Sustainable Groundwater Management
Concepts & Tools

Briefing Note Series Note 7

Economic Instruments for Groundwater Management

using incentives to improve sustainability

2004

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Why are economic considerations important in groundwater management and protection?

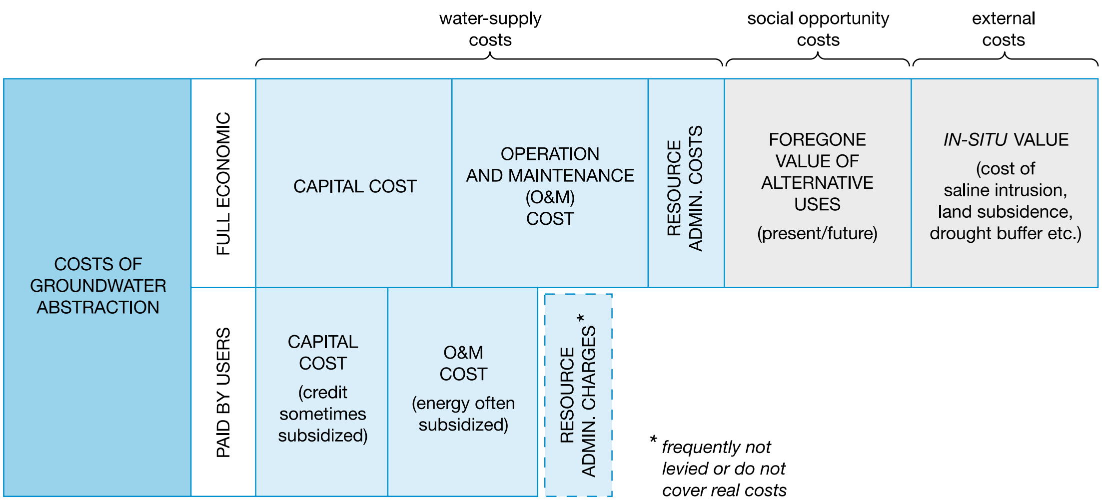
- Economics deals with the allocation and use of scarce resources. As long as a resource is abundant, there is little need to take such decisions. As the resource becomes more scarce (due to quantity or quality constraints) questions about how to utilize and protect it (preferably for the best of society) arise. Economic considerations can help the decision-making process and promote more efficient resource use.

- While economic instruments to manage surface water and groundwater are similar, they are not the same as a result of certain peculiarities of the groundwater resource:
  - relatively high cost and complexity of assessing groundwater (**Briefing Note 2**)
  - highly-decentralized resource use, which increases management monitoring costs
  - invisibility of groundwater to the general public, and time-lags with regard to resource impacts
  - varying impacts of contaminant load depending on aquifer vulnerability (**Briefing Note 8**)
  - long time-lags and near irreversibility of most aquifer contamination.

- These peculiarities explain why groundwater management tools are generally less developed and applied than those for surface water. However, with increasing water scarcity the economic value of groundwater, and thus the benefit to investment in management, is increasing. This Briefing Note focuses on economic considerations as one important part of the groundwater management equation—specific social, environmental and technical considerations are dealt with in the other Briefing Notes in this series.

- Groundwater tends to be undervalued, especially where its exploitation is uncontrolled. In this situation the exploiter of the resource (in effect) receives all the benefits of groundwater use but (at most) pays only part of the costs (Figure 1)—usually the recurrent cost of pumping (providing the energy input is not subsidized) and the capital cost of well construction, but rarely the external and opportunity costs. This undervaluation often leads to economically inefficient resource use.

Figure 1: Measuring the costs of groundwater use



What does the economic value of groundwater mean and how is it determined?

- The economic value of a resource depends on what one can do with it and on its relative scarcity compared to alternative resources. Thus the economic value of groundwater in a specific aquifer is derived from the use it can be put to, and from its local availability and quality compared to surface water. For instance, an aquifer in a region with abundant unpolluted surface water will generally have lower economic value than one in a region with polluted surface water or one in an arid region without alternative resources. The economic value of groundwater originates from the benefits that it generates or (in other words) the services that it provides (Table 1). In many areas of the world, the economic value of groundwater is increasing, due to population growth and economic development (and thus increased water demand), due to pollution of surface water basins and, increasingly, due to climatic variability and the necessity of having a drought-secure resource.

