TECHNICAL NOTE

Conjunctive Management of Water Resources

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Technical discussions and analyses of conjunctive water management[1] have been ongoing since the early 70's. However, apart from few examples of sound implementation of conjunctive management[2], well planned, financially viable and sustainable adoption is still rare across the world. The reasons are institutional constraints, uncertainty and risks concerning financial viability, inadequate understanding of potential benefits, and pre assumed complexity about the systems in the minds of decision makers.

Nevertheless, increasing scarcity and water stress in all climatic contexts, makes it imperative to overcome the above constraints. Therefore, engaging with decision makers is critical, so that where conjunctive management could make the difference between significant losses and overcoming them, they should approve and finance implementation. Having noted this, it is also worth stating that conjunctive water management is not a panacea, nor a solution to all conditions.

Prerequisites for conjunctive water management – Conjunctive management by definition means that more than one source of water is deployed to meet any given demand (see schematic illustrations below). It logically follows that the science of each of these used resources should be well understood and ground-truth data collected and well analysed before implementation. In addition, institutions should have adequate capacity, and a suitable legal framework should already be in place.

Since 'conjunctive' implies simultaneous or coordinated utilisation of more than one water resource, it also implies that the demand (e.g., for irrigation, municipal, aquatic ecosystems, etc.) is well defined, so that it can be met with the required manipulation of the various conjunctively managed resources.

Spontaneous vs. planned approaches – A survey of literature shows that there are many examples where spontaneous conjunctive use is progressing – meaning, for example, that farmers drill wells and draw water from aquifers when their surface irrigation water becomes insufficient due to new scarcity. This can, and has, led to the well-expressed situation of hydro-chaos, resulting in overdraft of resources. Converse to spontaneous use is planned and well-regulated management where the use of the two resources is complementary and cumulative. If the former is to be reversed, retrofitting, and the catch up of required rules will be significantly complex – not just from the regulatory and managerial perspective, but also economically and socially.

Common resources that best serve conjunctive management – The most obvious resources that are managed conjunctively are river water and groundwater. But there are many other subsets (lakes, glacier meltwater, brackish water, treated wastewater, etc.) – and as climate-induced freshwater scarcity intensifies, more of these types of sources could be mobilised as part of conjunctive and more cyclical approaches. Therefore, regulations and institutions need to (already) be prepared and coherent, and users need to be informed by best practice and access to design of viable options.

Geographic scale and focus in conjunctive water use and management – Almost all examples of planned, as well as spontaneous, conjunctive management appear at the field operational scale – i.e., a short stretch of river, a number of wells, (e.g., in a wellfield), and/or a nearby municipality or irrigation scheme. Literature review suggests that there are practically no examples at the 'catchment/basin or aquifer scale'. Further, the literature shows that the majority of current (spontaneous as well as planned) cases of conjunctive use are within domestic (national) jurisdictions.

Investigation, planning, and implementation – The technical investigations and socioeconomic planning for conjunctive utilisation is only slightly more complex than for other water resources studies and should not be considered a hurdle. However, retrofitting of resources management and governance to ongoing

[1] There is a significant amount of literature available on conjunctive use and management, see list of reviews at the end of this note.

[2] In this Note, the following terminology is used: (conjunctive) *use* = the utilisation of water (for irrigation, municipal use, etc.); (conjunctive) *management* = the construction and implementation of wells, canals, pumps, and their operational rules; (conjunctive) governance – the policies, regulations, institutions, and financing that underlie.

spontaneous practices can be complex. As mentioned, the downside of 'doing nothing' would be chaos and very likely decline in all the resources – many ongoing examples of this trend can be cited.

Conjunctive use of water derived from river – aquifer[3] – is the most common configuration (see diagrammatic illustrations below) – irrespective of whether the resources are hydraulically connected or not. When connected, induced leakage from rivers, and flood flow replenishment of aquifers are the key features. When not connected, water may be taken from the river during high flows, and disconnected aquifers may be drawn upon during drought / low flows. There are many more subtleties to this kind of configuration, not covered here to brevity of the document. See also Box 1 for more illustrative examples.

