Project no. **004074**

Project acronym: **NATURNET-REDIME**

Project title: **New Education and Decision Support Model for Active Behaviour in Sustainable Development Based on Innovative Web Services and Qualitative Reasoning**

Instrument: **SPECIFIC TARGETED RESEARCH PROJECT**

Thematic Priority: **SUSTDEV-2004-3.VIII.2.e**

Textual description of river Mesta case study

Due date of deliverable: **28/02/2006**
Actual submission date: **20/03/2006**

Start date of project: **1st March 2005** Duration: **30 months**

Organisation name of lead contractor for this deliverable:

Central laboratory of general ecology

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

This document represents detailed description of River Mesta case study, including all ingredient of stream ecosystem model. This includes background on the main sustainability issues affecting the river (organic pollution, erosion, and water abstraction) and model goals to educated about these issues. Structural details, including the entities, assumptions, and configurations of the system are described. The main biological, chemical, and physical processes relevant to dissolved oxygen, as an indicator of environmental quality, are also described, including how they relate to the external influences of organic pollution, erosion, and water abstraction. We describe a set of scenarios useful for investigating various processes within the system. Finally, we use the QR ontology to describe a set of model fragments that encapsulate knowledge of structural details and causal relations, for later implementation in the QR workbench Garp3.

Document history

Version	Status	Date	Author
1	Draft, initial version.	6/01/2006	Elena Nakova, Yordan Uzunov
2	Draft,	15/01/2006	Elena Nakova, Yordan Uzunov
3	Draft	31/01/2006	Elena Nakova, Yordan Uzunov
4	Final version 1st draft	06/02/2006	Yordan Uzunov, Elena Nakova
5	Revision	21/02/2006	Tim Nuttle
6	Final version	20/03/2006	Yordan Uzunov, Elena Nakova, Emilia Varadinova

Content

1 INTRODUCTION

Aquatic ecosystems provide humans with numerous natural services - water supply for drinking, irrigation, industries, energy production, biological resources like fish, etc. Sustainable use of all set of services an ecosystem can provide depends on the ecological status of water bodies – a relative measure for the ecosystem health. Human activities within watershed may substantially change the basic features of a water body, thus causing various disturbances, even destruction of main components and processes that ensure sustainable and long-term existence of the aquatic ecosystems. Worsening the ecosystem health means fewer services that humans can use from water bodies, decreasing total income of goods and benefits, jeopardizing human health and wealth.

A water body is a complex chain of life supporting systems containing many components and processes. Human pressures and impacts on water bodies can change these processes in a negative way. One of the indicative parameters of the ecosystem health is the amount of dissolved oxygen. Dissolved oxygen is a key and essential parameter for all living organisms in the ecosystem – aquatic animals, plants (both macrophytes and algae), microorganisms; that is why this parameter is considered as an important indicator for ecological status and ecosystem health.

Naturally, all water bodies contain some amount of dissolved oxygen due to simple physical process of diffusion from the atmospheric air driven by solar radiation (temperature). Due to the biological processes of oxygen production and consumption, normally there is a dynamic balance between inputs and outputs of dissolved oxygen. Water pollution, abstraction, erosion and many other activities driven by humans (both inside and outside the water body) can shift negatively this balance, causing worsening the ecosystem health and decreasing the ecosystem services humans can use in a sustainable way.

Thus, the dynamics of the amounts of dissolved oxygen and discrimination between anthropogenic and natural fluctuation of this simply measurable environmental variable could provide important information for the decision making about sustainable and integrated management of ecological status, water quality and ecosystem health.

1.1 River Mesta basin

In terms of the Water Framework Directive 2000/60/EC (Annex XIA), the river Mesta is located in the eco-region 7 (Eastern Balkans). It is a transboundary river shared between Bulgaria and Greece.

In the Bulgarian territory, the Mesta River (named Nestos in Greece) is a mountain stream with 1318 m average altitude, 129 km length and having 2767 sq.km of catchment area and annual water discharge of 34 m^3/s at the state border. At this point, the annual minimums (monthly and absolute) are estimated to be 1.55 (July 1993) and 0.851 m^3/s discharge (August 1993), respectively. The river system contains 25 tributaries; the largest of them (river Dospat) enters Mesta in the territory of Greece.

The catchments area of the Mesta is situated in the Continental-Mediterranean climatic zone, but the lower stretch (close to the state border) is influenced by purely Mediterranean climate. The typical feeding of the river is by snow (in high mountains) and rains (in lower stretches). There are two typical flow peaks – primary in springs (shifted to the early summer) and secondary one in winters. Low flow period may last 3-4 months (August-November).

There have been no significant changes in the flow regime for the last 30 years. Main water use is approached to irrigation of extensive agriculture along the river valley; there are several small hydropower stations on some of the tributaries. Industries in the watershed are in regress for the last 15 years.

The river Mesta has been intensively studied for the last 35 years due to the heavy organic pollution caused by yeast, cellulose and cardboard manufacturing in the town of Razlog. The industrial wastewater production exceeded 90 000 m^3 per day; the average daily levels of BOD_5 varied between 300-450 mg O_2/dm^3. Such an unfavorable ecological situation remained until 1990, when the operation of the plants – sources of great pollution, was banned by the respective authorities. Immediately, rapid improvements of the water quality and recovery of the affected ecosystem were registered.

By this way, the developments of the ecological status of the Mesta River could be defined in two large periods: until 1990, the period of heavy loading with organic matter of industrial origin, and after 1990, the period of recovery and stabilization of the ecological situation.

The available data base contains full set of information on hydro-morphological (incl. hydrological), physical (thermal conditions), chemical (oxygenation and nutrient conditions) and biological (mostly on macroinvertebrate species diversity, abundance/density, cenotic and trophic structures of bottom communities) and water quality assessments (saprobic, biotic and cenotic indices) from 1978 to 2005.

Figure1. Location of the river Mesta valley

Figure2. Overview of Mesta-Nestos watershed

1.2 Humans and human occupation of the basin

The overall population of the watershed of Mesta is estimated on about 170,000 inhabitants; of them 135,000 leave on Bulgarian territory, mostly in largest towns of Razlog (21,500), Gotse Delchev (33,000) and Satovcha (18,000). All the rest population inhabits many smaller villages, even single farms.

As a mountain region, the large part of the basin is covered by forests, and forestry is an important part of the economy within the watershed. Part of the territory, especially high mountain areas and headwaters are included in the two National Parks of Rila Mountains and of Pirin Mountains, the latter listed by UNESCO as a world natural heritage site. These regions provide excellent opportunities for tourism and lately become very popular centers for winter sports like skiing (the town of Bansko, for instance) and many other kinds of tourism like alpinism, rural or ecotourism, etc.

Arable land areas are located mostly along the stream channel and in the well irrigated most southern part and of the Bulgarian stretch. The dominating cultures are tobacco, potatoes, vegetables, corn, and grain. The agriculture is estimated as extensive, almost organic, with application mostly of manure instead of synthetic chemicals (fertilizers, pesticides). Cattle breeding are also very important for local people, located in small farms, where wild grazing on hills and natural meadows is the most popular practice.

