Watershed EUTROphication management through system oriented process modelling of Pressures, Impacts and Abatement actions.

1. Relevance to Miljø2015 Program - theme TVERS

Through system- and process oriented environmental research, generating new holistic policy relevant knowledge on governing pressures, processes and responses in nature and society, this project meets all of the main aims of MILJØ2015, primarily theme TVERS and secondarily themes VANN, FORURENS and SAMFUNN.

The proposed project complies with the main aim of the theme TVERS in that it will:

- Generate knowledge regarding the links among different natural systems and between the natural environment and society.
- Identify problems that arise due to fragmented management and research.
- Identify problems that arise due to the lack of comparability between the complexity in the natural systems and the selected management systems
- Contribute with suggestions for solutions to problems that arise due to these problems
- Promote cooperation between nature- and social science.

Furthermore the project has special relevance to the following specific topics in theme TVERS:

Chap. 4.3.1-1a System-oriented research (esp. bulletpoints 1 and 3);

Chap. 4.3.1-2 Model and method development (all bp.)

This project also complies with main objective (part 3) of the Miljø1015 program, by improving the scientific cooperation and thereby the scientific quality of the Norwegian environmental research. The projects link the environmental departments of the Universities (UiO, UMB) with the applied environmental research institutes at CIENS (NIVA, NINA and NIBR) and BioForsk, ensuring access to resources for both *basic scientific research* and *applied environmental research*. The improved scientific understanding and policy relevant knowledge evolved from the project will help to improve ecosystem based management and may be used as a basis for resource management under the Water Framework Directive (WFD)[1] and the Norwegian water-regulations. This will be achieved by:

- Developing *methods* for monitoring bioavailable P-fraction (NIVA/UiO-Chem)
- Linking terrestrial/hydrological *processes* governing the transport and fate of pollution/nutrients (UiO-Chem/-Bio/-Geo)
- *Integrating* the substantiated transport and fate models with existing P abatement costs and effect models using Bayesian network (NIVA/NINA/UMB-IØR)
- Studying through a systematic *response* component how the fragmented management may implement abatement strategies (NIBR/BioForsk)
- *Predicting* effect of changes in environmental drivers (e.g. climate, agriculture) (All).

2. Project description

2.1 Background and state of knowledge

The WFD, adopted by the Norwegian government, requires a good surface water status and that the condition of all water reserves should not have large deviations from their natural condition by the year 2015. The WFD has the effect that scientists and environmental managers are being required to *assess the original- and present-state of the environment, and to predict future changes* based on land-use, climate change and anthropogenic loading scenarios.

Eutrophication is usually the main cause for not fulfilling the requirements for good ecological quality in agricultural districts. In South-Eastern Norway, more than 30% of the water bodies are characterized as being at risk or possibly at risk, with eutrophication as a major problem[2]. Excessive fertilization over long periods has produced large P pools in agricultural soils. 45% of the anthropogenic P input to Norwegian surface water originates from agricultural areas. *An important challenge lies in determining the governing factors for natural background P loading for watersheds*. The natural background flux of P to western Vansjø (see chapt. 2.3) is estimated to be 20-25%. P leached from the terrestrial into the aquatic environment arrive mainly bound to mineral particles and to dissolved natural organic matter (DNOM). Generally, more than

90% of the total-P flux to aquatic systems may be transported in eroded clay sized aggregates[3], especially during stormflow. The P flux, related to the amount and characteristics of DNOM and particles is expected to increase due to forecasted changes in environmental pressures.

Cost-efficient and sustainable management practices need also to be select in order to meet the requirements set by the WFD. Based on the outcome and experience from the Eutrobayes project[4] we propose to improve the predictability and reduce the uncertainty by improving the underlying models reliability through specifically targeting the bioavailable P-fraction and to include conceptual knowledge rather than empirical correlations to relate pressure, state and response relationships. All these assessments *require that we are able to link geochemical and hydrological processes in the catchment with the processes controlling the level of nutrients (P, N, C) and its effect on water quality in the lake in a cost-effectiveness analysis of abatement measures and land users'/farmers' response to the these measures.* Especially an assessment of probability of implementation is lacking from previous assessments of measures.