Conceptual connection of the hydrological - hydrogeological systems – It is a prerequisite that the two resources are understood quantitatively, for which a plethora of scientific- technical tools are widely available for analysis. The main constraint is ground-truth data to support these analyses (i.e., reliable river flow records, measured groundwater levels and quality, characteristics of the hydrogeological system, etc.)

Technical skills and competences for successful conjunctive water management – availability of trained and experienced field staff, hydrogeologists, hydrologists, engineers, sociologists, and economists are obligatory. In addition, community liaison cadres for good communication with users are essential.

Regulatory and oversight (monitoring) requirements – In the absence of clear regulations that cover each of the resources that is to be conjunctively used, there will be hurdles. The licencing and permitting must explicitly address the hydrological reality, e.g., their prevalent interactions and overlap between surface water and aquifer, while wisely regulating the amounts and the durations of abstractions, as well as any remedial actions required (e.g., the obligation to replenish). Retrofitting implies access to significant institutional resources, and effective in-depth consultations may be needed. Retrofitting is not insurmountable – but it needs suitable resources.

Cost benefits and estimation of externalities – Review of literature has suggested that the transition from chaotic/spontaneous to planned conjunctive use and management can provide significant benefits. For those operating schemes that have made the transition from spontaneous to well-regulated ones, the benefits are easy to demonstrate, especially where externalities have been addressed, e.g., costs associated with changed river flow regimes, to fisheries or downstream abstractors, or additional drawdowns in wells outside of the immediate conjunctive use scheme.

The transboundary dimension – Conjunctive management in a transboundary context increases the complexity further, due to the need for harmonisation of institutions and regulations and for coordination of national and international allocation of financing. This complexity is also not insurmountable, and cases have been advanced to demonstrate potential tangible shared benefits (IW:LEARN, see Further reading below). See also examples of potential transboundary opportunities in Box 2 below.

Research and development needs in the short term to long term – The topic requires practical research and field implementation – in the short term, through a methodical inventorisation of cases of ongoing conjunctive water use - both spontaneous and planned/managed, including in transboundary context. In the longer term, more well-planned pilots on methods & benefits, to move from aspirations to actions, are highly recommended.

[3] Note the use of the term 'aquifer' here, as opposed to 'groundwater' – there are difference in the meaning of these terms.

Box 1. Examples of conjunctive water management with focus on water quantity and quality aspects

A simple but important example of conjunctive water management is when surface water is running low during a drought, but groundwater is still available, because it reacts more slowly to a drought. Conversely, during monsoon periods or when there are periods or situations of excess surface (or other) water, this becomes the primary source of use, while the groundwater systems (the empty parts of the aquifers) are left to replenish (Figure 1). The replenishment part, which can also be enhanced through the use of treated wastewater, is central, as it helps to accelerate the recharge a normally slowly renewable groundwater resource. Rules need to be established for the allocation of water for replenishment, in order not to over-exploit the resource.