As said above, industry has been in decline for over a decade. There are many small to medium enterprises manufacturing paper, card-board, textile, wood materials and furniture, etc.

The region is recognized as economically under-developed, with high level of unemployment in the northern municipalities and villages (50-80%). Regional development plans foresee intensification of all kind of economic activities based mostly on natural realities of the region. This includes further development and diversification of the intensive tourism; turn toward a modern, most intensive agriculture, farming and forestry; energy production from small-sized hydropower plants, urbanization of the larger settlements, including construction of new roads and streets, ecological infrastructure (sewage systems, wastewater treatment plants, and domestic waste landfills), etc.

Parallel to the population growth, all of these above need much more water than the watershed can generate. Potential conflicts might be recognized between water demand and supply sides in order to meet increasing needs of regional human developments. The competent state and local authorities are faced difficult solutions how to maintain both the vitality of the river system and satisfaction of the public needs for more and more water of high and/or acceptable amounts and quality. Reconciliation of these conflicts requires finding of sustainable solutions and appropriate environmental and/or ecosystem health indicators, besides economic and/or social ones usually taken into account only while one foresees future regional developments.

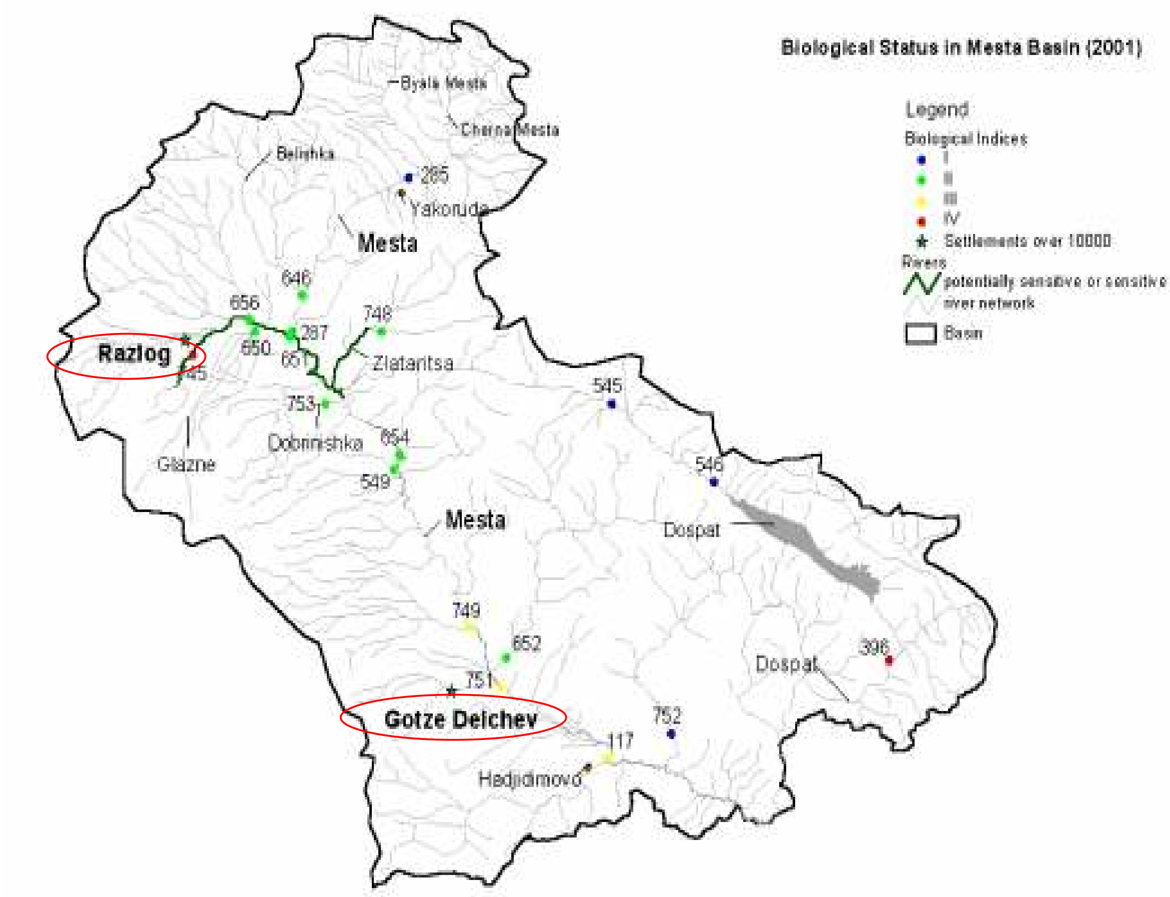

Figure3. River Mesta watershed

1.3 River Mesta environmental issues

The River Mesta is regarded as one of the most natural streams found in South Europe with minor disturbances of its hydro-morphology and moderate impacts from humans like water pollution, eutrophication, soil erosion, etc. The status of protected areas of most of the right-side tributaries in high-mountains preserves water quality, but not the amount of potential water abstraction for increasing human needs, including for energy production. Left-side tributaries however suffer from intensive deforestation of large areas and thus minimizing the water generation capacity of the watershed. Besides local pressures and impacts the river system is affected by, there are evidences of gradual decreasing of total water discharge following global changes and aridization of the regions, especially in its southern sectors of the basin and watercourse.

2 Orientation and initial specification

2.1 Main model goals

We have identified the following modelling goals to focus and narrow the scope of our model.

- To develop a model that can describe the behaviour of the Dissolved oxygen in a stream being under different condition – hydro-morphological, physico-chemical and biological.
- To build a model that examines the mechanisms of changing in functions of the stream ecosystem under anthropogenic influences of organic pollution, erosion,(due to agriculture and deforestation), and water abstraction.
- To use the model for scientific and management purposes to explain cause and effect processes to decision markers and stakeholders in sustainable solution.

2.2 Building up River Mesta concept map

We begin with a concept map that helps identify, clarify, and focus our knowledge about the system of interest (Figure 4). Two main groups of natural processes influence the amount of dissolved oxygen (DO) in the river. Physical processes involve solar radiation which provides light and heat, as well as water itself which modify the hydro-morphology or the channel (depth, width, bottom substrata, etc.), thus providing living organisms with habitats. Biological processes involve three groups of organisms responsible for oxygen production (producers: algae) and oxygen consumption (consumers and reducers). All aquatic organisms consume oxygen for their breathing.

