A Primer on the Hydro Foundational Ontology (HyFO)

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HyFO is joint work with:

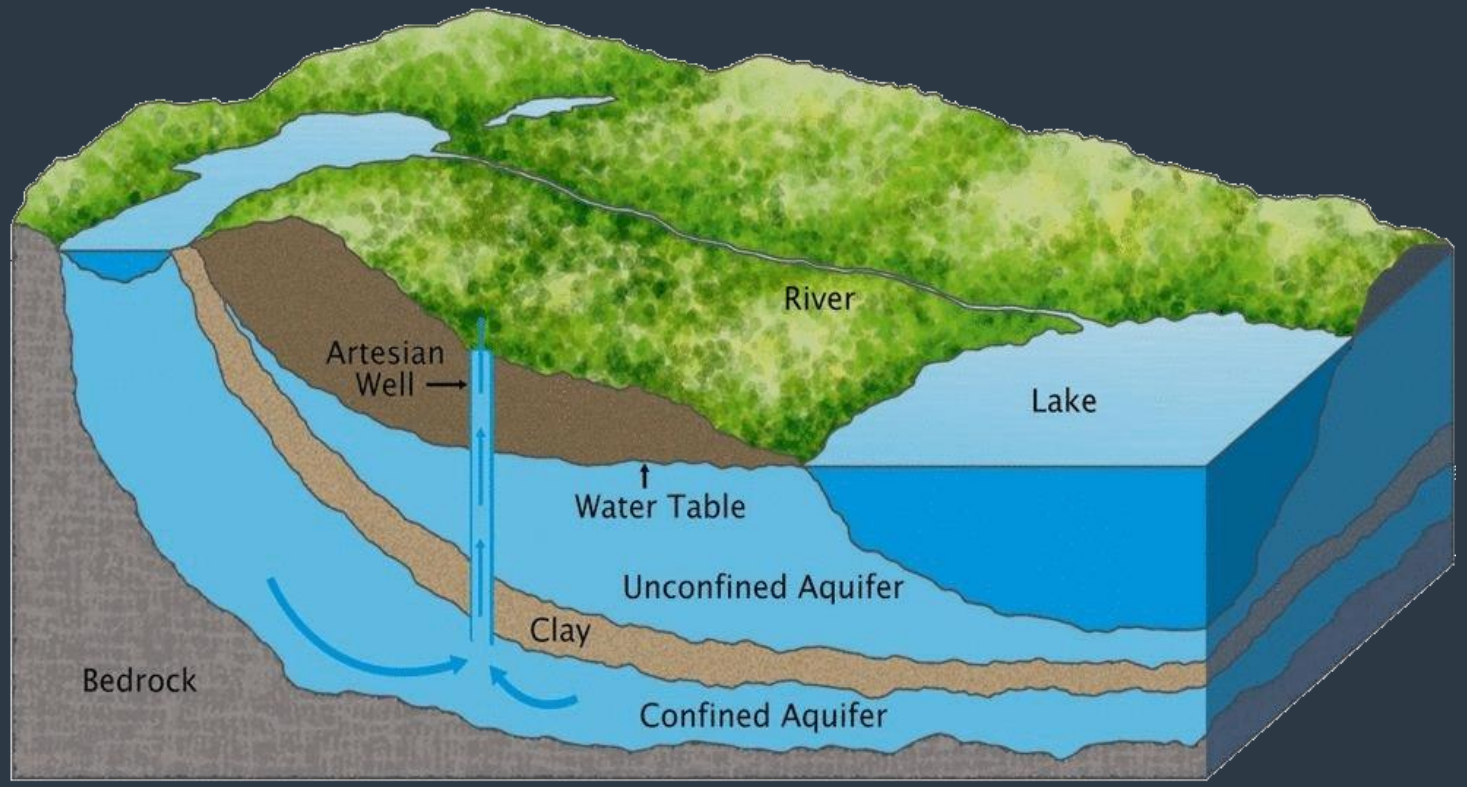
- **Boyan Brodaric, Geological Survey of Canada**
- **Michael Gruninger, University of Toronto**
- Shirly Stephen, PhD student
  - Work on GWML2 integration
  - Modeling of flow processes

- Incorporates aspects from the GWML2 (Groundwater Markup Language) and, indirectly, GeoSciML
- Also informed by discussions with GeoVoCamp participants on related topics:
  - Depression landforms, surface water pattern

Outline

- ❑Core HyFO concepts
- ❑Core HyFO relations
- ❑Water Features as central category of hybrid objects
    - ❑Do Glaciers fit into this category?
- ❑Flow Processes

HyFO: A domain reference ontology for the water domain



- ❑ Identify core concepts in the water domain
- ❑ Identify physical and spatial relationships
- ❑ Investigate their ontological nature
- ❑ Axiomatize them in first-order logic as extension of the DOLCE top-level ontology

HyFO: A domain reference ontology for the water domain

- Exhibits many characteristics of foundational ontologies: ***foundational for their domain***
  1. Foundationally grounded
  2. Broad coverage on the highest level in the domain: focuses on the **key concepts and relations** in the domain; but does not aim to capture the domain comprehensively
  3. Specified in a highly expressive and fully machine-interpretable ontology language
     - Provides “neutral” language to express semantic differences; Purpose is not to directly define the scientific terms (e.g. aquifer), but ontological helper concepts and relations

Core Concepts

Container Object

The object that contains water, e.g., a riverbed, or an aquifer's rock body.

Container Solid Body (CSB) [1-5]

Void

Space(s) in the container that can be filled with water, e.g., pores in an aquifer, a channel or depression.

Hydro Void (HV) [1]

Water Feature (WF) / Hydro Rock Body (HRB) [3,4,5]

Dependent Hydrologic Features (DHF) [5]

Matter

Material that constitutes a container or water object, e.g., solid rock matter, water matter.

Matter (M) [1,2,4]

Water Object

The physical object that is constituted of water matter.

Water Body/ Object (WB/WO) [1,2,4]

[1] Hahmann and Brodaric. "The Void in Hydro Ontology." FOIS 2012.
[2] Brodaric and Hahmann. "Toward a foundational hydro ontology for water data interoperability." HIC 2014.
[3] Hahmann, Stephen, and Brodaric. "Semantically Refining the Groundwater Markup Language (GWML2) with the Help of a Reference Ontology." GIScience 2016.
[4] Brodaric, Hahmann and Gruninger, "Water Features and Their Parts." Manuscript under review.
[5] Hahmann and Stephen. "Using a Hydro Reference Ontology to Provide Improved Computer-Interpretable Semantics for the Groundwater Markup Language (GWML2)." Manuscipt under revision for publication in Int. Journal of Geographic Information Science (IJGIS).