Significant changes in land-use, climate and atmospheric deposition in the Østlandet region have had significant impact on water quality and catchment processes. With respect to climate, there has been an increase in amount of precipitation and a 2ºC increase in the average winter temperature[5]. Frequency of heavy precipitation events has intensified and is expected to increase further[6]. As a consequence of reduced S emission, non-marine sulphate, which in acid lakes in southern Norway constitutes the dominant anion charges, has decreased by about 60%[7]. Increased surface runoff causing soil erosion has had a profound impact on the environment. This erosion increases the influx of nutrients adsorbed to the soil particles. Moreover, increased temperature causes more frequent freeze-thawing cycles during the winter leading to more soil erosion. Riverbanks and river sediment are also eroded more effective due to drainage ditching. The background amount of DOC has increased and characteristics of DNOM have changed radically in northern European lakes[8], causing an increased natural flux of nutrients and energy for heterotrophic micro-organisms in surface waters. This increase may be due to a combined effect of climate change and the reduction in S deposition[9].

Diffusive Gradients in Thin films (DGT) is a new promising sampling tool for (time-averaged) collection and fractionation of P in water[10]. The DGT sampler is believed to selectively collect the free phosphate ions in water, i.e. the P-fraction most important for algae growth. The DGT-sampler integrates free phosphate levels *in situ* for periods from hours to weeks. Beside more *reliable determination of free phosphate, the time integrating property will provide a more relevant growth potential parameters*, i.e. DGT weekly/bi-weekly averages may become a simple and cost-efficient alternative to daily grab-samples for sliding averages. DGT/DET and micropeeper sediment probe sampler will be used for flux estimations over sediment surfaces; an important property in eutrophic lakes. Results from the DGT's will be used in the prediction of fluxes of bioavailable species in the different compartment of the system.

Hydro-geochemical processes govern the transport of nutrients from the terrestrial to the aquatic environment. We estimate the total load of nutrients brought to a lake, but *we lack basic knowledge about the processes involved.* Many reports have shown that P transport occurs predominantly as surface runoff. However, P transport through subsurface drainage may be significant under soil and growth conditions prevailing in the Nordic climate. Furthermore, different water flowpaths contribute to flux of different P fractions. Sedimentation of eroded P rich soil particles, hydrogenous P minerals (e.g. Al and Fe hydroxides) and organic bound P builds up a pool of P in the sediments. Internal P-loading from these sediments can be significant if there is feedback between P release and biological response in the open water[11]. The implemented *abatement measures and new proposed actions in the Morsa river basin are based merely on total P assessments* despite that only a minor fraction of the P is considered to be bioavailable at optimal growth conditions (i.e. main part of inorganic P fraction along with some low molecular organic P, and a limited part of the particle bound P)[12]. This hinders a sound cost-effectiveness analysis of the different abatement measures. The basic shortcoming is due to a lack of knowledge of the processes and dynamics governing fluxes of the different P fractions. Improvements in analytical methodology for phosphorous fractionation are therefore needed.

Integrated simulation models allow us to account for the simultaneous processes governing the environmental conditions in watersheds. The KIWA[13] and MyLake[14] models will be adapted and applied for hypothesis testing as well as to identify knowledge gaps. The KIWA is a hydrological model developed for small catchment response. This model has been tested and applied for Scandinavian conditions and is presently used by Dr. Autrives (post.doc, UiO-Geo) in the project "Biogeochemistry of Northern Watersheds" funded by the RCN (Norklima). The idea is to *build on the experience already acquired under natural conditions in that project and extend it to cultivated land* under this application. A prolongation of the postdoc period of Dr. Auterive is therefore included in the application. The MyLake (Multi-year Lake) model[14] is a one-dimensional process-based model for simulating daily vertical distribution of lake water temperature and thus density stratification, evolution of seasonal lake ice and snow cover, sediment-water interactions, and phosphorus-phytoplankton dynamics. MyLake (1.2) has a simplified representation of the P cycle, covering algal-bound P and bioavailable P in partitioning equilibrium with suspended particulate material. The model is presently being refined within several projects funded by the EU 6th FP and by the RCN, and in the NIVA SIP (see WP3). This model was also used in the Eutrobayes project [i, 4] funded by RCN.

