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Advanced consideration of groundwater – river interactions for processes-based groundwater vulnerability mapping

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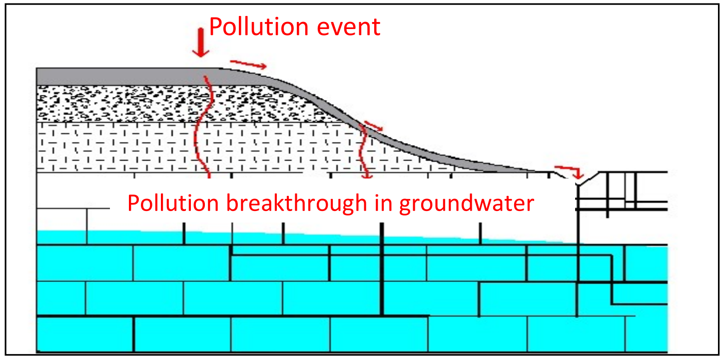
Apsû method for groundwater intrinsic vulnerability assessment

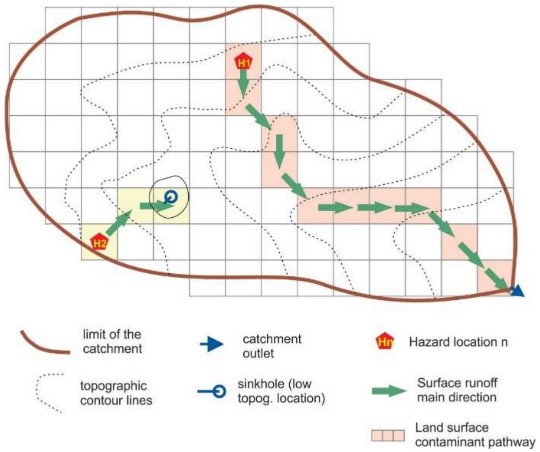
Process-based approach following the general concepts of the COST620 Action (Daly et al. 2002)

Adapted from N. Goldscheider



Degree of vulnerability	High	Moderate	Low
minimal travel time	Short (e.g. 24h)	Medium (e.g. 50 d)	long
Concentration level / attenuation	high	medium	low
duration	long	medium	short

Land surface hazard



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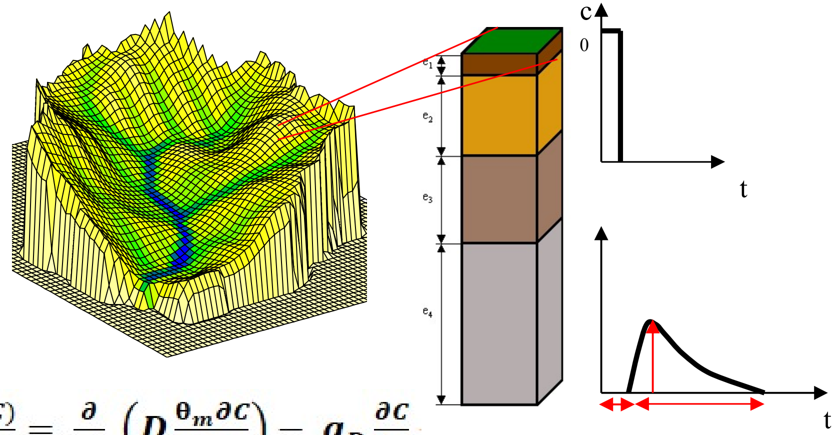
Underground attenuation capacity

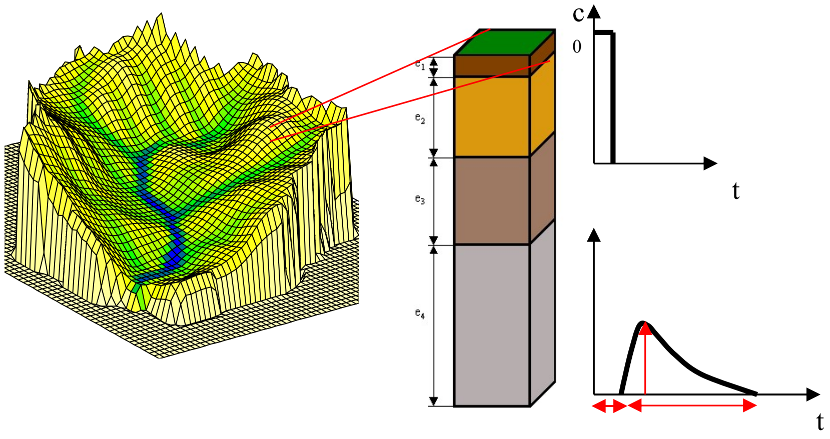


$$\frac{\partial(\theta_m C)}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\theta_m \partial C}{\partial z}\right) - q_D\frac{\partial C}{\partial z}$$

Apsû method for groundwater (intrinsic) vulnerability assessment

Physically based approach dealing with

- Direct and lateral infiltration of pollutants (land surface hazard)
- 1D vertical transport of contaminants from land surface to groundwater table (protective capacity of the unsaturated zone)
- Physical criteria (advective-dispersive minimal travel time, maximal concentration, duration)



Degree of vulnerability	High	Moderate	Low
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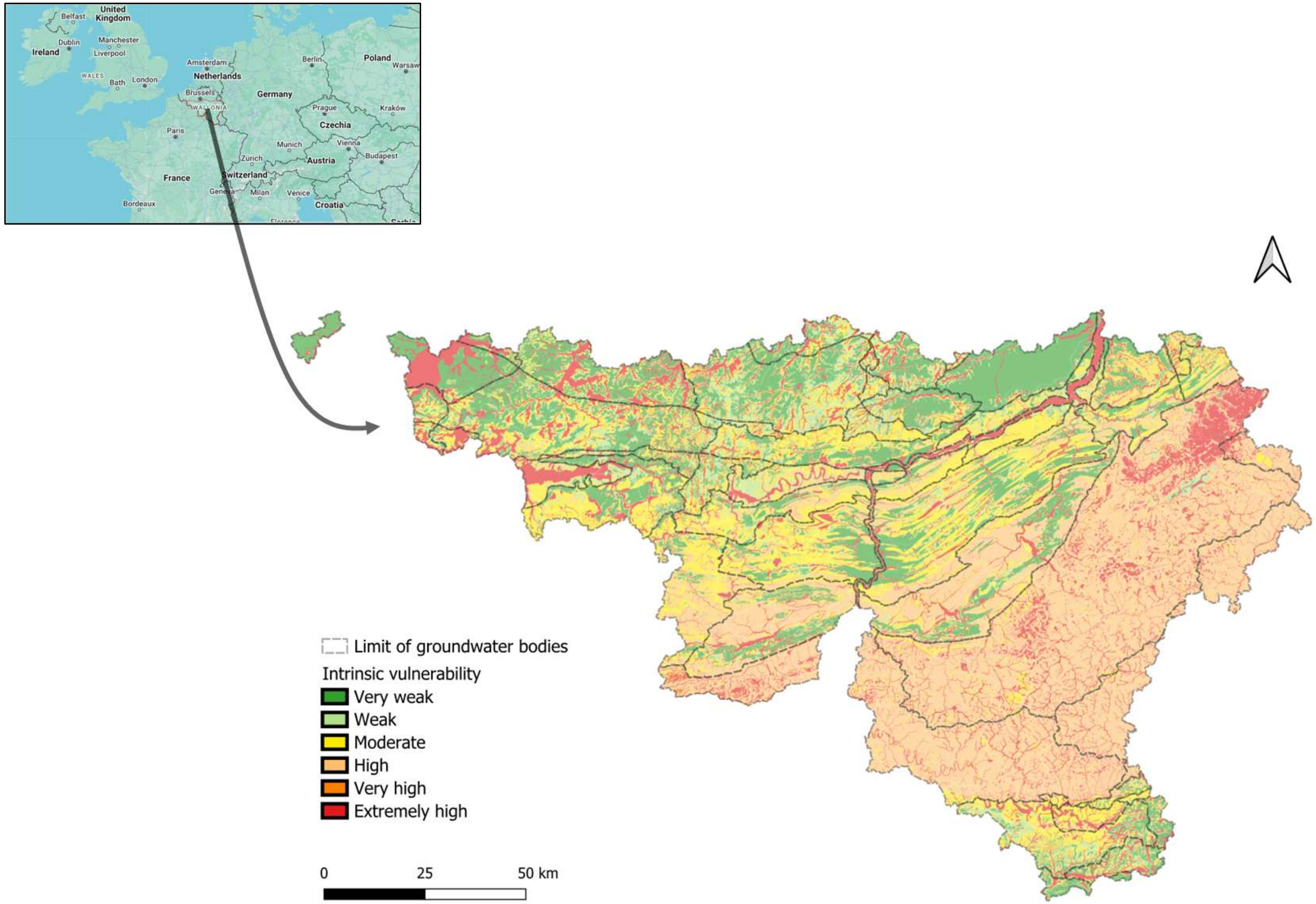
Original version of the Apsû method & assumptions



<u>**Working hypotheses**</u>

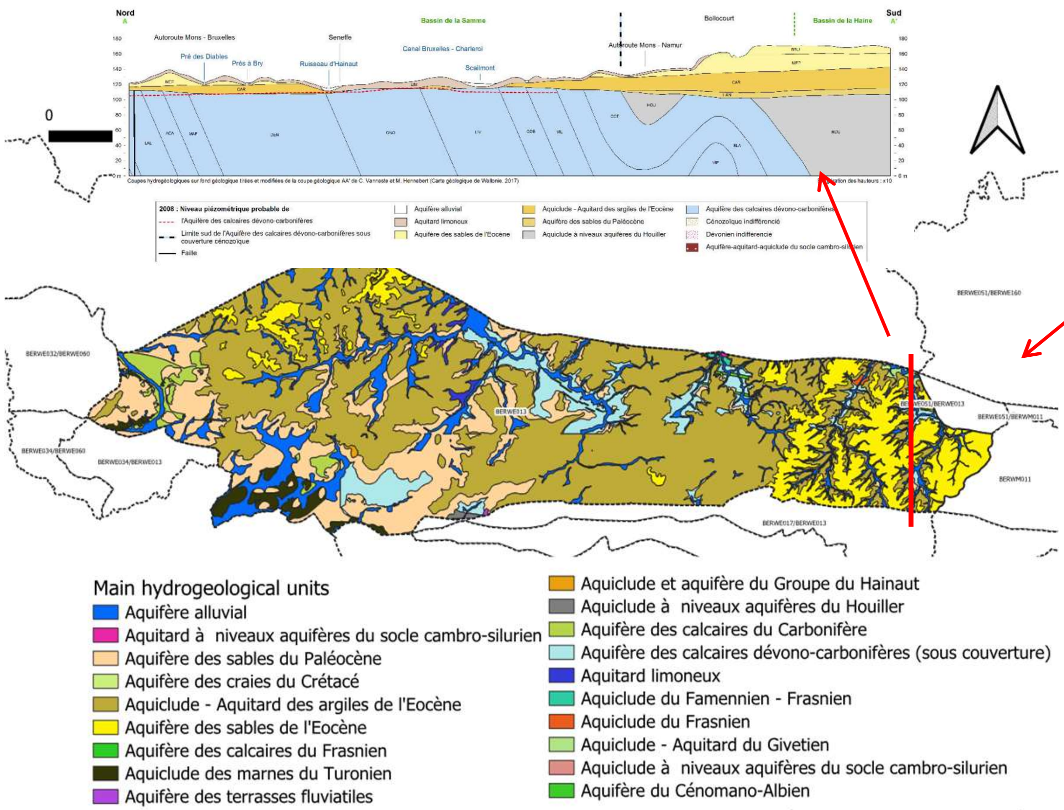
- <u>**Target**</u> = first aquifer from the land surface

