International Association of Hydrogeologists

Strategic Overview Series

ECOSYSTEM CONSERVATION & GROUNDWATER

KEY MESSAGES

- **groundwater-dependent ecosystems (GDEs) comprise a complex subset of ecosystems of major significance in the conservation of biodiversity - including many vital sites covered by the RAMSAR Convention and many others that remain unprotected**
- **GDEs have direct value for the human population from fish and plant production, water storage and purification, and indirect value in terms of landscape and/or habitat**
- **there is need to identify GDEs under three main types – aquatic, terrestrial, subterranean – and improve understanding of their relationship with the physical and chemical status of groundwater**
- **degradation of GDEs can occur because of anthropogenic modifications to aquifer flow regimes and salinisation or pollution of their groundwater**
- **potentially negative impacts on the functioning of GDEs from groundwater withdrawals for irrigated agriculture or urban water-supply need to be assessed and managed**
- **modest increases in groundwater salinity and/or pollution (with nutrients and pesticides) can drastically impact ecosystem structure and cause extermination of key species**

What are groundwater-dependent ecosystems and why are they important ?

A groundwater-dependent ecosystem (GDE) is a community of micro-organisms, animals and plants, and associated substrates, whose functioning relies on the presence of water under the ground and/or its emergence to the surface. Some GDEs are supported entirely by groundwater while others also receive water from different sources, but the groundwater contribution is critical as regards water chemistry to nourish certain species, and provide stable water temperature and absence of sediment load.

GDEs are mainly land-surface features of various types :

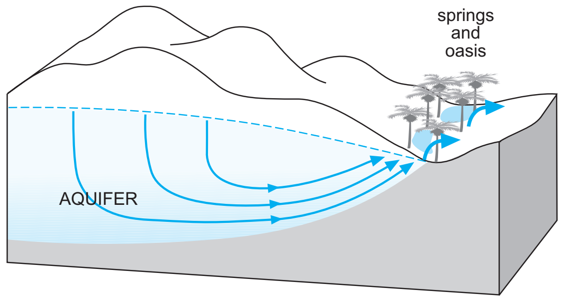
- aquatic – including springheads, and those wetlands, streams, rivers and lakes receiving groundwater discharge (which are the main focus of attention here)
- terrestrial – with phreatophyte vegetation, either shallow-rooted in alluvial settings (such as some lowland woods and meadows) or deep-rooted in arid zones with much deeper water-table.

But they can also be subterranean – notably in limestone formations with karstic caverns and fissures inhabited by small invertebrates and some specialised vertebrate species.

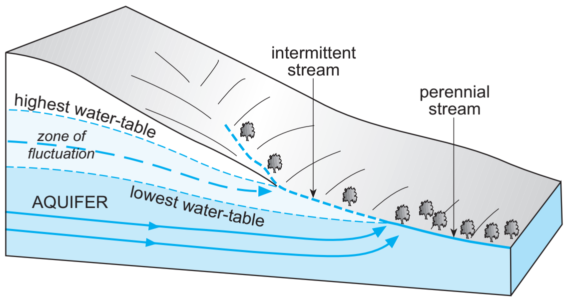
EL ROCIO WETLAND IN THE DOÑANA NATIONAL PARK OF SOUTHERN SPAIN

This Series is designed both to inform professionals in other sectors of key interactions with groundwater resources and hydrogeological science, and to guide IAH members in their outreach to related sectors.

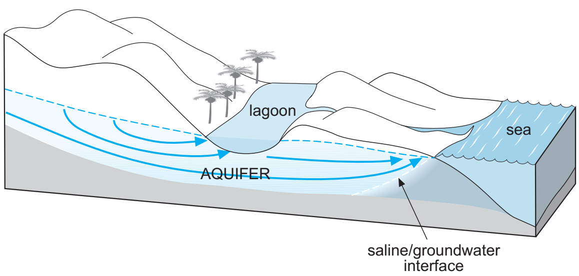
WETLAND ECOSYSTEM IN ARID REGION
WITH ONLY LIMITED CONTEMPORY GROUNDWATER REPLENISHMENT AND FOSSIL AQUIFER FLOW



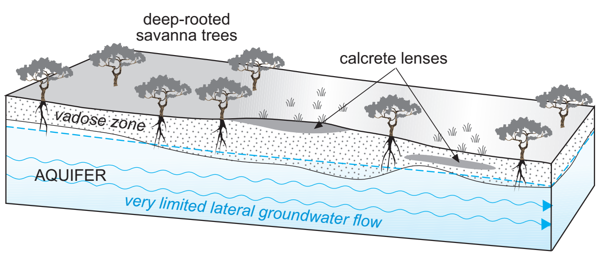
AQUATIC STREAMBED ECOSYSTEM IN HUMID REGION
ALONG UPPER REACHES OF RIVER FED BY PERENNIAL AND INTERMITTENT GROUNDWATER DISCHARGES



