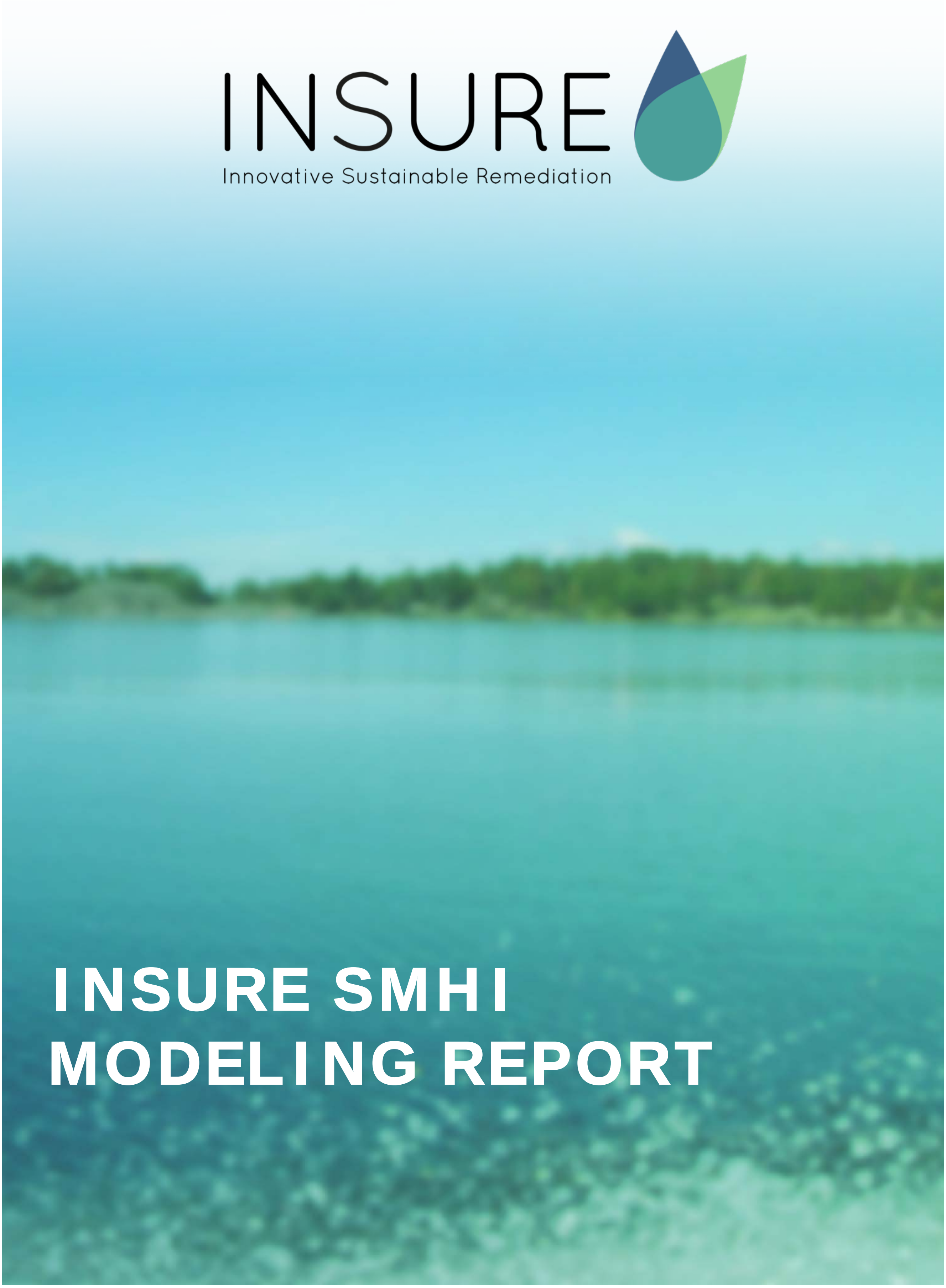

INSURE

Innovative Sustainable Remediation

INSURE SMHI MODELING REPORT

EUROPEAN UNION
European Regional Development Fund

Interreg
Central Baltic

LÄNSSTYRELSEN
ÖSTERGÖTLAND

Göran Lindström and Alena Bartosova

SMHI

Sabina Hoppe

Länsstyrelsen Östergötland

2019-02-01

CONTENTS

1. PREFACE

This report describes the application of the NET model to basins in the Östergötland County in Sweden. NET is a general upscaling tool for spatial estimation of water and substance fluxes. It has been developed and set-up for all of Sweden, for simulation of both nutrients and metals. In this report a more detailed study of five metals was conducted for the selected pilot areas in Östergötland. The areas used in this study were parts of the Motala Ström basin and the Storån basin. Based on the national set-up, local data and information was added and used for refining and improving the model thru sampling. Metals as well as basic water chemical parameters was sampled between 2016-2108.