Physical Relations between Concepts

Container Object

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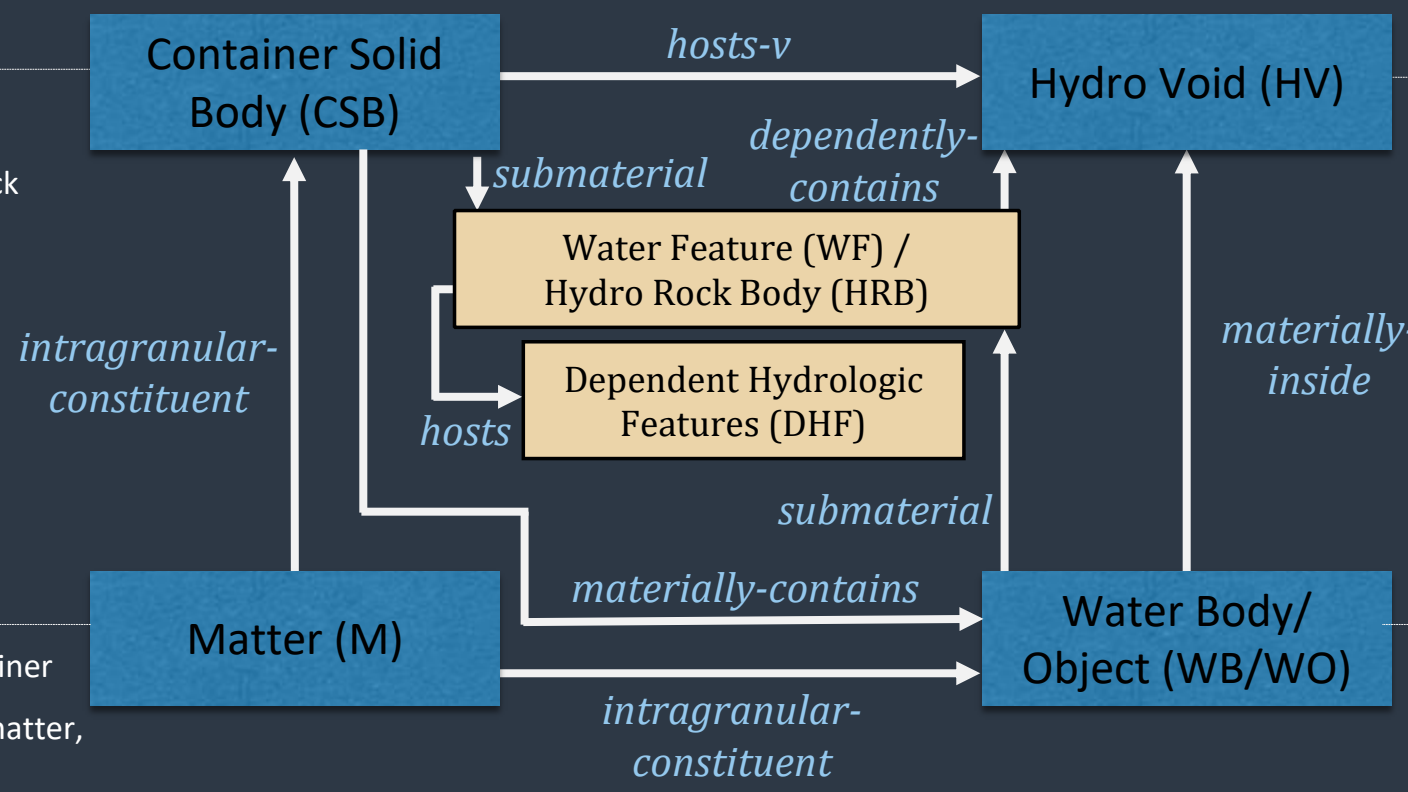

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[6] Hahmann and Brodaric. "Kinds of full physical-containment." COSIT 2011.

[7] Hahmann and Brodaric. "Voids and material constitution across physical granularities." FOIS 2014.

[8] Hahmann, Brodaric and Gruninger, "Interdependence among material objects and voids". FOIS 2014.

Relations used in HyFO

Spatial relations apply to space regions (S):

- Spatial containment (Cont) and specializations such as boundary containment (BCont), and tangential containment (TCont);
- Contact (C) and specializations such as partial overlap (PO), incidence (Inc), superficial contact (SC), and strong contact (C_S)

Spatial operations on space regions:

- intersection, difference and sums

Space regions can be 0 to 3-dimensional

Physical relations apply to physical endurants (PED):

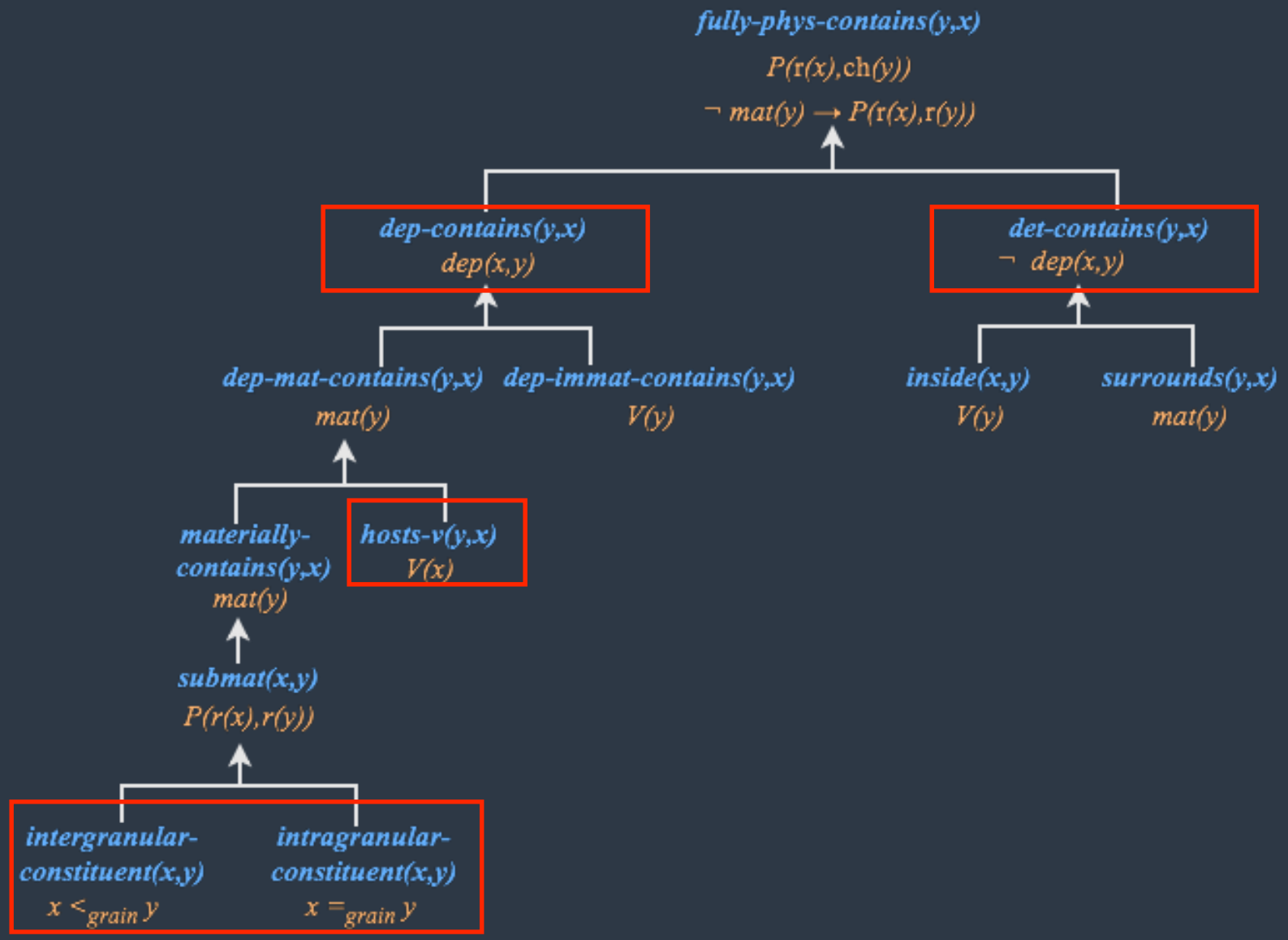
- Physical containment
- Constitution
- Hosting (of Voids and other Features)
- Support

Physical endurants are more restricted in their dimensions (typically 3D, some 2D)