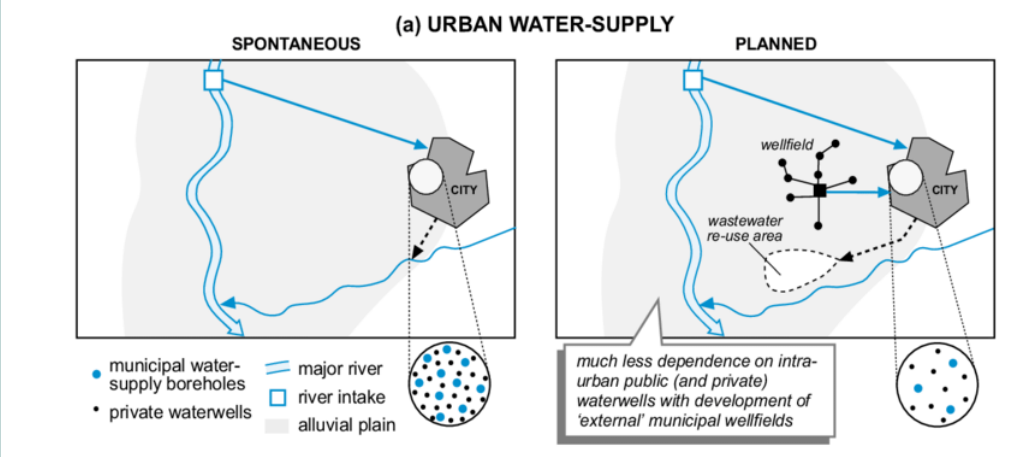


Figure 1. Planned conjunctive water use and management in an urban context.

Another example is in canal irrigation schemes where groundwater is used complementarily, in order to minimize water logging and salinization. As indicated in Figure 2, to enhance a more managed approach, it is important to strive towards equilibrating the groundwater use across upstream and downstream parts to achieve the necessary effect. Such approaches can be implemented when there is a good understanding among farmers that head-end users must release part of the fresh canal water to tail-end users who may otherwise suffer salinization of their land.

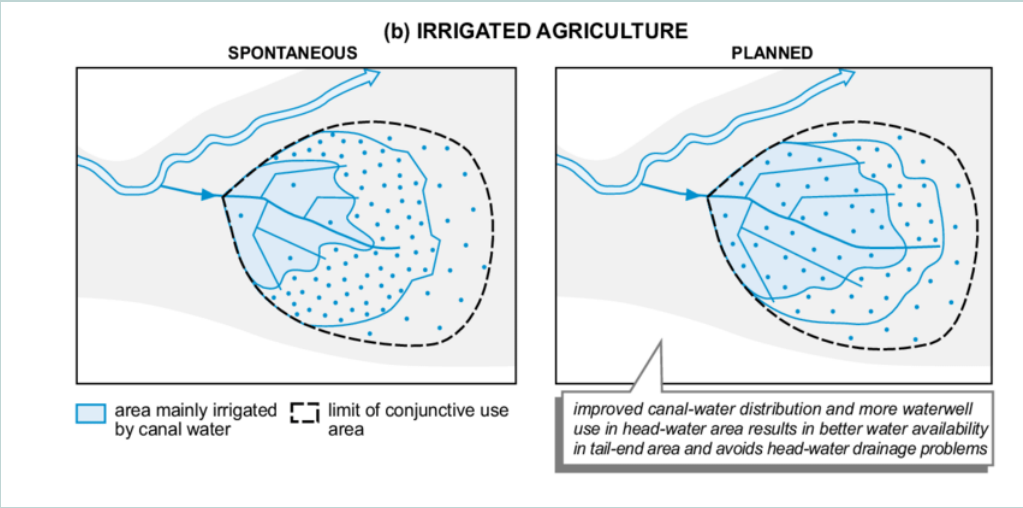


Figure 2. Conjunctive water management in canal irrigation systems.

