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Team 02: Week 2

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WP2: Uncertainty in Advanced Hydrological and Hydraulic Modelling
WP3: Climate Change Impacts on Flash Floods
WP4: Accidental Water Pollution
Case Study Tervuren-Belgium

Team02: Report Week 2:
Modelling and Analysis of Tervuren Catchment

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1. Introduction

Water pollution caused by sediment transport is a significant environmental issue, particularly in flood-prone river systems, where increased runoff transfer contaminants and redistributes them across the watershed. The movement of suspended sediments plays a crucial role in pollutant dispersion, as fine particles can bind to harmful substances such as heavy metals, organic pollutants, and excess nutrients like nitrates and phosphates. This process leads to water quality deterioration, impacting aquatic ecosystems, drinking water sources, and public health.

This report represents the third phase of the flood modeling project, focusing on water pollution analysis using sediment transport simulations in HEC-RAS. Specifically, the implementation of "Concentration Only" mode, which allows tracking the movement of suspended sediments in the water column without explicitly modeling sediment deposition and transport capacity along the riverbed. The simulating sediment transport, aims to:

- Identify groundwater-sensitive areas
- Establish total risk zones
- Compare with study results

A key challenge in our project arises from the limitations of HEC-RAS, which does not support 2D water quality modeling. To overcome this, we performed a 1D conversion of the river system, enabling a more detailed simulation of pollutant dispersion. This step ensures a more accurate representation of the interactions between sediments and contaminants, allowing the examination of how pollutants are transported and diluted under different flow conditions.

Furthermore, involves defining boundary conditions for sediment transport, implementing nitrate pollution modeling, and interpreting the spatial and temporal distribution of contaminants in the river. The results from this analysis will provide valuable insights into pollution transport mechanisms and help develop effective flood risk management and water quality protection strategies.

By integrating hydrodynamic modeling with pollutant transport analysis, this study contributes to a comprehensive understanding of how floods influence sediment-bound pollutant behavior, supporting efforts to mitigate contamination risks and enhance sustainable water management practices.

2. 1D Simulation for Water Quality

2.1 Justification for Using 1D Modeling

To accurately assess the impact of sediment transport on water quality, it is necessary to track how sediments and pollutants move through the river system over time. While 2D sediment transport models provide detailed spatial distributions, they are not directly compatible with water quality simulations in HEC-RAS. To overcome this limitation, a 1D conversion of the main watercourse is implemented. This approach enables the tracking of sediment concentration over time at different locations, allowing for the estimation of nitrate transport adsorbed onto sediment particles.

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Using a **1D model** is particularly advantageous for understanding the behavior of **nitrate pollution** in the river. It helps:

- Identify how pollutants travel along the river, influenced by flow velocity and sediment movement.
- Determine peak nitrate concentrations at various river sections.
- Estimate the time required for nitrate levels to return to baseline conditions after a flood event.

This analysis provides valuable insights into how sediment-bound pollutants interact with hydrodynamic conditions, allowing for a more comprehensive assessment of water quality risks.

2.2 Conversion Process and Assumptions

The conversion from 2D sediment transport modeling to a 1D water quality simulation is a crucial step in accurately representing sediment-bound pollutant dispersion within the river system. Since HEC-RAS does not support 2D water quality modeling, this approach allows for a detailed temporal analysis of sediment and nitrate transport, ensuring consistency between hydrodynamic conditions and pollutant interactions.

The process involves the following key steps:

1. Extraction of 2D Sediment Transport Results
    - The 2D sediment transport model provides detailed spatial distributions of sediment concentrations along the river.
    - These results serve as the initial conditions for the 1D simulation, ensuring continuity between the two modeling approaches.
2. Definition of 1D Computational Sections
    - The river is divided into multiple computational segments where sediment concentration and nitrate adsorption are tracked over time.
    - Flow properties, sediment transport characteristics, and pollutant loading conditions are assigned to each section.
    - This segmentation ensures that pollutant movement is accurately simulated along the river's course.
3. Application of Nitrate Adsorption Parameters
    - Since nitrates primarily bind to fine sediment particles, adsorption coefficients are applied to establish the relationship between suspended sediments and nitrate transport.
    - These coefficients are based on observed data, literature values, and environmental monitoring reports, ensuring a realistic representation of pollutant behavior.
4. Simulation of Longitudinal Pollutant Transport
    - The 1D model is executed over multiple time steps to analyze how sediment-bound nitrates are transported, deposited, and diluted under various hydrological conditions.
    - This step provides insights into where peak concentrations occur and how long pollutants remain in different river sections before dispersing or settling.
5. Validation Against Environmental Standards

- The simulated nitrate concentration profiles are compared with regulatory water quality thresholds to assess their impact on aquatic ecosystems and human health.
- This step helps determine whether contamination levels exceed safe limits and informs strategies for pollution mitigation and flood management.

Through this 1D conversion process, the study effectively integrates sediment transport dynamics with pollutant dispersion modeling, enabling a comprehensive assessment of water quality risks in the study area.

3. Creating a Layer to Display Sediment Transport

To effectively analyze sediment transport dynamics and their impact on hydraulic conditions, river morphology, and water quality, a sediment transport layer was developed within RAS Mapper. This layer provides a spatial representation of sediment movement throughout the river system, allowing for a more detailed assessment of erosion, deposition, and pollutant dispersion.

3.1 Sediment Concentration Visualization

The sediment concentration visualization is essential for understanding how suspended sediments are distributed over time and space. This layer enables:

- Tracking sediment concentration variations to assess changes during flood events.
- Identifying high-deposition areas where sediments accumulate, potentially leading to channel blockages or reduced water flow capacity.
- Mapping erosion-prone regions to highlight areas at risk of bank destabilization and sediment loss.

By utilizing HEC-RAS sediment transport outputs, these visualizations provide an in-depth analysis of sediment movement behavior in different flow conditions.