Physical relations prescribe certain spatial relations

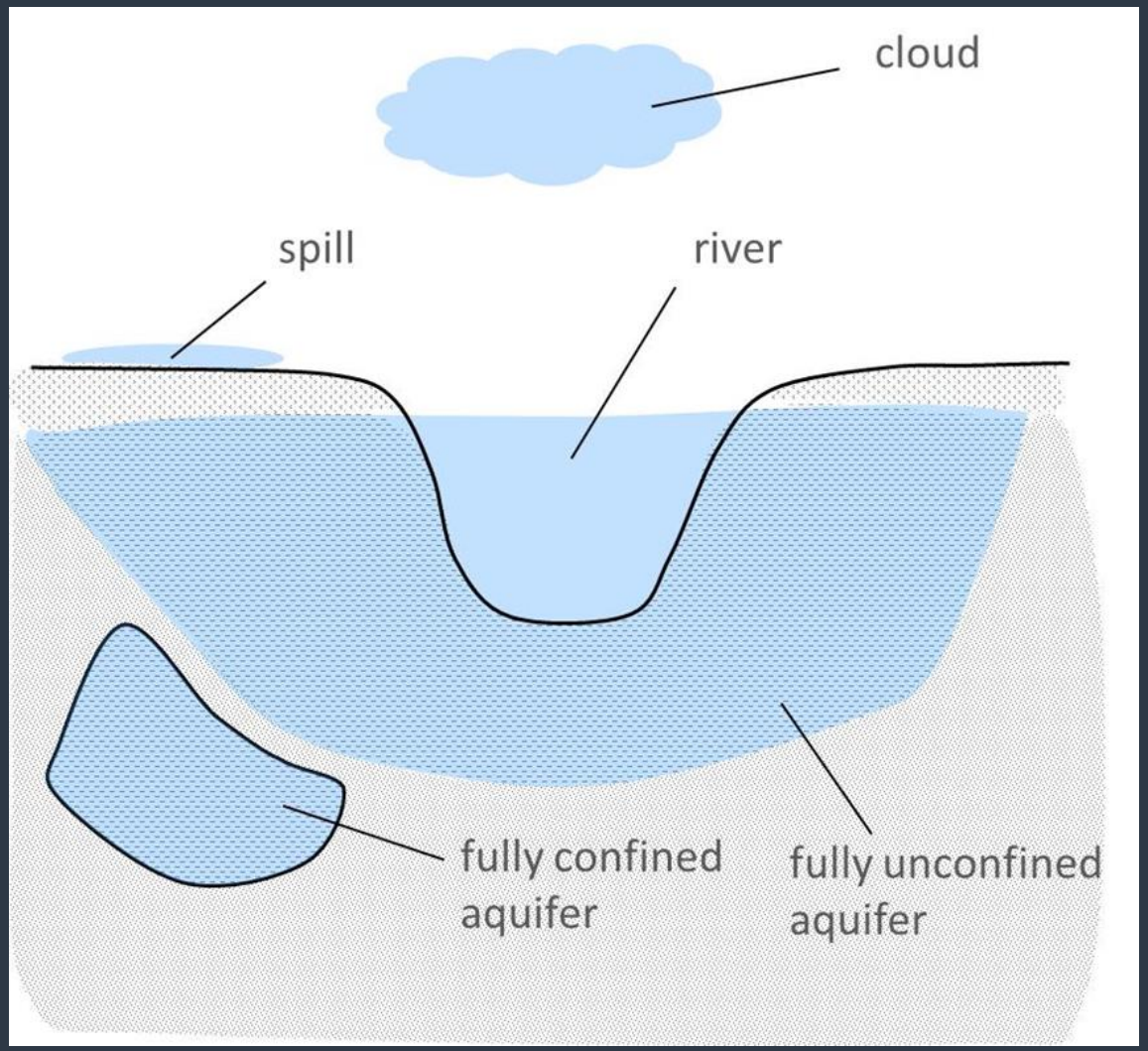
There are temporalized versions of all physical relations, e.g.

Foundational Physical Relations in HyFO



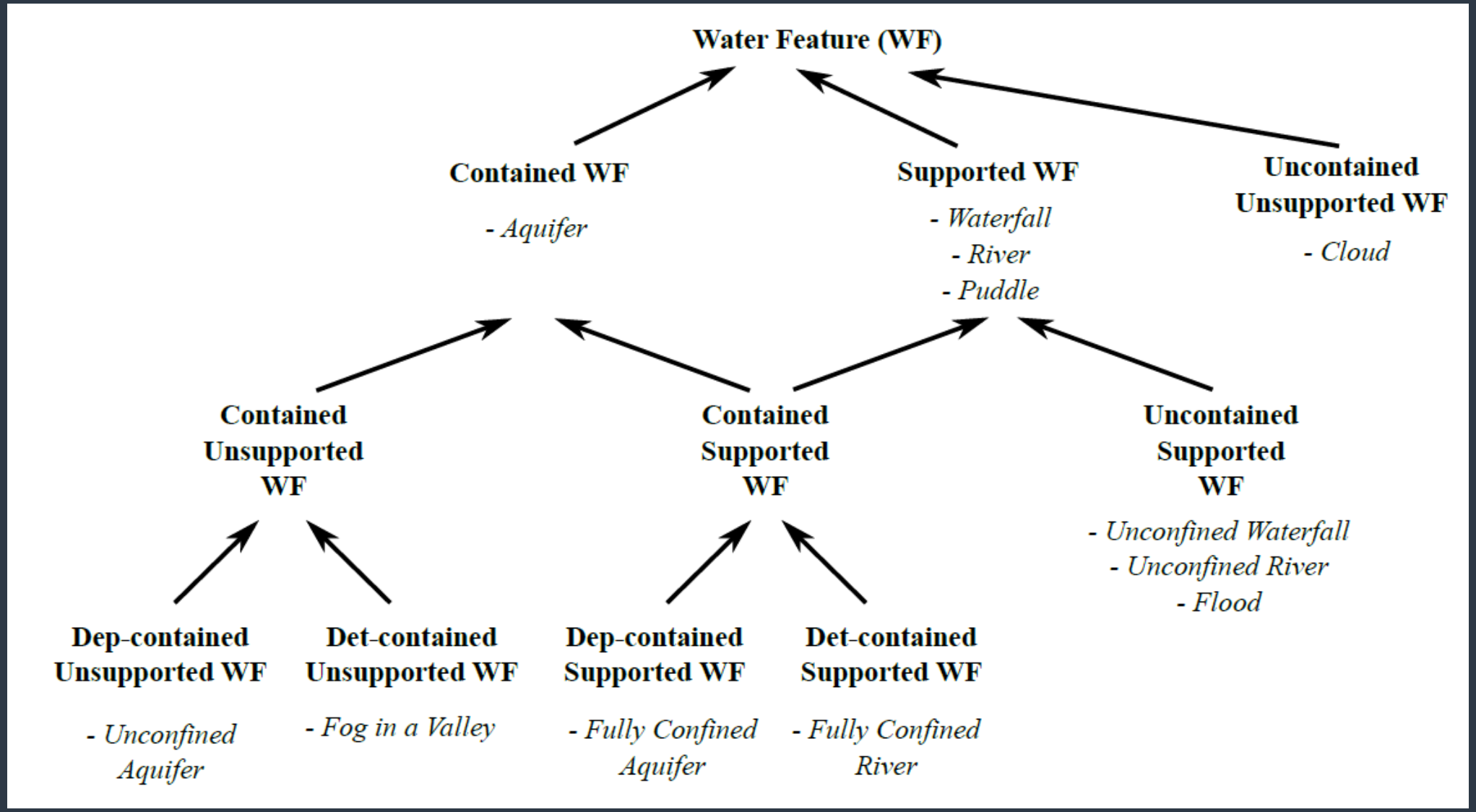
- **Containment** with distinctions about material detachability
- **Hosting** of an void by a container.
- **Constitution** depending on the granularity of the constituting matter.

