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The groundwater management plan: in praise of a neglected 'tool of our trade'

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Why put the spotlight on groundwater management planning?

The elaboration of groundwater management plans (GW-MaPs) aimed at:

- Conserving the overall resource base and protecting its quality
- Recognising and resolving local conflicts over resource allocation or pollution.

has received very little attention in the literature, compared for example to that dedicated to groundwater flow and pollutant transport modeling. Nevertheless, it will always be the technical adequacy, institutional suitability and implementation efficiency of such plans on which the sustainability of the groundwater resource base depends. Additionally, while a numerical model is critical for improved understanding of groundwater system behaviour, it is only part of the 'supporting act' when it comes to practical groundwater management and protection.

In some ways groundwater management planning is an art form, and a far from fashionable one! Some say why bother when we live in a rapidly changing world in which plans are rarely fulfilled. However, many recognise that if we are to confront the challenges of global change and scientific uncertainty we need to move to an adaptive style of management, which necessitates a structured and cyclic process of setting realistic targets, implementing planned action, critically reviewing progress and adjusting as necessary.

This article is especially focused on 'emerging economies' which are subject to rapidly increasing stress on groundwater systems, and where uncontrolled groundwater resource exploitation and unconstrained land-use on recharge zones is leading to unsustainable and inequitable outcomes. In the more arid regions, groundwater resource sustainability is seriously challenged by intensive use of groundwater for agricultural irrigation and the elaboration of a GW-MaP will in effect be a guide towards a desired future and more stable condition which is adopted by the main stakeholder groups. In other circumstances, a rising water table, due to excessive infiltration rates, may be causing serious problems of soil waterlogging and urban drainage. This article aims to put the spotlight on the process of management planning for groundwater by:

- Introducing key factors that need to influence the approach and balance of such plans
- Discussing how hydrogeologists can promote realistic GW-MaPs for their local aquifers.

A GW-MaP is an effective way to capture and integrate basic groundwater understanding, sustainable management measures and a focused action-plan in a single document. Each GW-MaP should specify clear objectives and desired outcomes, along with an agreed financial arrangement, operational time frame and monitoring network.

How is management planning related to groundwater governance?

Good groundwater governance of necessity must promote effective resource management and quality protection, through fostering socially responsible behaviour amongst waterwell users and potential polluters (Foster et al. 2009). And the best way to ensure that acceptable management and protection stem from governance strengthening is explicitly to require the establishment of a GW-MaP for priority groundwater management units (also sometimes

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known as 'bodies' or 'systems') as a key activity of the national and/or local groundwater resource agency. This has the major advantage of requiring articulated objectives, clear time-frame and critical review of the action-plan adopted.

The widespread failure of many past and present groundwater management efforts generally reflects inadequate governance more than just deficient legal provisions for resource management and pollution protection—with lack of political awareness of issues and/or urgency to address them being frequent concerns. However, in some instances for groundwater, resistance to governance reform and management strengthening will be encountered, because the current status quo is generating major benefits for the vested interest of some well-established groups. It is thus important to understand why previous governance provisions and/or day-to-day management arrangements have failed, and this requires the appraisal of existing institutional arrangements and recognition of (sometimes perverse) stakeholder incentives as a component of GW-MaP development.

Good governance will also require GW-MaPs that achieve improved coordination of planning and policy in the following senses:

- Vertical integration: between national and local level (including all relevant stakeholders) on plan elaboration and implementation
- Horizontal integration: with groundwater considered by related sectors (such as agriculture, energy, health, urban and environment) to avoid policies with contradictory signals and perverse incentives (such as non-targeted rural electricity subsidies)
- Land-use control: given that groundwater quality and quantity are highly dependent on land-use in the main recharge zones, and this is usually the domain of the municipal government both in the urban and rural environment.

Thus, GWMaPs also have an important governance function in helping to harmonise the groundwater-related activities of all government organisations involved.

Certain groundwater governance provisions are essentially 'generic'. These include the broad legal framework, the information/knowledge base, fundamental institutional capacity and finance for management measures. However, groundwater, whilst widely distributed, is essentially a local resource; thus, to assess whether effective governance arrangements are in place, one has to get down to the sub-national (provincial or district) level, since at the national level there is often a semblance of sufficiency that does not stand more detailed scrutiny.

What are the fundamental steps of the planning process?

The elaboration and implementation of GW-MaPs should be promoted by responsible national groundwater agencies (through provision of protocols and guidance), and undertaken (and eventually co-owned) by the corresponding local groundwater agency together with all relevant stakeholders. The planning process, outlined here from experience in a number of fast-developing economies, should comprise a number of distinct steps (Table 1), which should be implemented as a phased sequence.