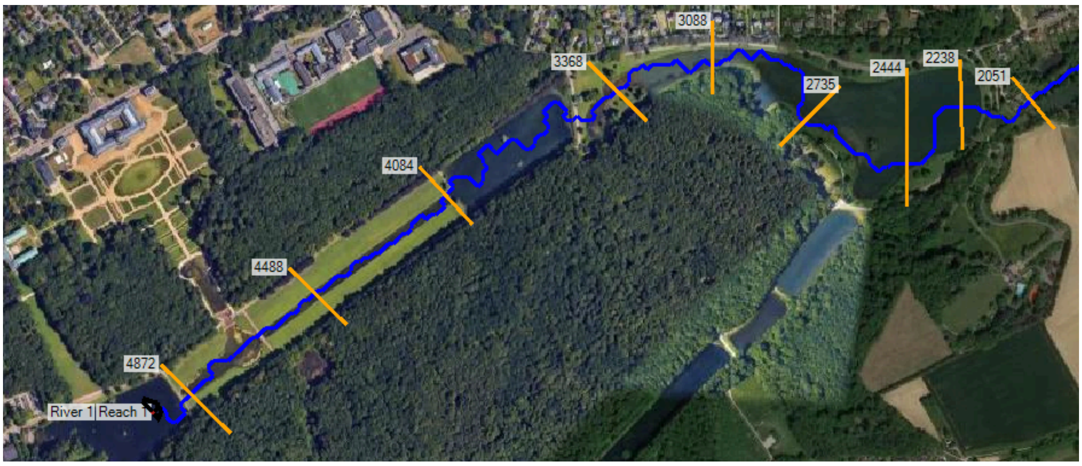

Figure 1. Created cross sections along the river.

3.2 GIS Integration for Mapping Sediment Movement

To enhance sediment transport analysis, GIS-based tools were integrated within RAS Mapper to improve visualization and interpretation. This step involved:

1. Importing Sediment Transport Data:
    - Sediment concentration outputs from HEC-RAS were imported into GIS software for further spatial analysis.
    - Layers were processed to generate time-series sediment concentration maps.
2. Overlaying Hydraulic Parameters:
    - Hydraulic properties such as flow velocity, shear stress, and water depth were incorporated to study their correlation with sediment transport.
    - This integration allowed for a more comprehensive analysis of how hydrodynamic forces affect sediment distribution.
3. Assessing the Interaction Between Sediment and Pollutants:
    - Sediment-bound pollutants (e.g., nitrates adsorbed on clay particles) were analyzed in relation to sediment movement patterns.
    - The GIS system helped in detecting pollutant dispersion pathways, which are crucial for water quality assessments.

3.3 Interpretation of Sediment Transport Patterns

By analyzing the sediment transport layer, several key findings were identified:

- Sediment accumulation hotspots were detected in low-energy zones, increasing the risk of channel aggradation and reduced floodplain drainage.
- Erosion-prone areas were observed in high-velocity sections, indicating risks to infrastructure stability and riverbank integrity.
- Pollutant dispersion trends showed that sediment-bound contaminants followed the same transport pathways as suspended sediments, reinforcing the role of sediment in water quality degradation.

These insights help predict sediment-related challenges and allow for better planning of flood management and pollution control strategies.

3.4 Implications for Environmental and Infrastructural Concerns

Understanding sediment movement and deposition patterns is critical for flood risk mitigation and maintaining river ecosystem health. The sediment transport layer provides valuable data that can be used to :

- Implement sediment control measures, such as riverbank stabilization and dredging, to prevent excessive accumulation.
- Develop flood management strategies by identifying areas susceptible to sediment-induced water level rise.
- Improve pollution mitigation efforts by tracking nitrate transport pathways and implementing best management practices (BMPs) for water quality improvement.

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By integrating sediment transport analysis with GIS-based mapping and hydraulic modeling, this study enhances our understanding of sediment dynamics in the Voer River, providing a scientific foundation for sustainable river and floodplain management.

4. Definition of Boundary Conditions

Establishing appropriate boundary conditions is essential for ensuring the accuracy and stability of sediment transport simulations. boundary conditions define how sediments enter and exit the modeled river system, influencing the overall transport dynamics and pollutant dispersion. in our report upstream and down stream boundary conditions are carefully defined to reflect real world hydrodynamic and sediment transport processes.

4.1 Hydrodynamic Boundaries (Inflow and Outflow)

The upstream boundary condition represents the sediment inflow, which is defined based on observed flow rates and sediment concentration data. This ensures that the simulation accurately captures the natural transport mechanisms occurring in the river. By incorporating real measurements, the model can replicate sediment dynamics under different hydrological conditions, including normal flow and flood events.

The downstream boundary condition is set using an equilibrium load approach, ensuring that the amount of sediment leaving the system is balanced with the upstream input. This assumption maintains a steady-state condition, preventing artificial sediment accumulation or loss at the model boundaries. The equilibrium condition is particularly important for long-term simulations, as it prevents numerical instabilities that could affect the accuracy of the results.

4.2 Pollutant Source identification

To effectively model pollutant dispersion, it is crucial to identify and define the sources of contamination within the river system. In this study, the primary focus is on nitrate pollution, which is often associated with agricultural runoff and sediment transport. Nitrate concentrations are assigned at the upstream boundary based on environmental monitoring data, ensuring that the simulation accurately represents the transport and dispersion of contaminants under different flow conditions.

4.3 Initial Sediment concentration Settings

The initial sediment concentration distribution within the river is another key factor influencing the simulation outcomes. This includes defining sediment fractions (silt, clay, sand) and their respective concentrations at various points along the river channel. These values are determined based on field measurements and literature data, providing a realistic starting point for the simulation. Proper initialization of sediment concentrations allows the model to predict how sediments interact with hydrodynamic forces, deposit in certain areas, or remain in suspension over time.

By carefully defining these boundary conditions, the model achieves a more accurate representation of sediment and pollutant transport processes. This step ensures physical

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consistency, improving the reliability of the results and supporting informed decision-making in flood risk management and water quality assessment.