Water Features



- Surface WFs: Rivers, Lakes, …
- Subsurface WFs: Aquifers, Wells, …
- Atmospheric WFs: Clouds
- Spans contained and/or supported WFs, such as spills or surface runoff
- **So far: water body contains (liquid) water matter; but the whole idea extends to water matter (ice, snow, slush, etc.) regardless of state**

Water Features



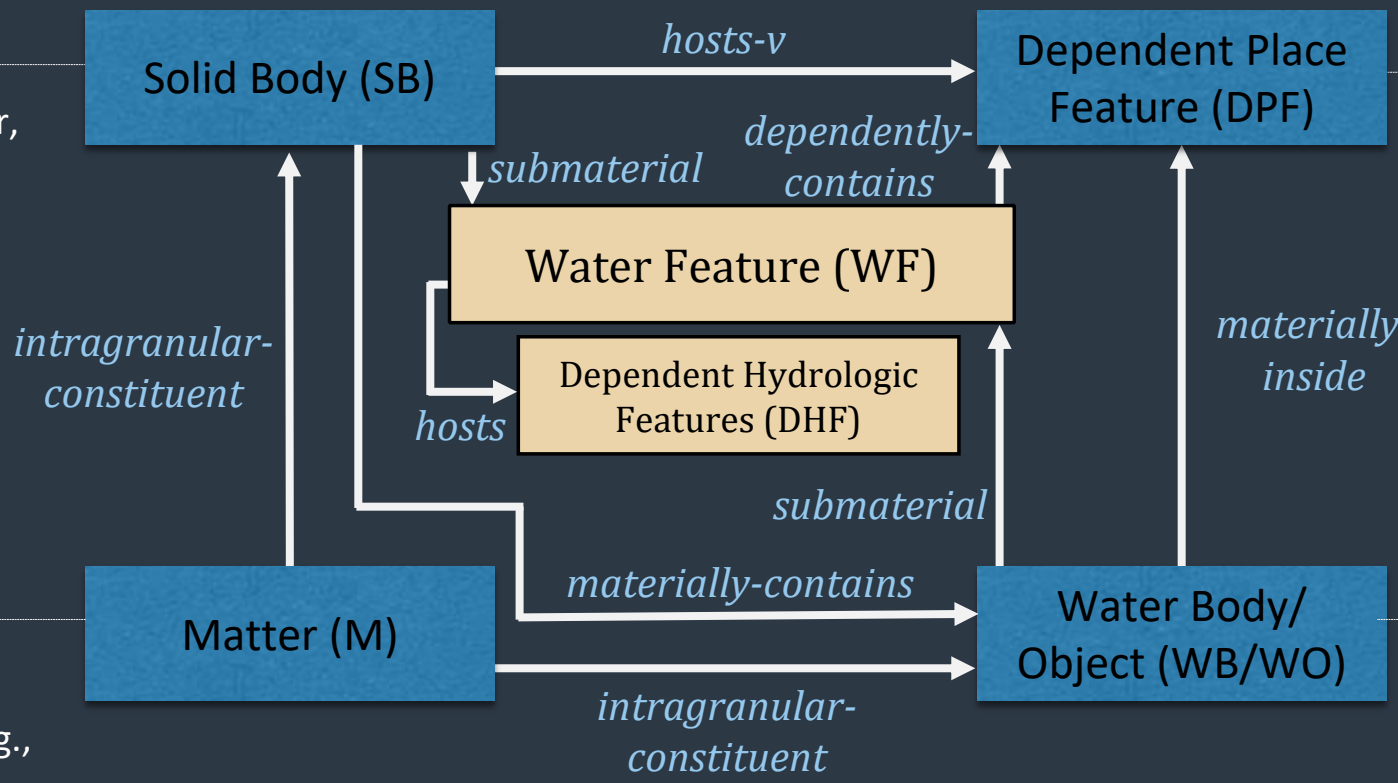
Generalizations: Supported Water Features

Container or Support Object

The object that contains water, or that supports water in a certain location.

Void or Supported Place

Space(s) in the container that can be filled with water, or spaces above a support object where water can be located



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Water Object

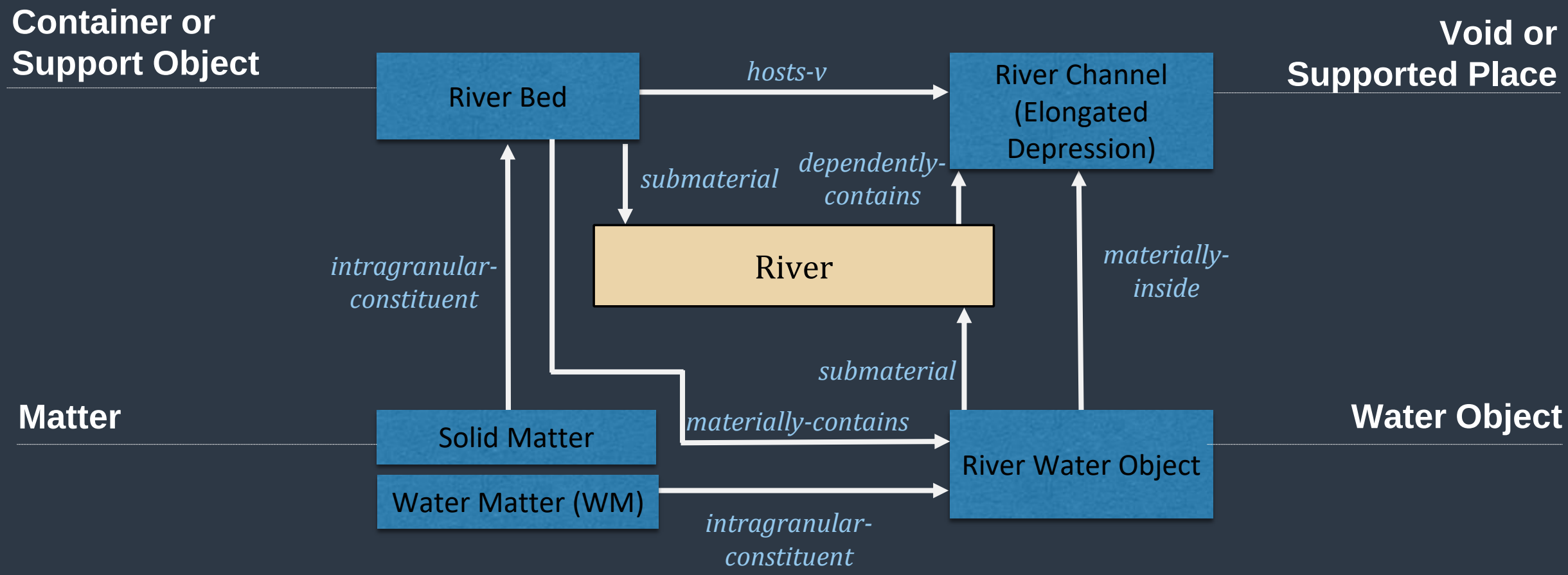
The physical object that is constituted of water matter.