Bayesian Belief Network (BBN) methodology provides a powerful, intuitively and visually appealing tool for combining (uncertain) information from different sources into a common framework, and for analyzing this particular system's functioning and characteristics. BBNs utilize probabilistic, rather than deterministic, expressions to describe relationships among variables[15]. Experience is gained in the EutroBayes Project[i] in the Storefjorden sub-catchment where it was used to link expert-based cost-assessment, empirical models of effectiveness of abatement measures on P-run-off, and the process-based MyLake model in a cost-effectiveness assessments of agricultural measures[16]. This has then been linked to existing valuation studies of the benefits to water users of algal bloom abatement[17]. BBNs have also been used for assessing participation of resource users under different resource management policy scenarios[18]. *These studies uncovered information gaps in providing decision-makers with a comprehensive decision-support tool. These will be addressed in the present proposal;*
(i) Sub-catchment of Western Vansjø was not included in the run-off and lake models. (ii) Effect of fertilizer reduction measures were modeled for the most extensive land use (wheat), while there is a strong hypothesis that blooms in Western Vansjø are driven by fertilization "hot spots" in particularly vegetable production. (iii) Impacts of fertilizer reduction on soil P-AL did not account for long-term leaching (iv) Impacts of reduced ploughing on the arge contributions from gully erosion was not assessed (v) Uncertainty in the cost-effectiveness of measures did not consider non-agronomical factors affecting farmer participation in implementation of abatement measures across different types of farm production systems (vi) Existing studies of willingness to pay for improved recreational water quality did not address water quality indicators predicted by lake water quality model (e.g. sight depth) (vii) Interaction between the Western Vansjø and Storefjorden was not modeled. (vii) The integrated uncertainty analysis did not assess the effect on joint uncertainty of correlated probability distributions across run-off and lake models.

The societal response to eutrophication is characterized by conflicting interests, from farmers focusing on agricultural productivity, to water related leisure time activities, general environmental concerns, public drinking water provision, and policy-making at different administrative levels trying to compromise between both private and public interests. Our focus is mainly on *farmers and the public authorities*; farmers because they are one of the immediate source of emissions, and public authorities because they will be responsible for regulating emissions and thereby the pollution level. The farmers are a main element of the above presented Bayesian network model. In a previous study the suitability of water resources for different user interests were presented, underlining the strong potential conflicts between different types of use; as drinking water and drainage from agriculture and recipient of waste water[19]. From a more

[i] The EutroBayes Project (Research Council of Norway Grant 171692/S30) was a one-year exploratory project on applying Bayesian networks to existing data within the Storefjorden catchment to identify the most important contributors to joint uncertainty about cost-effectiveness of abatement measures. The present project is expected to reduce uncertainty by a targeted collection of primary data based on the gaps identified in EutroBayes.

recent study[20] the conditions for collective action among different actors in the Morsa catchment has been studied, showing a growing contact, trust and reciprocity among the different actors in the river basin, based on shared knowledge as an important precondition for collective action against detrimental consequences of for instance agriculture. However, in a Swedish study[21] it was shown that despite farmers accounting for about 2/3 of anthropogenic discharges of nutrients to water, an insufficient number of farmers were willing to share the burden for reducing eutrophication. From literature we know that "trust" has been aligned with risk and uncertainty, suggesting that stakeholders replace uncertainty with trust in situations where information is too sparse to allow them to gauge others'[22] likely behaviour or action. According to game theory, specifically the game of solidarity in uncertain situations, it might be rational not to cooperate to implement measures as long as one does not know whether others intend to comply. In such games somebody needs to take the first move[23]. Nevertheless, we are still stuck with actors having different interests, and knowledge might serve powerful actors' self-interest[24].

