solids, which also allows implementation of transformation processes and structures



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FEMME – fortran environment for model

Structure of the 2DwithSolids

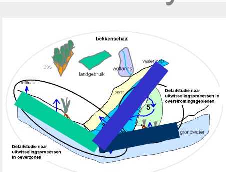
Parts:

- **general**
- **transport of water**
- **transport of solutes**
- **transport of solids**
- **reaction**
- **manning**

Parts are subdivided in

- **initialisation**
- **second initialisation**
- **dynamic routine with formulation what happens within a timestep**
- **finalising (specific writing of output or other)**

Exchange processes
in river ecosystems



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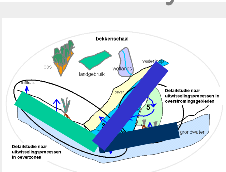
FEMME – fortran environment for model

Pro's

o Very flexible programming environment
o Handling of reading/writing, input data (forcing, initialisation)
o Integration (different options) is done by the environment => model formulation structured as processes within a timestep
o Different run types: single, calibration, sensitivity, monte carlo, batch runs,….
o Coupling of models is relatively easy achieved
o Growing environment, means if new routines are needed this could be implemented in the FEMME-environment (in cooperation with Karline Soetaert)

Con's

• Visualisation of data with FEMMEPLOT is in development. Could be improved.
• Specific (integration) routines for hydraulic and ground water modelling (2D/3D) are missing



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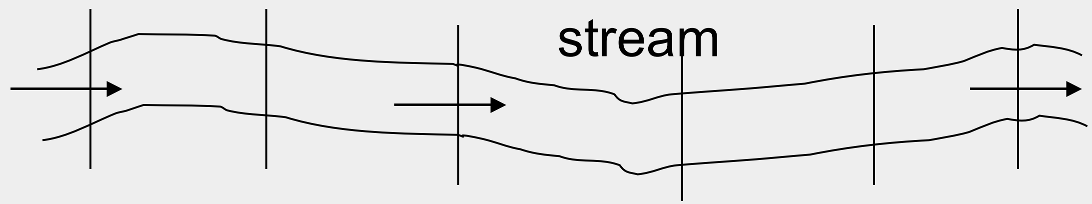
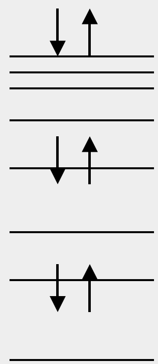
Box modelling

transport-reaction models





Advection-dispersion-reaction models

$$\frac{\partial C}{\partial t} = -v\frac{\partial C}{\partial x} + D_{comp}\frac{\partial^2 C}{\partial x^2} \pm reaction$$

sediment

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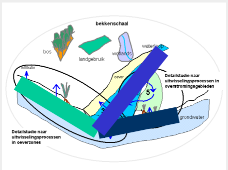

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