5. Sediment Transport Modeling: Suspended Load and Bed Load

To effectively model sediment transport within the river system, we utilize the Wu et al. (2000) formula for transport potential. This method distinguishes between two primary modes of sediment transport:

5.1 Concentration-Only Mode in HEC-RAS

Sediment transport occurs through two key mechanisms:

- **Suspended Load:** Fine sediment particles remain in suspension due to turbulent flow and are carried downstream with the water current. These particles are primarily influenced by flow velocity, turbulence intensity, and sediment settling velocity.
- **Bed Load:** Coarser particles move along the riverbed through rolling, sliding, or saltation. The movement of bed load is controlled by bed shear stress, grain size, and riverbed slope.

Using these transport mechanisms, we can estimate the total sediment flux and determine how variations in flow conditions affect sediment movement and deposition patterns.

5.2 Transport Equations and Dispersion Mechanisms

In our HEC-RAS simulation, we chose to use the Van Rijn (1984) and Soulsby (1997) equations because they provide a more accurate and detailed representation of sediment transport compared to simpler empirical models. These formulas allow us to capture both bedload and suspended load transport, making our model more reliable in simulating erosion, deposition, and sediment dynamics under varying hydraulic conditions.

The Van Rijn equation is particularly suited for sand-dominated environments, as it differentiates between sediment moving along the bed (bedload) and sediment carried in suspension (suspended load). It considers key factors such as flow velocity, sediment size, and bed shear stress, ensuring a realistic simulation of sediment transport processes.

The Soulsby equation is ideal for coarser sediments such as gravel and mixed grain beds, where the dominant transport mechanism is through shear stress exceedance. This equation is well-suited for high-energy sections of the river, where strong flows cause significant movement of larger sediment particles.

By combining these two approaches, we ensured that our model accurately captures sediment transport variations across different river sections, preventing over- or under-estimations that could lead to unrealistic results. This dual approach provided a more precise representation of riverbed evolution, ensuring the simulation properly reflects both fine and coarse sediment transport dynamics over time.

The transport capacity for both bed load and suspended load is determined using the **Wu et al**. formula, which accounts for sediment density, water density, bed shear stress, and critical shear stress. The governing equations are:

1) Fractional Bed-Load Transport Potential:

$$q_{bk}^{*} = \begin{cases} 0.0053\sqrt{R_k g d_k^3}\left(\frac{\tau_b'}{\tau_{ck}} - 1\right)^{2.2}, & \text{for } \tau_b' > \tau_{ck} \\ 0, & \text{otherwise} \end{cases}$$

2) Fractional Suspended-Load Transport Potential:

$$q_{sk}^{*} = \begin{cases} 2.62 \times 10^{-5}\sqrt{R_k g d_k^3}\left(\frac{\tau_b}{\tau_{ck}} - 1\right)^{1.74}\left(\frac{u}{w_{sk}}\right), & \text{for } \tau_b > \tau_{ck} \text{ and } \tau_b' > \tau_{ck} \\ 0, & \text{otherwise} \end{cases}$$

where:

- q_{bk}^{*} = Fractional bed-load sediment transport potential
- q_{sk}^{*} = Fractional suspended-load sediment transport potential
- $R_k = \frac{\rho_{sk}}{\rho_w} - 1$ = Submerged specific gravity of a particle
- ρ_{sk} = Sediment density
- ρ_w = Water density
- τ_b = Bed shear stress
- τ_b' = Skin bed shear stress
- τ_{ck} = Critical shear stress
- d_k = Sediment diameter

These equations define how sediment transport occurs under varying flow conditions. Bed shear stress plays a crucial role in determining whether sediment particles remain stationary, are transported as bed load, or become suspended.

5.3 Comparison of Suspended vs. Bed Load Transport

The choice between modeling suspended or bed load transport depends on sediment properties and river dynamics. In high-energy environments, suspended load transport dominates, as fine particles remain in motion over long distances. In contrast, in low-energy zones or during lower flow conditions, bed load transport becomes more significant, leading to sediment deposition.

By applying the **Wu et al**. transport equations in HEC-RAS, this study aims to quantify sediment fluxes, predict deposition patterns, and assess how sediment transport influences water quality through the redistribution of pollutant-bound particles.

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6. Pollution

6.1 Nitrate Concentration Adsorbed on Clay Particles

One of the primary concerns in sediment transport studies is the ability of fine sediments, particularly clay, to act as carriers for pollutants such as nitrates. Due to their large surface area and high adsorption capacity, clay particles can bind with dissolved nitrates, influencing the spatial and temporal distribution of contaminants within the river system. Understanding this process is crucial for assessing water quality risks, particularly in agricultural regions where nitrate pollution is a common issue.

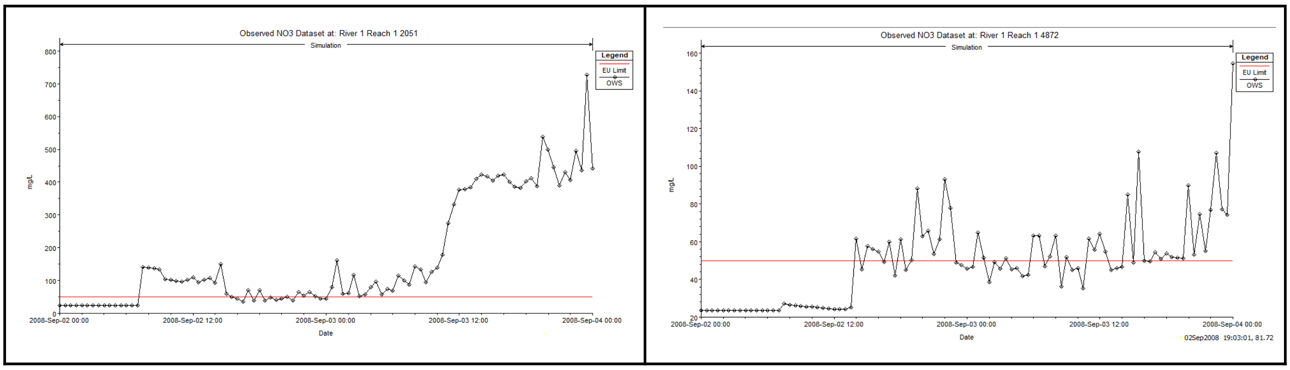

Figure 2 and 3. Observed nitrate concentrations at cross section 2051 and 4872, respectively.

