Toward an Integrated Surface and Subsurface Water Ontology

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Scientific and societal drivers

- **Integrating surface water and groundwater**
  
  Water budgets: reporting units are ‘surface water basin’ + ‘groundwater body’

  - Increase in regulations to develop water budgets
  - ~25% of Canadian rely on groundwater (StatsCan 2010)
Technologic drivers

- **SDI**: a promising approach to deliver data for water budgeting

  numerous distributed, heterogeneous data sources
  emerging, competing water data standards, e.g. ‘groundwater body’
Semantic heterogeneity

- what’s a ‘groundwater body’

  specific amount of **matter** or the **object** composed of the matter?

  - e.g. water body of the Ogallala aquifer is a timeless object but its water matter (slowly) changes over time

  - water quality issue: the matter travels, object is fixed

  - water quantity issue: the matter disappears (dry river), object persists

  fills a **void**?

  - water quantity and quality issue: size and connection of voids constrains quantity and flow

**INSPIRE**

  object or matter?

  no voids

**GWML**

  object

  object fills voids

- **use reference concepts for disambiguation**
Types of reference ontologies

- **science ontologies**: non-contextual focus

**Foundational (general)**
- matter
  - constitutes objects

**Domain (essential)**
- granite
  - fixed constitution
  - varying texture
  - can have cracks
- countertop granite
  - larger crystals
  - non-porous (no cracks)

**Task/Application (contextual)**
- physical object
  - constituted by matter
- water body
  - can be constituted by water
  - can be connected
  - can have human uses
- Spanish River
  - can be dry (no water)
  - may not connect
  - not navigable
- German River
  - has water
  - connected
  - navigable

(Matter constitutes objects)
Inland Water Ontologies... many

▪ **Surface Water Features**
  - lake vs pond, river vs stream? UK Ordinance Survey
    (Santos et al. 2005; Hart et al. 2007)

▪ **Measured Properties**
  - stream flow, level, arsenic, evapotranspiration: CUAHSI
    (Bermudez & Piasecki, 2003; Beran & Piasecki, 2009; Privesetev et al.)

▪ **Events and Processes**
  - floods, flow: ‘water falls but waterfall doesn’t’ (Galton & Mizoguchi, 2009)

▪ **Hydrogeology**
  - aquifer, groundwater body, well: SWEET
    (Tripathi & Babaie, 2008; Brodaric & Probst 2009)

▪ **Schema: Surface and Subsurface**
  - OGC WaterML, GWML, HydroFeatures; INSPIRE GE
Elements of essential hydro ontology

- **contrast concepts**: different natural situations for gw & sw
- **boundary concepts**: bridge between gw & sw, e.g. flow
- **common concepts**: shared container concepts for gw & sw

![Diagram showing elements of essential hydro ontology](image)
Essential common concepts

- container schema for water

Essential common concepts

- applied to surface water and groundwater

- container
- container
- matter
- object
- water flow
- void
- water body
- object
- water matter

Ontology for Groundwater and Surface Water
Brodaric, Ontology, 01 Nov 2012
DOLCE: boundary, shared, contrast concepts

- **perdurant**
  - process
    - water flow
  - amount of matter
    - rock matter
    - water matter
- **endurant**
  - physical object
    - water body
    - aquifer
  - feature
    - ground depression
    - river
- **quality**
- **volume**
- **has quality**
- **participation**
- **hosting**
- **flow**
- **matter**
- **container**
- **void**
- **body of ground**
- **surface water basin**
Voids

- **holes** (Casati & Varzi, 1994)
  - depressions, cavities, tunnels
  - formal logical theory (FOL)
  - **no gaps:** suitable for surface water but not groundwater
- **gaps** (Hahmann & Brodaric, 2012)
  depressions, cavities, tunnels
  formal logical theory (FOL)
  suitable for ontology of pores in rocks

- cavity
- depression
- tunnel
Voids

- voids: generalize holes and gaps

need containment relations with voids (‘inside a hole’)

\[(V9) \text{hosts-} h(x, y) \equiv \text{hosts-} v(x, y) \land ICon(x) \quad \text{(non-scattered host of a void)}\]

\[(\text{Hole-D}) \quad \text{Hole}(y) \equiv \exists x[\text{hosts-} h(x, y)] \quad \text{(hole has a non-scattered host)}\]

\[(V10) \text{hosts-} g(x, y) \equiv \text{hosts-} v(x, y) \land \neg ICon(x) \quad \text{(scattered host of a void)}\]

\[(\text{Gap-D}) \quad \text{Gap}(y) \equiv \exists x[\text{hosts-} g(x, y)] \quad \text{(gap has a scattered host)}\]

\[(V-T2) \quad V_S(x) \leftrightarrow \text{Gap}(x) \lor \text{Hole}(x) \quad \text{(gap and hole exhaustive classes of simple voids)}\]
Tiered hydro ontology

- **perdurant**
  - process
    - water flow
- **endurant**
  - amount of matter
    - rock matter
    - water matter
  - physical object
    - water body
    - aquifer
  - feature
    - ground depression
    - void
- **quality**
- **volume**
- **has quality**
- **participation**
- **contains**
- **hosting**
- **inside**
- **Contextual**
  - INSPIRE gw body
  - GWML gw body
  - surface water basin
  - Spanish river
  - German river
- **Foundational**
  - body of ground
  - river
  - hole
  - gap
Conclusions

- progress on reference hydro ontology that integrates surface and groundwater entities
- includes expanded ontology of voids and some topological relations
- foundational and essential domain ontologies can help:
  - disambiguate conceptual differences in emerging SDI standards
  - inform SDI data standards design

Thank you!