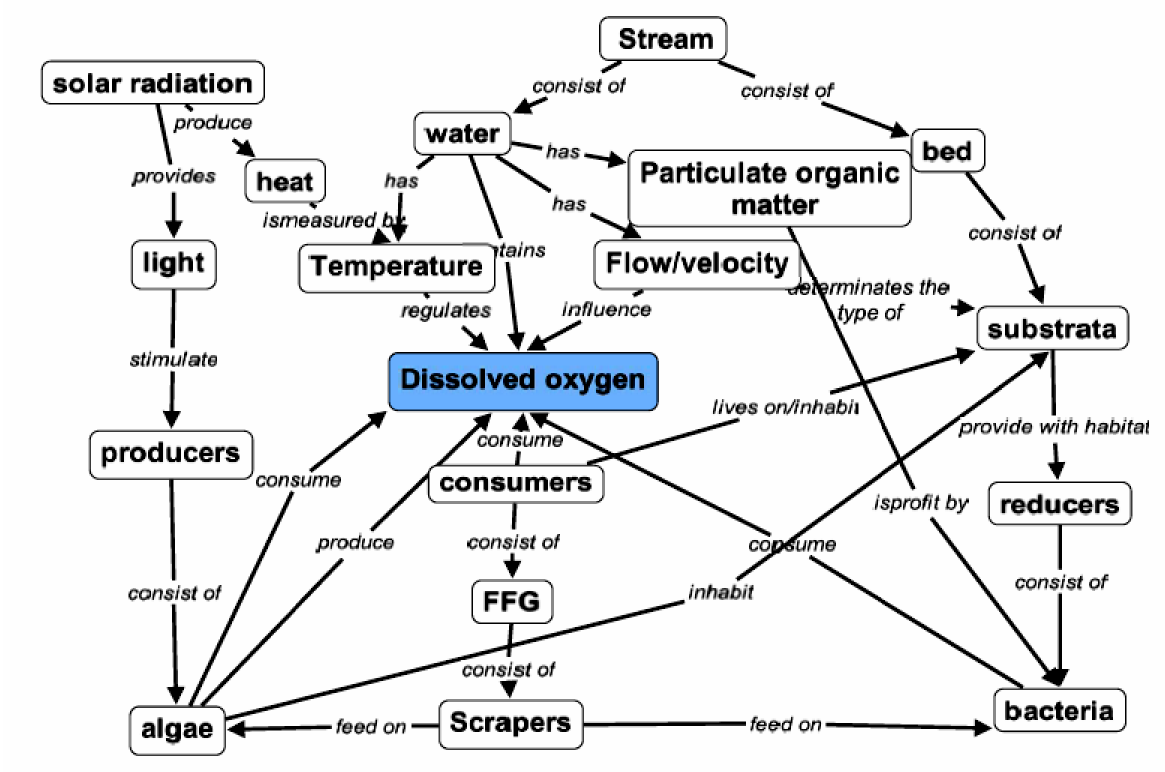

Figure4. River Mesta concept map

3 System Selection and Structural Model

3.1 Description of entities

Based on the constructed concept map and main model goals, we identify the entities involved in the River Mesta system (Table 1).

Table 1: Entities involved in the River Mesta QR model

Entity	**Description**
Stream	A natural water body which consists of some amount of running water and river bed/bottom.
Water	Part of the stream, a fluid that possibly contains dissolved gases and Substances. Water has its flow/velocity and temperature.
River bed	The solid background within which the water runs downstream. The bed consists of different types of substrata, the size of particles of which depends on current velocity.
Algae	A kind of producer. Periphytic algae inhabit (live on) substrata (river bed)
Bacteria	Reduce the organic substances and bodies of dead organisms. They play important role in self-purification processes.
Scrapers	A functional feeding group of trophic structure of the macrozoobenthos, which feed on small-sized organisms like algae and bacteria, scrapping /grazing them from surface of the bottom substrata they used to live on.
Solar radiation	An environmental factor which is the main source of energy (light and heat) for the aquatic ecosystems.

3.2 Structural relation between entities

Figure 5 depicts the structural relationships among entities graphically. These relationships pertain to entities within the River Mesta system—we identify processes happening within the stream itself to be part of the system structure, whereas anthropogenic influences will be considered as external agents: outside the system, but influencing its behaviour

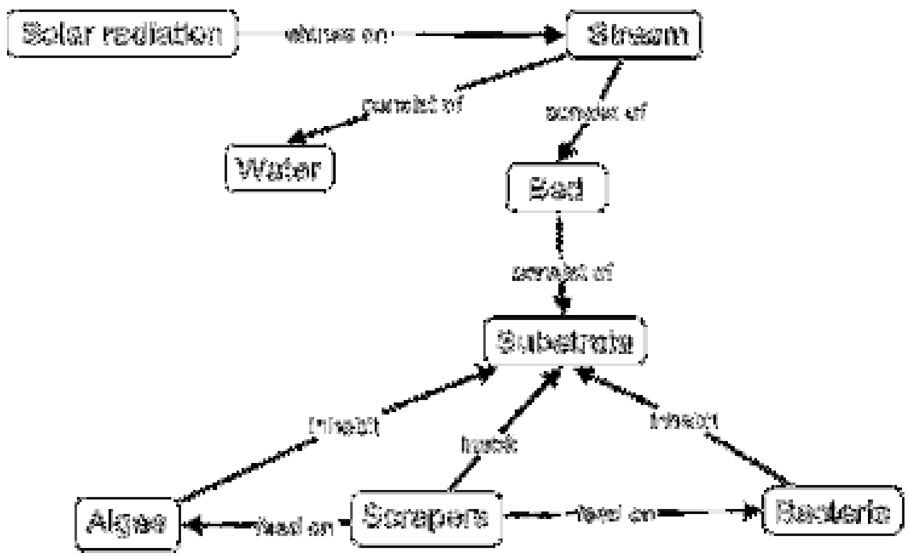

Figure 5: Structural model of the stream system

3.3 System environment and external agent

There are several human activities that have potential to impact the amount of dissolved oxygen Figure 6. Water abstraction for various purposes decreases the total amount of water running downstream the channel and thus affecting several important parameters relevant to amount of dissolved oxygen – discharge, stream velocity, type of substrata, temperature, etc., thus affecting biological components of the ecosystem and their functions. Forestry, especially deforestation, increases the soil erosion and amount of suspended solids in water, thus affecting the solar light penetration into the water and ability of algae to produce more oxygen. The effect of agriculture is similar and some chemicals used in agricultural practices can contaminate the water thus jeopardizing the aquatic living organisms and biodiversity of river biota. Human settlements, industries, tourism may also be sources of harmful pollution when discharge stream water with extra amounts of organic matter and specific pollutants. Such effects could change significantly all basic physico-chemical parameters of a stream and ecosystem biota as a whole.