2.3 Problems, hypotheses and methods

The study area is Morsa (i.e. Vansjø-Hobøl basin) lake and catchments, near Oslo. This watershed, terminating in the coastal environment of the Oslofjord, receives considerable attention due to its eutrophication problems causing frequent blooms of cyanobacteria; Morsa is selected by the Ministry of the Environment as a pilot case for the practical implementation of the WFD. *The region possesses wide spatial gradients* with regard to land-use, urbanization, pollution and geological conditions. The larger Morsa watershed (690 km^2) stretches from small forested catchments with dystrophic ponds to larger agricultural areas downstream. The states of environment and nutrient fluxes have been thoroughly studied**.** *Monitoring data of water quantity and quality is available for the last 25 years*. Main focus will be on Western Vansjø, facing the greatest eutrophication problems and was the most intensively used recreational part of the Vansjø lakes. Benefits of improvement are therefore the greatest for this area. Furthermore, vegetable cultivation (i.e. fertilization hot-spots) is more common in this sub-catchment.
Water chemistry is monitored at several locations by Aquamonitor[25] and JOVA[26]. Morsa have been used by several international projects: EUROHARP, REBECCA, NOLIMP, BMW, EU AQUAMONEY and Eutrobayes. Despite these studies, there is a lack of a comprehensive research, as proposed here, where catchment processes are linked to societal response. The coupling of process oriented models using conceptual knowledge and 25 yrs. monitoring of water quality data allow us to assess the importance of local effects relative to regional drivers.

Hypothesis: Several specific hypotheses are proposed and will be tested within the project;

- Improved P-fractionation monitoring methods will enhance our ability to identify the processes governing fluxes of bioactive fractions and algal growth
- It is possible to assess the processes governing mobilization and transport of nutrient (P, N and C) from soil and sediments by determining phosphate pools and water chemistry
- More frequent intensive rain episodes enhance eutrophication through increased erosion and leaching of nutrients.
- Continued flux of P from over fertilized soils and sediments will maintain eutrophication of lakes in agricultural regions despite appropriate abatement measures.
- Based on generated knowledge it is possible to adequately parameterize governing processes to improve performance of the conceptual models, used for improved ecosystem-based management and to predict responses to future pressures.
- Joint uncertainty regarding the cost-effectiveness of abatement measures will be reduced by accounting for correlation between drivers common to two or more sub-models. Uncertainty will be increased by accounting for behavioural responses as implementation uncertainty.
- A process of learning among different users' interests can contribute to reduce uncertainties about other actors' motives thereby facilitating collective action, but although this knowledge might also serve as an instrument for powerful actors to follow their self-interest in a situation with contradictory interests, the hypothesis is that knowledge of these interests will be essential for the success of the overall public policies.

Project structure:

The hypotheses will be tested through an integrated DPSIR framework[ii] that maintains the overall focus on the system as a whole. The specific tasks, involving analytical development, catchment studies, modelling and analysis of societal response will be divided into 5 work packages (WP) (Figure 1 and section 2.4). Sampling and handling of samples will be in accordance with ISO standards (IMPACTS manuals[27], and ICP Forest level II program) and ISO 17025 accredited methods at well equipped environmental laboratories at UiO and NIVA. Analytical ability to monitor P fractions relevant for flux estimates and algal growth will be improved. Geochemical and hydrological processes governing the mobilization of nutrients (P, N, C) from the terrestrial to the aquatic environment will be identified through regional and plot studies (in forested and agricultural land) focusing on hydro-geochemical soil-soil/water processes. In addition monitoring data will be employed to identify conceptual links between various environmental pressures and changes in the state of environment.

A catchment model will be parameterized and used with a lake model to check hypotheses, identify nutrient sources (hotspots) and pressures governing transport.

All the improved conceptual understanding and knowledge developed (in WP2, 3 and 5) will be *integrated* in an existing Bayesian network model from Storefjorden that will be adapted to western Vansjø. This will reduce the uncertainties in cost-effectiveness analysis of eutrophication abatement measures.

Based on the suggested abatement measures (from WP2-5) the societies ability to respond to these challenges will be addressed through systematic response analysis.