2. INTRODUCTION

NET is a general tool for upscaling water quality information to points without measurements. The NET model was developed by Lindström et al. (2017) and calculate substance fluxes using information collected for the S-HYPE hydrological model for Sweden (Strömqvist et al., 2012). S-HYPE describes the hydrology of Sweden in high temporal and spatial resolution. In the set-up which was used for this project, Sweden is divided into about 37000 subbasins, modelled dynamically with a daily time step. An important feature of NET is that calculations for all of Sweden, with the same spatial resolution, are completed in only a few seconds and for some 10 substances, whereas a 10 years simulation with S-HYPE for Nitrogen and Phosphorus typically takes some 4 hours. NET only estimates average flow weighted concentrations and loads, but this is often what is desired for a first screening of the status of a large drainage basin. The NET model is independent from S-HYPE for retention rates and is general for many substances transported by water.

3. AIM

The aim of this study was model five metals in the pilot areas of the Motala Ström basin and the Storån basin in Östergötland, using the NET model. An objective was also to further improve the NET model thru incorporating the sampling done in the pilot areas.

4. METHODS AND DATA

The NET model is a stationary description concerning fluxes of water and substances through a network of rivers and lakes. The gross load can either be estimated using the tool itself, by comparison with measurement points, or taken as input, from e.g. other models. NET has so far been used to model nutrients (Nitrogen and

Phosphorus), Total Organic Carbon and metals: Cadmium (Cd), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb) and Zinc (Zn). The model uses different variables to estimate how the fluxes of the substances of interest will behave and disperse. For example, it calculates the retention time in different water streams and lakes as well as compare the sampling spots with the concentration of the substance of interest, to the rest of the country.

The retention in streams and lakes is calculated as a function of residence time. The same retention equation is assumed for all substances, but with different rates (k). For each substance, i, with concentration C_i, the retention is assumed as:

$$\frac{d(C_i - C_{mi})}{dT} = -k_i(C_i - C_{mi})$$

with the solution:

$$C_i = (C_{0i} - C_{mi})\exp(-k_i T) + C_{mi} \; .$$

Residence times (T) in lakes (T_L) and rivers (T_R) are estimated as:

$$T_L = V / Q$$
$$T_R = s / u$$

Where V is the lake volume, Q is the mean discharge, s is the length of the river reach and <u>u</u> is the water stream velocity (see Lindström et al., 2017 for details).

The NET upscaling tool is described briefly in Figure 1 and in Lindström et al. (2017) in greater detail.