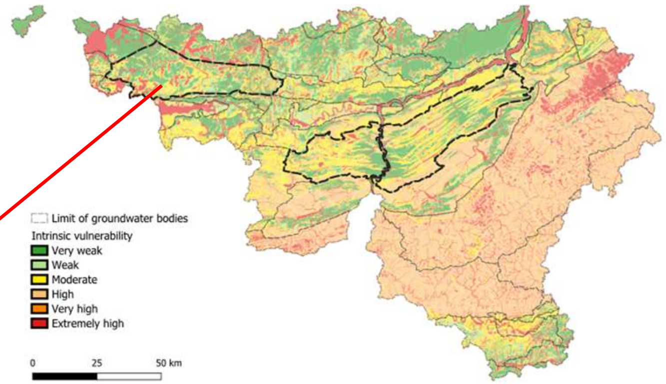
- <u>**Rivers**</u> = loosing streams by default with maximum land surface hazard associated with

However, your working hypotheses can sometimes be discussed

The aquifer of interest is not always the first from the land surface…

e.g. Groundwater bodies delineated in the scope of the EU WFD and GWD





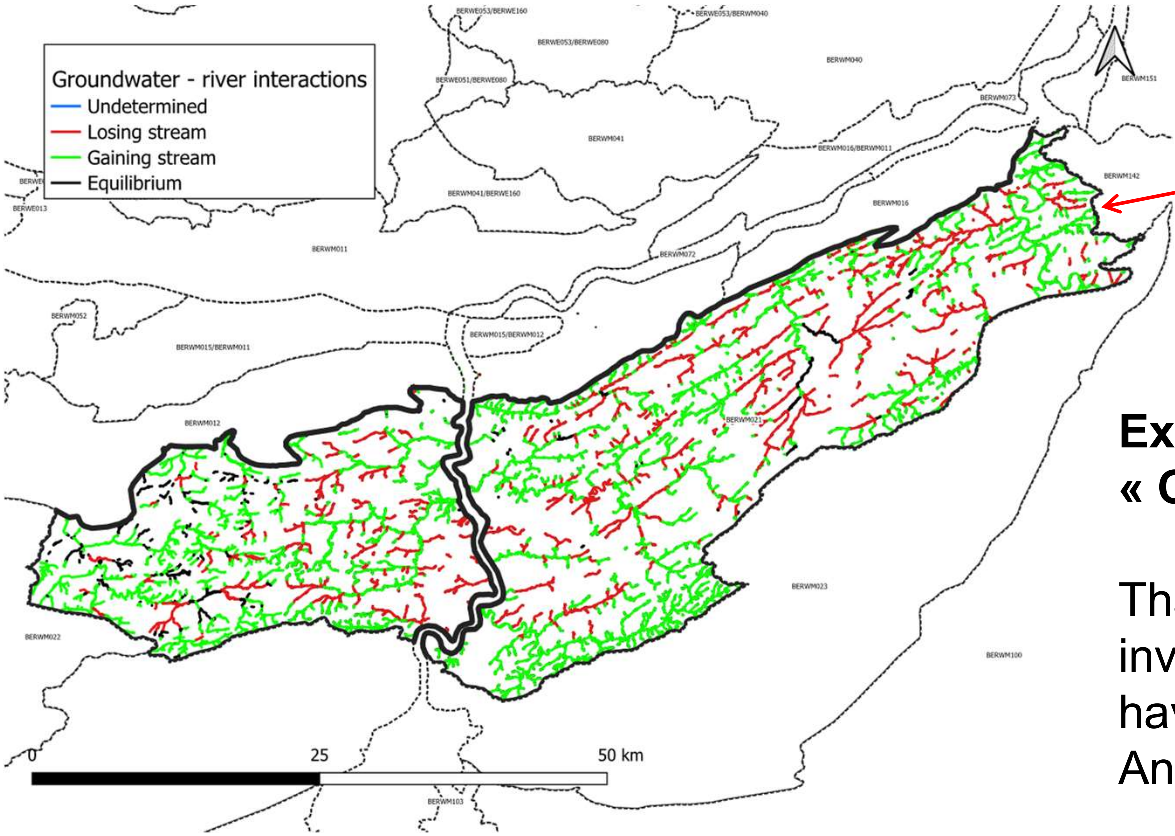
Example : GWB BERWE013 « Limestones of Pérulwez-Ath Soignies »

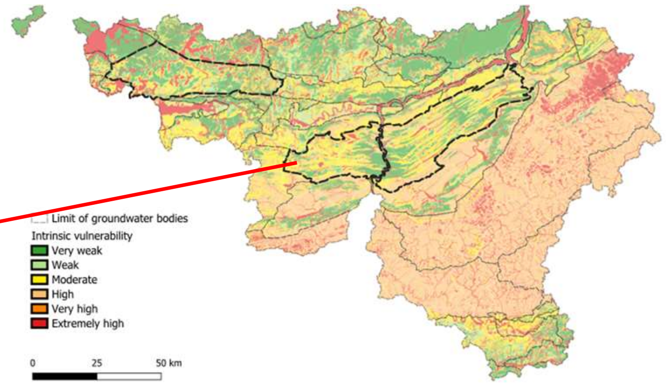
The Limestone aquifer is locally overlain by recent layers of Eocene Sands which may influence the vulnerability of the underground aquifer …

However, your working hypotheses can sometimes be discussed

The aquifer of interest is not always the first from the land surface…

e.g. Groundwater bodies delineated in the scope of the EU WFD and GWD

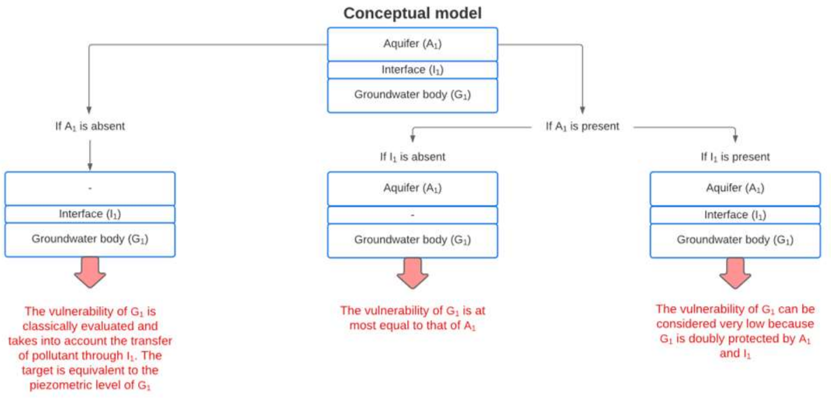




Example : GWB BERWM021
« Condroz Limestones & Sandstones »

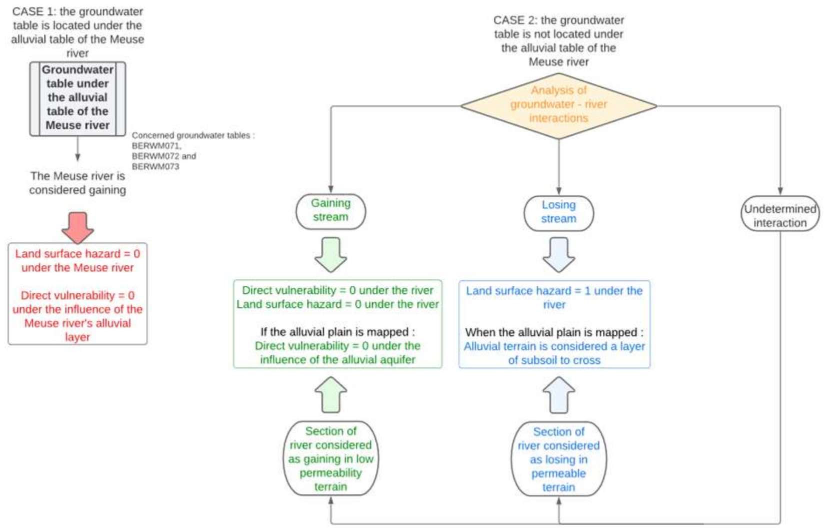
Thanks to detailed regional scale investigations, groundwater – river interactions have been characterized in detail…
And rivers are not always losing!

