Generate Geospatial Analysis Results

Once selected, the appropriate geospatial method is used to generate information for optimization. The type of results can vary depending on the study question being addressed, but the results usually include a set of predictions at unsampled locations and, for some methods, a measure of prediction uncertainty (such as standard errors or variances). If the geospatial method is being used to optimize a sampling plan, then the output of the method might be a proposed sampling plan or a metric that can be used to select new sampling locations or to remove existing sampling locations.

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Many optimization tasks depend on assessing or minimizing the prediction uncertainty. Geospatial methods differ in their ability to provide quantitative measures of uncertainty for predictions at unsampled locations. The simple methods do not provide any form of statistical uncertainty estimates. For these methods, uncertainty in the predicted values can only be evaluated qualitatively by considering whether the results are consistent with the CSM and whether the available data are sufficient to answer the questions of interest.

More complex methods, such as regression and spatial correlation approaches, use standard probability theory to quantify uncertainty. Since spatial regression models include a statistical noise or error term, this method can be used to quantify uncertainty in the model predictions as with a regular, nonspatial regression model. However, the estimates of uncertainty from spatial regression models may be underestimated if spatial correlation is not fully accounted for. In principle, methods such as kriging, which account for spatial correlation, may produce better estimates of prediction uncertainty. The uncertainty estimates from kriging are also too low because they generally do not include the uncertainty associated with estimating the parameters of the spatial correlation model.

The uncertainty in the geospatial method results can be visualized by plotting the prediction variance (from regression or kriging methods) or statistical summaries of the results of conditional simulation. The most common ways of characterizing uncertainty are described in more detail in the following subsections.

Variance Map

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The prediction standard error or variance provides an estimate of the interpolation accuracy that can be generated by more complex and advanced methods. This measure of uncertainty can be mapped in order to show areas of greater and lesser uncertainty. The map can be used qualitatively or quantitatively for the optimization of sampling plans. For some kriging methods, the standard errors depend only on the sample locations, estimated variogram, and kriging method, but not on the measured values at sampling locations. These conditions simplify the use of these methods for sampling plan optimization. Figure 48 shows an example of a prediction variance map generated from kriging.