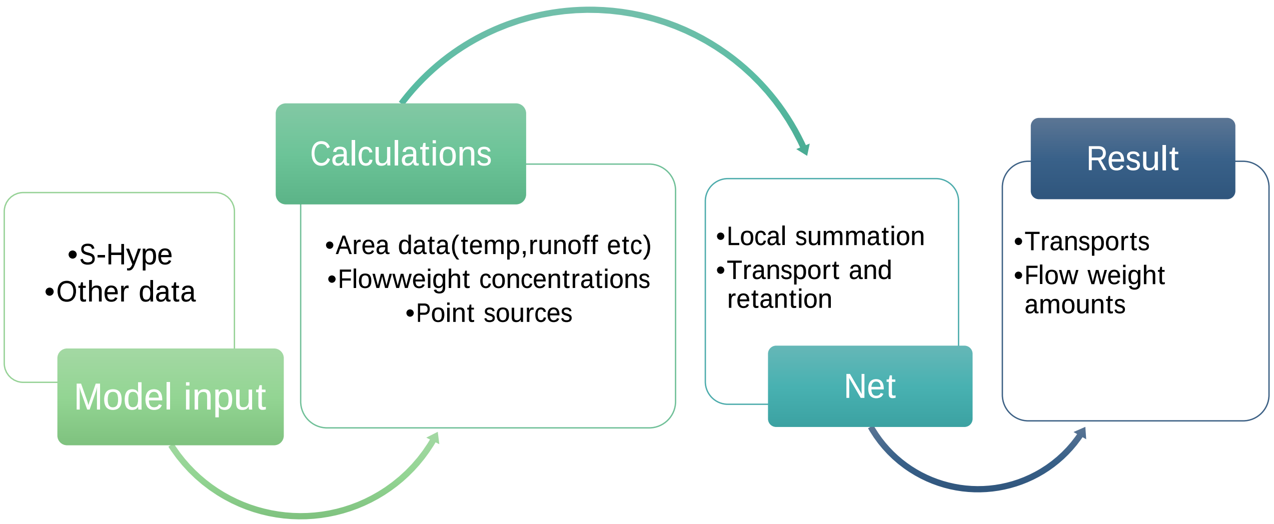

Figure 1. Schematic description of the general upscaling tool NET.

Input data were collected from the S-HYPE hydrological model set-up for Sweden (Strömqvist et al., 2012). This includes data for all of Sweden. National measurements of metal concentrations were collected from the Swedish University of Agricultural Sciences (SLU). Additional local data from the pilot areas of Åtvidaberg and Finspång (fig.2-4), were sampled between 2106-2018.

Figure 2: displaying the pilot sites selected in Östergötland for INSURE. In Finspång by lake Skutbosjön and in Åtvidaberg by Lake Håcklasjön.

This was done to make the model more adaptable to the pilot areas of interest for this modeling study. Samples were taken by the County Administrative Board in Östergötland and analyzed for various metals (fig. 3-4). The results for the following metals were included in the local NET analysis: Cd, Cu, Ni, Pb and Zn. The samples were primarily taken in the Hällestadsån stream upstream and downstream of Finspång, and in the Storån stream in the Åtvidaberg.