In response to this, adaptations of the Apsû methods in 2 directions



Surperimposed aquifers

Groundwater – river interactions



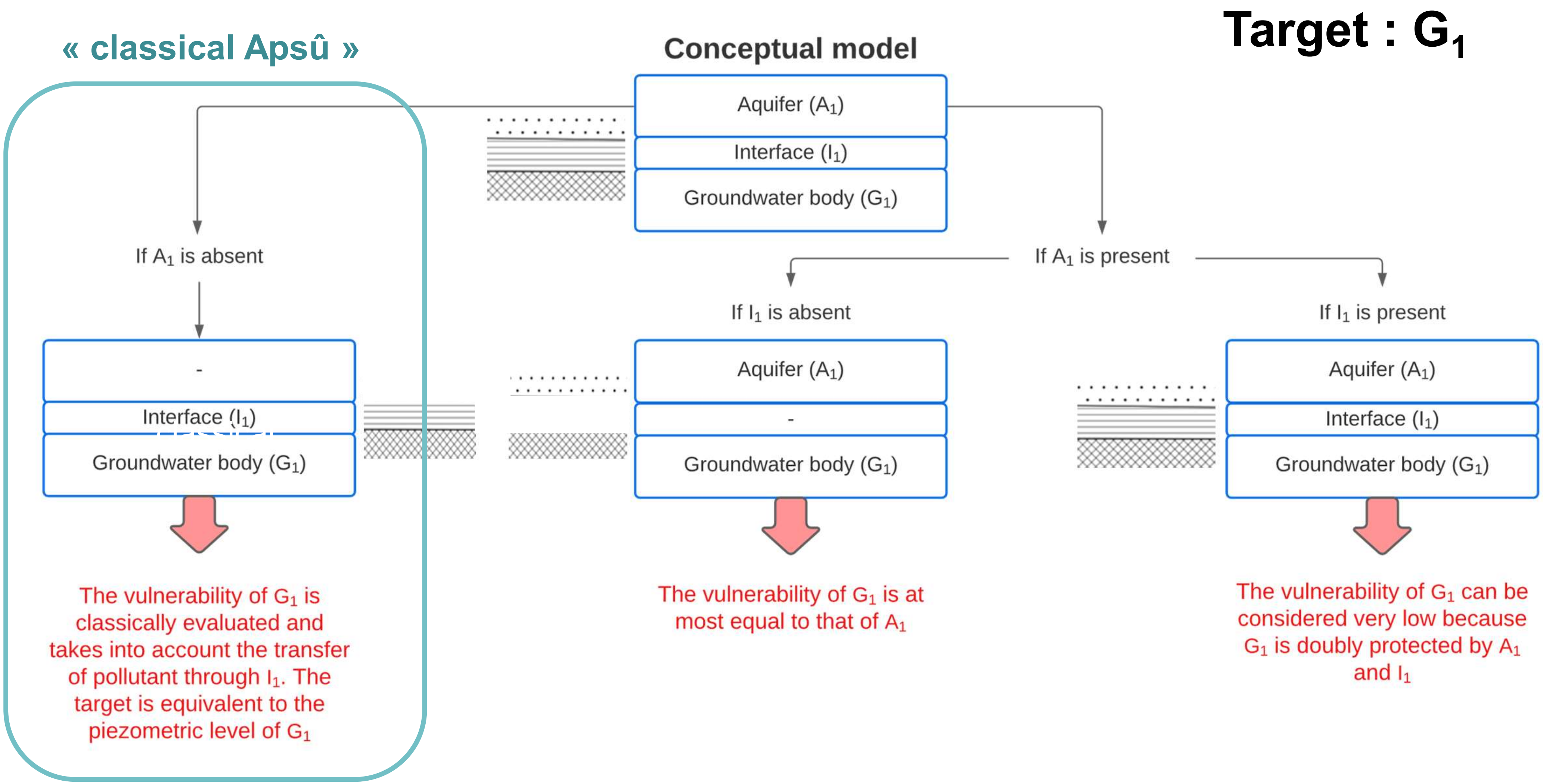
Conceptual model : « surimposed aquifers »

Conceptual model considering that the targeted groundwater body (G_1) is possibly covered by an aquifer hydrogeological formation (Aquifer A_1) with possibly an aquitard or aquiclude type hydrogeological unit (Interface I_1) separating them.

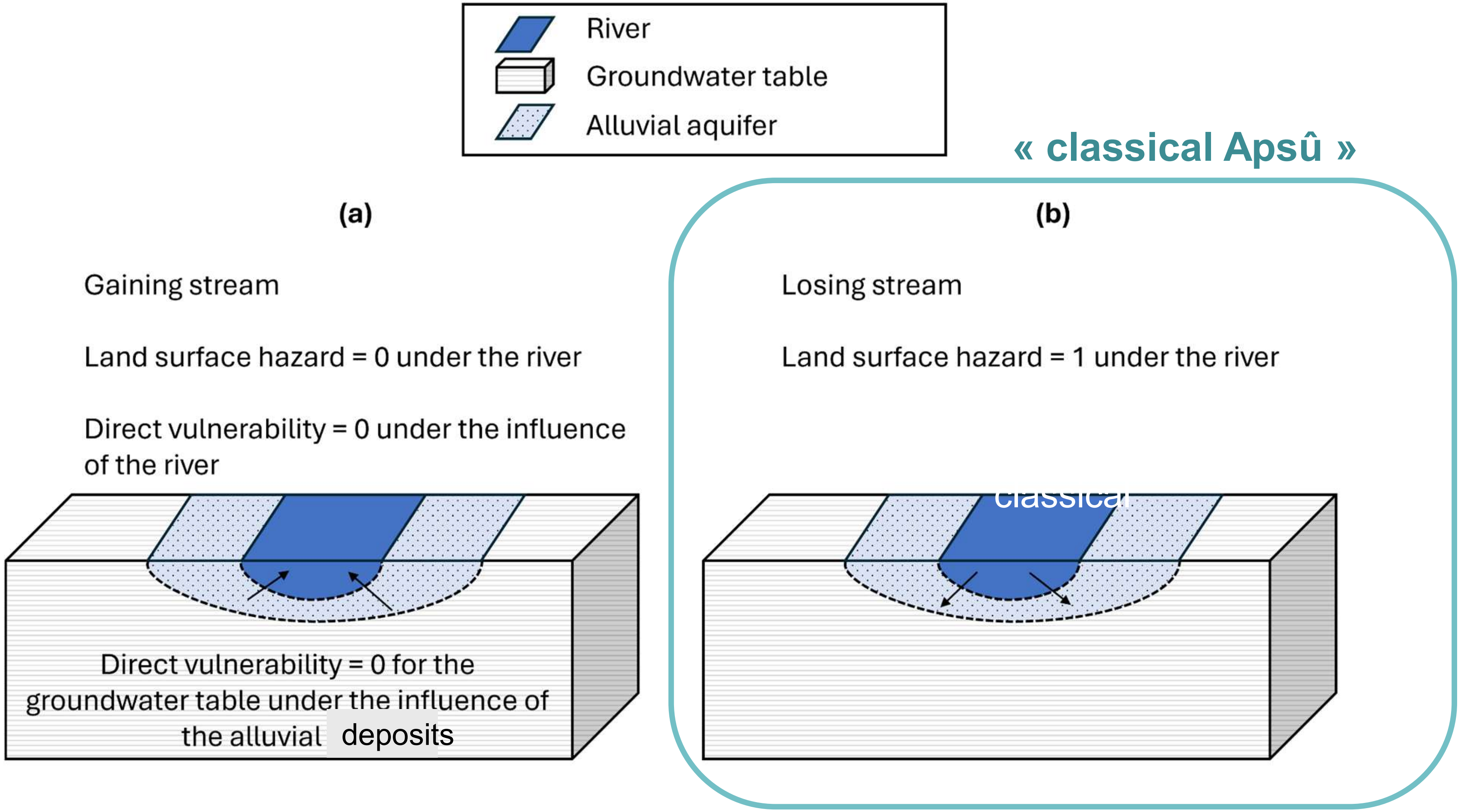
Groundwater body (G_1)

- If A_1 is absent, the vulnerability of G_1 (VM_1) is classically evaluated, taking into account the transfer of pollutants through I_1 (target = piezometric level of M_1).
- If A_1 is present:
  - If I_1 exists, the VM_1 vulnerability can be considered very weak because M_1 is doubly protected by A1 and I_1
  - If I_1 is absent, VM_1 is at most equal to that of A_1 (VA_1)

Conceptual model : « superimposed aquifers »

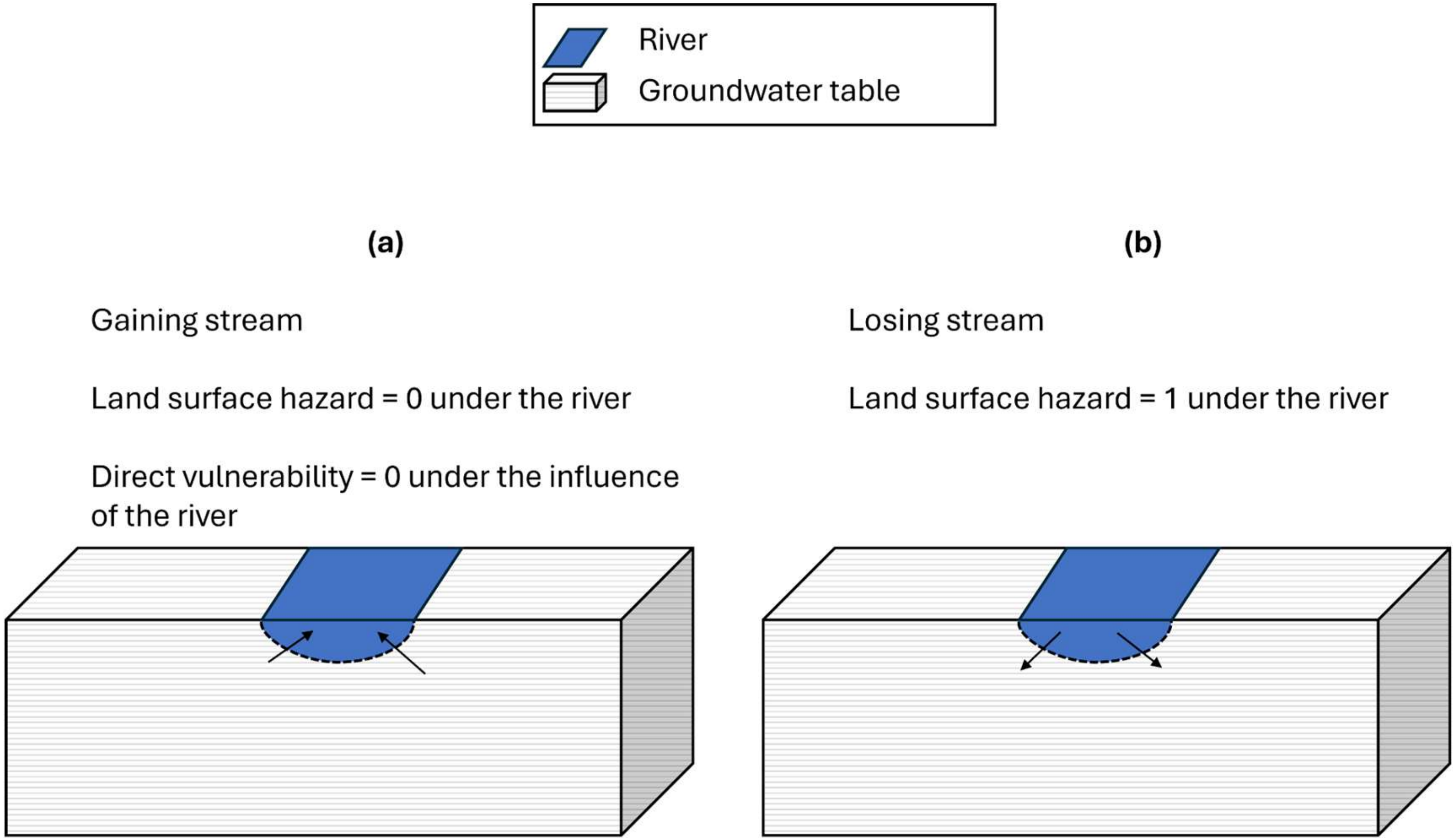


Conceptual model : « groundwater – river interactions »