Cooperation: Policy-relevant research on the effect of environmental drivers on water resources requires an interdisciplinary approach. The Oslo region host several research groups at the Universities and the R&D institutes with complementary knowledge in environmental science. *Considerable synergistic effects will be gained by coupling the capacity for **basic scientific research on system and process understanding** at the universities (UiO,UMB) with the **applied environmental research groups** at CIENS (NIVA, NINA & NIBR) and BioForsk.*

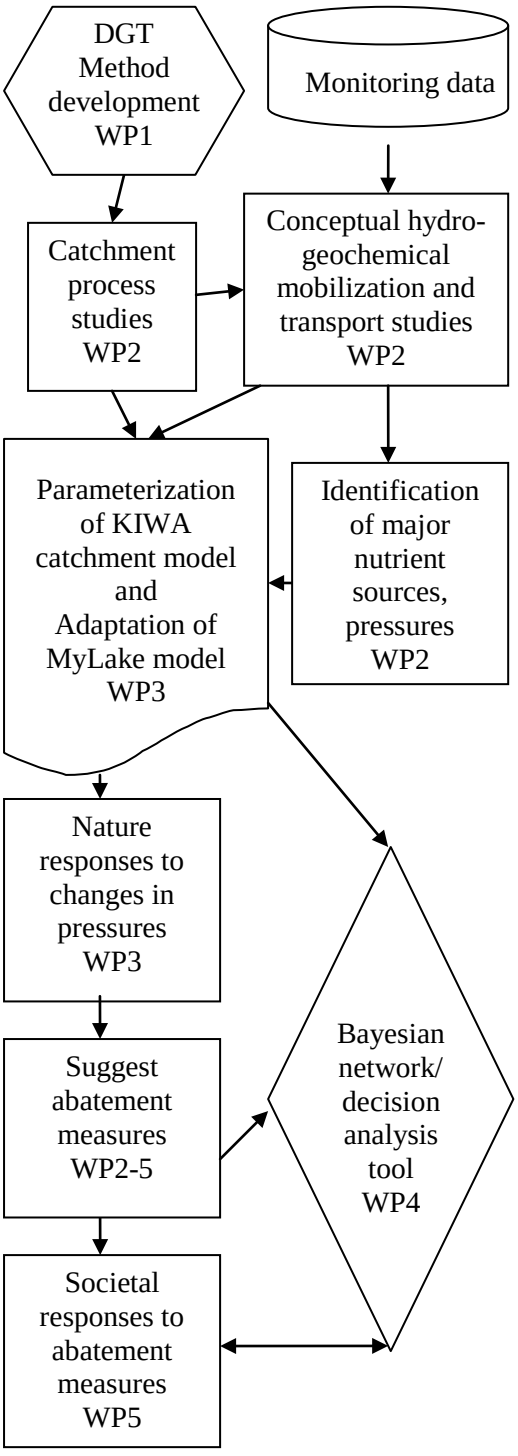

Figure 1 Basic project design and information flow

[ii] The DPSIR model (**D**rivers, **P**ressure, **S**tate, **I**mpact **R**esponse) Provides the basic conceptual framework for cross disciplinary co-operation in CIENS (CIENS 2006) and is the further refinement of the "Pressure-State-Response framework" initially developed by OECD (OECD 1997) and used inter alia as an analytical tool for determining pressures and impacts under the WFD (Galparsoro et al. 2006) and as a conceptual framework for Integrated Environmental Assessment by EEA (see e.g. (Kristensen 2004) also illustrating how the DPSIR-model may be applied to studying eutrophication and pollution from organic matter (fig. 6). Other examples where the DPSIR model has been used to study eutrophication water pollution include e.g. (Trombino et al. 2005).

2.4 Project plan

Work Package 1: Development of sampling and laboratory methods for P

Responsible: **NIVA** (Dr. **Røyseth**) in cooperation with UiO-Chem. (Prof. Vogt).