Table 1: Values of groundwater as determined by individual stakeholders

TYPE OF VALUE	GROUNDWATER SERVICE
Use Value	drinking water irrigation supply/industrial use recreational use
Non-Use Value	uncertain use potential existence for future generations
Indirect (Ecosystem) Value	discharge to ecosystems discharge to rivers and lakes

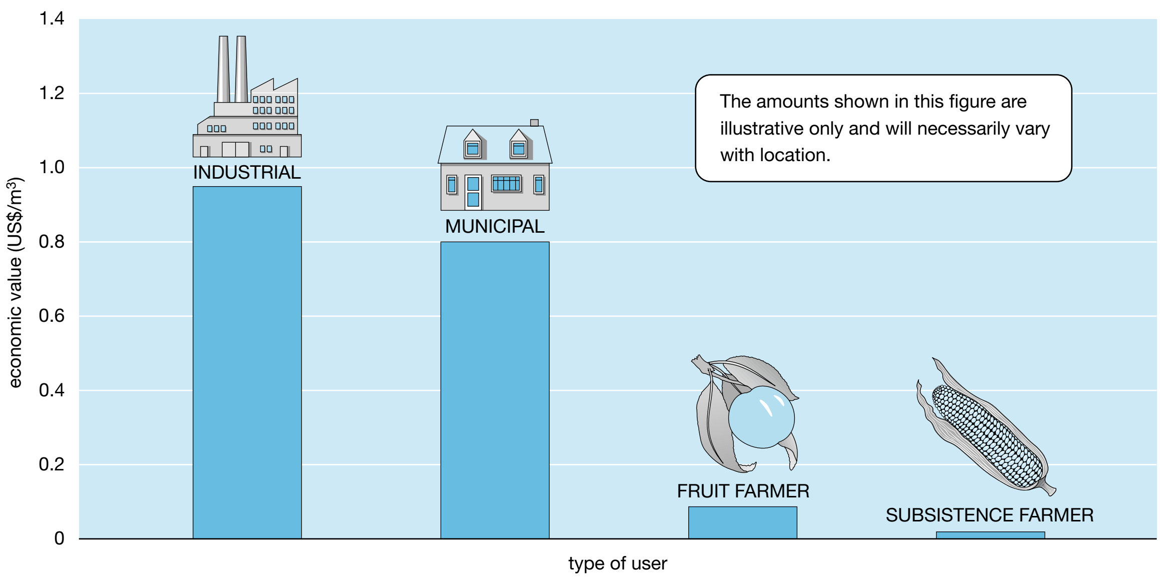
- The economic value of a given groundwater resource is determined by its prospective use. In the absence of a market price for groundwater, economists often measure its value through user ***willingness to pay*** for a given quantity and quality of supply. For instance, an industry that needs water as an input for car production will be willing to pay more per unit volume than a fruit farmer. The economic value of groundwater in the area concerned is thus determined by the willingness of industry to pay—up to the point that their demand is met. The economic value of the next volume used by the fruit farmer will be lower, but still higher than what a subsistence farmer would be willing to pay (Figure 2).

- When 'willingness to pay' is not known (usually the case because groundwater markets revealing true price rarely exist), the ***residual value method*** can be used to value groundwater. This method values all inputs for the good produced at market price, except for the groundwater itself. The residual value of the good, after all other inputs are accounted for, is attributed to the water input.

- Another method is ***hedonic pricing***, where the behavior of users and markets is observed. For instance, farm prices in an area with good groundwater availability are likely to be higher than in an area with scarce water resources. By comparing differences in farm prices across the region (and assuming other variables are the same), the difference in price would lie in the value of groundwater access.

- The above are a selection of methods used by economists to determine the value of public goods such as groundwater, and while none are perfect they do provide guidance to decision makers on the valuation of groundwater resources and on possible courses of action. An important consideration in this regard is the distinction between short- and long-term benefits expected from groundwater use. Depending on the discount rate used to estimate the benefit stream from the use of groundwater, it may appear advisable to use the resource more rapidly or more slowly. Thus, the choice of a realistic discount rate is very important and needs careful evaluation.

Figure 2: Economic value of water resource by use



What are economic instruments and how can they be used to improve groundwater resource management?

- An economic instrument tries to stimulate an economic actor (groundwater user) to voluntarily adopt a certain behavior. The underlying rationale is that human beings react to price incentives—when prices are high less resource will be consumed. Moreover, while groundwater could be widely used in high-value enterprises and create more income, jobs and wealth, too often it is still put to low-value economic uses and thus is increasingly overabstracted, creating social tension between users.

- Economic instruments can provide incentives to allocate and/or use groundwater more efficiently, thus helping to stabilize groundwater levels by reducing overabstraction, diminishing the risk of negative impacts and social conflict, and delaying the need for investment in alternative water resources. There are two categories relevant to groundwater (Table 2), namely those that focus upon:
  - ***changing groundwater abstraction costs*** by (a) direct pricing through resource abstraction fees, (b) indirect pricing through increasing energy tariffs and (c) the introduction of water markets
  - ***positive economic incentives*** for certain activities by (a) modifications to agriculture and food trade policies and (b) subsidies to encourage the use of more efficient irrigation technologies to achieve real water savings.