Conceptual model : « groundwater – river interactions »

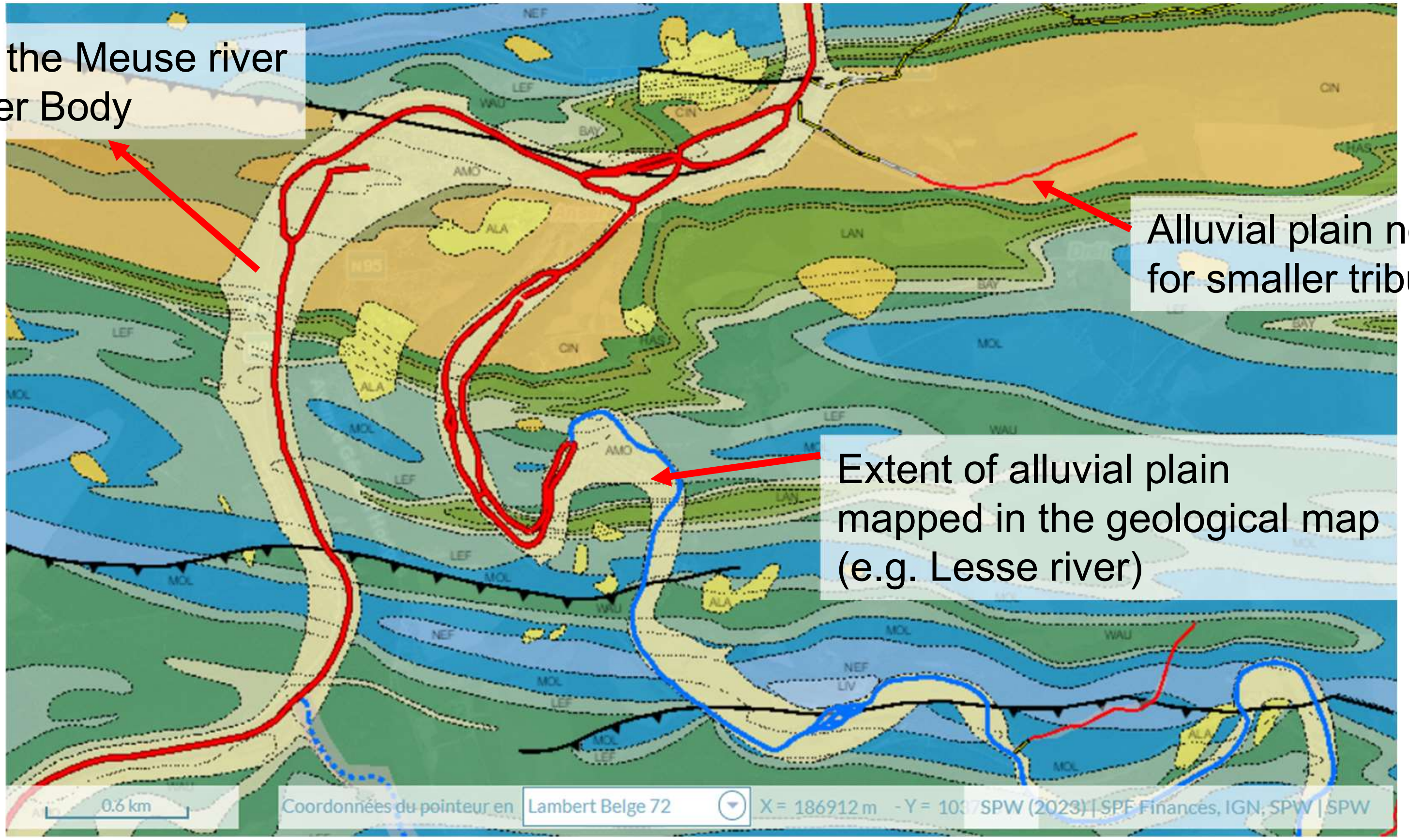
Considering water exchanges and alluvial plain deposits



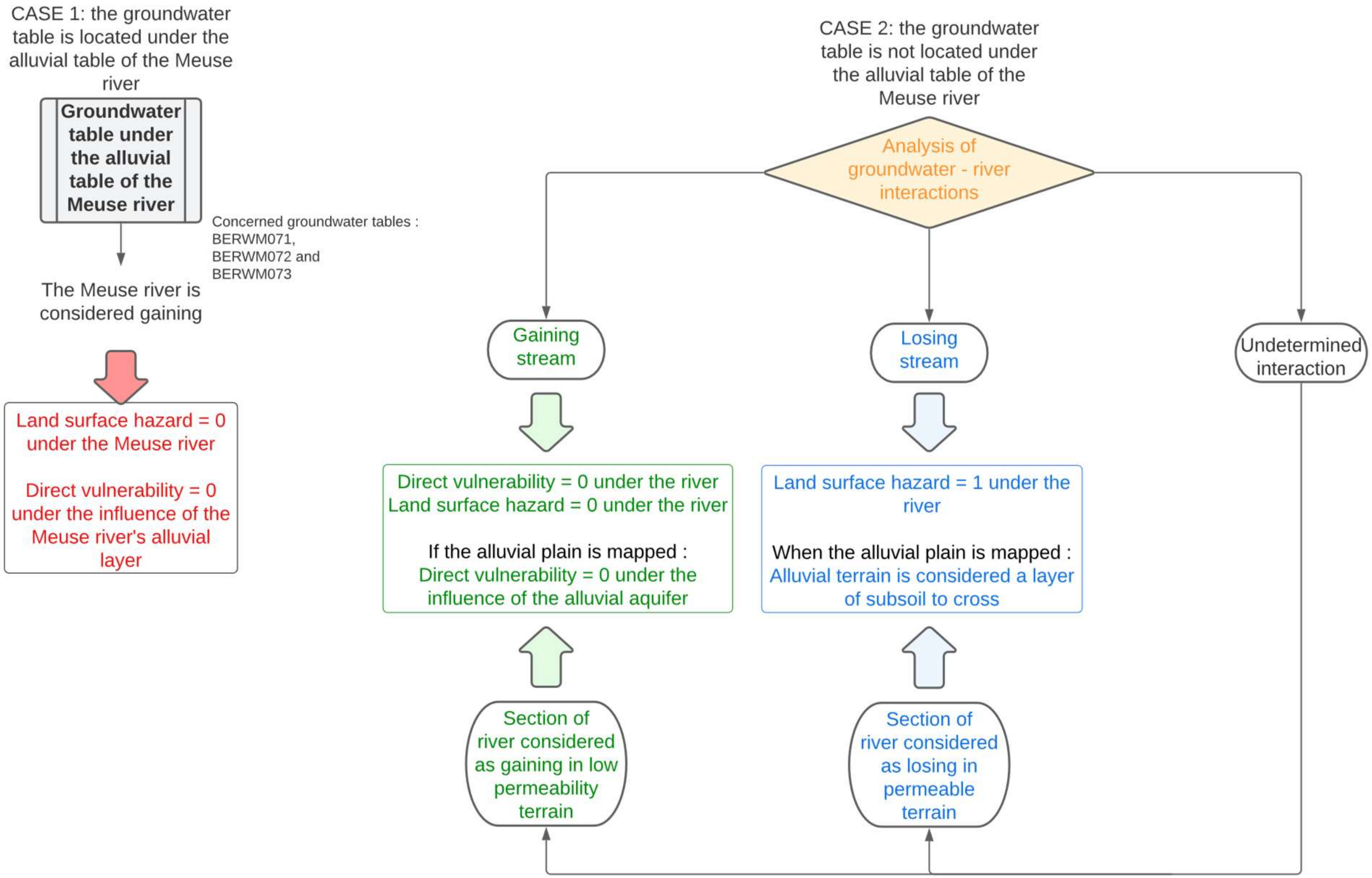
Land surface hazard and direct vulnerability applied to gaining/losing streams when the alluvial table is not mapped

Conceptual model : « groundwater – river interactions »