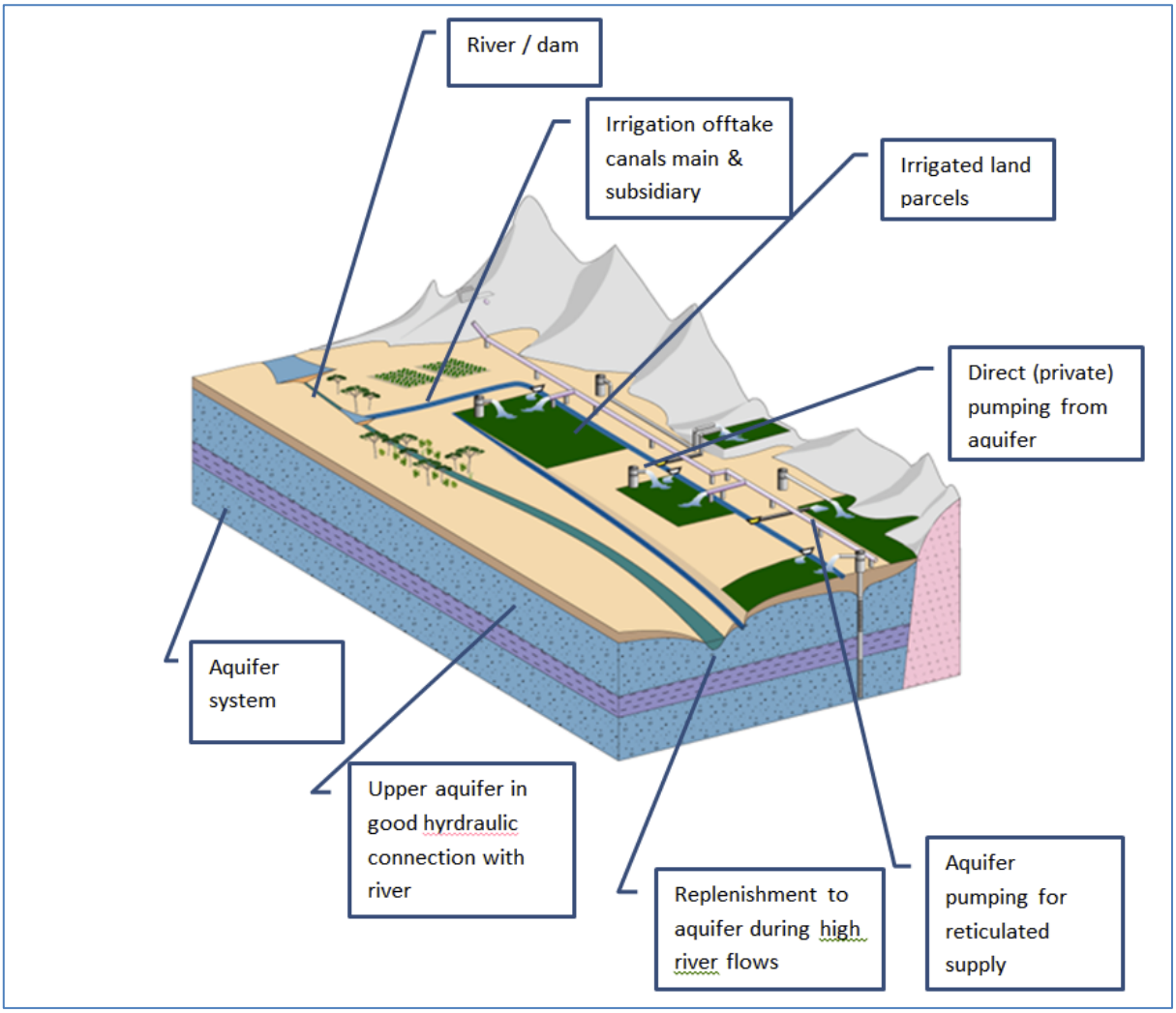
Box 2. Opportunities and co-benefits of conjunctive water management in a transboundary context

Opportunities across borders for sharing benefits around conjunctive water management can enhance climate resilience through intelligent water storage solutions that also incorporate aspects of water retention, capture and storage underground. An example of this is in the Fergana Valley in Central Asia, which is shared among four states. Due to the need for hydropower generation in the winter, water cannot be stored in high elevation reservoirs for subsequent irrigation in the summer. However, storage of released dam water in lower-level areas with good aquifers would allow pumping groundwater for irrigation in the summer. The costs and co-benefits of hydropower and water for irrigation could be shared between upstream and downstream countries.