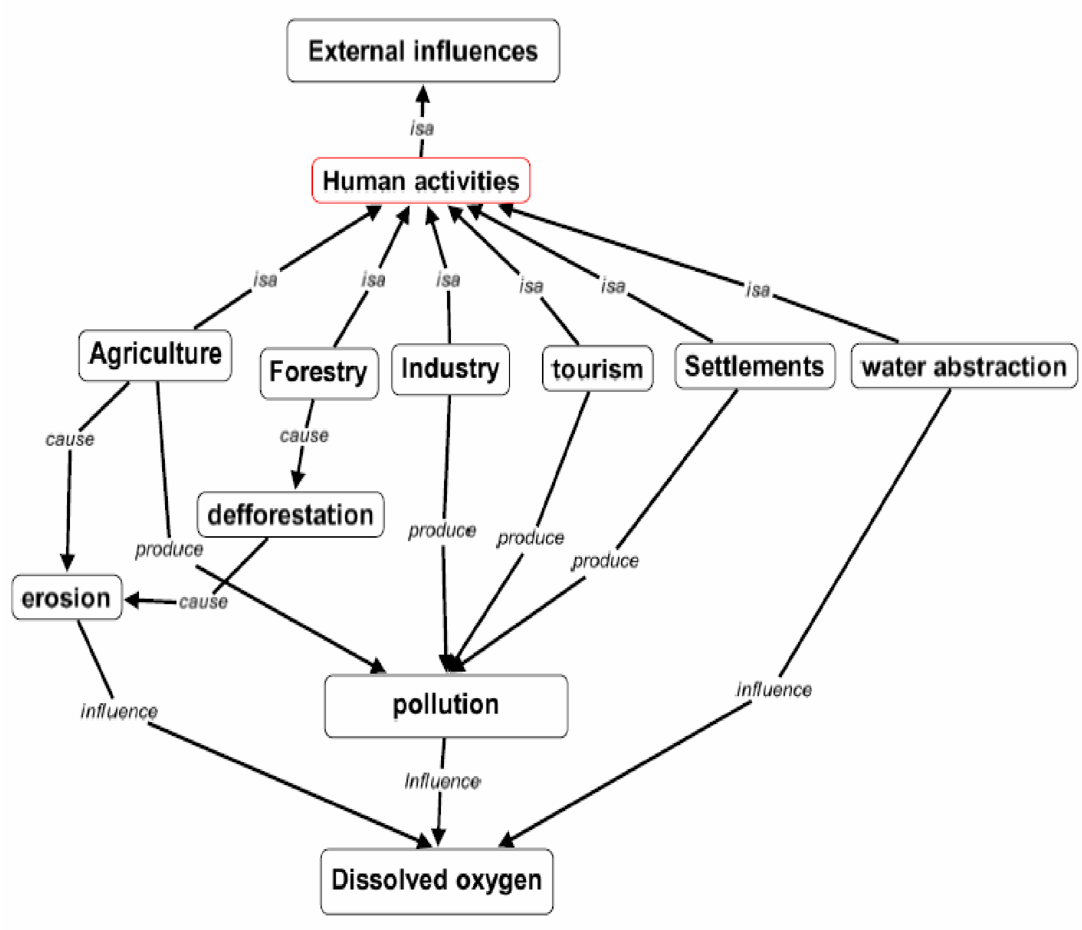

Figure 6. Concept map of human activities as external agents affecting the ecosystem of the River Mesta

3.4 Assumption

- Steady flow velocity
- The channel morphology (slope, depth and width) is considered to be constant and not changeable without external influence.
- Steady nutrient and substance availability
- Steady amount of Particulate organic matter (POM)
- Rate of mortality of aquatic organisms and input of POM from outside the water body are considered to be constant at normal levels that don't change the stability of the system.
- Natural level of suspended solids (turbidity) is considered to be constant at normal levels that don't change stability of the system.

4 Global behavior

In this part, we identify and describe the main causal processes and how these combine to form the full causal model of the system as well as describe typical scenarios and expected outcomes. The idea is to move from textual description of causal processes to how to implement these using QR dependencies and think about how these affect the system quantities of interest.

4.1 Building up global behaviour of the River Mesta system

4.1.1 Defining the main internal processes

Two basic types of processes - physical and biological, could be defined, when describe the behavior of the all entities involved in setting up the dissolved oxygen balance. The description of below identifies basic entities, main quantities, effects of processes, start and stop condition and assumption where necessary.

Physical processes:

Name: Oxygen diffusion [Solar radiation related process]
Entities: Water
Quantities involved: Temperature, Amount of Dissolved oxygen, Light intensity, Heat amount
Effect: This is a physical law on the dependence of the amount of dissolved oxygen on the water temperature. The lower is the temperature; the higher is the amount of dissolved oxygen which penetrates from the atmospheric air through the process of diffusion, and vise versa.
Start/stop conditions: The process is always active while any water body contains some amount of heat measured by its temperature. The amount of dissolved oxygen used to decrease following warming of water downstream and during the summers. Discharges of thermal pollution (effluents of cooling waters from thermal plants for energy production and other industries) may reduce substantially the amount of dissolved oxygen in streams and rivers.
Assumptions: Water temperatures considered to be always higher than 0˚C.

Name: Aeration [Water related process]
Entities: Water,
Quantities involved: Amount of Dissolved oxygen, Flow/Velocity
Effect: This is an additional process to the diffusion of oxygen from the air facilitated by the turbulent movement of water masses downstream a river. This turbulence mixes air and water and thus increases the amount of oxygen dissolved from these mixture.
Start/Stop conditions: In normal condition, this process is always active as far as the streams and rivers run and thus are capable to mix water and air. The process is facilitated at higher velocity in shallow brooks and streams with stony beds.

Name: River bed substrata [Water related process]

Entities: Stream, Water, Bed, Substrata
Quantities involved: Flow/Velocity, Size of substrata particles (stones/gravel)
Effect: The kinetic energy of running water modifies the river bed and its cover by various types of mineral substrata. At a given stretch, the speed of running water (current velocity) depends on amount of water discharge (debit) and the slope. The higher current velocity, the larger sized particles form the bottom bed. Larger particles (like stones and gravel) provide much more relative bottom surface to be colonized and inhabited by living organisms, in contrast to the sand and mud deposited on the river bed at a slower velocity.
Start/Stop conditions: The process is always active in watercourses. Significant changes of water amount (discharge) may modify the type of bottom substrata. The size of bottom substrata particles tends to decrease with decreasing current velocity.

Biological processes

Name: Oxygen production
Entities: Light, Algae,
Quantities involved: Light intensity, Number of algae, Photosynthetic rate, Amount of dissolved oxygen
Effect: In all aquatic environments, light from solar radiation is the primary factor for oxygen production through the process of photosynthesis. All plants, including aquatic algae and macrophytes, are capable to photosynthesize utilizing the light in the range of wavelengths between 400 – 700 nm (visible light). The final result of the process is production both of organic matter of their bodies and of free oxygen which is dissolving in water.
Start/stop conditions: Light intensity is crucial for the rate of photosynthesis and thus for amount of oxygen produced by algae. To this end, during the nights there is no photosynthesis. In small sized brooks and streams the forest tree canopy can shadow the water and decrease the light availability. Effects of pollution and erosion due to effluents of organic and/or inorganic particles in water can also seriously reduce the light penetration and rate of photosynthesis.

Name: Oxygen Consumption (respiration)
Entities: Scrapers, Bacteria, Algae.
Quantities involved: Number of scrapers, Number of Algae, Amount of bacteria of Bacteria, Amount of dissolved oxygen
Effect: Respiration is a process of oxygen consumption when organisms utilize the energy from their food. All aquatic organisms, including producers, consume dissolved oxygen for their respiration thus decreasing its amount in water.
Start/Stop conditions: The process is always active in natural water bodies. The process is strongly and positively related to water temperature. Higher water temperatures accelerate the consumption rate.