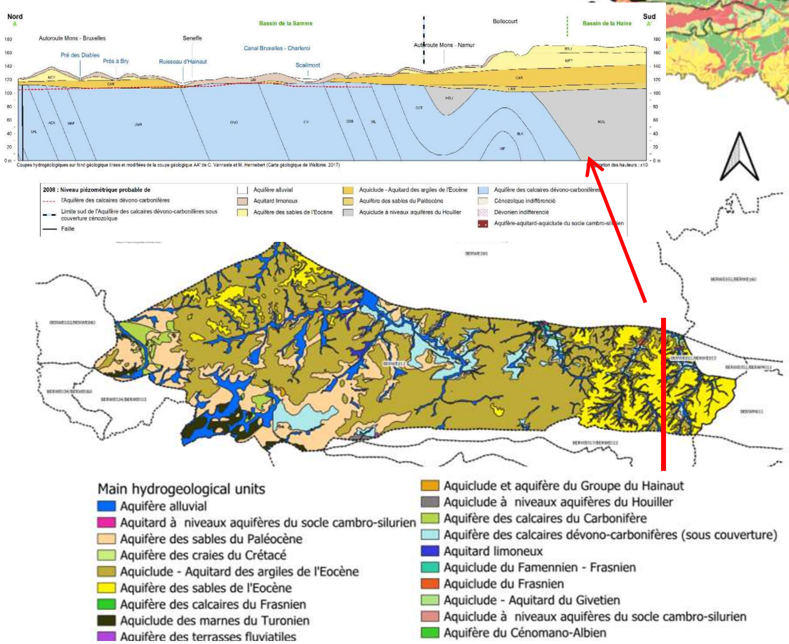
3 contexts for alluvial plains

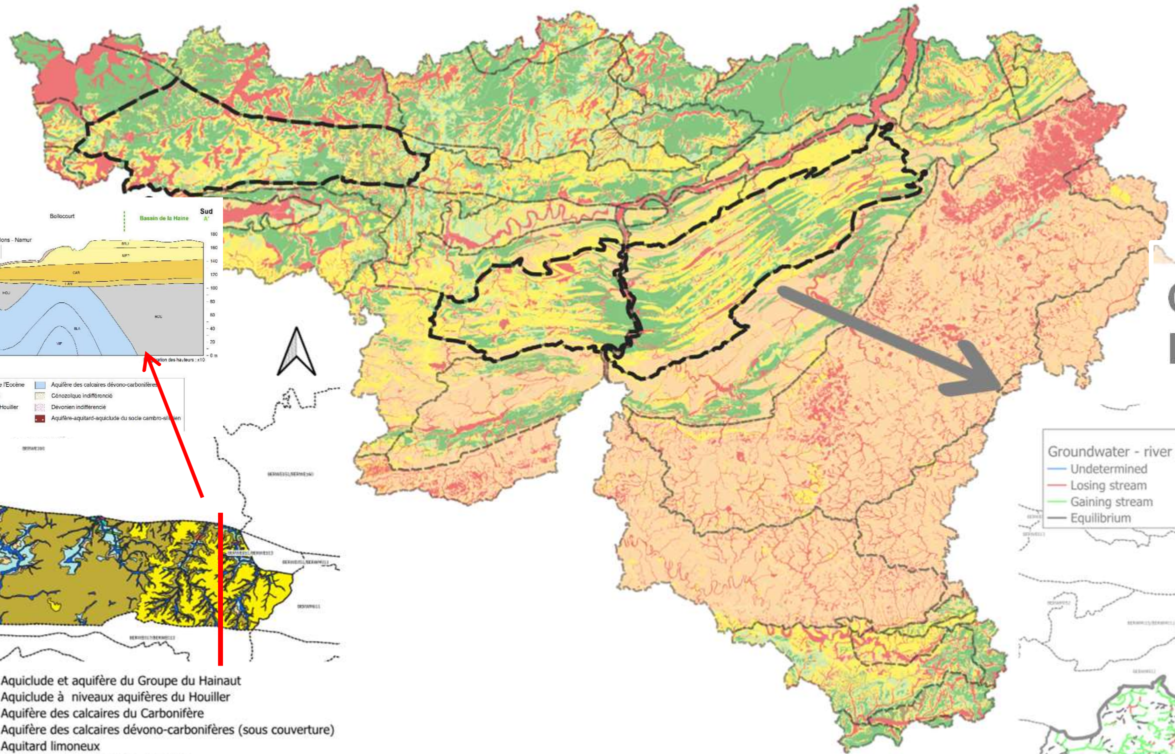


Conceptual model : « groundwater – river interactions »

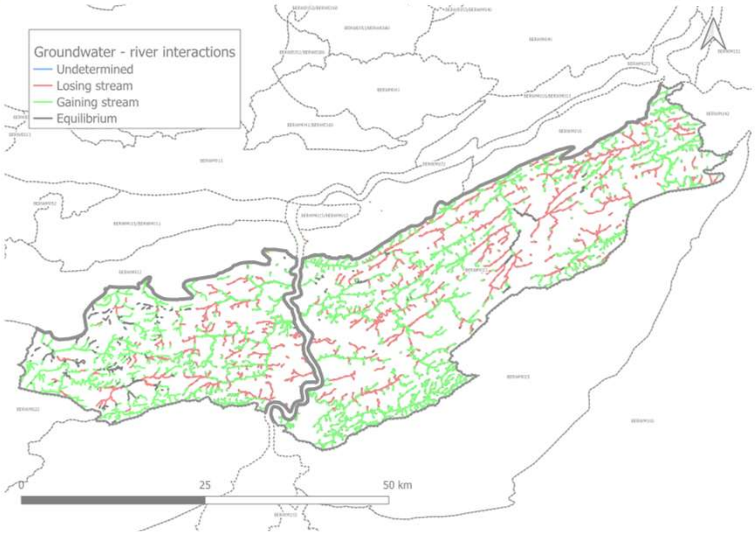


Application : Wallonia (Belgium) → « superposed aquifers »



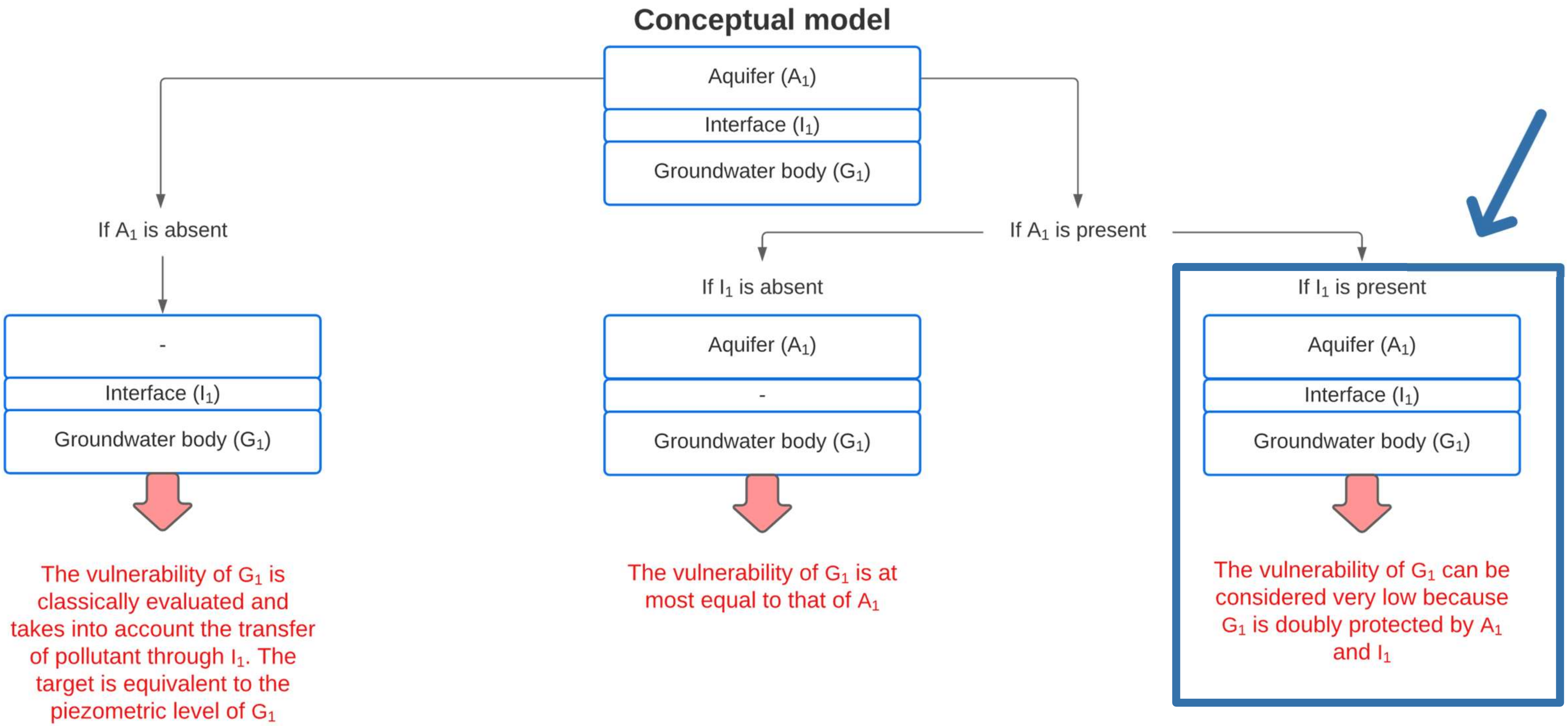


GWB BERWM021 « Condroz Limestones & Sandstones »



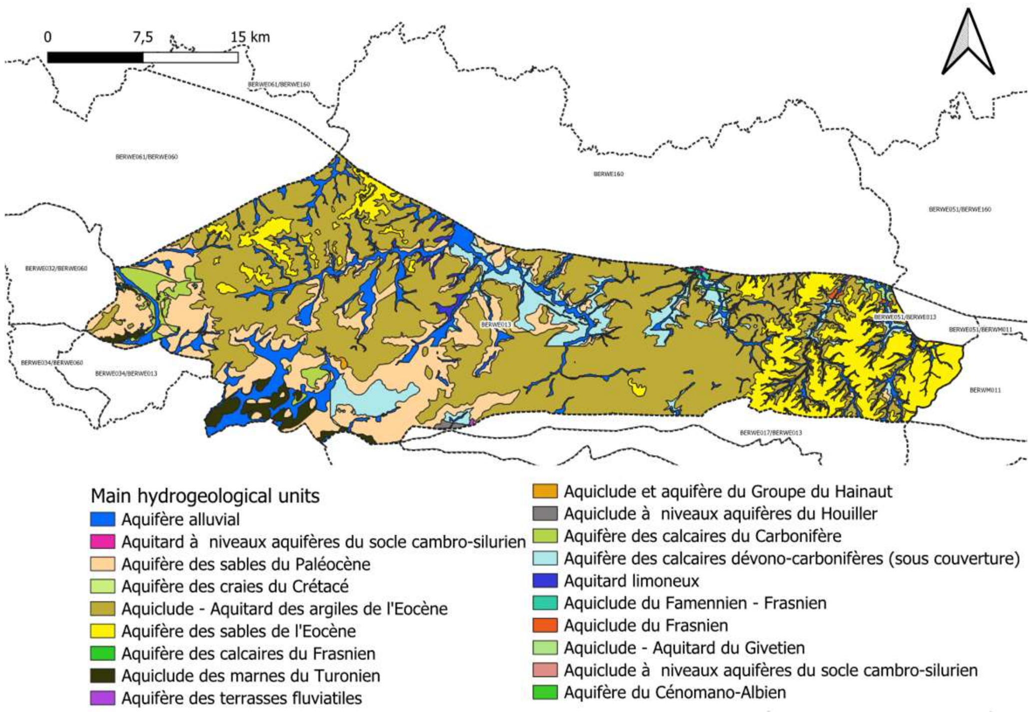
GWB BERWE013
« Limestones of Pérulwez-Ath Soignies »

Application : Wallonia (Belgium) → « superposed aquifers »