In this study, the focus is on three key aspects of nitrate transport and adsorption:

1. Initial Nitrate Concentration in the River
    - The baseline nitrate concentration in the Voer River was set at 23.7 mg/L, representing the typical nitrate levels observed in the study area.
    - This value serves as an input for water quality modeling, allowing us to track how nitrate levels fluctuate under different flow and sediment transport conditions.
2. Adsorption of Nitrates onto Clay Particles
    - Fine-grained sediments, such as clay, have a high affinity for adsorbing nitrates, affecting their movement within the river.
    - Adsorption rates are influenced by sediment concentration, water chemistry, and flow velocity, determining how much nitrate remains suspended versus how much is deposited.
3. Transport and Dispersion of Nitrates in Response to Sediment Dynamics
    - The dispersion of nitrate-laden sediments follows hydrodynamic forces, with peak transport occurring during high-flow conditions such as floods.
    - Areas with high sediment deposition may act as long-term nitrate storage zones, leading to gradual leaching back into the water column over time.

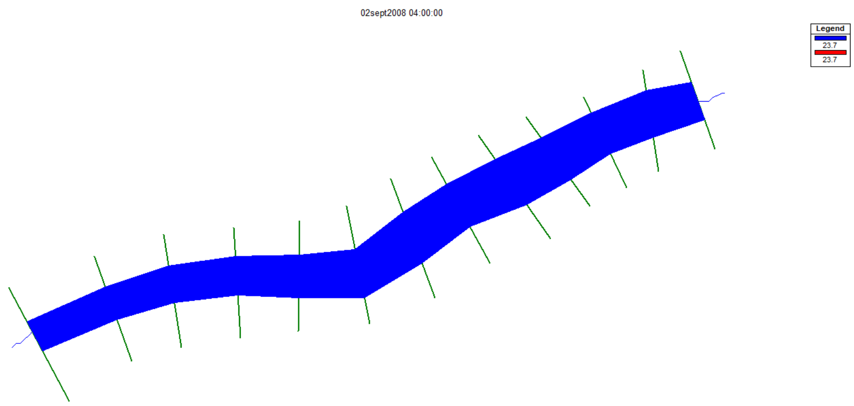

Figure 4. Animated representation of nitrate mass injection (100 kg), cross section 1-13 from left to right.

By analysing sediment-nitrate interactions, we can better understand how agricultural runoff, wastewater discharge, and other pollution sources contribute to water quality deterioration in the river basin. This knowledge is essential for designing effective mitigation strategies, such as riparian buffer zones, sediment control measures, and improved agricultural practices, to reduce nitrate pollution and its associated environmental impacts.

6.2 Impact of Nitrate Pollution

Nitrate pollution is a serious issue that poses a risk to humans and the environment. Nitrates are used in agriculture, leeches of nitrates into the environment primarily result from excessive fertilizer application and manure runoff. When nitrogen-based fertilizers are overapplied or improperly managed, nitrates can leach into groundwater or be carried by surface runoff into nearby rivers and streams.

This influx of nitrates can disrupt aquatic ecosystems, contributing to eutrophication—a process where excessive nutrients lead to the overgrowth of algae. Algal blooms can deplete oxygen levels in the water, leading to anoxic conditions that threaten fish and other aquatic organisms.

High nitrate concentrations in drinking water sources pose health risks to humans, studies have shown that ingestion of nitrate from drinking water can cause medical issues, including, but not limited to, cancer, birth defects and thyroid problems.

The Nitrates directive requires EU Member States to monitor the quality of waters and to identify areas of vulnerability. These concern waters that are eutrophic or contain a concentration of more than 50 mg/l of nitrates, these areas are identified as Nitrate Vulnerable Zones (NVZs). The Nitrates Directive ensures that EU countries must; designate NVZs, establish codes of good agricultural practice to be implemented by farmers, establish action programmes to be implemented by farmers within NVZs, limit the application of nitrogen from manure, and, to identify polluted water or waters at risk.

Purifying excess nitrates from water is a costly process, methods for nitrate removal include ion exchange, reverse osmosis, and biological denitrification. Ion exchange uses resins to replace nitrate ions with chloride, while reverse osmosis filters out nitrates through a semi-permeable membrane. Biological denitrification, often used in wastewater treatment, relies on bacteria such as Ammonium Oxidising Bacteria to convert nitrates into nitrogen gas. Preventive measures, such as reducing fertilizer runoff and improving wastewater management, also help minimize nitrate contamination at the source.

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Flooding significantly exacerbates nitrate pollution by mobilizing and transporting large amounts of nitrogen from agricultural fields, urban areas, and wastewater sources into water bodies. Heavy rainfall and rising water levels wash excess fertilizers, manure, and other nitrogen-rich materials into rivers, lakes, and groundwater, increasing nitrate concentrations. This sudden influx can overwhelm natural filtration processes and water treatment systems, leading to contamination of drinking water supplies and promoting harmful algal blooms. Additionally, prolonged flooding can disrupt soil microbial activity, reducing the capacity for natural denitrification, which would otherwise help convert nitrates into nitrogen. As climate change intensifies extreme weather events, managing nitrate runoff through improved land use practices, buffer zones, and floodplain restoration becomes increasingly crucial.

In 2024 Belgium was referred to the court of justice of the EU for failing to take insufficient action on nitrate pollution in the Flemish Region, pollution of ground and surface waters has worsened significantly in this region and the waters are said to be amongst the most polluted in the EU. Reports show successive Flemish nitrate action programmes have failed to deliver results and that pollution levels remain excessively high, risking human life and the environment. This highlights the necessity of taking appropriate action in this area to assess nitrate levels and reduce nitrate pollution.