- **Direct Groundwater Pricing through Resource Abstraction Fees**
  This is the most direct method, since users have to pay an abstraction fee based on volume—preferably metered (rather than licensed) use to ensure that an incentive exists. Unfortunately, groundwater use by agriculture (usually the largest consumer) is rarely metered and thus controlling irrigation use is not

Table 2: Economic instruments for groundwater management

INSTRUMENTS TO CHANGE ACTORS' BEHAVIOR	RESOURCE CONSERVATION	POLLUTION PROTECTION
Changing Groundwater Abstraction Costs		
direct pricing through resource abstraction fee	X	
indirect pricing through increasing electricity or diesel tariffs	X	
groundwater markets	X	
Positive Economic Incentives		
modifications to agriculture and food trade policies	X	X
subsidies to encourage real water-saving measures	X	
subsidies for use of more efficient irrigation technology to decrease agrochemical leaching		X
subsidies for industries and municipalities to implement appropriate water treatment technology		X

straightforward. Alternative techniques to estimate actual agricultural water use include:

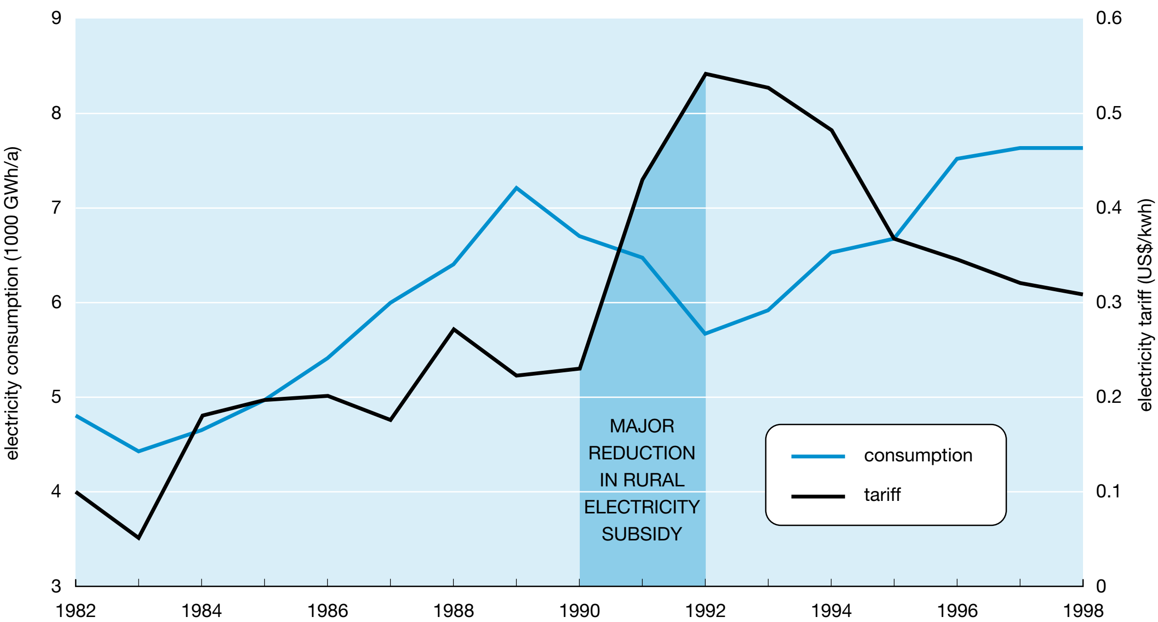
- deriving volume pumped from electrical energy use
- assessing actual water consumption by remote sensing techniques.

- **Indirect Groundwater Pricing through Energy Tariffs**

  The major cost in groundwater abstraction (once a well is installed) is the energy required to lift water. This cost will depend not only on water table depth, aquifer characteristics and well efficiency, but also on the unit cost of energy for pumping. Thus, energy (electricity or diesel fuel) pricing can be a powerful tool to influence groundwater pumping trends (Figure 3). Paradoxically, in many areas of the world, energy prices are used in the opposite way, with large subsidies in place to decrease farming costs. While it can be legitimate to subsidize poor farmers to improve their livelihood, subsidizing groundwater abstraction in general may not be the best vehicle to do so, because excessive groundwater abstraction can erode the same farmers' resource availability in the longer term. Other measures need to be defined which have a neutral effect on the resource, such as lump-sum payments to poor farmers at the beginning of the year to cover their estimated energy bill. In this way, they would have an incentive to use water more efficiently and consume less, maybe through a shift to higher-value crops. Since they receive lump sum payments to offset their increased energy bills, they can actually gain twice by being more efficient, and thus improve their livelihoods.