COASTAL LAGOON ECOSYSTEM
DEPENDENT UPON SLIGHTLY BRACKISH WATER GENERATED BY MIXING OF FRESH GROUNDWATER AND LIMITED SEAWATER INCURSION



TERRESTRIAL SAVANNA ECOSYSTEM
DEPENDENT UPON EXCEPTIONALLY DEEP-ROOTED TREES AND BUSHES TAPPING THE WATER TABLE IN ARID REGION



FROM RAMSAR SITES TO KNOWING YOUR LOCAL SPRINGS

The RAMSAR Convention (named after the town in Iran where it was signed in 1971) constitutes an agreement by 169 countries to take action on the conservation of priority wetlands (aquatic ecosystems many being GDEs), in the special interest of protecting wildfowl habitats. The agreement currently involves over 2,200 sites amounting to a land area in excess of 210,000 km^2. At a very different scale, the 'Conoce Tus Fuentes' ('Know Your Springs') web-based initiative of the Andalucian Government of Spain has succeeded in mobilising the general public, under academic coordination, in primary mapping of 10,100 springs across this relatively arid region. Both are excellent examples of approaches to raising political and public awareness of GDEs.

GDEs are fundamental to the conservation of biodiversity – many being vital for survival of a wide variety of species and figuring prominently in sites covered by the RAMSAR Convention. Moreover, GDEs can be of significance as a renewable source of human nutrition and as key features in the local landscape such as springs and lagoons.

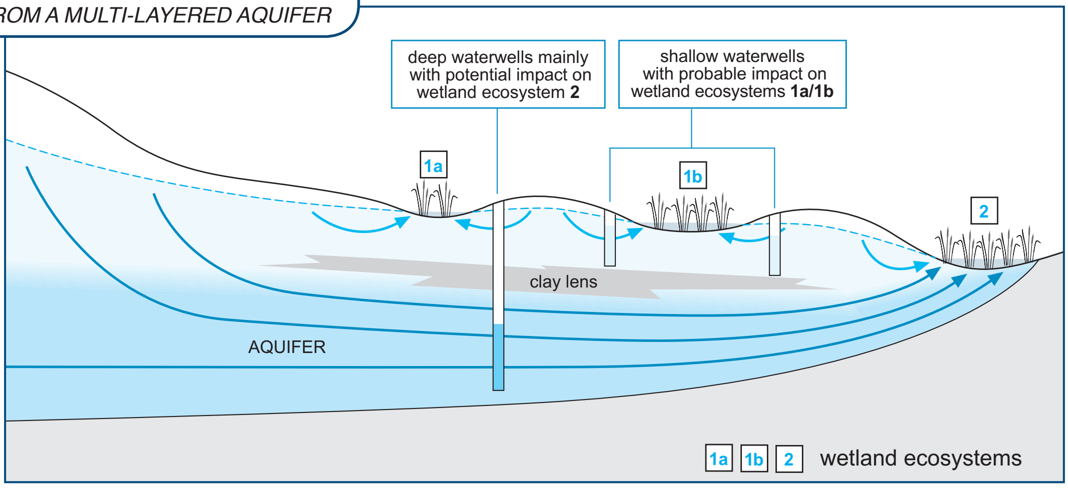
Some prefer to introduce the term 'aquifer-dependent ecosystem' to emphasise that aquifers constrain the groundwater flow on which ecosystems depend. It should also be noted that some aquatic ecosystems occur in aquifer recharge zones and represent a major source of groundwater system replenishment.

How can degradation of groundwater-dependent ecosystems arise?

The degradation of GDEs occurs as a consequence of both modification of natural groundwater flow regimes and salinisation or pollution of groundwater.

All groundwater pumping has some effect on water-table levels – but in terms of ecosystem impact the main concern is where the cumulative effect of major extraction (for agricultural irrigation or urban water-supply) causes substantial and persistent water-table lowering. This can also sometimes arise in the absence of intensive groundwater use:

POTENTIAL INTERFERENCE WITH GDEs OF GROUND-WATER PUMPING FROM A MULTI-LAYERED AQUIFER



- if recharge zones experience major changes that increase consumptive water-use (eg : low-land afforestation) or riverbed modifications that decrease aquifer replenishment (eg : impermeabilisation or diversion)
- where dewatering for tunnel construction or mining operations seriously impacts the groundwater flow regime.

The resulting reduction in groundwater discharge can trigger a change in ecosystem functioning and in turn ecosystem structure, and in extreme cases cause its complete elimination.