Name: Feeding (scraping/grazing)
Entities: Algae, Bacteria, Scrapers
Quantities involved: Number of Algae, Number of Scrapers, and Amount of Bacteria.
Effect: Scrapers/grazers are a functional feeding group of large number of invertebrates which feed on while scraping/grazing the thin layer of algae and bacteria (so called bio-film) associated to the surface of the bottom substrata particles. The amount of scrapers/grazers depends on the amount and availability of their preys.
Start/Stop conditions: The process is always active in natural aquatic environment if the food is available. The process of feeding is strongly and positively related to water

temperature and rate of oxygen consumption. External impacts like pollution may influence negatively the process changing the amount and availability of the food.

Name: Bacterial degradation (decomposition of the organic matter)
Entities: Bacteria, Water
Quantities involved: Number of Bacteria, Amount of Dissolved oxygen, Amount of POM
Effect: Bacterial degradation is a process of consequent decomposition of the organic matter originated from dead bodies of aquatic organisms and inputs from watershed (leaf litter, any residuals from living activities and dead bodies of terrestrial organisms) The process is driven by reducers (bacteria) which utilize dead organic matter using dissolved oxygen for biochemical processes of degradation. The number of bacteria depends strongly on the amount of POM in water bodies.
Start/Stop conditions: The process is always active as far as there is always some amount of POM in water bodies regardless of its origin - inside or outside a water body. The rate of bio-degradation is strongly and positively related to the amount of POM and negatively related to the amount of dissolved oxygen. Extra input of POM by urban and/or industrial wastewaters accelerates the biodegradation and oxygen consumption until full exhaustion. External factors like pollution with organic matter can also increase the consumption rate until full exhaustion of the dissolved oxygen in water bodies due to intensive biological degradation of POM by reducers.

4.1.2 External influences

All pressures and impacts generated/originated outside a water body are defined as external influences. In contrast to the solar radiation, which is a part of a natural system, all external influences are considered to be anthropogenic in their origin. Some of them may cause effects on physical part and another may affect the biological part of the modeled system, which is responsible for setting up the oxygen balance in aquatic environment.

Most of the anthropogenic impacts are related to the human activities within the watershed, which could be directly (water use) or indirectly (land use) related to the ecosystem health and ecological status of the system. Three main processes were identified as external agents influencing by some way the amount of the dissolved oxygen as an indicator of the ecosystem health and sustainability of the studied river.

Name of the process: Erosion (input of suspended solids)
Agent: Human
Collection of entities: A stream Water,
Quantities involved: Erosion active agent, Amount of suspended solids
Effect: Therefore erosion is a process of removal of upper soil horizons by precipitation and wind resulting in reduction of soil fertility and loss of essential nutrients for terrestrial plants. Removed particles entering the water body as suspended solids increase the turbidity thus decreasing light conditions necessary for oxygen production by algae. The higher is the turbidity, the less is the number of algae; respectively the rate of photosynthesis and amount of oxygen produced are lower.
Start/Stop conditions: Even small-scale deforestation and un-sustainable agricultural practices can cause soil erosion in the watershed thus increasing the amount of suspended solids in downstream stretches of a watercourse. Sustainable agricultural and forestry practices may stop the soil erosion in watershed and thus to improve the oxygen balance in affected water bodies.

Name of the process: Pollution (input of organic matter)
Agent: Human, Pollution
Collection of entities: Bacteria, Water,
Quantities involved: Pollution active agent, Amount of particulate organic matter
Effect: Pollution is a process of discharging water with extra amount of substances originated outside the water bodies, mostly from households, industries and other human activities in watershed. These extra amounts of substances may change significantly the ecological status of a water body and thus the ecosystem health deteriorating the structure and functioning both physical and biological processes in aquatic ecosystems. In contrast to other water contaminants both inorganic (nutrients, heavy metals) or organic (pesticides, various other chemicals) in their nature, external loads with particulate organic matter (POM) affect directly the oxygen balance accelerating the oxygen consumption by reducers until full exhaustion of the dissolved oxygen. The result is substantial shift, even destruction of other biotic components (producers, consumers) of aquatic ecosystems and loss of many of ecosystem services humans can use from water bodies such as good water quality (clean water for different purposes) and safe biological resources (fish). The effects of pollution depend on the amount of wastewater discharge and water temperatures responsible for rate of physical and biological processes relevant to the oxygen balance of a water body.
Start/stop conditions: The process is active in case of discharging water body with wastewater from point-sources (effluents of POM from sewage pipes). Wastewater treatment prior discharging water bodies can reduce even stop the pollution and consequent effects on ecological status of water body and ecosystem health.

Name: Water abstraction (intake of water from water bodies)
Agent: Human, Water abstraction
Collection of entities: A stream, Water
Quantities involved: Water abstraction agent active, Flow/velocity, temperature
Effect: Humans need water for various purposes of their every-day life (drinking, washing, bathing) and many economic activities – agriculture (irrigation), industry (supply for technological processes and manufactured goods), etc. The common practice is water abstraction from water bodies and re-direction of some water amounts through water supply systems for further use by humans. Decreasing water discharge in natural water bodies affects significantly all physical and biological processes which are responsible for setting up the oxygen balance and thus may affect negatively the ecological state and ecosystem health of water bodies downstream the abstraction point.
Start/stop conditions: The process is active in case of water abstraction for human needs. The effects of water abstraction depend on the amount of water abstracted. The greater is the abstracted amount, the less is the residual water in affected water bodies and consequent effects on ecological state and ecosystem health relevant to the physical and biological processes responsible for dissolved oxygen balance in a water body.

4.2 Causal model

The effects of internal and external processes as just described are further refined as causal dependencies following Qualitative process Theory (Forbus 1984). The full causal model of the River Mesta system is thus depicted in Figure 7. Model documentation fully describes each of the dependencies depicted in the figure.