6.3 Relationship Between Sediment Transport and Pollutant Dispersion

Sediment transport plays a critical role in the movement and dispersion of pollutants within river systems. As fine-grained sediments, particularly clay and silt, travel through the water column, they act as carriers for contaminants, including nitrates, heavy metals, and organic pollutants. Understanding the interaction between sediment dynamics and pollutant transport is essential for assessing the long-term impact on water quality, aquatic ecosystems, and flood management strategies.

Modeling Sediment-Pollutant Interaction in HEC-RAS

To assess the relationship between sediment transport and pollutant dispersion, HEC-RAS was used to:

- Track suspended sediment movement and identify high-deposition and erosion zones.
- Simulate nitrate adsorption and transport under different hydrodynamic conditions.
- Compare pollutant concentration levels across different sediment transport scenarios.

7. Interpretation of Results

The sediment transport simulation results provide key insights into the movement of sediments, their role in pollutant dispersion, and their impact on water quality. Since HEC-RAS does not provide a direct visualization of how sediment transport evolves over time, the results are primarily analyzed using cross-section profiles. These profiles allow for a detailed examination of sediment concentration changes at specific locations along the river, helping to identify critical trends in erosion, deposition, and nitrate transport.

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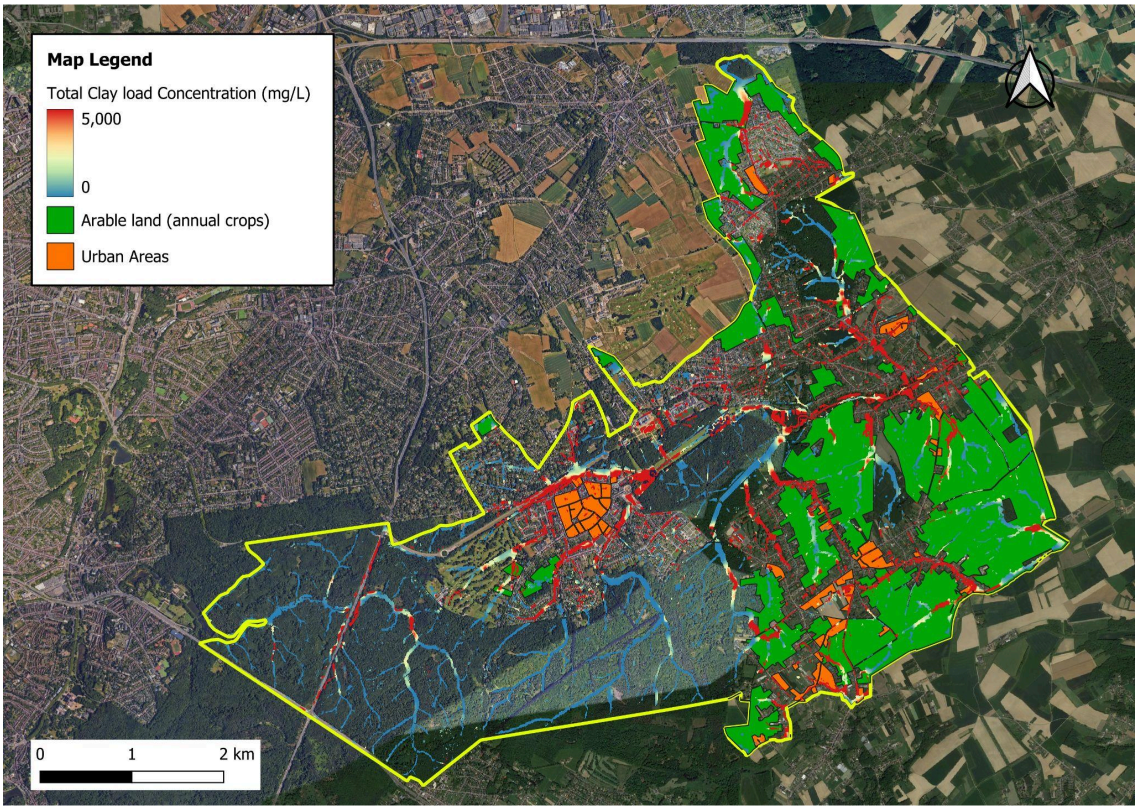

Figure 5. Map of Tervuren catchment.

7.1 Analysis of Sediment Movement Patterns

The cross-section profiles generated from the simulation help track sediment transport dynamics at various river sections. The analysis revealed:

- Variability in transported sediment loads, with higher concentrations observed in areas with strong flow velocity and turbulent mixing.
- Deposition zones forming in low-energy regions, where fine sediments settle, potentially trapping pollutants over time.
- Increased suspended sediment concentrations during high-flow events, particularly after heavy rainfall and flood surges, leading to widespread redistribution of sediments.

Understanding these patterns is crucial for predicting sediment accumulation zones and assessing the long-term impact on river morphology and flood risks.