There is often uncertainty about the reaction of individual species to hydrological change and species interdependence within a GDE. Moreover, the way that groundwater discharges into, and interacts with, the surface environment (in the transitional hyporheic zone) can be critical to aquatic life (not just the presence of water). Whilst certain irreversible changes can occur in relatively short periods (such as oxidation of wetland or streambed sediments), some species are well adapted to survive hydrologic extremes, and those naturally exposed to variations in groundwater behaviour (for example in ephemeral streams) are more resilient.

Modest increases in groundwater salinity can change ecosystem structure dramatically, and cause extermination of some species. This can occur where irrigation waterwells mobilise salts from depth in aquifers (or contained in aquitards), which are then further concentrated in irrigated soils before leaching to shallow groundwater.

Groundwater pollution can have a similar impact – and the most widespread cause is agrochemical leaching from land-use practices. Pesticides and nutrients that are leached from soils eventually reach the water-table, and can migrate to GDEs in natural discharge zones. The effect of groundwater quality deterioration, notably increases of nitrate, ammonium or phosphate (even at low concentrations) and/or trace pesticide contamination, may lead to greater ecosystem impacts than groundwater flow diminution. Elevated nitrate and phosphate concentrations can cause ecosystem eutrophication, eliminating oxygen and killing fish and small aquatic animals.

What can be done to protect groundwater-dependent ecosystems?

Two main lines of action are required for protection of GDEs and have been strongly advocated for all sites covered by the RAMSAR Convention:

- increasing knowledge of their hydrogeological and ecological condition, and the economic consequences of degradation for human well-being
- integrating their protection into basin/aquifer water-resource and land-use management.

Systematic assessment is required for each GDE to understand its evolving relationship with underlying aquifers, to evaluate groundwater quality and define chemical baseline, to identify anthropogenic pressure trends, and to determine the socioeconomic contribution of ecosystem services. The end product should be a conceptual model of GDE functioning, using GIS and other data management systems to display results clearly.

All measures that strengthen the governance and practical management of groundwater can contribute, or be adapted, to the cause of protecting GDEs – by including criteria to maintain groundwater levels and conserve groundwater quality to meet the requirements of the ecosystem receptor. This will often imply greater constraints on the volume and distribution of groundwater withdrawals than would otherwise have been necessary, together with more severe controls over groundwater contaminant load than needed to conserve drinking-water quality. A balance between improving rural livelihoods and sustaining ecosystem health needs to be achieved.

However, social development pressures may be such as to prevent control of groundwater levels and quality in an entire aquifer system in the interest of GDE conservation, and alternatives may need to be pursued such as:

- acting selectively to introduce 'protection zones' around GDEs, capable of assuring shallow groundwater quality and reducing groundwater level interference
- artificial recharge to supplement groundwater flows and improve quality over limited areas in the interest of GDE conservation, or even pumped compensation flows when aquifer levels fall below some critical level.

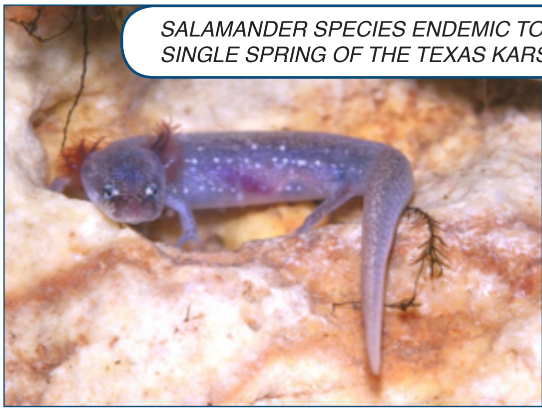
How can the value of groundwater-dependent ecosystems be assessed?

GDE functions are an important component of overall environmental services provided by a groundwater system. Economic assessment of GDEs will require clear definition of the benefits of these ecosystem services including :

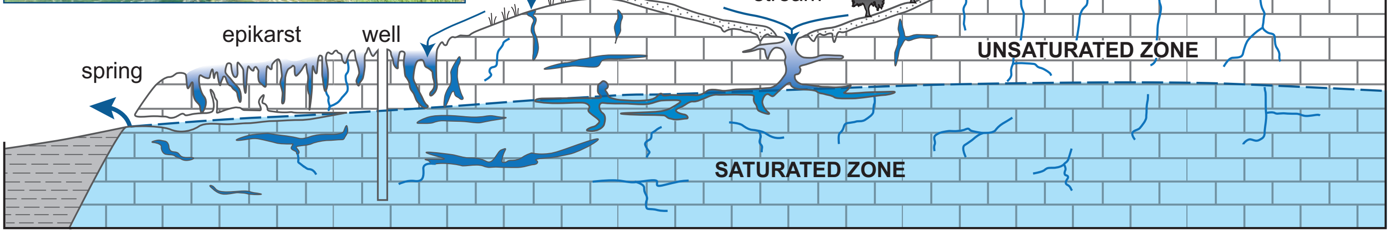
- direct values to the human population in terms of fish and plant production, and providing water storage and purification
- indirect values from sustaining biodiversity, habitat and landscape for social, cultural, aesthetic and ethical reasons.