River as Water Feature

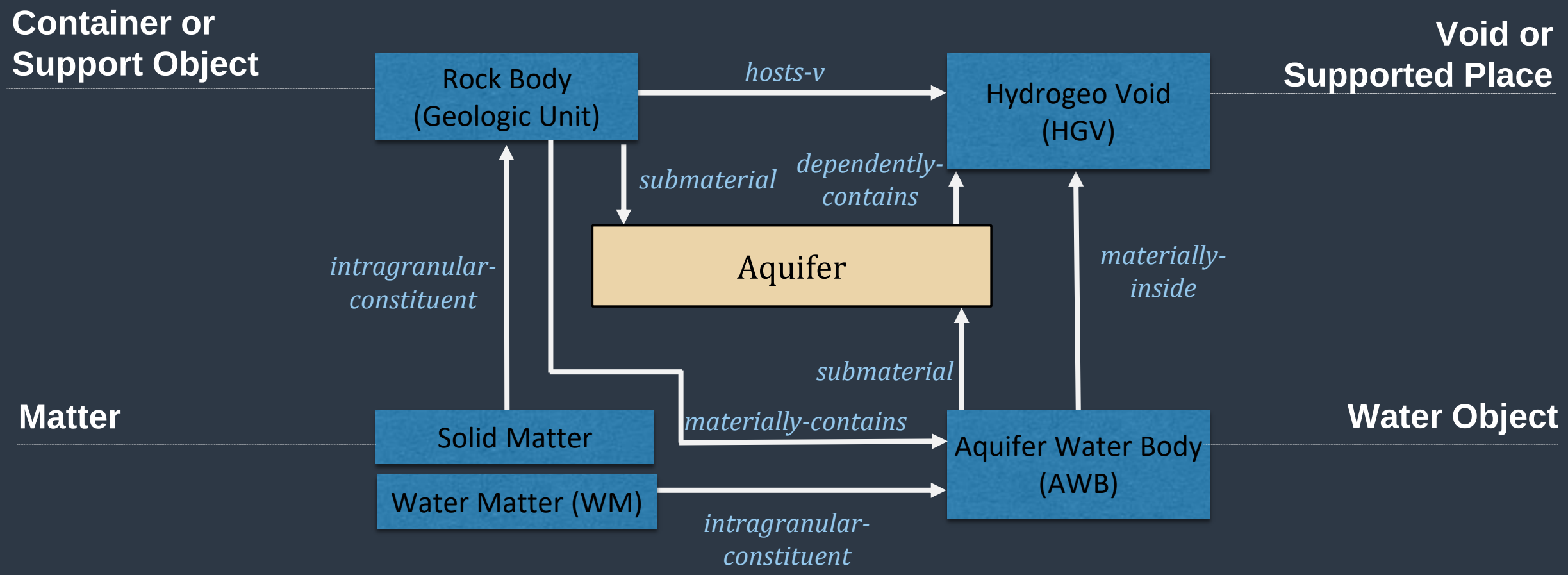
- **river** = void + water object (Hayes, 1978)
- **river** = container + water object (Galton & Mizoguchi, 2009)
- **river** = water object (Hart et al., 2007; SWEET 2011)
- **river** = possibly not water matter: ‘dry river’ (Duce & Janowicz, 2010)

- The term “river” may also refer to specific parts of a River WF:
  1. The River Water Object (e.g. “the river is 5m high”)
  2. The River Channel (e.g. “The river is 100km long”)
  3. The River Bed (e.g. “The river is sandy”)
  4. The Water Matter in the River (e.g. “the river is polluted”)