Improvements of existing and developments of new methods for sampling and analysis of phosphorus fractions in surface-, soil- and sediment water, in order to separate particulate/colloidal, low molecular and anionic/neutral/cationic phosphorus compounds. The new and improved methods will be used for better system and process understanding in WP2 and as input to the improved models in WP3. The work will be performed in cooperation between NIVA and MSc students at UiO-Chem (Prof. Vogt), and focuses on:

i) *Phosphorus fractions in river and surface water*. Study the new DGT sampler for collection of free phosphate fraction as well as low molecular organic phosphorus compounds (AMP and similars). We have limited knowledge of the latter fraction, and will examine the performance of these to the DGT. NIVAs Size Charge Fractionation (SCF) method will be further examined to separate particulate, low molecular and free anionic/neutral/cationic phosphorus compounds and compared with DGTs.

ii) *Phosphorus fraction in sediment and soil pore water*. For fluxes over sediment surfaces, new pore-water profiling tools of P fractions in top lake sediments will be examined, by use of DGT probes, DET-micropeeper probes (Diffusive Equilibrium in Thin films), as well as conventional peeper systems under development in cooperation with NIVA and UiO-Chem.

iii) *New high sensitivity analytical tools for P measurements*. SCF/FIA/SIA techniques with long path flow cells/molybdate blue chemistry as well as HRICPMS, will be examined.

Work Package 2: Catchment processes - the influence of land-use and hydrology on nutrient fluxes into aquatic systems.

Responsible: **UiO-Chem** (Prof. **Vogt)** in cooperation with Dr. Røyseth (NIVA), UiO-Geo (Prof. Aagaard) and BioForsk (Dr. Bechmann)

Geochemical and hydrological processes (water flow-paths) governing the mobilization of P fractions and spatial distribution (identification of hot-spots) of bioavailable P fractions leading to the temporal and spatial variation in nutrient flux from soil to surface waters, will be investigated by conducting the following tasks:

i) *Study of soil-soil/water interactions* in agricultural land used for different types of crops (grain and vegetables), draining into western Vansjø, and a forested site. Biogeochemical cycles and processes governing the nutrient flux from the soil to soil water will be studied on plot scales. Throughfall and soil water from genetic horizons incl. ground water will be monitored along topographic gradients in the catchments. The relationship between soil pools and P fractions in solution will be assessed in terms of biogeochemical processes governing the mobilization of P in relation to soil characteristics and overall soil water chemistry (WP3) using multivariate statistics (SIMCA-P). Significance of DNOM to background nutrient load and its governing drivers will be assessed.

ii) *Mobilization and fluxes* of bio-relevant nutrient fractions (WP1) will be studied through a regional survey to identify hotspots and preferential hydrological flow-paths governing the mobilization of nutrients from the terrestrial to the aquatic environment by means of End Member Mixing Analysis (WP3, 4).

iii) *Process oriented studies* of monitoring data from i). This will be used to identify conceptual based and empirically founded relationships between environmental pressures and changes to the levels of bio-available nutrient species in the lake. Speciation will be conducted with MINEQL+. These studies will be used to parameterize and evaluate the influence of different flow paths on loading of nutrient fractions by means of the KIWA[13] model (WP3).

iv) *Synoptic surveys* of discharge and hydrochemistry along the river system during recession episodes will allow validation of model hypotheses (WP3) of transport processes (i, iii) and link between hydrological and chemical outwash processes.

Work Package 3: Modelling of catchment and lake processes

Responsible: **UiO-Bio/NIVA** (Prof. **Andersen)** in cooperation with UiO-Geo (Prof. Gottschalk) and NIVA (Dr. Saloranta)

Simultaneous processes governing mobilization, transport and fate of nutrients in the terrestrial and aquatic environment (WP2) will be integrated in conceptually based models. These models will be used to test hypothesis and to predict responses to expected changes in pressures, as well as to be integrated in the Bayesian network methodology (WP4).

i) *The KIWA* (KInematic WAve) mathematic hydrological model[13] will be parameterized for western Vansjø and used to test hypotheses of nutrient mobilization and hydrological runoff formation in sloped areas and how it matches observed episodic hydrological and chemical data from field studies (WP2). Response to future environmental change will be investigated by using climatologically scenarios (based on downscaling).

ii) *MyLake model* will be adapted to western Vansjø and integrated with the output of the KIWA model to simulate effects of changing pressures (including climate scenarios) on the past and future eutrophication history on the lake system.

iii) *Markov chain Monte Carlo (MCMC)* techniques will be used to estimate model parameters and assess uncertainties in the model predictions [28].