But in the developing nation context it is recognised that direct use values from harvested plants and animals, and from landscapes or habitats for tourism are likely to be more important. If the livelihoods of poor and vulnerable people depend directly on the functioning of GDE's there is a risk that ecosystem value may be systematically under-estimated.

Disputes are often likely to arise over the balance between improving rural livelihoods and sustaining healthy ecosystems. Decision-making needs to be informed by sound technical and economic analysis, and it is thus important to incorporate economic evaluation into the analysis. A useful framework for GDE valuation, and the relationship between human wellbeing and ecosystems, is the so-called 'ecosystem services approach' of the UN Millennium Ecosystems Assessment Project. It argues that human progress has always relied on natural resources and functioning ecosystems. The assessment must use reliable historic data and scientific studies.
The method also includes assessment of the impact (observed and forecast) of a set of 'driver factors' that change GDE behaviour.



SALAMANDER SPECIES ENDEMIC TO A SINGLE SPRING OF THE TEXAS KARST



An economic analysis for this purpose will normally entail a relative assessment of the :

- cost of protection in terms of the loss of alternative uses of groundwater and land, and the administration of the land-use and groundwater control policy
- benefits of protection in terms of in-situ value of groundwater and groundwater-related ecosystem services.

In this context an analysis based on marginal cost-benefit is likely to better reflect the situation on-the-ground, and scenarios of partial protection (as opposed to total protection) of GDEs will also need to be considered.

What institutional and legal arrangements can facilitate consideration and protection of groundwater environmental functions?

Policies need to be elaborated and implemented through interaction between national and local environment agencies based on the following principles :

- GDEs have important and diverse value for human wellbeing
- groundwater use should be managed so as to give priority to protecting GDEs
- land-use planning and development should aim to minimise impacts on GDEs.

There is a major need to promote public awareness of the groundwater-dependence of many ecosystems. As such it is critical that GDEs are identified, located, characterised and inventorised – including designation of GDEs of major importance, such as those covered by the RAMSAR Convention.

An appraisal of GDE vulnerability with respect to potential impact from land development and resource withdrawal is a critical aspect of the assessment. Appropriate legal provision and institutional arrangements will be required to implement the required GDE protection.

In developing countries, strong social pressures are likely to arise for further agricultural and urban development, which are likely to impact GDEs either directly (through increased groundwater withdrawals) or indirectly (through increased groundwater contaminant load). Thus an important issue in relation to the implementation of groundwater management is which stakeholder should represent the interests of a given ecosystem. There are a number of possiblities:

- an NGO representing the local community dependent on a healthy ecosystem or generally interested in ecosystem conservation
- the local land authority representing the balance of interests of all land-owners
- an environmental agency at national or local territorial level.

Without the existence of a groundwater use rights system and the participation of a clearly-identified stakeholder group, it is unlikely that

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the interests of GDE sustainability will get an adequate hearing in the discussion of land and water development options.

Given the likelihood of significant uncertainty over the precise level of impacts on GDEs arising from a given water-resource and/or land-development proposal, the regulatory agency generally needs to adopt a clear decision-making strategy. This will normally have to embrace one or other of the following :

- the precautionary principle of not authorising developments until ecosystem risks are established and managed (which may be too conservative for most developing countries)
- pragmatic initial groundwater resource development, with careful monitoring, evaluation and adaptation of plans in the event of significant impact
- reserving specific environmental flow or conserving water-table level within the overall groundwater resource management strategy and planning to sustain key wetlands.

The complexity of estimating the impacts of groundwater extraction and pollution make it difficult to define limits that can be readily measured and legally enforced – but legislation can provide for this by stipulating that 'in cases where stakeholders do not agree with the regulatory authority's determination they can undertake more detailed studies at their own cost'

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PRIORITY ACTIONS

- foster social awareness of the importance of groundwater for sustaining viable ecosystems – and mobilise appropriate stakeholders for GDEs (such as conservation NGOs and local land authorities)
- increase knowledge of hydrogeological and ecological conditions of GDEs and the economic consequence of their degradation for human well-being
- include GDE conservation within integrated catchment management or at least act selectively to incorporate GDE protection zones into groundwater resource use and land-use control policy
- adopt an adaptive management approach to conserving GDEs, informed by careful monitoring and assessment, given the likelihood of significant uncertainty in predicting ecosystem impacts
- consider augmentation of groundwater inflows to aquatic ecosystems if the water-table should fall below a defined critical level due to abstraction or drought

Supported by:
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