Groundwater is quintessentially a local resource (with large numbers of actual abstractors and potential polluters). Thus, priority groundwater management units should generally be defined at the lowest rational spatial scale, and managed as close as possible to these local stakeholders—usually differentiating between areas in which the major source of groundwater resource and quality stress is urban development or intensive agriculture. There are, however, some exceptions to this rule—for example, where a larger aquifer system extends across international frontiers and a component of transboundary cooperation will be required for its successful governance, even if many aspects of routine management can be handled locally in groundwater sub-catchments. The same applies to some large aquifers extending across state boundaries in federal countries.

Specific management instruments and measures will need to be tailored to the local context as regards (Table 2):

- Hydrogeologic setting of the groundwater body under consideration
- Social, economic and political circumstances of the country or province concerned.

These will thus vary significantly with position along the developmental cycle.

It will also be necessary to pursue inter-ministerial cross-sector coordination (Fig. 1) to avoid agricultural or industrial development plans which are incompatible with groundwater resource constraints and the co-mobilisation of financial investment for the required demand management measures. The plan should be dynamic in nature, with capacity for adaptation to changes in groundwater knowledge and in external drivers. Indicators of resource status (for example a predefined groundwater level or quality at a strategic monitoring site) can act as barometers of aquifer condition and facilitate the adaptive management approach.

Some typical timelines and key steps for the development and implementation of GW-MaPs are illustrated in Fig. 1 from examples in Latin America and Australia. Those dealing with large fast-growing metropolitan areas such as Lima (Peru) and San Luis Potosi (Mexico), typically require central participation (and even leadership) of the corresponding urban water utility, together will multi-million dollar investments in supplementary water sources, demand-side measures, conjunctive use provisions and aquifer recharge enhancement to reach a situation in which the groundwater resources of the main local aquifer are treated as a strategic reserve (Foster et al. 2010; Martinez et al. 2010). GW-MaPs for aquifer systems in areas of intensive commercial irrigated

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Table 1 Summary of the principal steps in groundwater management planning

Step	Main activities	Necessary procedures
1. Identification of priority groundwater management units	• Physical delineation of units (from natural recharge to discharge zones) taking account of any major man-made perturbations • Evaluation of socio-economic and/or environmental dependence in terms of public water-supply, irrigated agriculture, industrial production, ecosystem sustainability	Identification protocol should be provided by national agency and implemented by local agency and stakeholders (with support of academic collaborators and/or specialist consultants)
2. Assessment of groundwater status, potential and risks	• Assessment of present resource status for each priority unit selected and risk of degradation due to current groundwater extraction/use and pollution pressures in the aquifer recharge zone • Evaluation of unit 'sustainable yield' (level of groundwater consumptive and export use at which provisional cap on extraction should be set)	Assessed directly (from field monitoring data) or indirectly (using surveys of ecosystem condition, pollution pressures and evaluation of aquifer degradation susceptibility, downstream dependency and pollution vulnerability)
3. Agreement on required groundwater services	Identify, profile and categorise all groundwater users and potential polluters, and then seek social consensus/ establish agreement on priority services required from groundwater management units concerned which could be: • water-supply security for urban/agricultural use • water-table stability to guarantee access for small private users • sustaining dependent ecosystems or dry-weather riverflows	Must be a consultative participatory process, but important that consultations are soundly informed by recognised independent experts (on current groundwater status, any related trends, consequences of 'no action' and management options)
4. Design of appropriate suite of management measures, instruments and strategies	Definition of plan to achieve defined objectives by: • selecting technically/economically sound and balanced array of demand-side /supply-side measures to achieve required control over groundwater withdrawals • introduction of pollution abatement/mitigation/ control measures in the aquifer recharge zone, such that risk of irreversible damage and quality impacts on aquifers and ecosystems are managed • strengthening local institutional arrangements so as to facilitate implementation of such management measures	Identify a practical balance between top-down government regulation and bottom-up stakeholder participation and, thus, arrive at a preferred strategy for implementation; consider feasibility of introduction of abstraction/use charging and trading
5. Plan implementation with periodic review and revision	• Progressive GW-MaP implementation with structured periodic stakeholder interaction, systematic monitoring and reporting • Use of monitoring feedback to refine GW-MaP, with further strengthening of institutional arrangements/ linkages, raising capital investment, improving groundwater use/protection measures and aquifer response monitoring	Promoting effective public information campaigns and undertaking necessary capacity building amongst stakeholders, together with effective mechanisms for conflict resolution

Table 2 Facets of local hydrogeologic setting and socioeconomic situation influencing groundwater management strategy

