

# Chapter 4

## Cartography and Geovisualization in Groundwater Modelling

**E. Cascelli**

*Saipem SpA (ENI), Italy*

**E. Crestaz**

*Saipem SpA (ENI), Italy*

**F. Tatangelo**

*Saipem SpA (ENI), Italy*

### ABSTRACT

*This chapter investigates role of cartography and geovisualization in quantitative hydrogeology and groundwater modeling processes, stressing, further to their communication role, their relevant impacts on cognitive processes in the framework of a spatial exploratory paradigm. Review of current methods and tools reveal a very fragmented framework with an undesired prevalence of loose coupling strategies among spatial databases, GISs, and advanced analysis and groundwater modeling environments. This approach leads to both technical (as data integrity failure and exponentially increased development times) and management effectiveness problems. Case studies, focused on water supply at regional scale and groundwater flow containment for environmental remediation, document both benefits and shortcomings of current practice, including advanced issues as 3D and time-dependent analysis. Definitely, following current trends in GIScience towards standardization and interoperability, requirements for seamless integration of different approaches and tools are further stressed.*

### INTRODUCTION

Most developed areas in the world are affected by relevant environmental pressure due to large urban and industrial settlements, imposing high rates of groundwater exploitation, with increasing risks of contamination, further to salinization of aquifer

systems along coastal areas, due to groundwater overexploitation (Kresic, 2009). Other remote areas in dry climates, often exposed to humanitarian crises and regional conflicts for resources control (Ward, 2001), suffer from major water shortages with relevant impacts on economy and human life (Dosi, 2001; FAO, 2010; UN WATER, 2010).

DOI: 10.4018/978-1-4666-1924-1.ch004

Quantitative hydrogeology (de Marsily, 1986) and groundwater modelling provide a relevant contribution to water availability and quality assessment, supporting groundwater systems interpretation and conceptualization, definition of water exploitation and protection strategies, assessment of integrated environmental policies.

GIScience and related disciplines, as ViSC (Visualization in Scientific Computing), integrate the overall framework by providing sound theoretical basis for effective data management, analysis and communication, with a specific focus on well designed cartography and geovisualization, addressing advanced 3D and time dependent issues from an ESDA (Exploratory Spatial Data Analysis) perspective.

Different proprietary groundwater modeling systems, such as Visual MODFLOW (Schlumberger Water Services, 2010), GMS (Aquaveo, 2010) and FEFLOW (DHI-WASY GmbH, 2010), integrate finite difference and/or finite element numerical codes within pre- and post-processing environments, addressing requirements for model implementation and calibration, as well as advanced visualization. Generally loosely-coupled with third party (geo)database, as Groundwater Hydro Data Model (CRWR, 2010; Maidment, 2002; Strassberg & Maidment, 2003) and HydroGeo Analyst (Schlumberger Water Services, 2010), and standard GIS platforms, i.e. ArcGIS (ESRI, 2010), these systems address complex issues as 3D and time-dependent (for transient simulations) visualization, including 2D slicing, 3D fence diagrams, iso-surfaces, pathlines and animation.

Based on lessons-learned in the framework of various projects, which since early 90ies have been focused on regional water management for water supply (Crestaz et al., 1995a; Catani et al., 1996; Adamés et al., 2002) and local scale groundwater flow containment for environmental remediation (Crestaz et al., 1995b, 2008; Amadei et al., 2003), current paper briefly reviews cartography and, geovisualization theory, methods and tools in

the context of hydrogeological and groundwater modeling applications.

Based on review of cartography and geovisualization impact in various projects, which since early 90ies have been focused on regional water management for water supply (Crestaz et al., 1995a; Catani et al., 1996; Adamés et al., 2002) and local scale groundwater flow containment for environmental remediation (Crestaz et al., 1995b, 2008; Amadei et al., 2003), current paper investigates both benefits and shortcomings in current practice, addressing main lessons-learned.

## **BACKGROUND**

Time has gone, when textual data sources were the only mean to import/export data to/from numerical codes. Pre- and post- processing tools of late 80ies (Kinzelbach, 1986) have been soon evolved towards integrated modelling systems, providing mapping facilities, visualization of 3D conceptual models, supporting advanced features as slicing and fence diagrams visualization, further to animation for inspection and effective communication of complex transient simulations to experts and non-expert public.

Implementation times were cut of order of magnitude, as the expert was not anymore obliged to go through the files, line by line, to update hydrological properties or to check output, nor to export data to external packages (as spreadsheets, contouring tools) to perform even elementary spatial data analysis and visualization tasks. As most modelling packages became more user-friendly, they also spread from research domain to real-world applications.

The many practical benefits of integrated modelling systems were soon perceived by the modelling community, face to increasing requirements for integration with traditional data sources, stored to spatial databases and Geographical Information Systems (GISs), supporting more effective data mining, analysis of huge amounts of data, build-

17 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

[www.igi-global.com/chapter/cartography-geovisualization-groundwater-modelling/69048](http://www.igi-global.com/chapter/cartography-geovisualization-groundwater-modelling/69048)

## Related Content

---

### Collaborative 3D Modeling: Conceptual and Technical Issues

Rafika Hajji and Roland Billen (2016). *International Journal of 3-D Information Modeling* (pp. 47-67).

[www.irma-international.org/article/collaborative-3d-modeling/177240](http://www.irma-international.org/article/collaborative-3d-modeling/177240)

### The Landscape Cultural Construction: A Recognition of the Roman Tradition

Isabel Sousa Rosa, Joana C. Lopes and Ricardo J. Ribeiro (2016). *Geospatial Research: Concepts, Methodologies, Tools, and Applications* (pp. 142-168).

[www.irma-international.org/chapter/the-landscape-cultural-construction/149492](http://www.irma-international.org/chapter/the-landscape-cultural-construction/149492)

### Cognitive Maps

Stephen Hirtle (2009). *Handbook of Research on Geoinformatics* (pp. 58-64).

[www.irma-international.org/chapter/cognitive-maps/20387](http://www.irma-international.org/chapter/cognitive-maps/20387)

### Mapping Gated Communities: An Empirical Assessment of Wikimapia Data Quality

Zia Salim (2020). *International Journal of Applied Geospatial Research* (pp. 48-67).

[www.irma-international.org/article/mapping-gated-communities/257770](http://www.irma-international.org/article/mapping-gated-communities/257770)

### An Integrated Heuristic Approach for the Long-Distance Heterogeneous Vehicle Routing Problem

Mehmet Sevkli, Abdullah S. Karaman, Yusuf Ziya Unal and Muheeb Babajide Kotun (2021). *Interdisciplinary Approaches to Spatial Optimization Issues* (pp. 20-48).

[www.irma-international.org/chapter/an-integrated-heuristic-approach-for-the-long-distance-heterogeneous-vehicle-routing-problem/279248](http://www.irma-international.org/chapter/an-integrated-heuristic-approach-for-the-long-distance-heterogeneous-vehicle-routing-problem/279248)