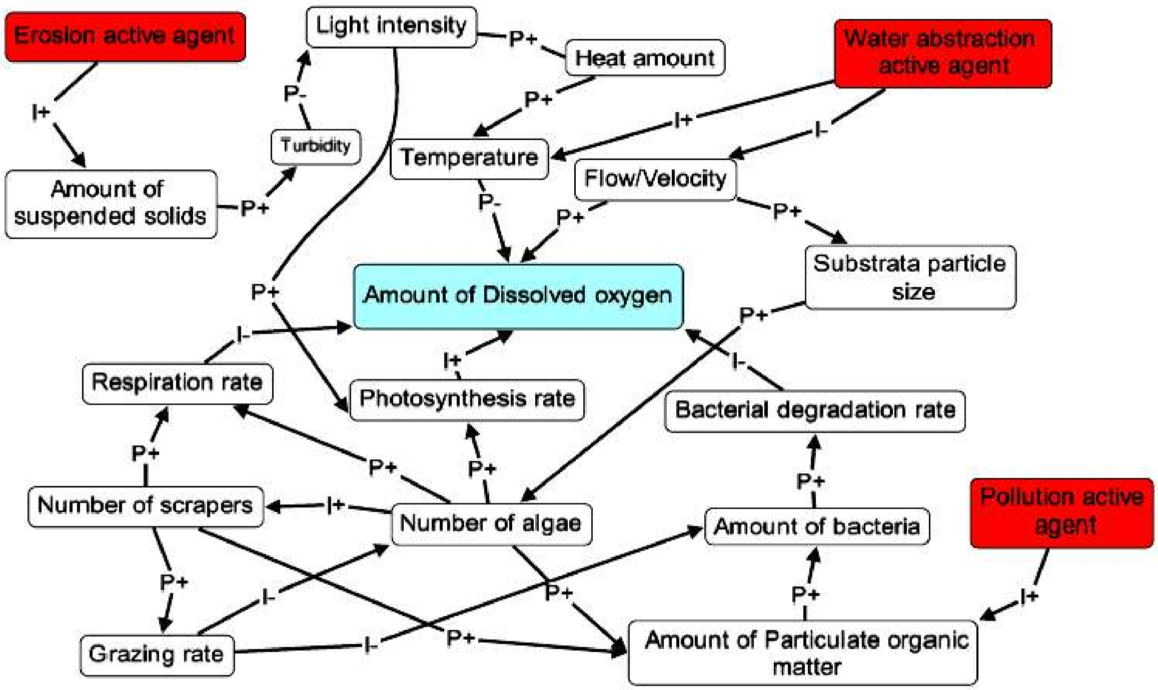

Figure 7. Mesta river causal model

- If the light intensity increases therefore the heat amount increase too, so there is a **P+** relation. As intensive is solar radiation, the higher is the amount of accumulated in the water heat.
- If the heat amount increases, the temperature of the water also increases, so there is a **P+** relation. The higher is the amount of accumulated in the water heat, the higher is the temperature of the water.
- If the temperature of the water increase, the amount of dissolved oxygen decreases, therefore there is a **P-** relation between them. This is a physical low on the dependence of the amount of dissolved oxygen on the water temperature. The higher is the temperature; the lower is the amount of dissolved oxygen.
- If the flow/velocity of the water increase, the amount of dissolved oxygen also increase so there is a **P+** relation between them. The higher is the flow/velocity of the water, the higher is the turbulence of the water. This turbulence mixes air and water and thus increases the amount of dissolved oxygen.
- If the flow/velocity of the water increase the size of substrata particles also increases, therefore is **P+** relation between them. The higher is the current velocity, the larger is size of the bottom bed substrata.
- If the size of substrata particles increases, the number of algae also increases, so there is **P+** relation. A larger substratum particles (like stone and gravel) provides much more relative surface to be colonizes by algae.
- If the number of algae increases, the Photosynthesis rate also increases, so there is **P+** relation. As higher is the number of algae, as intensive is the process of photosynthesis.
- If there is a positive photosynthesis rate, the amount of dissolved oxygen will increase, so there is **I+** relation between them. The final result of the process of

photosynthesis is the production of free oxygen in the water body, which increases the total amount of dissolved oxygen.

- If the number of algae increases, the number of scrapers also increases, so is a **P+** relation between them. The higher is the amount of available food (number of algae), the higher is the Number of the consumers (scrapers). The amount of scrapers depends on the amount and availability of their preys.
- If the number of scrapers increases, the Grazing rate also increases, so there is **P+** relation.
- If there is a positive grazing rate, the Number of algae will decrease so there is **I-** relation. The active grazing process always leads to decreasing of the number of algae.
- If there is a positive grazing rate the amount of bacteria will decrease, so there is **I-** relation. The active grazing process always leads to decreasing the amount of bacteria.
- If the number of scrapers increases, the respiration rate also increases, so there is **P+** relation. As higher is the number of scrapers, as intensive is the process of respiration.
- If the number of algae increases the respiration rate increase too, so there is **P+** relation. As higher is the number of algae, as intensive is the process of respiration.
- If there is a positive respiration rate, the amount of dissolved oxygen will decrease, so there is **I-** relation. All aquatic organisms including consumers, consume dissolved oxygen, for their respiration. This process always diminishes the total amount of dissolved oxygen in the water.
- If the number of scrapers increases the Amount of particulate organic matter increase too, so there is **P+** relation. The higher is the number of aquatic organisms, the higher is the остатъчни продукти от тяхната жизнена дейност, което увеличава количеството на разтворената частичкова материя.
- If the Number of Algae increase, Amount of particulate organic matter increase too, so there is **P+** relation.
- If the amount of particulate organic matter increases, the amount of bacteria increases too, so there is **P+** relation. The higher is the amount of POM (available food of bacteria), the higher is the number of bacteria.
- If the amount of particulate organic matter increases the Bacterial degradation rate increase too, so there is **P+** relation. As higher is the number of bacteria, as intensive is the process of bacterial degradation.
- If there is a positive rate of Bacterial degradation, the amount of dissolved oxygen will decrease, so there is **I-** relation. Bacteria reduce dead organic matter using dissolve oxygen for biochemical process, thus diminish the total amount of dissolved oxygen in the water body.
- If the amount of suspended solids increases, the turbidity of the water also increases, therefore there is **P+** relation. The higher is the amount of suspended solids, the higher is the turbidity of the water.
- If the turbidity of the water increases, the light intensity in the water decreases, therefore there is **P-** relation. The increasing turbidity, decrease the light condition in the water body.
- If the light intensity of the water increases, the photosynthesis rate decrease, so there is **P-** relation. The worse is the light condition, the intensity of the photosynthesis decrease.
- If there is positive Erosion active agent, the amount of suspended solid will increase, so there is **I+** relation. The higher is the erosion, the higher is the

amount of removed solids entering in the water body, thus increase the total amount of suspended solids in the water.

- If there is positive Pollution active agent, the amount of particulate organic matter will increase, so there is **I+** relation. The higher is the pollution the higher, thus increasing the total amount of particulate organic matte in the water body.
- If there is a positive water abstraction agent, the flow velocity of the water will decrease, so there is **I-** relation. The greater is the abstracted amount, the less is the residual water, and the low is the flow/velocity.
- If there is a positive water abstraction agent, the temperature of the water will decrease, so there is **I-** relation. The greater is the abstracted amount, the less is the residual water, which will accumulate more heat and thus the water temperature increases.

4.3 Scenario and behaviour graph

- Typical scenario and behaviour graph

Typical scenario illustrated the behaviour of stream ecosystem and all their components, without any hard influence, affecting concentration of dissolved oxygen – pollution is low, water abstraction is low and erosion is low. The behaviour of concentration of dissolved oxygen depends mainly of the stability of the processes manifesting in stream ecosystem.

- Next state describing a situation, when erosion is high.
- Next state – Flood together with high erosion
- Next state-Pollution is high
- Water abstraction is high
- Situation when Erosion and Pollution is high
- Situation when Erosion and Water abstraction is high
- Situation when Pollution and Water abstraction is high
- The bad perspective is when Pollution, Erosion and Water abstraction are high. The three main uncontrolled human impacts may change substantially the behavior of the system.