Specific facet	Mode of influence
Hydrogeological factors	
Extent of aquifer and size of its groundwater storage	Determines how identifiable the aquifer will be to local stakeholders and, thus, the possibility of encouraging self-regulation
Degree of connectivity with surface water	Determines if fully integrated management with surface water will be essential for efficient and/or sustainable use of both resources
Level of contemporary recharge	Most aquifers in arid regions are weakly recharged and groundwater use will be from non-renewable resources, which requires special criteria
Groundwater susceptibility to irreversible degradation	Affects the urgency for management action and the need for a systematic regulatory approach
Groundwater vulnerability to pollution	
Social, economic and political factors	
Density of groundwater abstraction points/users and potential polluters	If elevated, it will not be realistic for public administration to promote conventional regulatory approach unless users can be brigaded into appropriate groups
State of institutional evolution	Regulatory/charging approaches will require considerable public administration capacity and full acceptance/recognition of their authority
Proportion of population abstracting groundwater	If very high, democratic pressure may be exerted for continuation of perverse subsidies not favouring groundwater sustainability
Economic significance of groundwater use	Affects the ease with which finance can be raised to invest in governance provisions and instruments

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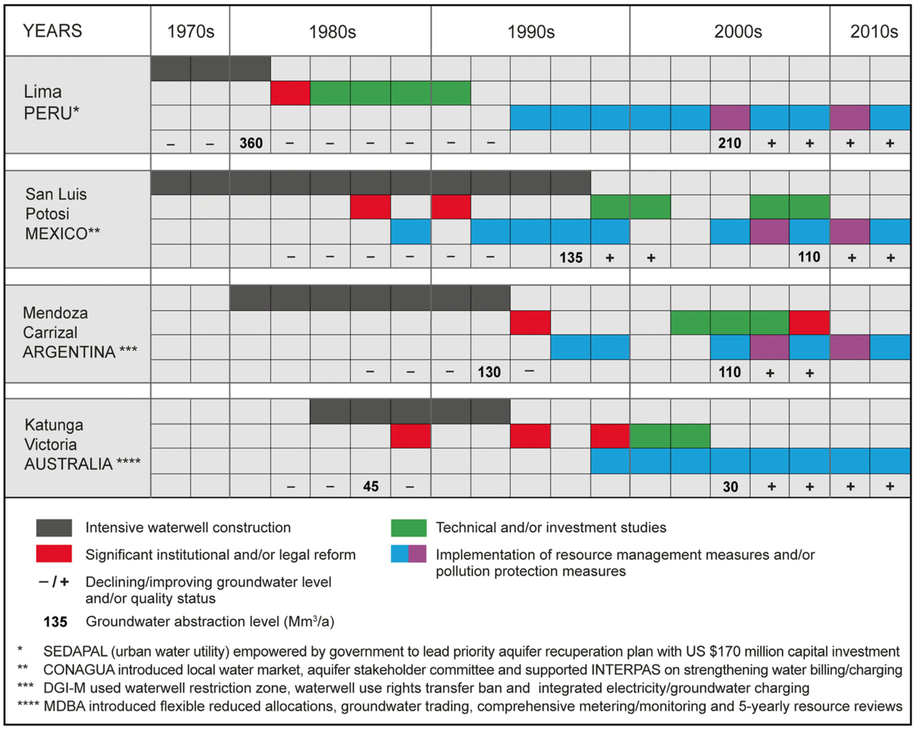

Fig. 1 Groundwater management planning; examples of timelines for on-going successful initiatives

agriculture such as the Carrizal Valley (Mendoza) in Argentina and Katunga (Victoria) in Australia, require clear restrictions on waterwell drilling and groundwater rights transfer, improved groundwater use measurement and innovation in charging, adaptation to modifications in groundwater recharge regime, active participation of rural stakeholders (which can take years to mature), and investments in the progressive transformation of agricultural cropping with improvements in water-use productivity (Goulburn-Murray Water 2006; Garduño and Foster 2010).

What can hydrogeologists do to promote effective management plans?

Hydrogeologists have a critical role to play in promoting the elaboration and implementation of realistic GW-MaPs for priority aquifers. They should familiarise themselves with the administration of their local aquifer(s) in relation to existing provisions that regulate abstraction and protect against pollution such that they can translate all relevant technical information in an understandable form and also can lobby from an informed position on:

- The risks associated with 'no action' or 'business as usual' in groundwater management
- The design of, and benefits accruing from investing in appropriate management measures
- The weakness of current governance provisions.

The perspective of such an authoritative neutral stakeholder is especially important for the public administration, when it comes to the need to focus constructive discussion on the required management action. This will facilitate provincial, and possibly national dialogue, and influence stakeholder opinion. Moreover, wherever possible, hydrogeologists should try to develop and communicate a vision of what they consider would represent a sustainable and balanced economy for the area concerned, recognising the natural limitations and vulnerabilities of its groundwater resources.

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