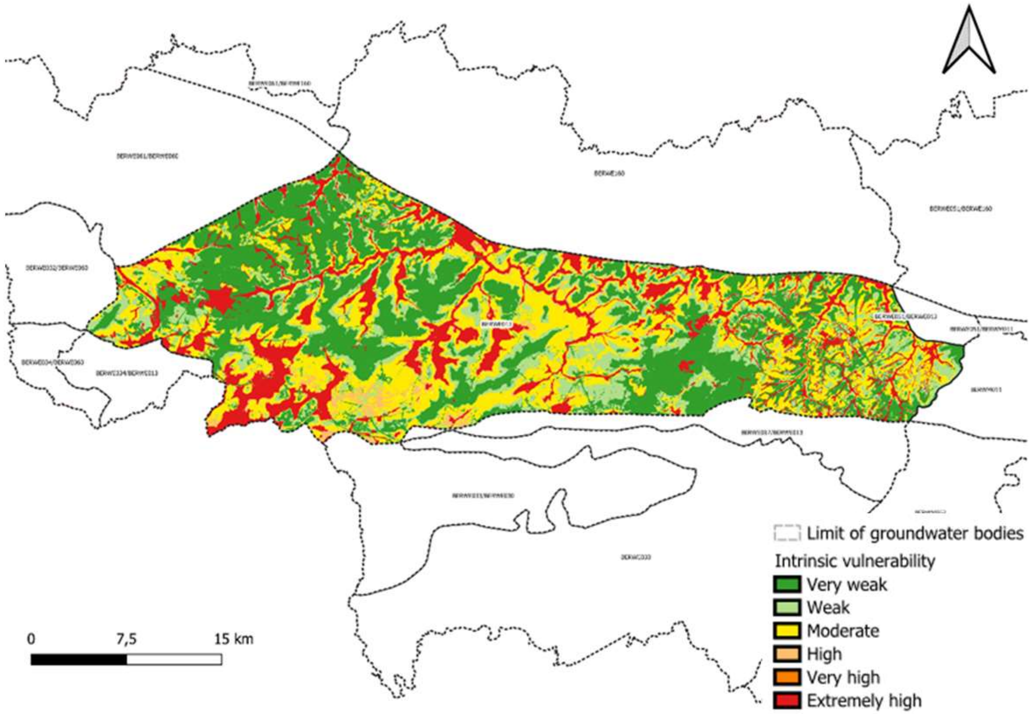


Application : Wallonia (Belgium) → « superposed aquifers »

GWB BERWE013 « Limestones of Pérulwez-Ath Soignies » overlain by sands



Vulnerability of first encountered aquifer (including sands)



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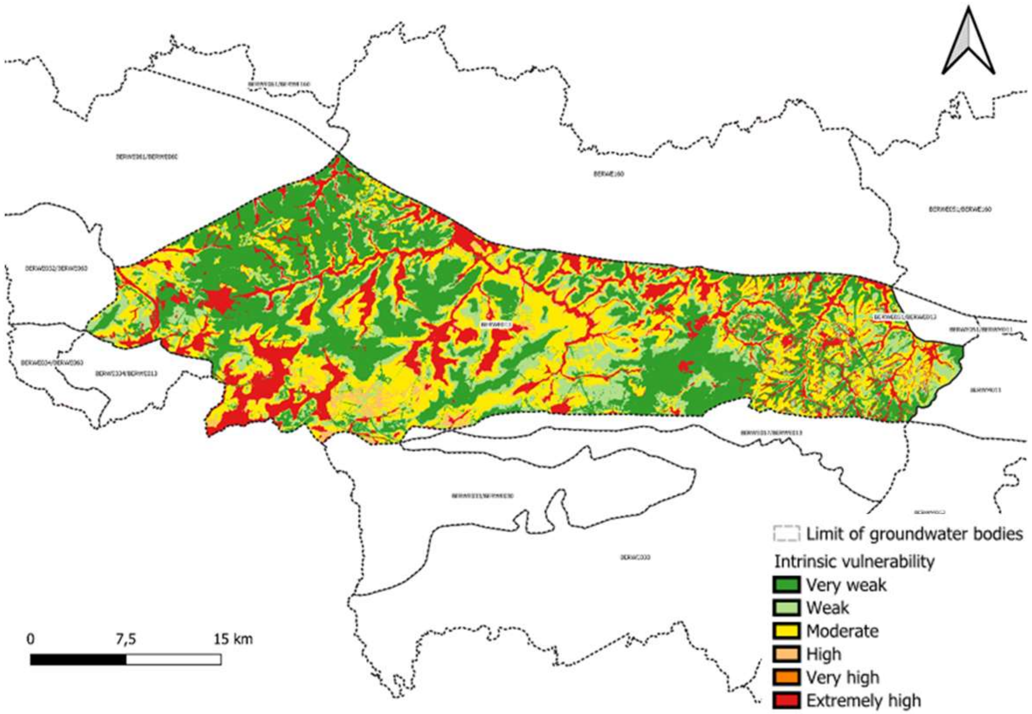
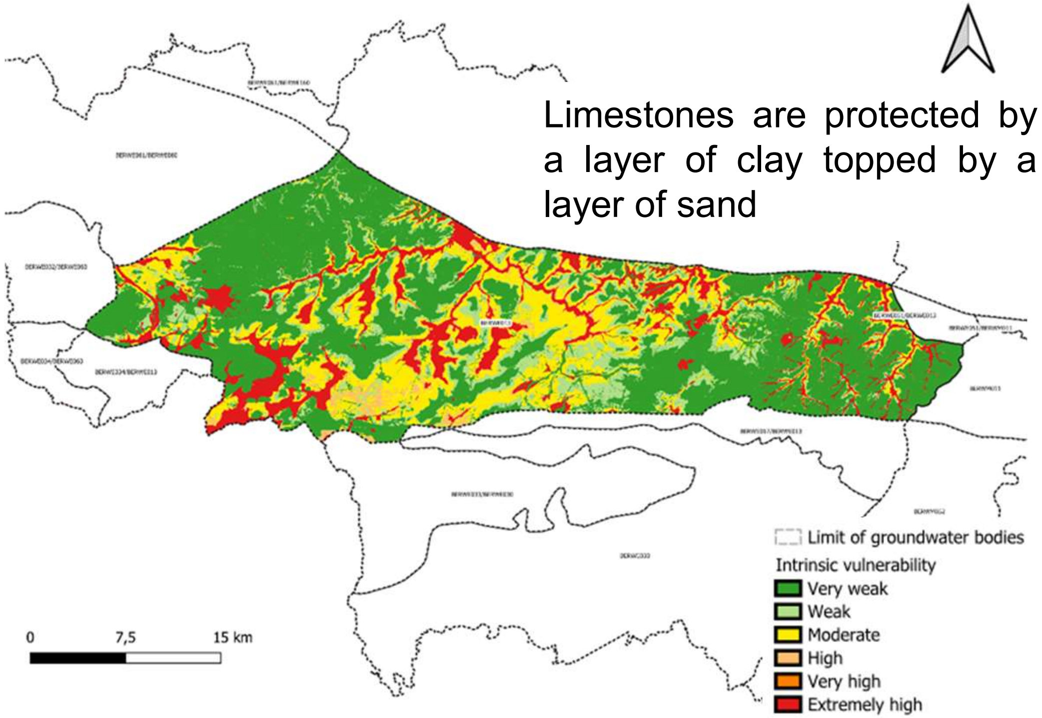
Vulnerability of first encountered aquifer (including sands)

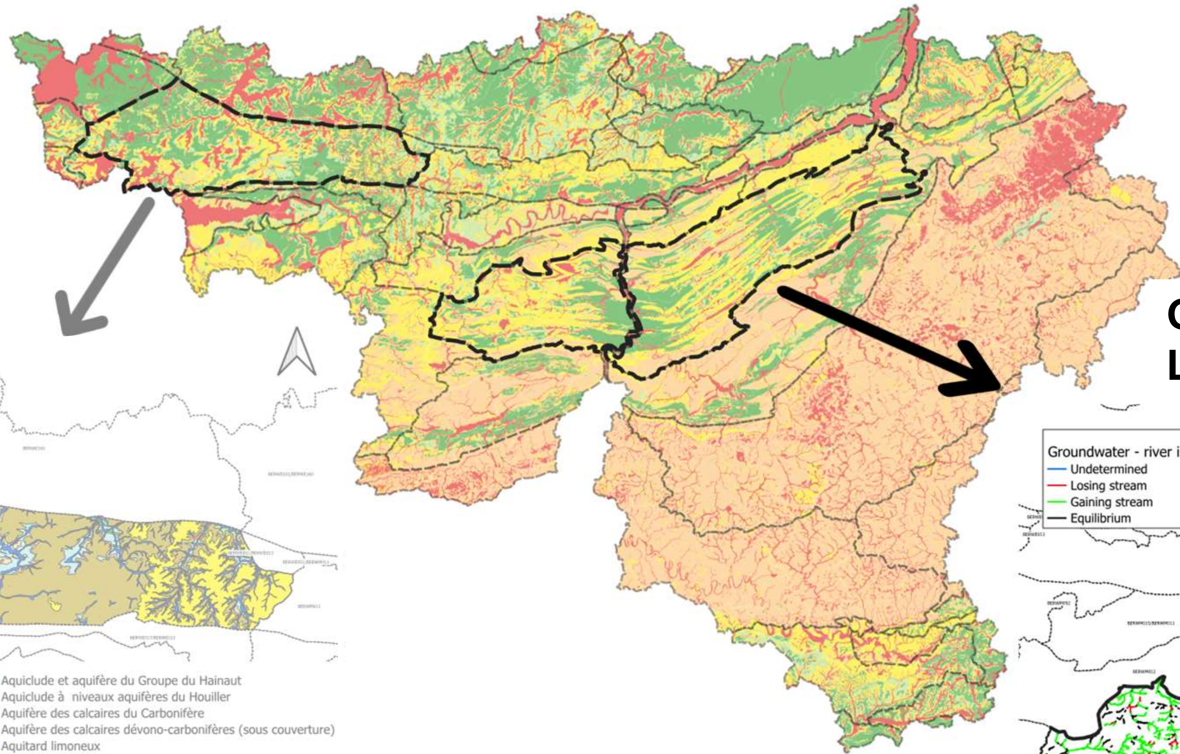


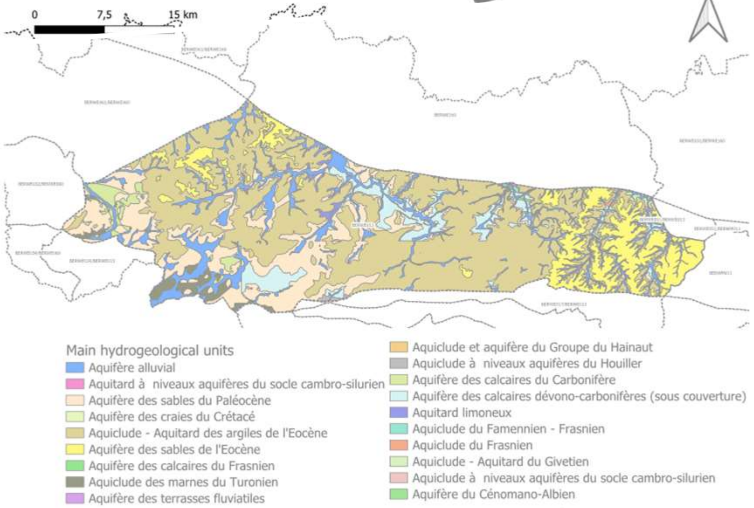
Vulnerability of the deep aquifer G1

Limestones are protected by a layer of clay topped by a layer of sand



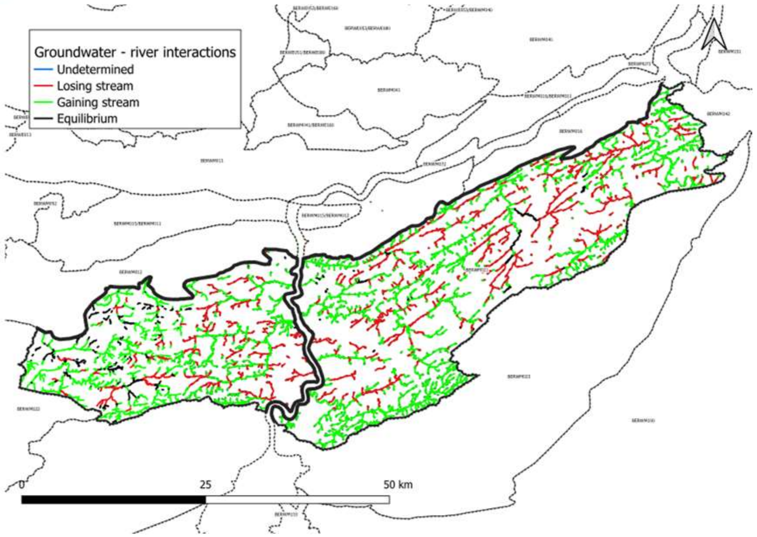
Application : Wallonia (Belgium) → « groundwater – river interactions »