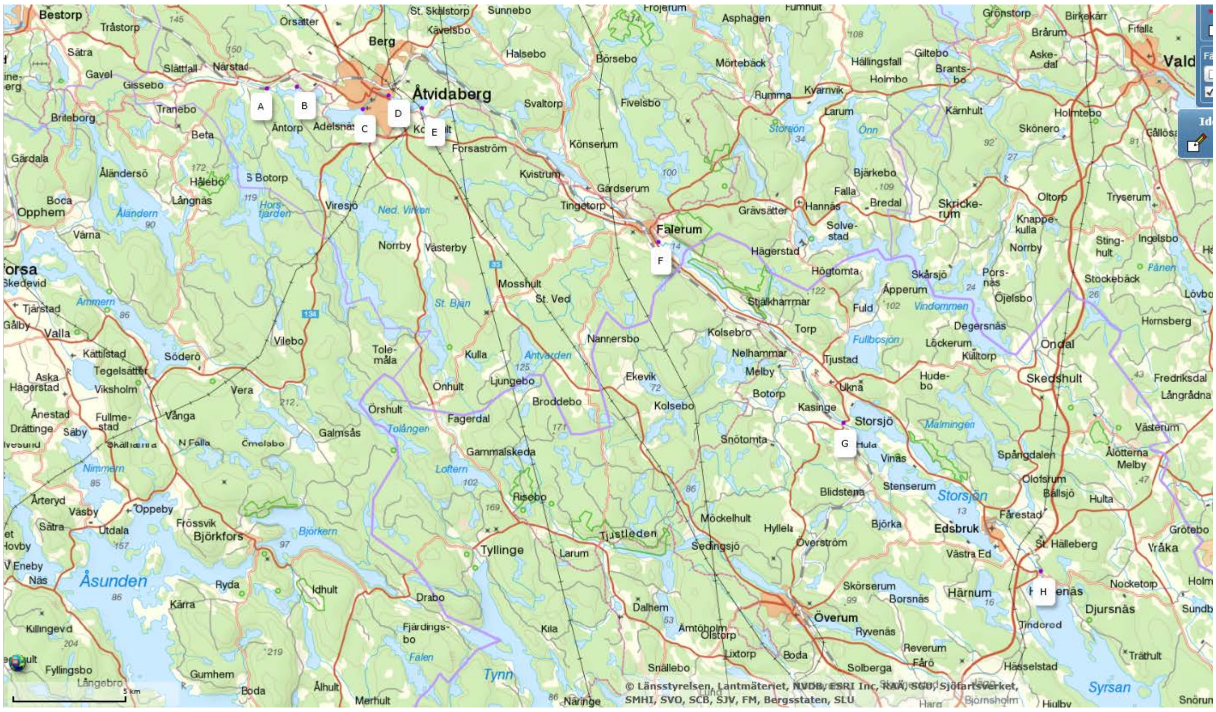

Figure 3: Sampling points in the Åtvidaberg pilotarea which are added into the INSURE model.

Figure 4: Sampling points in the Finspång pilot area which are added into the INSURE model.

The NET model was also complemented with local estimates of lake depths, since the residence time in large lakes greatly affects the retention in the model.

Leakage concentrations (μg/L) and retention rates (%/year) were calibrated by minimizing the difference between modelled and observed concentrations at the available sampling points. Both modelled and observed concentrations were flow weighted averages.

The locations of potentially contaminated sites were made available by the County Board. The number of such sites within each sub-basin was counted and used as a proxy for the contribution from the metals in the study. The metal leakage from each site (kg/year) was calibrated as described above.

5. RESULTS AND DISCUSSION

Simulated concentration maps for Copper, Nickel and Zinc are shown in Figures 5-7. The maps are produced using the NET model with leaching concentrations for different land uses, obtained by calibration to sampling stations for all of Sweden.

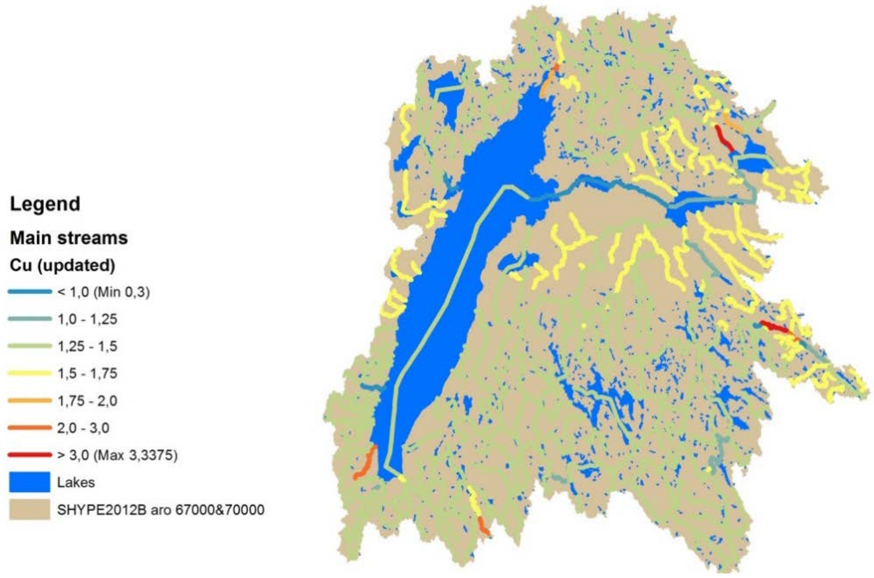

Figure 5. Example of simulated concentrations for Copper (µg/L) within the study area. Red equals high concentrations and green-blue low.