NIVA's Strategic Institute Program (SIP) (funded by RCN) "Integrated environmental modelling for river basin management: Models, uncertainties and good modelling practise" will be connected to this project for 2009. Several models are examined with Morsa/Vansjø as the most important case. Further modelling work in 2010-11 will be based on the SIP experiences.

Work Package 4: Integrated uncertainty analysis of cost-effectiveness of measures using Bayesian belief network methodology

Responsible: NINA/NIVA (Dr. **Barton**) in cooperation with UiO-Geo (Prof. Gottschalk), NIBR (Dr. Orderud), UMB-IØR (Dr. Romstad) and BioForsk (Dr. Bechmann)

Use Bayesian belief network models to integrate diverse social and natural science models of cost-effectiveness of nutrient abatement in the Western Vansjø catchment, taking advantage of modelling improvements

i) *Reduce uncertainty in existing network models of effectiveness of fertilisation and ploughing measures* by including additional process (e.g. long term soil-P storage, gully erosion) and calibration against new monitoring data studied in WP2 and 3

ii) *Reduce uncertainty in nutrient abatement cost models* by adequately accounting for opportunity costs of switching production processes due to abatement measures.

iii) *Farmer response*: conduct a farm-level survey to obtain primary data on farm production functions for main crops in Western Vansjø sub-catchment and qualitative, and non-agronomical factors affecting abatement measure implementation.

iv) *Develop a new model of farmer response to abatement measures* based on opportunity costs and qualitative non-agronomical factors (e.g. agricultural extension information)

v) *Adapt the Bayesian network to MCMC simulation results* from hydrological KIWA and MyLake water quality models for Vanemfjorden from WP3.

vi) *Assess the effectiveness of abatement measures* in terms of changes in predicted water use suitability by adapting the results from a recent (2007) choice experiment study on water quality suitability thresholds of recreational uses in Western Vansjø[iii].

vii) *Use the Bayesian network methodology to integrate (ii-vi).* Assess joint uncertainty of cost-effectiveness of abatement measures. Assess the role of implementation probability in providing more realistic assessments of abatement measure cost-effectiveness under uncertainty. Assess the role of drivers in inflating uncertainty due to multi-correlation.

viii) *Interact with managers of the Morsa Project and farmers* in explaining the results of the joint uncertainty analysis model (Bayesian network).

[iii] Data collected in EU AQUAMONEY project. http://www.aquamoney.ecologic-events.de/

Work Package 5: Societal response

Responsible: NIBR (Dr. **Orderud**) in cooperation with NINA (Dr. Barton).

i) *Conduct a baseline study of the policy process* of dealing with eutrophication in the Vansjø-Hobøl area; that is, how different policy makers and public officials are conceiving of the case of eutrophication and possible abatement strategies, and trying to balance different interests and conflicts relating to policy formulation and implementation.

ii) *Carry out an analysis of the political/administrative decision-making process* in relation to eutrophication, based on a game theoretic approach and collective action, comprising different actors preferences. Address how new information (e.g. about eutrophication) and the Bayesian Belief Network affects the learning process among policymakers. Apply stated and revealed preference methods as the empirical basis, and also draw upon the results from WP4

iii) *Develop and improve the DPSIR model* by analysing how the link between State/Impacts and society's Response works in practice; also addressing the contribution of Bayesian Belief Network in concretizing the DPSIR.

2.6 Project team and organization.

This project, led by Prof. Vogt (Dept. of Chemistry UiO), is a cooperation between the research groups at:

UIO Chemistry	Environmental chemistry, catchment processes, environmetrics, DNOM, analytical chemistry (ICP-MS, IC, speciation and fractionation)
UiO Geo Sci	Biogeochemical processes, environmental geology, hydrology, modelling;
UiO Biol sci	Modelling, ecological stoichiometry, plankton biology, limnology
NIVA	Analytical and environmental chemistry (HR-ICP-MS, IC, DGT, SCF, fractionation), long-term environmental monitoring, time series analysis and ecosystem modelling
NINA	Bayesian network, modelling
NIBR	Societal response
Bioforsk	Crop yield and P-yield functions
UMB-IØR	Economic farm production functions

Profs. Davisson and Zhang, University of Lancaster, UK, are the inventors of the DGT technology and will contribute in WP1 in the development of analytical the methods. Sakari Kuikka, Helsinki University, is an expert on Bayesian network quality assurance and will participate in the Scientific advisory board. Helga Gunnarsdottir from the Morsa River Basin Organization and Tyra Risnes Høyås and Line Meinert Rød from the Provincial Commissioner in Østfold and Oslo & Akershus, respectively, will participate in all project meetings ensuring local stakeholder involvement and influence in planning and accomplishment of the project.