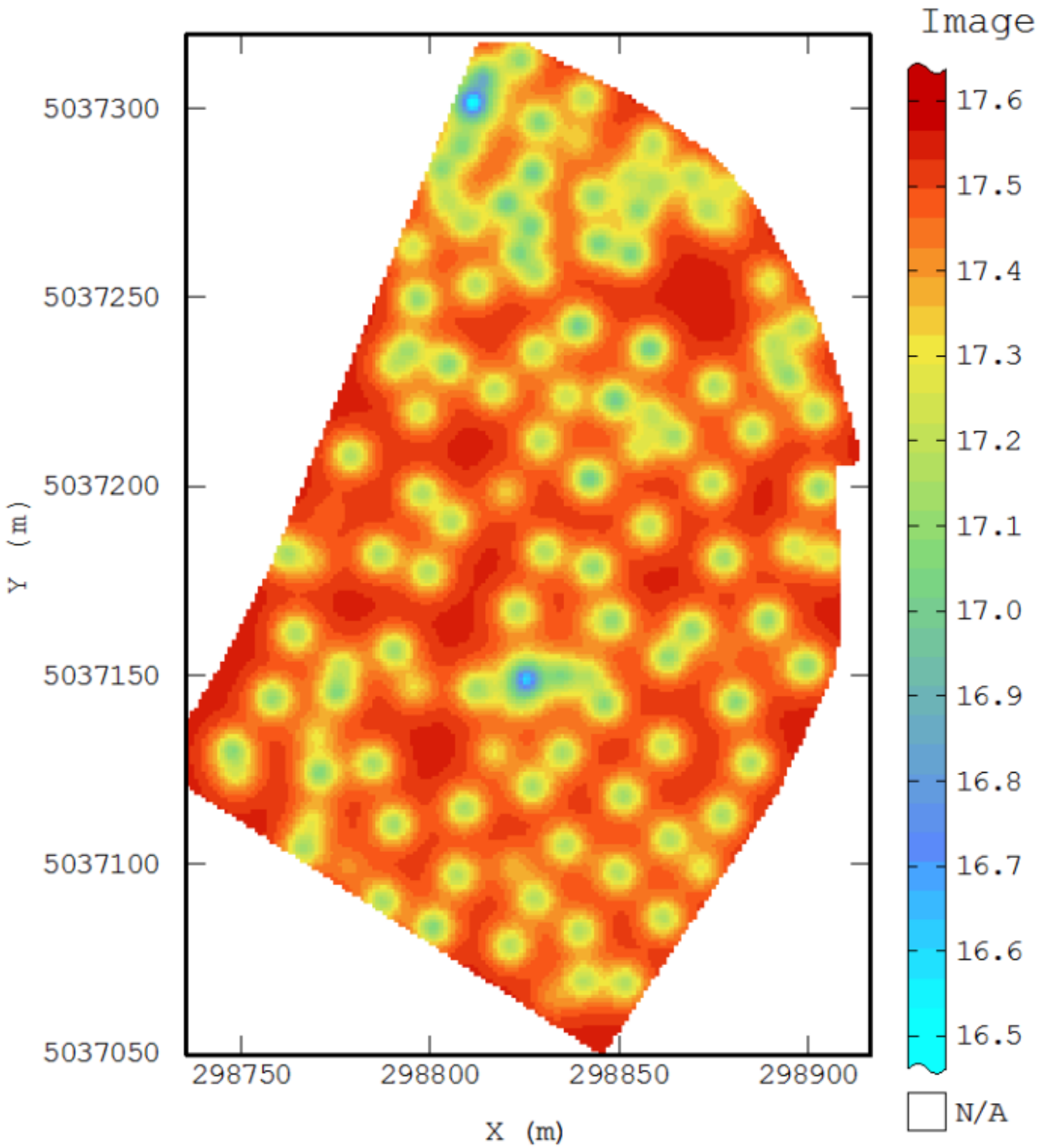

Figure 48. Example of a prediction variance map generated using kriging.

The most accurately estimated areas correspond to sampling points where the value is exactly known (blue areas). The interpolation is less reliable in areas, where no samples have been collected (red areas).

Statistical and Probability Maps

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Conditional simulation provides a method to more completely quantify the uncertainties of the estimates. Interpolation using conditional simulation can produce maps of the contamination which are based on the input data, the estimated variogram, and the kriging model. The maps are all equally probable and conditioned on the observed values at each location. The maps are consistent with both first order statistics (histogram) and the second order statistics (variogram). Postprocessing of conditional simulations (compilation of all equally probable maps) can produce two types of maps that can help to analyze the degree of uncertainty of the estimate: a standard deviation map (Figure 49A) and a probability map (Figure 49B).

Standard Deviation Map

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A standard deviation map quantifies the standard deviation at each block, taking into account the values measured at each sampling location. Figure 49A shows an example standard deviation map.