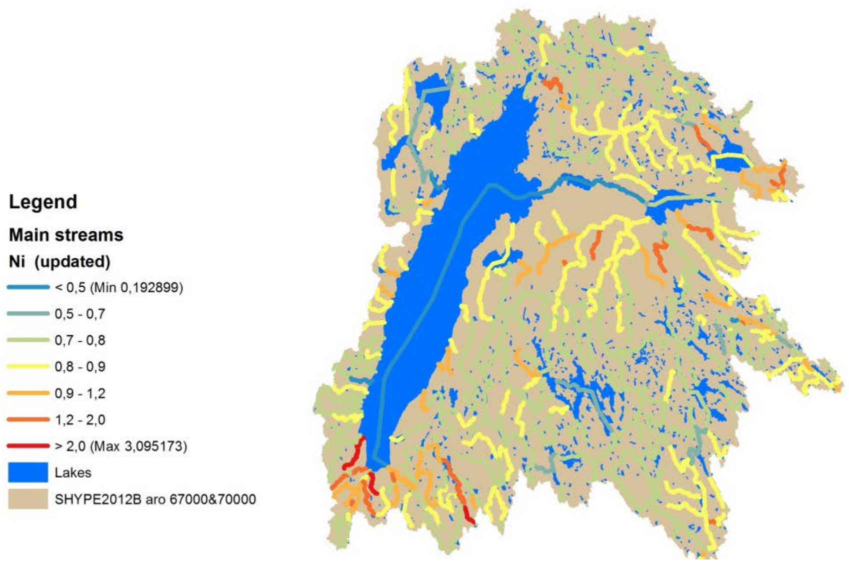

Figure 6. Example of simulated concentrations for Nickel (µg/L) within the study area. Red equals high concentrations and green-blue low.

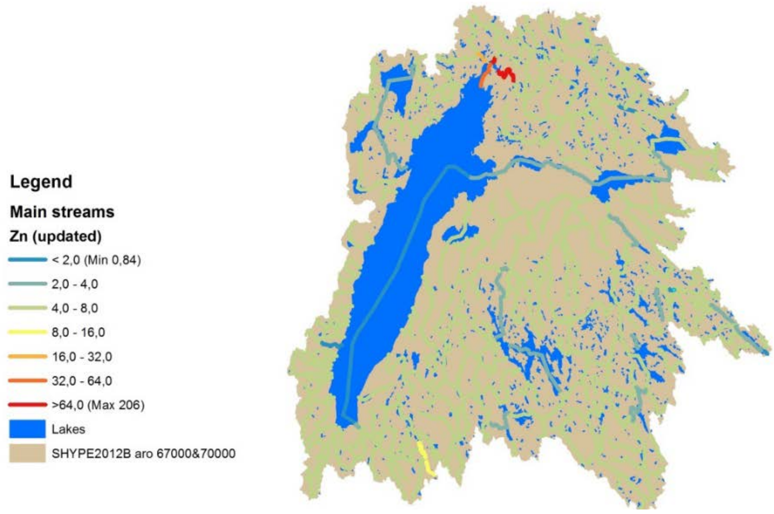

Figure 7. Example of simulated concentrations for Zinc (µg/L) within the study area. Red equals high concentrations and green-blue low.

The maps show concentrations of different metals which are updated at the sampling points from this project. High levels of Copper can be seen in both pilot areas, Hällestadsån and Storån. High Zinc levels can be seen in the mining area north of the large lake; Lake Vättern. These maps show results obtained from the national model set-up (Lindström et al., 2017), i.e. prior to accounting for the local information gathered within the INSURE project.