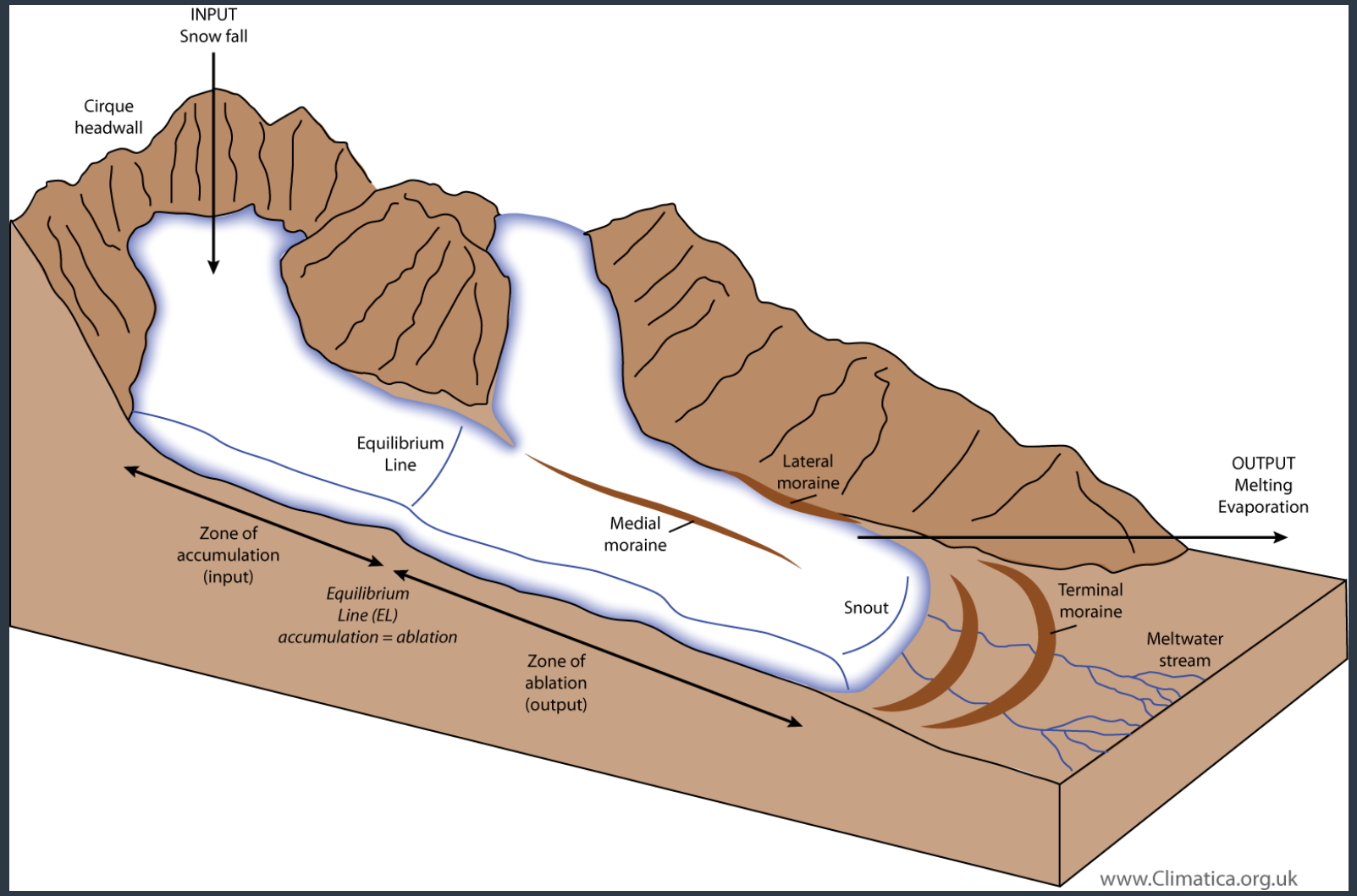
Example Water Feature: River



Example Water Feature: Aquifer



Glaciers

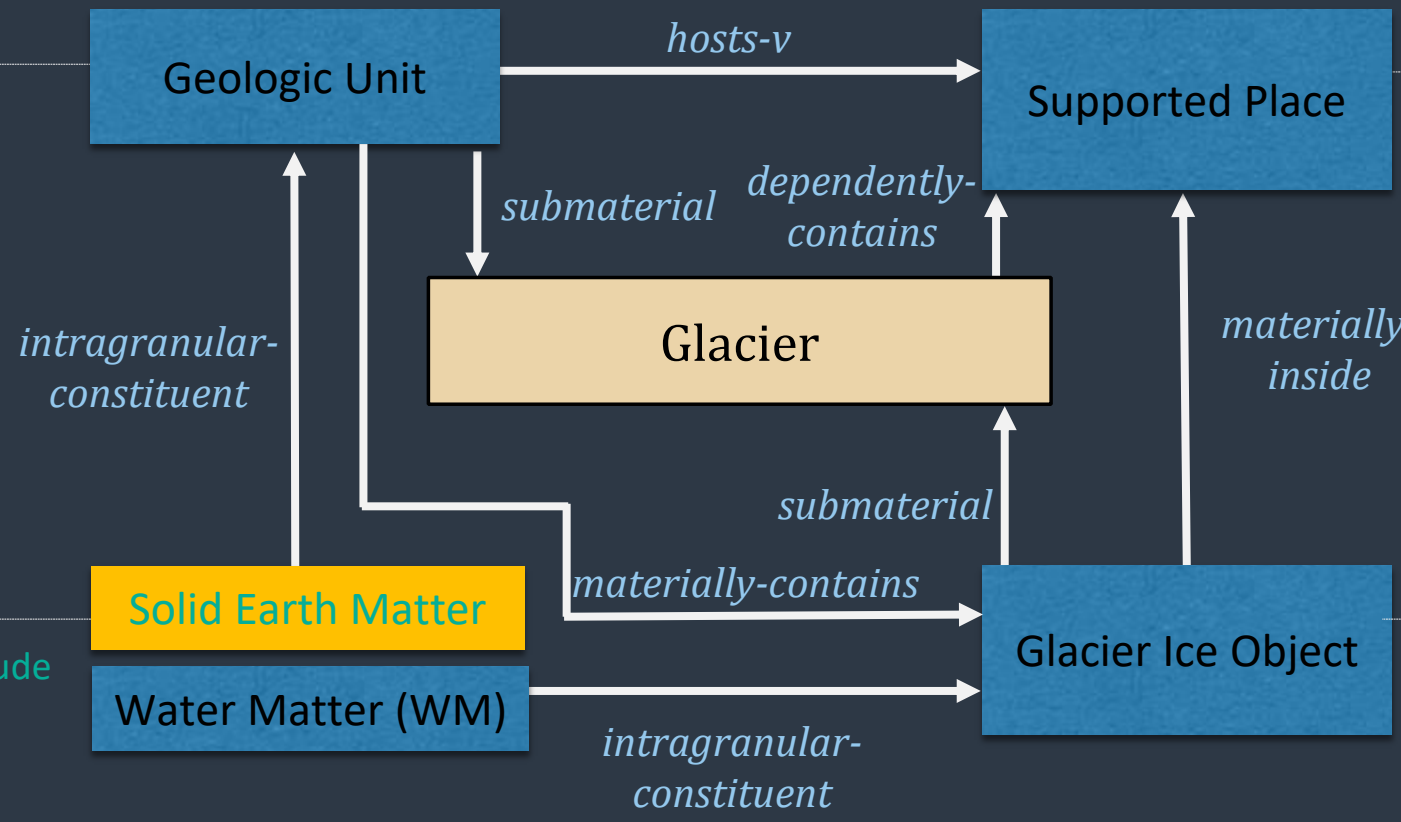


- Glaciers are supported by a Solid Rock Body: a GU
- Glaciers have a well-defined space: Supported Space
- Glacier have a “Water Object”: “Ice Object”
- Glaciers and their support objects are constituted of Material: Rock Matter and Frozen Water Matter

Glacier as Water Feature?

Container or Support Object

Void or Supported Place



Matter

Water Object

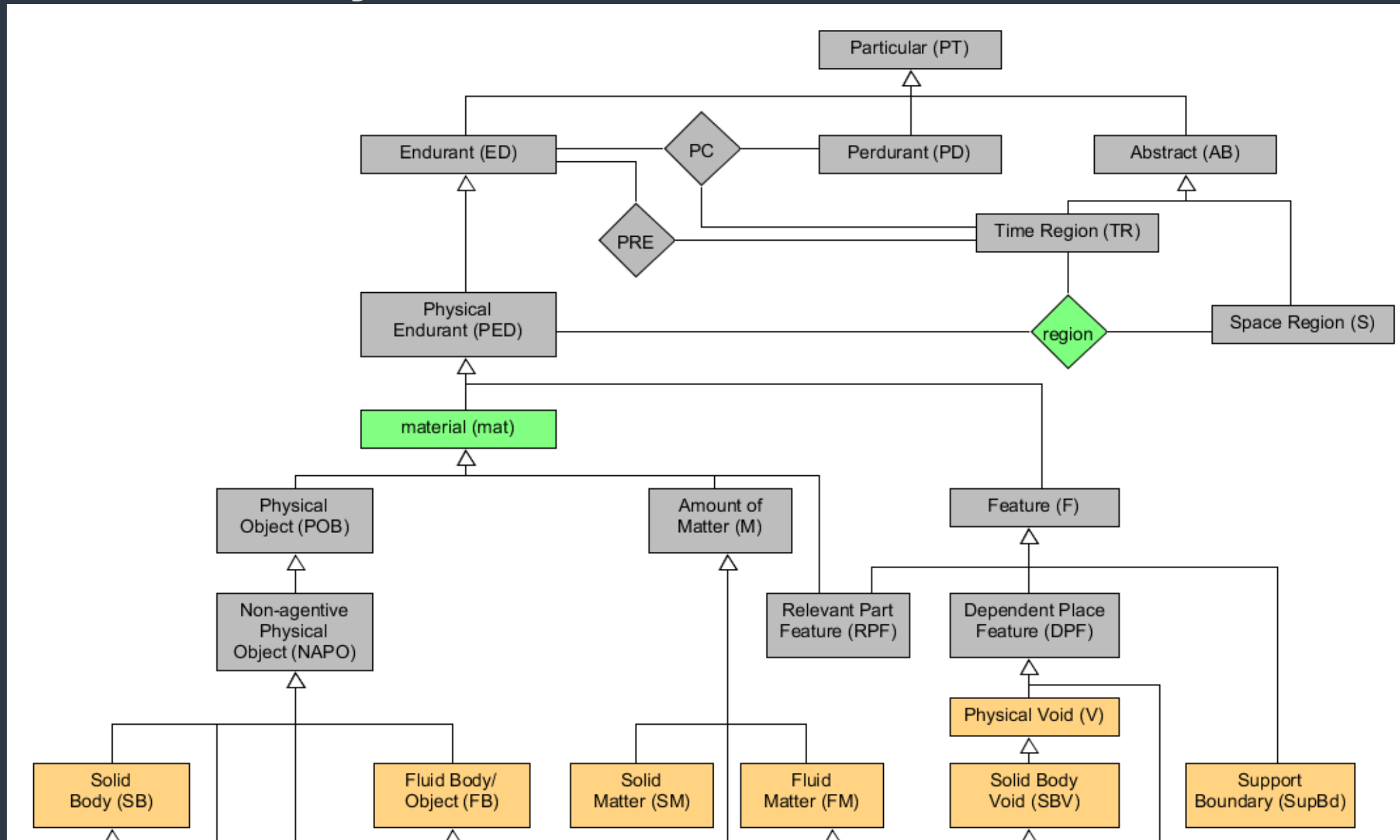
Extend Water Matter to include Frozen Water Matter; Introduce specialization of Fluid Water Matter