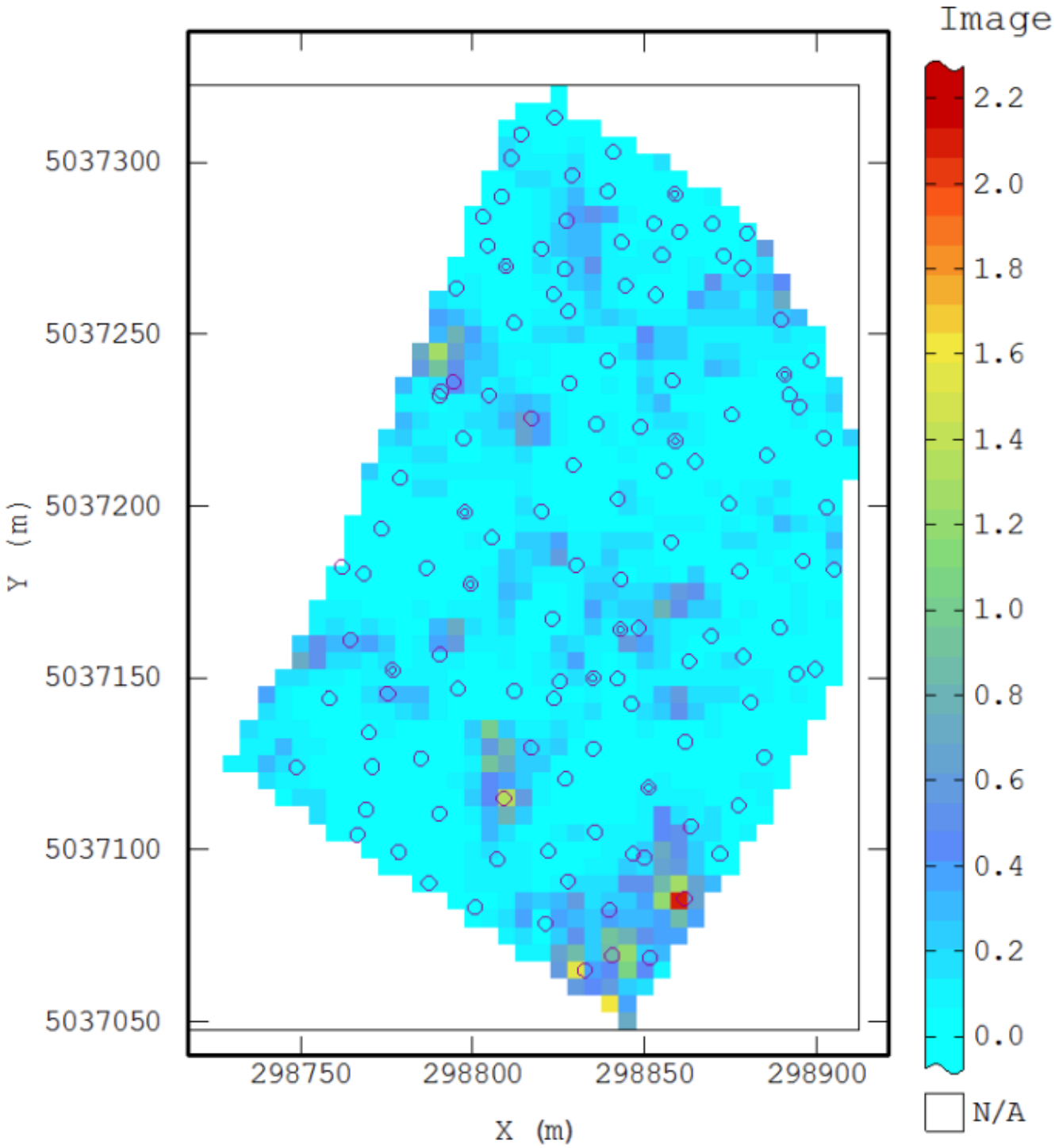

Figure 49A. Example of a prediction standard deviation map generated using conditional simulation.

Probability Map

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It is possible to estimate the certainty that the average concentration in a block exceeds the cleanup level. These maps are expressed in terms of the probability of exceeding the cleanup level. Figure 49B is an example probability map.