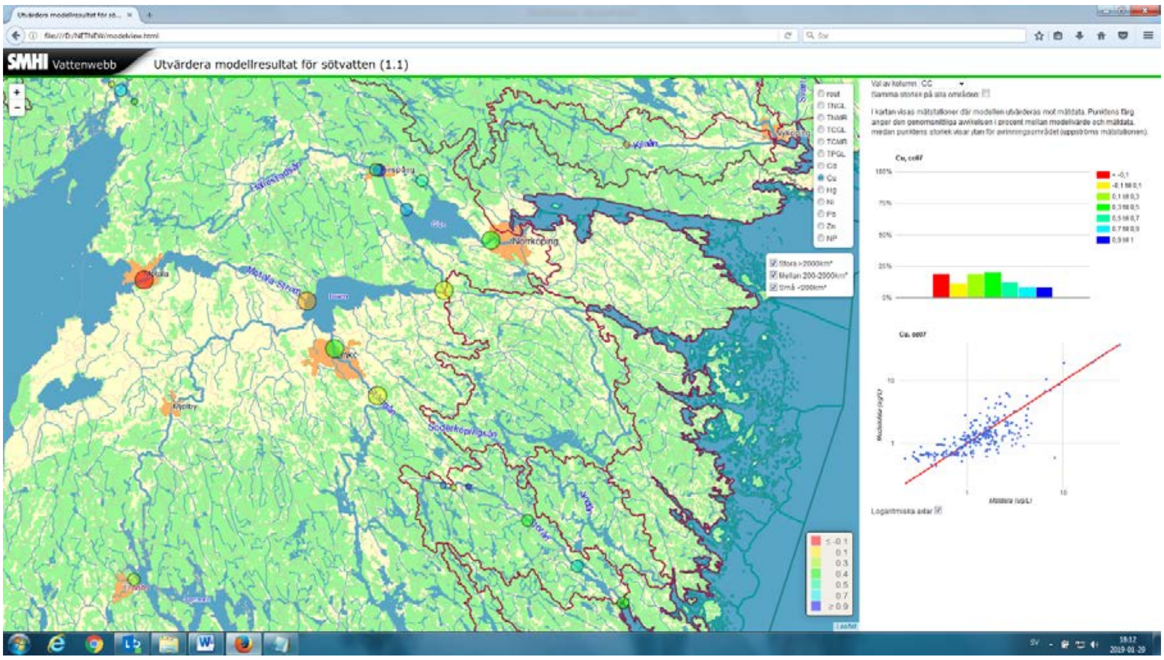

Figure 8. Observed levels of copper, including samples from the INSURE project. Red equals values above general Swedish means for copper

Copper is the metal for which the concentrations in the pilot areas stand out in a Swedish context (observed concentrations of copper are shown in Figure 8), as quite high compared to the rest of the country. High values are shown as blue circles and low values are shown as red circles by the model.

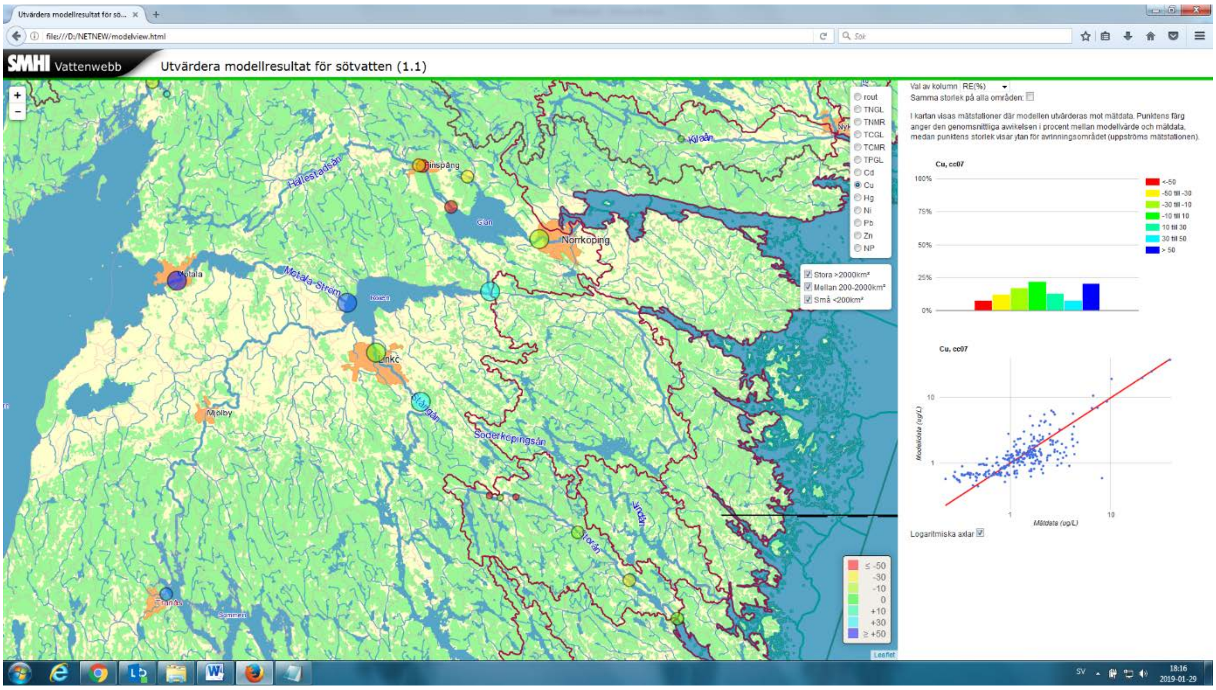

Figure 9. Relative difference between simulated and observed levels of Copper, including the local information from the INSURE project. Red equals underestimation by the NET model indicating an unknown source of copper in the vicinity of the sampling spots.