Other relevant “frozen water“ entities

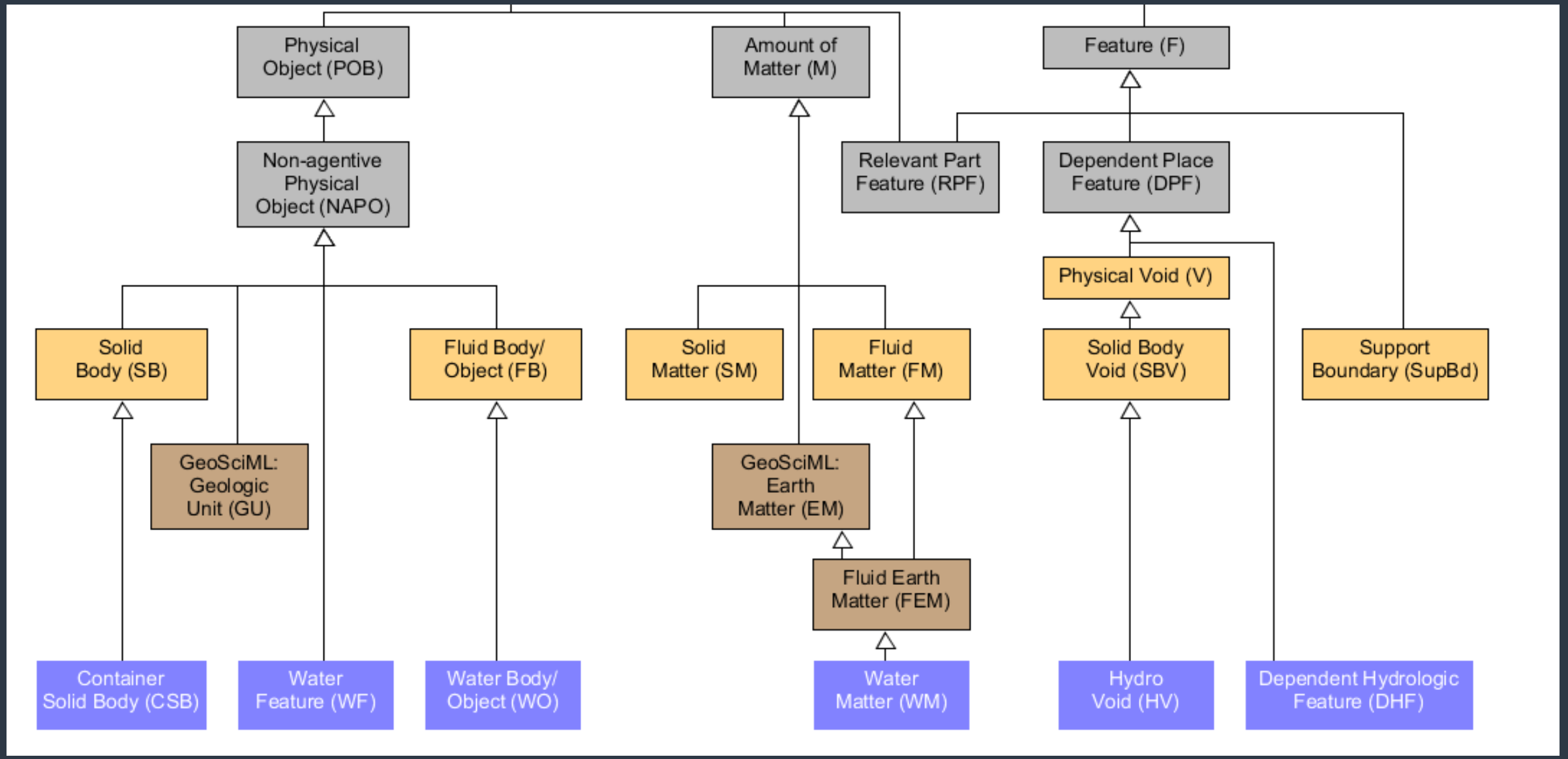
- Permanent snow, sea ice, iceberg, ice pack also as Supported WFs
- Is permafrost related (or rather just frozen ground)?

- Can different types of glaciers be characterized by differences in the parts?
  - http://nsidc.org/cryosphere/glaciers/questions/types.html: mountain glaciers, valley glaciers, tidewater glaciers, Piedmont glaciers, ice sheets, ice caps, ice streams, icefields, ice shelves, rock glaciers, cirque glaciers, hanging glaciers, ice aprons, icepack, etc.

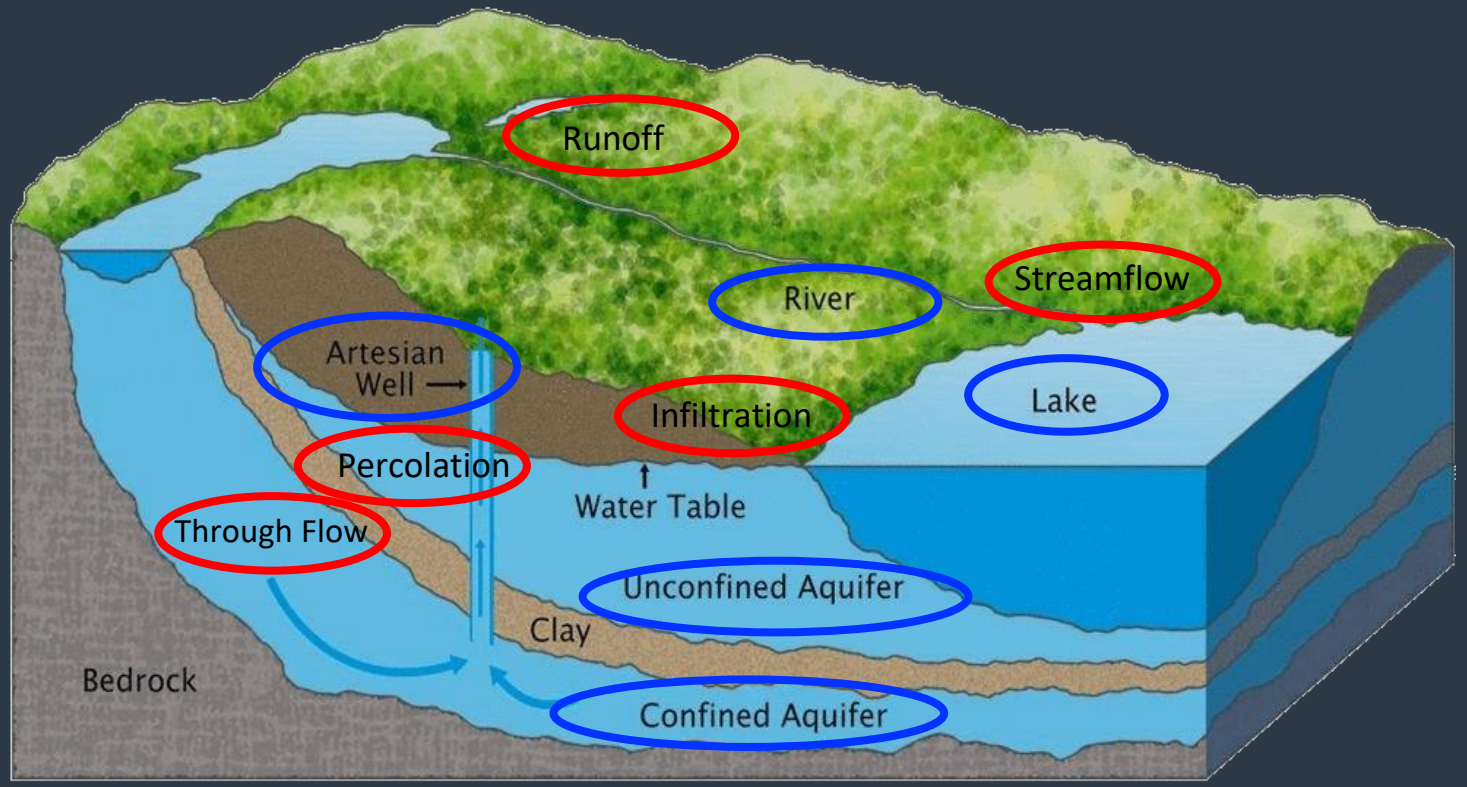
HyFO as DOLCE extension



HyFO as DOLCE extension



Flow processes connect the hydrology domain



- Hydrologic information is not just about static storage of water
- Movement of water connects the "places" where water can be
- Connects surface and subsurface water features

Modeling Hydrologic Flow in HyFO

- Need to model flow consistently with HyFO and DOLCE
- Hydrologic flow is modeled as a specialization of DOLCE's ***perdurant*** process.