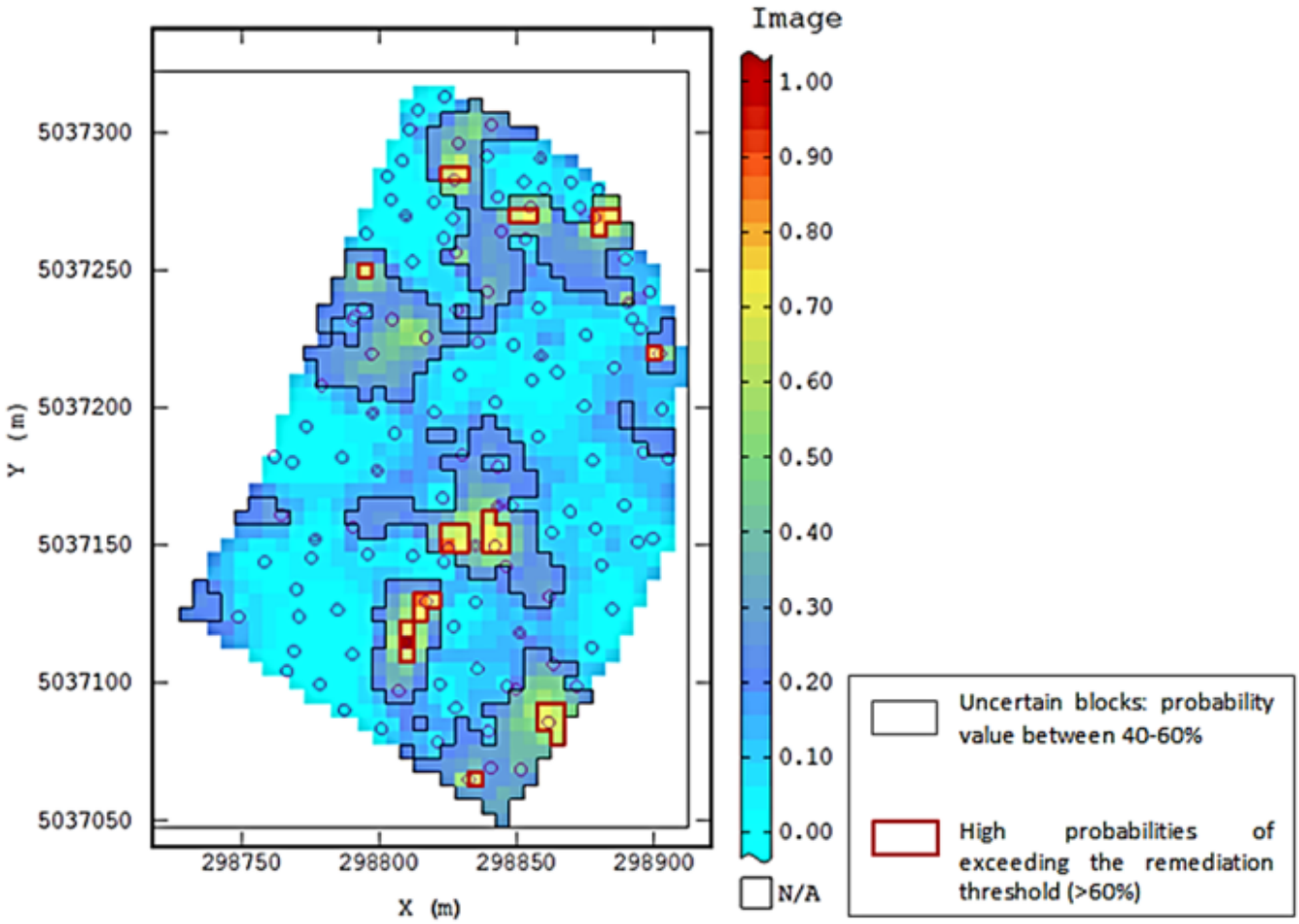

Figure 49B. Example of a prediction exceedance probability map generated using conditional simulation.

The blue blocks correspond to probabilities of exceeding the threshold that are lower than 25%. These are the areas where the risk of contamination is low. On the other hand, yellow and red zones correspond to high probabilities of exceeding the remediation threshold (above 60%) and may represent potential contaminant source areas. Particular attention should be paid to the green blocks corresponding to the uncertain areas. These blocks have a probability of exceeding the remediation threshold between 40% and 60% (fifty-fifty chance of exceeding the threshold). These blocks represent areas where the information about the occurrence of contamination is less accurate. Quantifying these uncertain blocks allows a better understanding of the uncertain volume in order to manage the risks of the remediation.