Relative differences between simulated and observed levels of Copper, including the local information from the INSURE project, are shown in fig. 9. The local information consists of results from water quality sampling, local lake information and mapping of potentially hazardous sites. Red circles in fig.9 denote an underestimation by the model, which indicates that the observed concentrations are higher than expected from the upstream land use and lakes only. This occurs for example near Finspång in Hällestadsån and around Åtvidaberg in Storån. The underestimation of the model indicates an unknown source of copper which has not been included into the model. As the whole area surrounding the pilot areas has been involved in industrial activities since long ago this is not a surprising result but indicates how the NET model can be used to find areas where there are unknown sources that can then be treated and cleaned. A change in color, as from yellow to red, between the two points in Finspång (Figure 9) suggests that there is an unaccounted source between these two sampling points.

The NET tool can also be used to estimate the source and sinks between the sampling points. For instance, the load of Copper is about 800 kg/year higher at one of the sampling points upstream in the Finspång pilot area compared to the other one downstream, according to the analysis. The increase in area between these two points, essentially upstream and downstream of Finspång, is only 0.2%. It therefore seems that there is an unaccounted source of Copper between these two points. However, there is considerable uncertainty in the load estimates, due to the small number of samples, among other things.

The flow weighted concentrations estimated based on the samples collected within the project are summarized in Table 1. Since the number of samples were limited there is an uncertainty in flow weighted concentrations that needs to be taken into consideration.

Table 1. Flow weighted metal concentrations in the study area, collected in the project. Subid is the identification number in the SMHI tool vattenwebb (vattenwebb.smhi.se), of the sampling points included into the INSURE project.

Subid (from SMHI)	Cd (µg/L)	Cu (µg/L)	Ni (µg/L)	Pb (µg/L)	Zn (µg/L)
40599	0,039	3.59	1.15	0.28	25.0
40714	0,020	2.93	1.28	0.54	5.28
40597	0,005	1.18	0.42	0.07	1.18
3775	0,020	1.69	0.98	0.09	10.7
3670	0,045	2.05	2.48	0.26	14.2
3552	0,008	1.55	1.11	0.07	2.09
4801	0,023	1.78	1.35	0.59	6.16
4795	0,017	4.35	0.93	0.49	5.69

6. CONCLUTIONS

The pilot areas of Finspång and Åtvidaberg has had large metal industries for many years, affecting the surrounding environment and making the pollution in these areas from metals widespread. When sampling several high concentrations were found that needs to be addressed by the municipalities. Even thou there were samples taken, it has proven difficult to pin down where all the metal pollution is originating from, leaving the need for more samples to find the hot-spots in the pilot areas. However, according to the available information, the following observations were made: the concentrations in the study areas stand out as very high in a Swedish context. Moreover, there seems to be unaccounted contaminant sources of copper in Finspång, as seen in the sampling and modelling which should be investigated further.

The NET model is based on large quantities of data entries and as such can be considered a rather robust model. However, it can not be considered user-friendly and for the greater mass to be able to use it the model should be worked into an easier framework. The NET model also uses basic geochemical processes for the metal's behavior such as retention time, but it does not look at bioavailability or the different potentials of binding to other organic matter, which can influence the dispersal of the heavy metals. Summarizing the modelling in the pilot areas with the NET model there are some advantages as being able to detect unknown sources of contamination. However, the model needs to be worked into a more user-friendly framework to be seen as a good help when working with metal polluted areas.

ACKNOWLEDGEMENTS

Financial support for this work was received from the County Board, Östergötland County in Sweden. The work was an activity within the EU project INSURE.

REFERENCES

Lindström, G., Bartosova, A., Hjerdt, N. & Strömqvist, J. (2017) Uppehållstider i ytvatten i relation till vattenkvalitet - NET, ett generellt uppskalningsverktyg. SMHI Rapport Hydrologi Nr. 119. ISSN 0283-7722

Strömbäck, L., Pers, C., Strömqvist J., Lindström G. & Gustavsson, J. (2018) A web based analysis and scenario tool for eutrophication of inland waters for Sweden and Europe Environmental Modelling and Software. https://doi.org/10.1016/j.envsoft.2018.07.012

Strömqvist, J., Arheimer, B., Dahné, J., Donnelly, C. & Lindström, G. (2012) Water and nutrient predictions in ungauged basins: set-up and evaluation of a model at the national scale, Hydrological Sciences Journal, 57:2, 229-247.