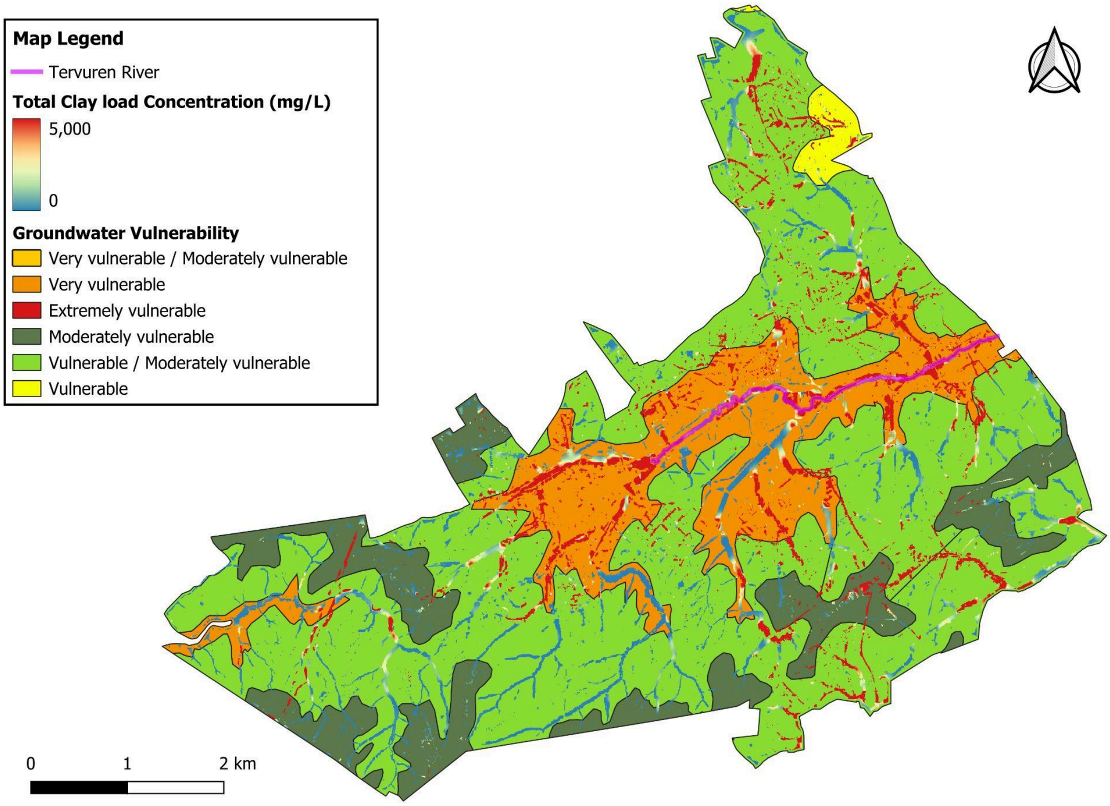

Figure 6. Created Map representing the clay load distribution in vulnerable groundwater areas.

7.2 Pollutant Distribution Across the River System

A key aspect of sediment transport analysis is evaluating its impact on pollutant movement, particularly nitrates adsorbed onto fine sediments. The simulation results demonstrated that:

- Nitrate concentrations varied significantly depending on sediment transport intensity, with higher levels observed in areas experiencing strong sediment movement.
- Pollutant accumulation occurred in depositional zones, increasing the risk of long-term water quality degradation.
- During peak sediment transport events, nitrate dispersion intensified, suggesting that flood conditions play a major role in pollutant spread.

By analyzing sediment-pollutant interactions, we can better understand how land use activities (such as agriculture and urban runoff) influence water quality and develop targeted pollution control strategies.

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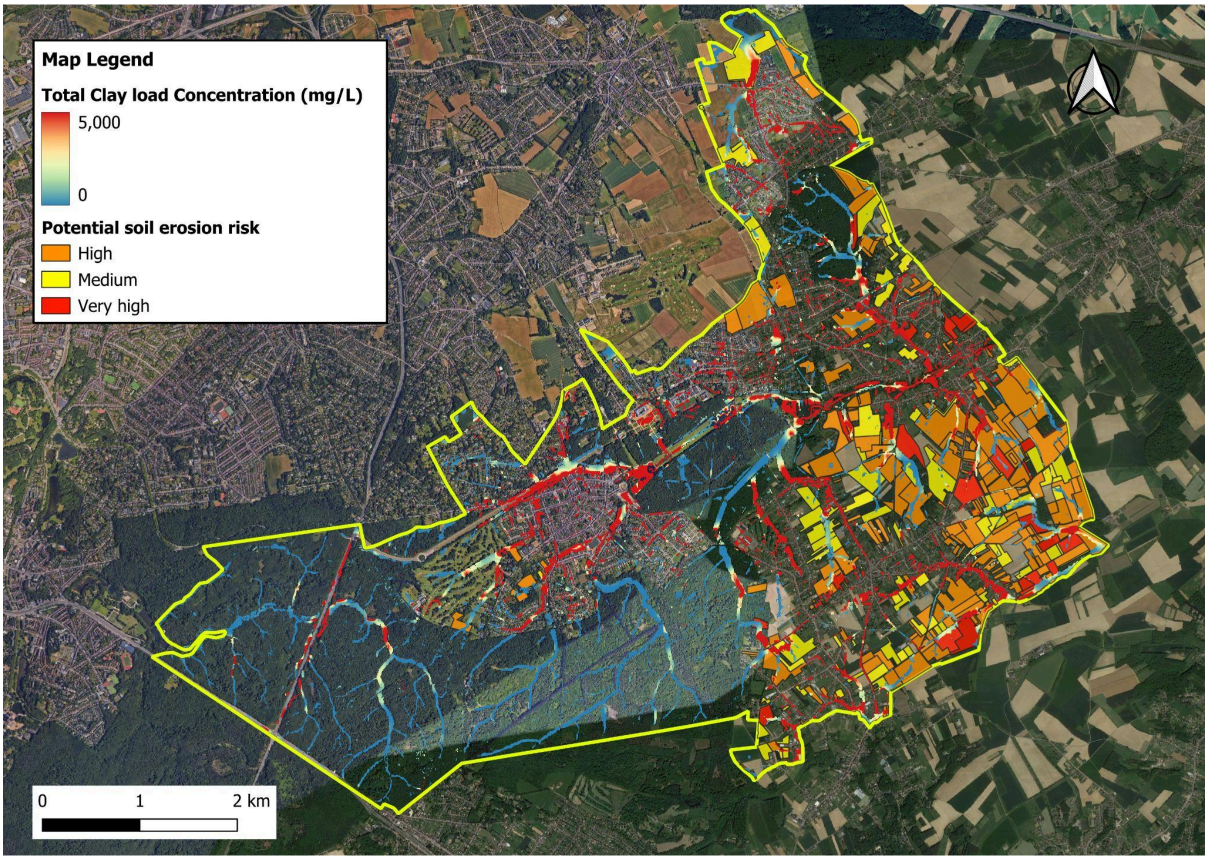

Figure 7. Map illustrating clay load distribution in erosion-prone areas.