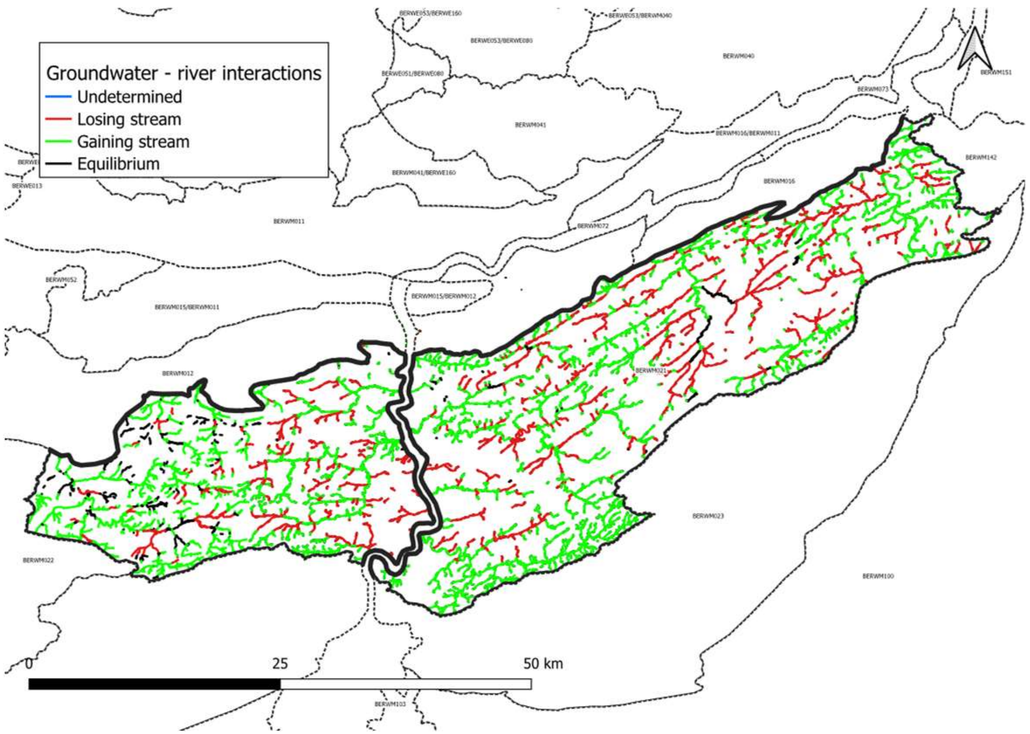
GWB BERWE013 « Limestones of Péruwelz-Ath Soignies »

GWB BERWM021 « Condroz Limestones & Sandstones »

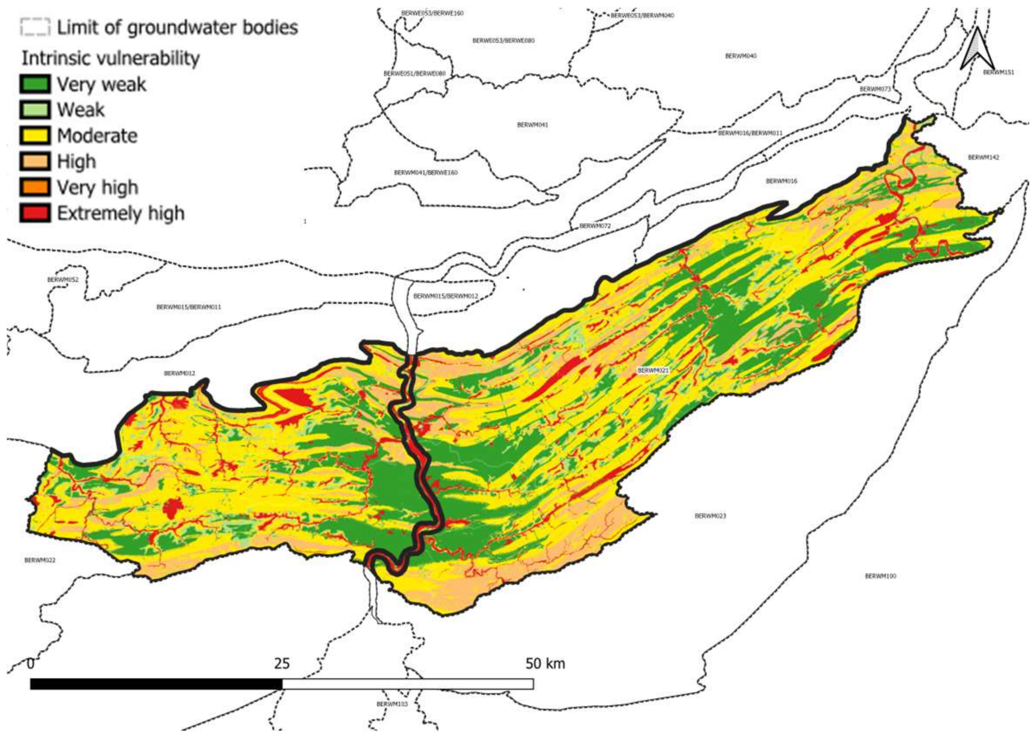


Application : Wallonia (Belgium) → « groundwater – river interactions »

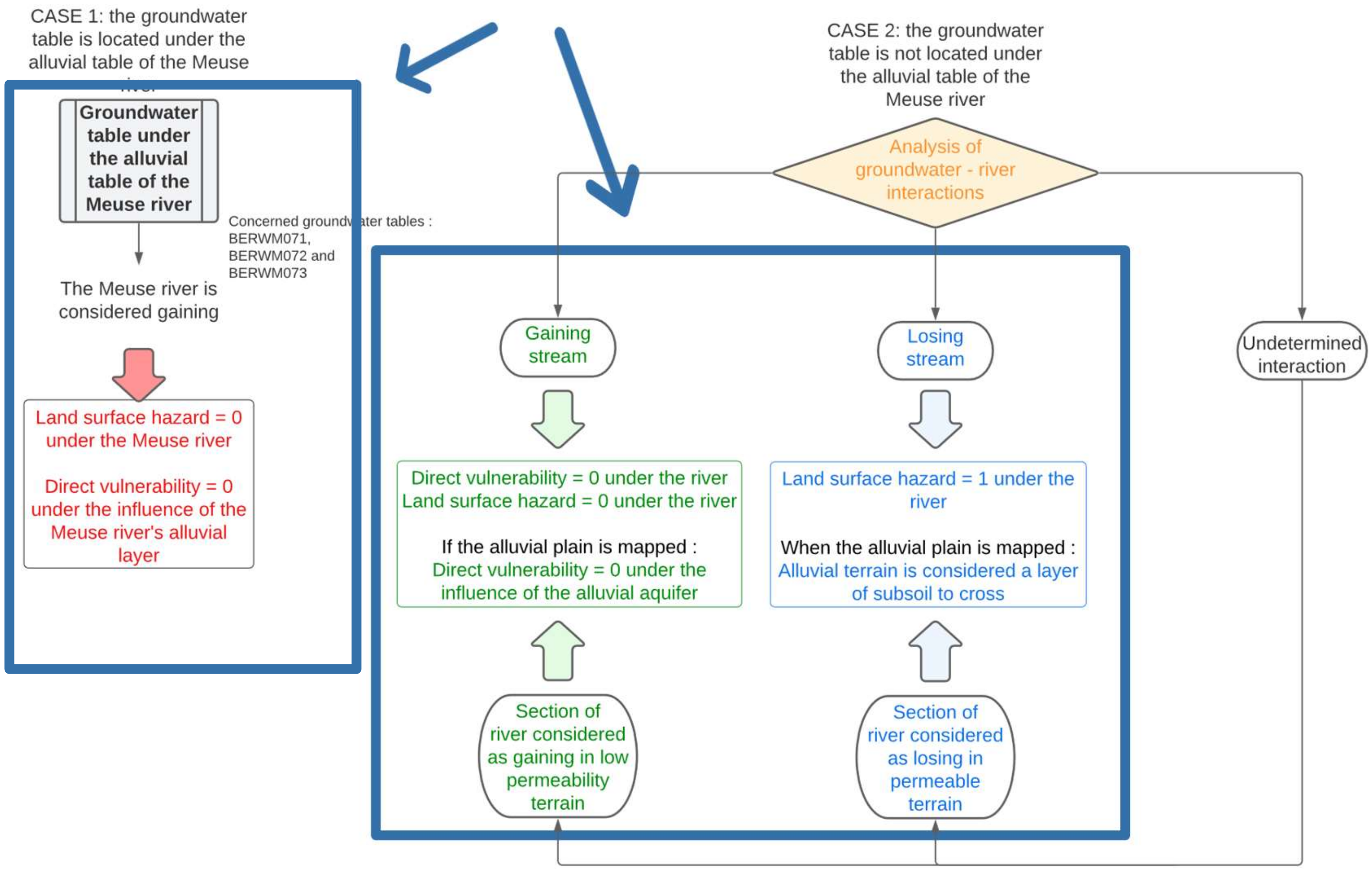
Well known groundwater – river interactions



Vulnerability of first accountered aquifer



Application : Wallonia (Belgium) → « groundwater – river interactions »