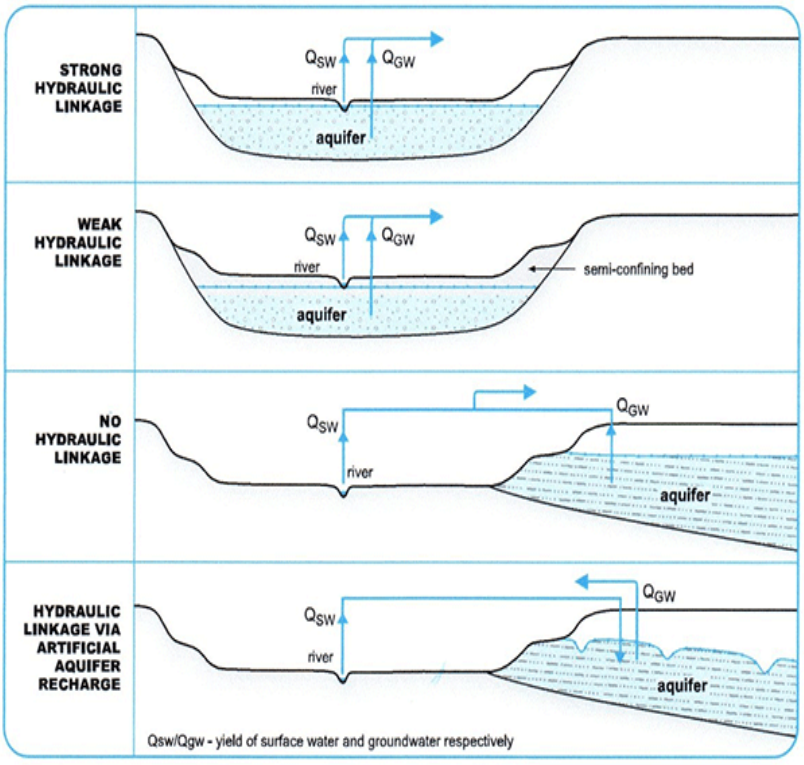
Another example is the shared management of extreme floods between Burkina Faso and Ghana. Here, recurrent flooding at the border between the two countries results in severe downstream devastation to many communities. An opportunity lies in the diversion of flood waters to areas of aquifers that have been drawn down during the dry season for irrigation. The feasibility of such an approach, which has been successfully implemented in national settings, like in India, should be further investigated in cases like the transboundary Burkina Faso-Ghana one.

DIAGRAMMATIC ILLUSTRATIONS

A schematic illustrating the main components of conjunctive use and management.



Aquifers and river systems come in several configurations. Some examples are illustrated below. In these, both river and groundwater are used. All these configurations fall under the heading of conjunctive use and management.

Conjunctive Management: (= operating the river/aquifer abstraction systems)	
(i) River – aquifer, in strong continuity: groundwater pumping close to river induces natural infiltration into aquifer.	 Conjunctive use = using the water from a river and an aquifer for a specified need, e.g., irrigation, or municipal supply. Conjunctive governance = the rules and regulatory frameworks that all parties adhere to.
(i) River – aquifer in poor continuity: groundwater pumping close to river has a slow / delayed impact on river.	
(i) River – aquifer, with no replenishment offset – no connection: each can be pumped simultaneously or separately – no mutual direct impact.	
(ii) River – aquifer, with replenishment offset: river water can be used to recharge the aquifer or vice versa, aquifer can be pumped to keep river flow going	

Further reading

- Conjunctive Water Management: A powerful contribution to achieving the Sustainable Development Goals (UNESCO, 2020).
- Conjunctive management of surface and groundwater in transboundary watercourses: a first assessment (Lautze et al., 2018).
- Conjunctive use and management of groundwater and surface water (Groundwater Governance Project, 2014).
- CWM in Transboundary Context (IW:LEARN).
- Water 'banking' in Fergana valley aquifers—A solution to water allocation in the Syrdarya river basin? (Karimov et al., 2010).
  Conjunctive Use of Groundwater and Surface Water from spontaneous coping strategy to adaptive resource management (Foster et al., 2010).
- A three-dimensional numerical groundwater flow model to assess the feasibility of managed aquifer recharge in the Tamne River basin of Ghana (Okofo and Martienssen, 2022).