7.3 Impact of Flood Events on Water Contamination

Flood events were identified as major drivers of sediment mobilization and pollutant dispersion. The simulations revealed that:

- Heavy rainfall increased sediment transport rates, leading to a surge in suspended sediment-bound pollutants.
- High-velocity floodwaters resuspended deposited sediments, releasing previously trapped contaminants back into the water column.
- Prolonged flood conditions contributed to sustained high nitrate levels, extending the duration of water quality degradation beyond the initial flood event.

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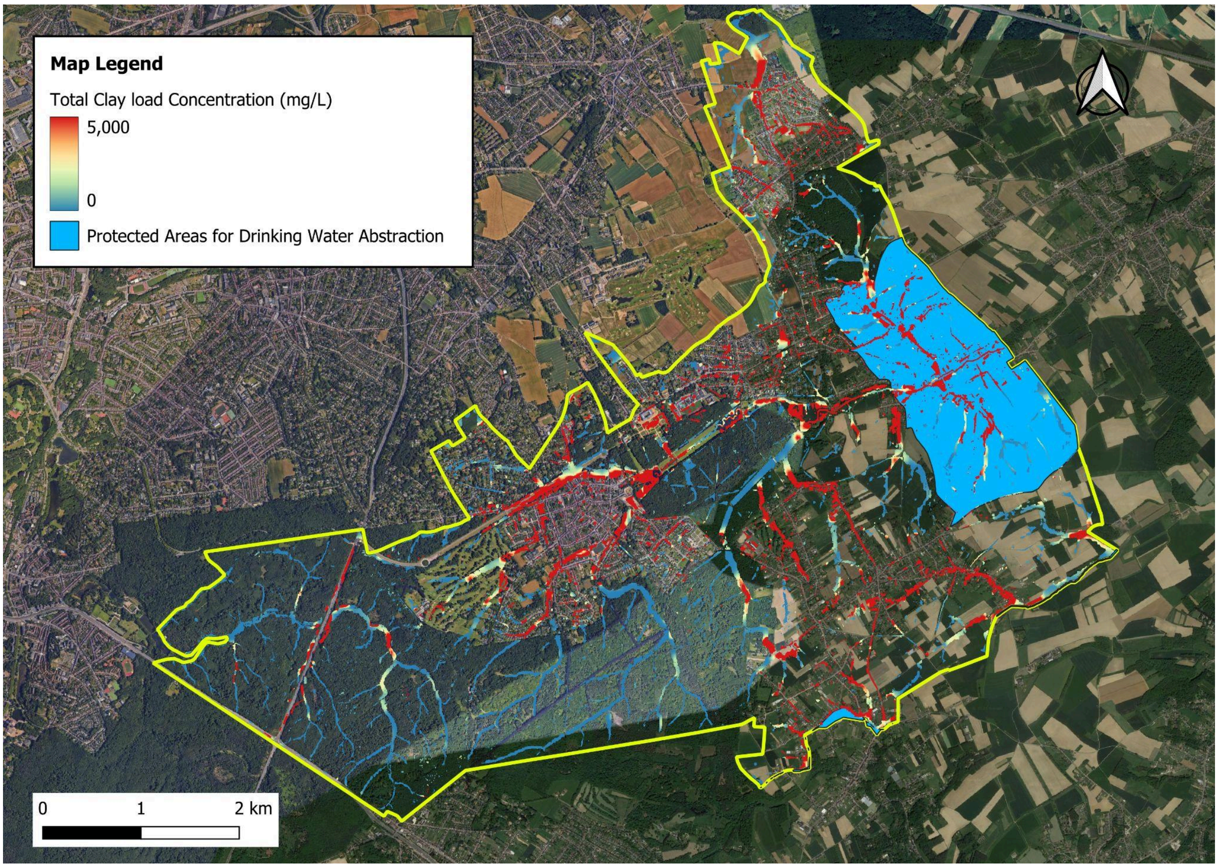

Figure 8. Map illustrating the distribution of clay load in protected drinking water areas.

These findings highlight the importance of integrating flood risk management with water quality protection measures, ensuring that sediment and pollution control strategies are designed to mitigate flood-induced contamination.

8. Issues Encountered and Solutions Implemented in the HEC-RAS Simulation

During our HEC-RAS simulation, we encountered several challenges related to the stability of the hydraulic model and the accuracy of the results. These issues were mainly due to numerical instabilities, poor interpolation between cross sections, and connection errors between different model entities. To improve the robustness and reliability of the simulation, we applied several adjustments.

8.1. Numerical Instability and Time Step Adjustment

One of the critical errors we faced was the failure of the numerical solver ("ERROR: Solution Solver Failed"). This issue arose due to instability in hydraulic calculations, primarily caused by an excessively large time step. When the time step is too large, rapid variations in flow and water level are not accurately captured, leading to excessive deviations in results and making the model unstable.

To address this problem, we progressively reduced the time step based on the CFL (Courant-Friedrichs-Lewy) condition, which ensures that water does not travel more than one cell or cross section per time step. This correction significantly improved the model's stability and ensured better accuracy in the results.