  - time-indexed: "x participates in y during t"

Something that does not wholly exist at any one time

$$PC(x,y,t) \rightarrow ED(x) \wedge PD(y) \wedge T(t)$$

Participation relation

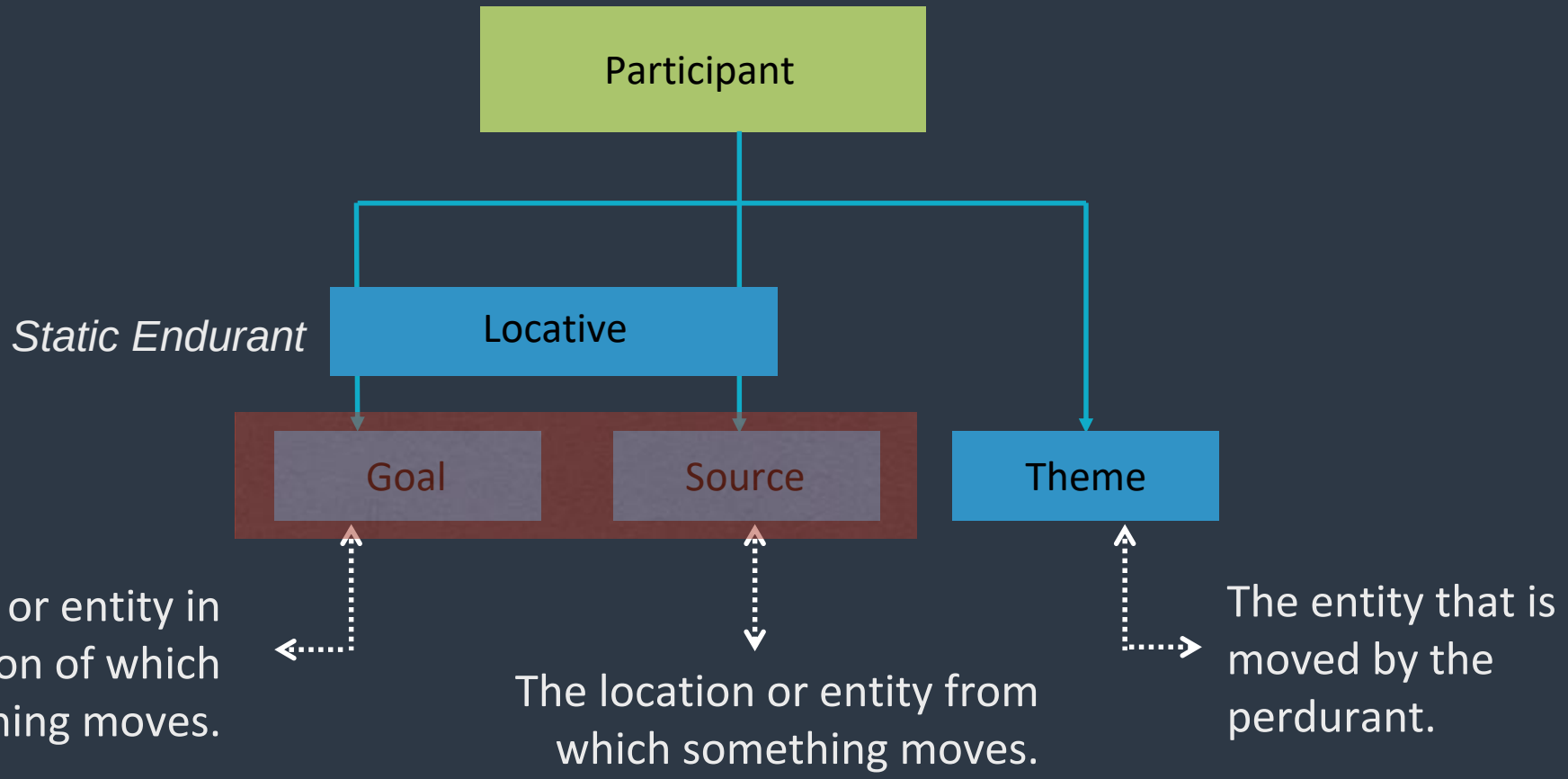
Participating endurant

$$HF(y) \rightarrow PD(y)$$

Hydrologic flow is a perdurant

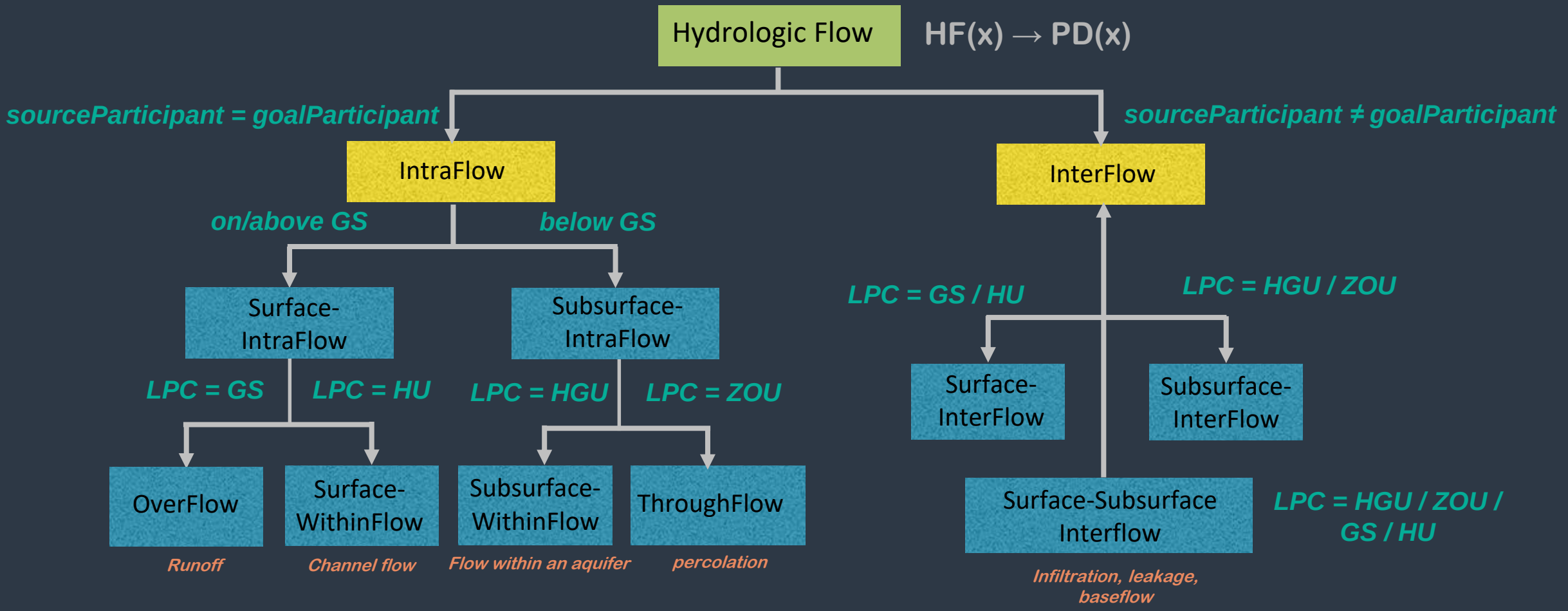
Three Types of Participants in Hydrologic Flow

PC(x,y,t) → ED (x) ∧ PD(y) ∧ T(t) ..... **(x participates in y during t) — *from DOLCE***



[1] Walter A Cook. *Case grammar: development of the matrix model (1970-1978)*. Georgetown University Press, 1979

HyFO Taxonomy of Flow Processes



1) Spatial restrictions on the participants of subtypes of hydrologic flow (domain and range restrictions)
2) Temporal restrictions on hydrologic flow processes