5 Detailed system structure and behaviour

The purpose of this section is to elaborate and furthered specify the concepts first introduced in the previous sections, so that they can be easily implemented in the QR model –building and simulation workbench Garp 3.

5.1 Structural details

Refer to section 3 which describe main structural details and ingredients of River Mesta model.

5.1.1 Entity types

Refer to the entity description of section 3.1.

5.1.2 Attributes

In our system in this stage of description of system structure we are not define the attributes.

5.1.3 Configuration

Refer to the configuration description of section 3.2.

5.2 Agents

The agents represent an external influence on a system. All pressures and impacts generated/originated outside a water body are defined as external influences. All external influences in stream ecosystem are considered to be anthropogenic in their origin. Most of the anthropogenic impacts are related to the human activities within the watershed. We describes following agents, according described previously in section 4.1 external influences.

Human activities
- Pollution
- Erosion
- Water abstraction

5.3 Assumptions

Section 3.4 represent the assumption that we made when describe the behaviour of the system.

5.4 Quantities and quantity spaces

Entity	Quantity	Types	Quantity spaces
Environment Water	Temperature	*State variable*	Low, medium, high
	Dissolved oxygen	*State variable*	Low, medium, high
	Flow/velocity	*State variable*	Low, medium, high
	Amount of particulate organic matter	*State variable*	Low, medium, high, very high
	Turbidity	*State variable*	Zero, low, medium, high
	Amount of suspended solids	*State variable*	Low, medium, high, very high
Environment River bed	Size of substrata particles	*State variable*	Small, medium, large
Biological entity Algae	Amount of	*State variable*	Zero, low, medium, high
	Respiration rate	*Rates*	Zero, plus
	Photosynthetic rate	*Rates*	Zero plus
Biological entity Scrapers	Amount of	*State variable*	Zero, low, medium, high
	Respiration rate	*Rates*	Zero, plus
	Grazing rate	*Rates*	Zero, plus

Biological entity Bacteria	Amount of	*State variable*	Zero, low, medium, high
	Bacterial degradation rate	*Rates*	Zero, plus
Environment Solar radiation	Light intensity	*State variable*	Zero, low, medium, high
	Heat amount	*State variable*	Low, medium, high

Agent	**Quantity**	**Types**	**Quantity spaces**
Human activities Pollution	Pollution active agent	Rates	Zero, plus
Human activities Erosion	Erosion active agent	Rates	Zero plus
Human activities Water abstraction	Water abstraction active agent	Rates	Zero, plus

5.5 Detailed description of scenarios

Name: "River behaviour"
Instance of entities: Environment, Solar radiation, Stream, Water, Bed
Biological entities: Bacteria, Algae, Scrapers
Configuration: Consist of, Inhabit, Feed on, Shines on
Quantities and initial values:

Quantities	**Initial values**
Temperature	Low, medium, high
Amount of dissolved oxygen	Low, medium, high
Flow/Velocity	Low, medium, high
Amount of particulate organic matter	Low, medium, high, very high
Size of substrata particles	Small, medium, large
Turbidity	Zero, low, medium, high
Amount of suspended solids	Low, medium, high, very high
Amount of biological entities	Zero, low, medium, high
Light intensity	Zero, low, medium, high
Heat amount	Low, medium, high

Name:" River behaviour-physical part of the system"
Instance of entities: Environment, Solar radiation, Stream, Water, Bed
Configuration: Consist of, Shines on
Quantities and initial values:

Quantities	**Initial values**
Temperature	Low, medium, high
Amount of dissolved oxygen	Low, medium, high
Flow/Velocity	Low, medium, high
Amount of particulate organic matter	Low, medium, high, very high
Size of substrata particles	Small, medium, large
Turbidity	Zero, low, medium, high
Amount of suspended solids	Low, medium, high, very high
Light intensity	Zero, low, medium, high

Heat amount	Low, medium, high

Name: “River behaviour-biological part of the system”
The scenario describes
Instance of entities: Biological entities, Algae, Scrapers, Bacteria
Configuration: Feed on
Quantities and initial values:

Quantities	Initial values
Amount of biological entity	Zero, low, medium, high

Erosion active

Name: “Erosion is high”
This scenario describes..
Agent: Human activities, Erosion
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantities	Initial values
Turbidity	Zero, low, medium, high
Amount of Suspended solids	Low, medium, high, very high

Name:” Flood”
The scenario
Agent: Human activities, Erosion
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantities	Initial values
Turbidity	Zero, low, medium, high
Amount of Suspended solids	Low, medium, high, very high

Pollution is active

Name: “Pollution is high”
The scenario describes
Agent: Human activities, Pollution
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantities	Initial values
Amount of particulate organic matter	Low, medium, high, very high

Name: “Pollution is low”
The scenario describes
Agent: Human activities: Pollution
Instance of entities: Environment, Stream, Water

Configuration: Consist of
Quantities and initial values

Quantities	Initial values
Amount of particulate organic matter	Low, medium, high, very high

Water abstraction active

Name:" Water abstraction is high"
The scenario describes
Agent: Human activities, Water abstraction
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantity	Initial value
Temperature	Low, medium, high
Flow/velocity	Low, medium, high

Name:" Water abstraction is low"
The scenario describes
Agent: Human activities, Water abstraction
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantity	Initial value
Temperature	Low, medium, high
Flow/velocity	Low, medium, high

Erosion and water abstraction active

Name:" Erosion and water abstraction is high"
The scenario describes
Agent: Human activities, Water abstraction, Erosion
Instance of entities: Environment, Stream, Water
Quantities and initial values:

Quantity	Initial value
Amount of suspended solids	Low, medium, high, very high
Turbidity	Zero, low, medium, high
Flow/Velocity	Low, medium, high
Temperature	Low, medium, high

Pollution and water abstraction Active

Name:" Pollution and water abstraction is high"
Agent: Human activities, Pollution, Water abstraction,
Instance of entities: Environment, Stream, Water

Configuration: Consist of
Quantities and initial values:

Quantity	Initial value
Amount of particulate organic matter	Low, medium, high, very high
Flow/velocity	Low, medium, high
Temperature	Low, medium, high

Pollution and erosion active

Name:" Pollution and erosion is high"
Agent: Human activities, Pollution, Erosion
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantity	Initial value
Turbidity	Zero, low, medium, high
Amount of particulate organic matter	Low, medium, high, very high
Amount of suspended solids	Low, medium, high, very high

Erosion, Pollution and water abstraction is active

Name: "Erosion, pollution and water abstraction is high"
The scenario describes
Agent: Human activities, Erosion, pollution, water abstraction
Instance of entities: Environment, Stream, Water
Configuration: Consist of
Quantities and initial values:

Quantity	Initial value
Amount of particulate organic matter	Low, medium, high, very high
Flow/velocity	Low, medium, high
Temperature	Low, medium, high
Turbidity	Zero, low, medium, high
Amount of Suspended solids	Low, medium, high, very high

5.6 Detailed description of model fragment

The model comprises a hierarchical library of model fragments, utilizing the quantities previously defined. The model fragments of " River Mesta case study model" are classified as static fragment, process fragment and agent fragment.