8.2. Excessive Interpolation and Cross Section Adjustment

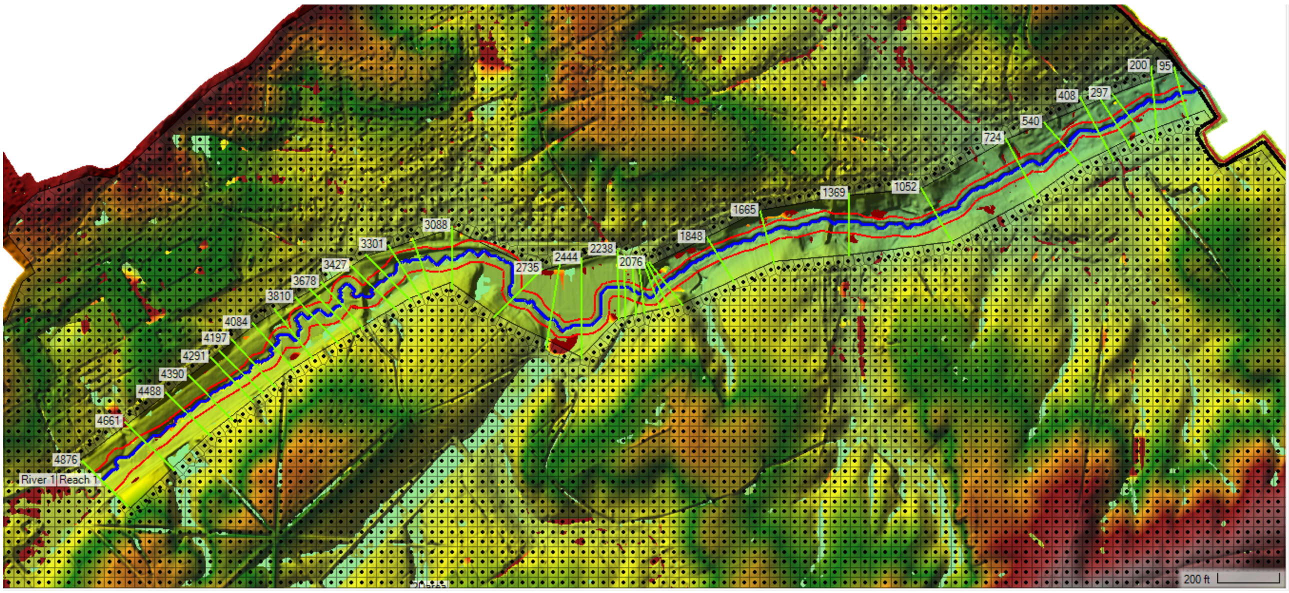

Figure 9. Cross section

Another major issue was the poor distribution of cross sections. We observed that some cross sections were too far apart, particularly in areas with steep slopes or rapid changes in terrain. This setup caused excessive interpolation between cross sections, which could distort water depth and velocity calculations.

To fix this, we increased the number of cross sections in critical areas, thereby reducing the spacing between them. This modification helped to avoid uncontrolled extrapolation and provided more accurate results, especially in sections where flow and topography change rapidly.

8.3. Fixing Connection Errors Between 1D and 2D Entities

In our 1D/2D coupled model, we also encountered errors related to connections between different hydraulic entities, including the warning "Cross Sections Require Edge Line Intersection". This message indicates that some cross sections were not correctly intersecting the edge lines of the 2D domain, which could prevent proper flow transfer between different model areas.

To resolve this issue, we manually verified and adjusted the connection points between cross sections and edge lines. We also used HEC-RAS's "Check Geometry" tool to identify and fix any remaining anomalies. By refining these connections, we ensured proper hydraulic exchange between the 1D and 2D domains, avoiding simulation errors.

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8.4. 2D Mesh Adjustment for Better Stability

Finally, we identified that some instabilities were also linked to the size of the 2D mesh. A coarse mesh can prevent water from spreading correctly, while an excessively fine mesh can increase computation time and cause numerical oscillations.

To enhance stability, we refined the 2D mesh in critical areas, particularly where water level and velocity variations were significant. We also avoided excessively small cells that could unnecessarily slow down calculations without providing a substantial accuracy gain. This optimization allowed us to better capture flow behavior while maintaining a good balance between precision and computation time.

9. Conclusion and future work!

The study successfully demonstrated how sediment transport modeling can be used to analyze pollutant dispersion and assess water quality risks within a flood-prone river system. By utilizing HEC-RAS in "Concentration Only" mode, we were able to track sediment-bound nitrate transport, evaluate flood-induced contamination, and identify critical areas for sediment deposition and erosion. The findings provide valuable insights for flood risk management, pollution control strategies, and hydrodynamic modeling improvements.

9.1 Summary of Findings

The key outcomes of the report for last week works include:

- Sediment Transport and Water Quality: The simulation results confirmed that suspended sediments play a significant role in nitrate dispersion, with higher pollutant concentrations observed in areas of intense sediment movement.
- Impact of Flood Events: Flood conditions were found to mobilize large quantities of sediment-bound pollutants, increasing contamination risks in downstream areas.
- Limitations of 1D Modeling: The conversion from 2D to 1D modeling provided a practical solution for water quality analysis but also introduced some simplifications that may require further validation.
- Technical Challenges: Several modeling issues were encountered, including numerical instability, cross-section interpolation errors, and 1D/2D connection problems, all of which were addressed through model refinements and stability improvements.

These findings highlight the importance of integrating sediment transport analysis into flood and water quality management efforts to improve pollution monitoring, risk assessment, and decision-making.

9.2 Recommendations for Model Improvement

To enhance the accuracy and reliability of future simulations, several improvements can be made:

- Refinement of 2D Water Quality Modeling: Since HEC-RAS does not support direct 2D pollutant dispersion simulations, future studies could explore the use of external GIS-based

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tools or hydrodynamic models (e.g., Delft3D, MIKE 21) for a more detailed 2D pollutant transport analysis.
- Improved Sediment-Pollutant Interaction Modeling: Incorporating adsorption-desorption kinetics into the model would provide a more realistic representation of how pollutants interact with sediments under different flow conditions.
- Enhanced Calibration Using Field Data: Conducting on-site water quality sampling to measure actual nitrate concentrations and sediment loads would allow for better validation of model predictions.
- Higher-Resolution Mesh for Complex Flow Areas: Further refining the 2D mesh in critical zones could improve hydraulic accuracy, especially in areas with rapid flow transitions or high sediment transport rates.

By implementing these enhancements, future studies can achieve more precise water quality predictions, supporting better flood mitigation and pollution control strategies.

9.3 Final Remarks

By integrating sediment transport modeling with water quality analysis, this study demonstrates the complex relationship between flooding, sediment movement, and pollutant dispersion. The findings emphasize the urgent need for improved sediment and pollution management strategies to mitigate flood-related contamination risks and support sustainable water resource management.

Future research should focus on enhancing model accuracy, incorporating real-world field data, and expanding 2D pollutant transport capabilities to provide even more robust assessments for environmental decision-making.

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