Application : Wallonia (Belgium)
→ « groundwater – river interactions »

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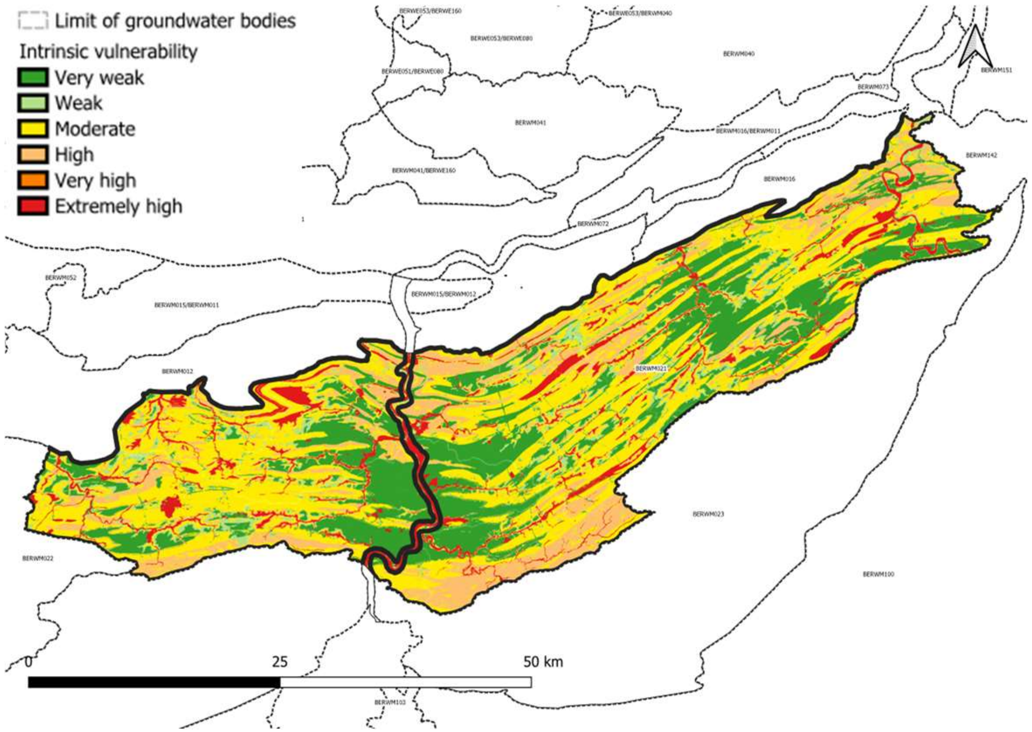
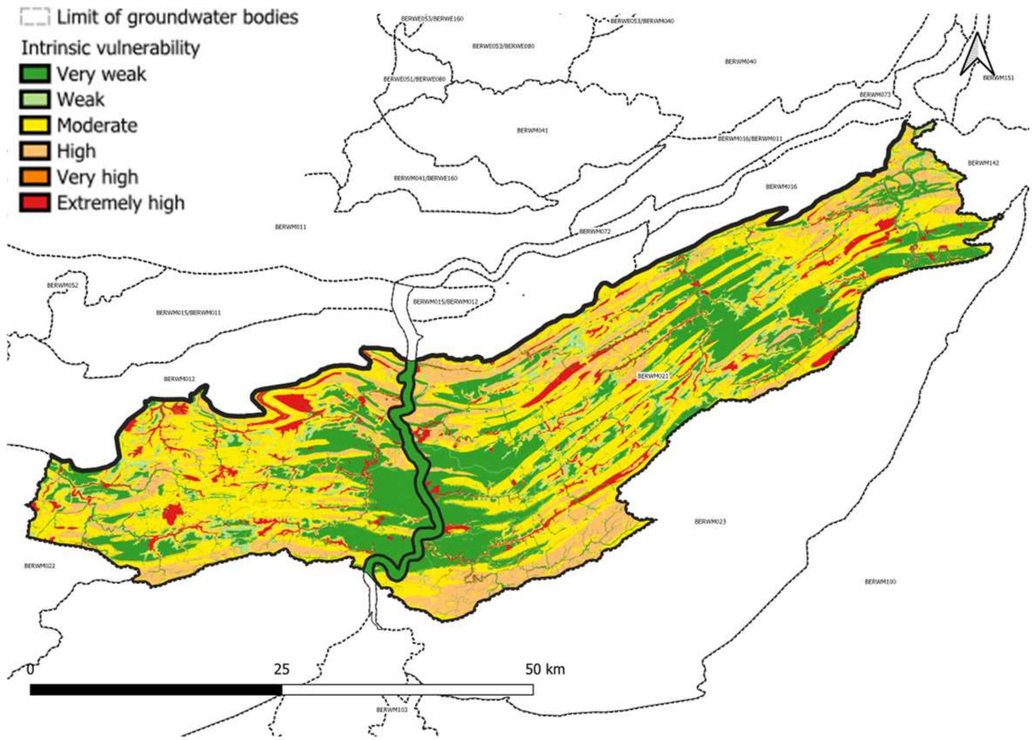
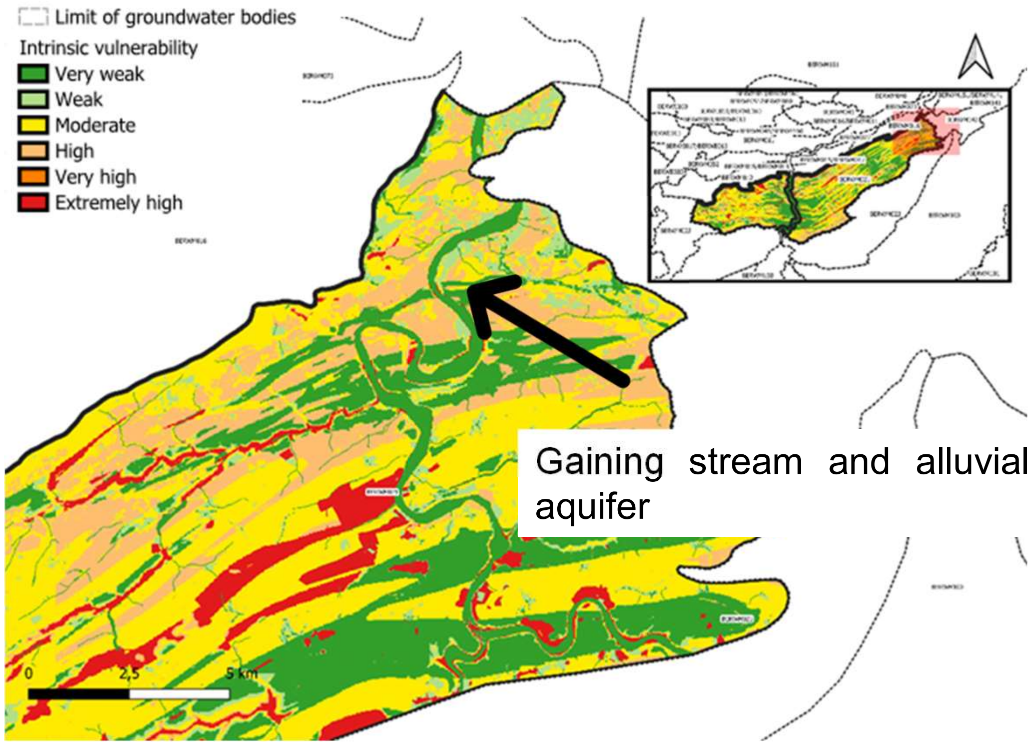


Vulnerability of groundwater body BERWM021 considering groundwater – river interactions

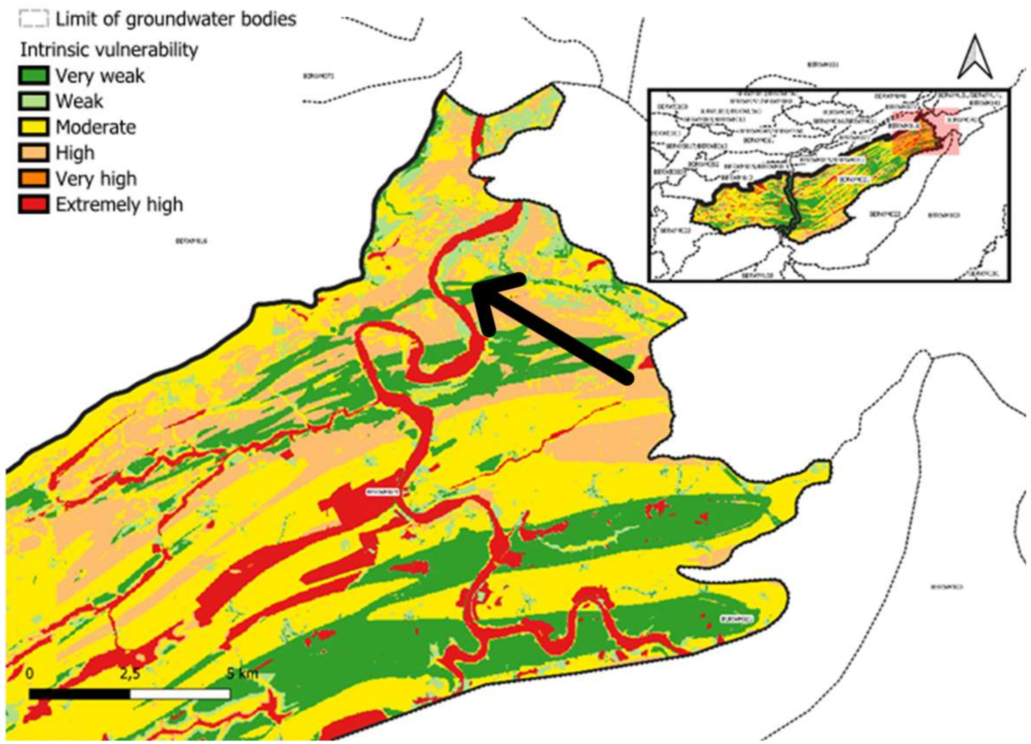


Application : Wallonia (Belgium) → « groundwater – river interactions »

Vulnerability of first encountered aquifer



Vulnerability of BERWM021 considering groundwater – river interactions



Conclusions – Perspectives

« Classical » Groundwater vulnerability assessment methods usually focus on the first aquifer saturated zone

→GW Vulnerability maps often biaised (« too red colored »)

Very often, main aquifers of interest (e.g. GW bodies) are deeper and protected by shallower geological layers

→ Alluvial aquifers in particular may act as effective barriers to the transfer of pollutants to deeper aquifers but this strongly depends on groundwater – river exchanges