Static model fragment:

The purpose of static model fragments is to define structural relations between entities as well as to indicate propagation of changes from one quantity to another using proportionalities (P+ and P-).

Name: River
Conditions:
Entities: *Environment, Stream, Water*

Configurations: *Consist of*

Consequence:

Quantities: *Dissolved oxygen, Temperature, Flow/velocity*

Causal dependencies: *Temperature of the Water propagates negatively (P-) to Amount of Dissolved oxygen. The Flow/ Velocity of the water propagates positively (P+) to Amount of Dissolved oxygen.*

Explanation:

Name: Substrata

Condition:

Entities: Environment, Stream, Water, Bed, Biological entity Algae

Configuration: Consist of, Inhabit

Consequence:

Quantities: Flow/Velocity, Substrata particle size, Amount of algae

Causal dependencies*: Flow/ Velocity of the water propagates positively (P+) to Bottom substrata particle size. Bottom substrata particle size propagate positively (P+) to Number of algae.*

Explanation:

Name: Photosynthesis

Condition:

Entities: Environment, Stream, Bed, Biological entity Algae

Configuration: Consist of, Inhabit

Consequence:

Quantities: Number of algae, Photosynthesis rate

Causal dependencies: *Number of algae propagate positively **(P+)** to Photosynthesis rate.*

Explanation:

Name: Respiration

Condition:

Entities: Environment, Stream, Bed, Biological entities Algae, Scrapers

Configuration: Consist of, Inhabit

Consequence:

Quantities: Amount of biological entity

Causal dependencies: *Amount of algae and amount of scrapers propagate positively (P+) to Respiration rate.*

Explanation:

Name: Grazing

Condition:

Entities: Environment, Stream, Bed, Biological entity, Scrapers,

Configuration: Consist of, Inhabit

Consequence:

Quantities: Amount of scrapers, feeding rate

Causal dependencies: Amount of scrapers propagates positively (P+) to Feeding rate

Explanation:

Name: Bacterial degradation

Condition:

Entities: Environment, Stream, Water, Bed, Biological entities Bacteria

Configuration: Consist of, Inhabit

Consequence:

Quantities: Amount of bacteria, Bacterial degradation rate, Particulate organic mater

Causal dependencies: *The amount of particulate organic matter propagates positively (P+) to Amount of bacteria. The amount of bacteria propagates positively* ***(P+)*** *to Bacterial degradation rate*

Explanation:

Name: Solar Radiation

Condition

Entities**:** Environment, Solar radiation, Stream, Water,

Configurations: Consist of, Inhabit, Shines on

Consequence

Quantities: Light intensity, Heat, Temperature

Causal Dependencies: *Light intensity propagates positively* ***(P+)*** *to Heat amount. Heat amount propagates positively* ***(P+)*** *to temperature of the water*

Name: Turbidity

Condition:

Entities: Environment, Solar radiation, Stream, Water, Bed, Algae

Configuration: Consist of, Inhabit, Shines on

Consequence:

Quantities: – Light intensity, Amount of Suspended solids, Turbidity, Rate of photosynthesis

Causal dependencies*: Amount of suspended solids propagates positively* ***(P+)*** *to Turbidity of the water. Turbidity of the water propagates negatively* ***(P-)*** *to Light intensity. Light intensity propagates positively (P+) to Photosynthesis*

Explanation:

Name: Particulate organic matter

Condition:

Entities: Stream, Algae, Scrapers

Configuration: Consist of, Inhabit

Consequence:

Quantities: Amount of particulate organic matter, Amount of biological entity

Causal dependencies: *Number of algae propagates positively* ***(P+)*** *to amount of particulate organic matter. Number of scrapers propagate positively* ***(P+)****to amount of particulate organic matter*

Explanation

Process Model Fragments

Process model fragments describe how values of quantities cause changes to occur in other quantities via direct influences (I+ and I-).

Name: Photosynthesis process
Condition:
Entities: Environment, Stream, Water, Bed, Biological entity Algae
Configuration: Consist of, Inhabit
Consequence:
Quantities: Dissolved oxygen, Photosynthetic rate
Causal dependencies: *Photosynthesis rate have positive influence **(I+)** to Amount of dissolved oxygen*

Explanation:

Name: Respiration process
Condition:
Entities: Environment, Stream, Water, Bed, Biological entity, Algae, Scrapers
Configuration: Consist of, Inhabit
Consequence:
Quantities: Dissolved oxygen, Respiration rate
Causal dependencies: *Respiration rate have negative influence (I-) to Amount of Dissolved oxygen*
Explanation:

Name: Grazing process
Condition:
Entities: Environment, Stream, Water, Bed, Biological entity, Algae, Scrapers, Bacteria
Configuration: Consist of, Inhabit, Feed on
Consequence:
Quantities: Grazing rate, Amount of biological entity
Causal dependencies: *Grazing rate have a negative influence (**I**-) to Amount of Algae and Amount of bacteria. Amount of algae has a positive influence (I+) to amount of scrapers.*
Explanation:

Name: Bacterial degradation process
Condition:
Entities: Environment, Stream, Water, Bed, Biological entity Bacteria
Configuration: Consist of, Inhabit
Consequence:
Quantities: Bacterial degradation rate, Dissolved oxygen
Causal dependencies: Bacterial degradation rate have negative influence (I-) to Amount of dissolved oxygen.
Explanation:

Agent Model Fragment

Agent model fragments are a special kind of process model fragment (containing direct influences, I+ and I-), that model how external influences cause changes in a system. They generally relate to processes that humans can potentially exert some control over, as opposed to natural processes that humans generally can't or don't directly control.

Name: Pollution
Condition:
Agent: Human activities, Pollution
Entities: Environment, Stream, Water

Configuration: Consist of
Consequence:
Quantities: Pollution active agent, Amount of Particulate organic mater
Causal dependencies: *Pollution active agent has positive influen*ce **(I+)** *to Amount of particulate organic matter*

Name: Erosion
Condition:
Agent: Human activities, Erosion
Entities: Environment, Stream, Water
Configuration: Consist of
Consequence:
Quantities: Erosion active agent, Amount of Suspended solids
Causal dependencies: *Erosion active agent has positive influence* ***(I+)*** *to Amount of suspended solids*

Name: Water abstraction
Condition:
Agent: Human activities, Water abstraction
Entities: Environment, Stream, Water
Configuration: Consist of
Consequence:
Quantities: Water abstraction active agent, Flow/ Velocity, Temperature
Causal dependencies: *Water abstraction active agent has positive influence* ***(I-) t****o Flow of the river and Temperature of the water.*

6 Conclusion

This document sets the textual description of River Mesta case study, using QR vocabulary. Concepts and the all modeling includes in detailed description of the case study are the basis for the next step in the modeling effort – implementation of the model .

7 Literature

BREDEWEG, B. SALLES P. (2005) Framework for conceptual QR description of case study. Deliverable document 6.1. of the Project: Naturnet-Redime: New education and Decision Support Model for Active Behaviour in Sustainable development.