This constellation provides multidisciplinary competence required to carry out the research task and act as supervisors for doctoral fellows. The individual groups have access to a range of conventional and new technologies and laboratories. Project members are all productive and internationally well-respected in their disciplines.

UiO applies for 1 PhD (WP2), 1.5 year prolongation of the post.doc period of Chrystelle Auterives (WP3) and 1.5 year post doc in modelling (WP3/4). At least 3 MSc students from UiO will contribute to the project.

3. Perspectives and strategic aspects

3.1 Strategy

The research project is rooted in the strategic focus on life sciences and interdisciplinary research as expressed in the long-term strategic plans of the participating institutes, faculties and CIENS[29]. It will contribute with basic research needed within the policy oriented Theme 3 *Integrated river basin and coastal zone management* in CIENS's plan for common research (SACRE). The research complies with the aims of parliamentary whitepaper no. 20 *Vilje til*

Forskning, and the government's declaration (*Soria-Moria*). Furthermore, it is a direct response to the recommendations for future environmental chemistry at the UIO Dept. of Chemistry, made by an international evaluation panel.

3.2 Societal relevance

This project improves cross-disciplinary cooperation between the 6 strongest environmental research institutions of the Oslo region, enabling more holistic and policy relevant environmental research. Specifically it responds to the new challenges posed by the EU WFD as the Morsa water's course are given special attention during the implementation of the WFD (full characterisation). Knowledge generated by this project is a prerequisite for the selection of further cost-efficient and sustainable management practices needed to reach the WFD requirements. Several of the central scientists are advisors for local authorities (municipalities and Provincial Commissioner), the Norwegian ministry of agriculture (LD) and environment (MD) and its executive bodies (SLF; SFT). Local stakeholder involvement is assured through participation by representatives from the Morsa River Basin Organization and the concerned Provincial Commissioners.

The study site is a domestic water supply source, important wildlife and plant habitat, and popular recreational area in South-Eastern Norway, with strong interest conflicts with agriculture and further urbanization. The eutrophication has required abatement measures and investments in the Morsa basin on the order of approx 500 MNOK. These decisions affect everyday life of a large number of people, especially related to agricultural practice.

3.3. – 3.5 Environment, research ethics and gender equality

No serious detrimental **environmental effects** have been identified. The enhanced knowledge of environmental status/processes and more accurate future predictions based on improved models, will give decision makers better tools (Integrated Assessment Model) to improve water resource management practices.

The project will not violate any of the points in RCN's checklist of **research ethics**[30].

All participating institutes adhere to the current Norwegian regulations and guidelines regarding **equal opportunities** with respect to gender, religion and race, and strive to achieve equality of genders in recruitments

4. Communication with users and use of results

4.1 Communication with users

The activities and output of this project will:

- Be of value as input to the HAVKYST and NORKLIMA program of the RCN.
- Enhance knowledge and access to data among the environmental authorities (WFD region 1) and the project participants, of mutual value for all parties.
- Transfer new, valuable and relevant knowledge to students at UMB and UiO, as the study site is frequently used for student courses, field excursions and Master theses.
- Provide knowledge concerning fertilizer use and crop production/risk for runoff for the agricultural advisory service.

Policy relevance and stakeholder participation are assured through the participation of project leader of the Morsa River Basin Organization as well as the Provincial Commissioners in Østfold and Oslo & Akershus.

4.2 Dissemination of results

- Scientific articles will be published in peer-reviewed international print and online journals and through conference papers.
- A project web site will be established.
- There will be dissemination activities with stakeholder and related networks.
- A final conference to present the main findings and initiate further discussion/research.

This is elaborated on further in the electronic application form.

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