- **Groundwater Markets**
  - Water markets have been advocated to improve resource management, especially with regard to more efficient water use, and allocation within and between sectors. They are more flexible than command-and-control instruments in allocating water to higher-value uses in a manner acceptable to all parties, thus promoting economic growth and diminishing social tension.

Figure 3: Impact of rural electricity tariff variations on energy consumption for groundwater pumping in Mexico *(data from CFE/Comision Federal de Electricidad–Mexico)*



- In its most basic definition, a groundwater market is an arrangement in which holders of groundwater rights trade in them or with outside parties. There is no single market model, but the characteristics for market design will depend on (a) the prevailing hydrogeological regime, (b) the previous history of informal trading and/or rights, (c) the types and numbers of groundwater rights holders and users and (d) the physical arrangements for moving water between users. The water market is nothing more than a set of arrangements that permit water to be traded. But it will not function effectively unless specific conditions are fulfilled.
- A gradual approach to introducing groundwater markets is generally appropriate, first putting into place water measurement systems, defining groundwater rights (initially not necessarily tradable) and water-user participation. In most settings this will provide the basis for much improved groundwater management and permit the stakeholders to adjust to the new set of rules. Eventually groundwater use rights could be made tradable, while taking into account the vulnerability of different user groups and making provision for their protection.
- While the benefits of groundwater markets can be substantial, potentially negative socio-economic or environmental impacts need to be included in the ex-ante analysis. With regard to groundwater in particular, markets do not set a limit on total groundwater use and (while they may lead to more efficient allocation) overall groundwater use will not be diminished. If the goal is to reduce groundwater abstraction, the market will require significant regulation, including the enforced reduction of the total volume of water rights over time. Decisions about the introduction of a groundwater market in a specific setting always need to be informed by thorough analysis of the local socio-economic, institutional and hydrogeological context.

- **Modifications to Agriculture and Food Trade Policies**
  An indirect economic instrument for groundwater management derives from agricultural and food trade policies. Since most groundwater is consumed by irrigation, agricultural policies have a major impact. For instance, subsidies encouraging highly water-intensive farming in semi-arid areas (e.g. rice or wheat cultivation) will provide an economic incentive to use groundwater. From an economic perspective, however, the allocation of groundwater to this type of consumptive use is not very efficient, and agricultural policy should better reflect the scarcity of groundwater resources. Moreover, international trade policy can have an indirect impact on groundwater use—for instance by creating barriers to the export of high-value agricultural products thereby confining production to local, often low-value, uses.

- **Subsidies to Encourage Real Water-Saving Measures**
  Certain engineering and management measures can lead to substantial water saving through the reduction of so-called non-beneficial evapotranspiration from systems of agricultural irrigation (**Briefing Note 3**). Their feasibility needs to be carefully appraised and consideration given to subsidizing their introduction where appropriate.

What steps are needed to introduce economic instruments for groundwater resource management?

- The most crucial element in making economic instruments work is to ensure **enforcement**. Groundwater use is a decentralized activity with many private users normally involved, who drilled their own wells, installed their own equipment and follow their own pumping schedules. In the case of major aquifers, with hundreds of thousands of users, enforcement of well discharge metering is impossible if users have no incentive to comply. Consequently, it is essential that incentives be created for users to participate actively in aquifer management (**Briefing Note 6**). This can be achieved by providing data on the status of groundwater resources, promoting aquifer management associations (through which users exert peer pressure to achieve management goals) and also by making increased use of innovative technologies.

- One such technology is remote sensing. Satellite images are now affordable and various organizations have developed interpretation tools to map crop distributions and to estimate actual evapotranspiration at high resolution. Aquifer management (and groundwater user) associations can be provided with such data, and thus the control of groundwater use becomes more enforceable.

- In the USA, certain states rely on self-reporting by users of the groundwater volumes pumped on a quarterly or annual basis. This system has been put in place because it would be too expensive for water resource agencies to visit every well individually. Self-reporting, however, does not work in every setting and another technological option is to link groundwater use with electrical energy bills.

- The introduction of economic instruments will depend on current hydrologic, economic, social and political conditions. The **feasibility analysis** should include an assessment of costs and benefits of each instrument and possible combinations. It should also take into account long-term recurrent costs and institutional capacity (for administration, monitoring, enforcement) and the transaction costs involved to set up systems. The expected costs and benefits would also influence the trade-off between the use of economic instruments and other groundwater management tools.

- While it is relatively straightforward to estimate the costs of putting certain instruments in place, it can be far more difficult to estimate the benefits. Alternative options (before embarking on expensive cost-benefit analyses) are:
  - **cost-effectiveness analysis,** which compares costs of different policy options leading to the same target
  - **multi-criteria analysis,** taking account of different objectives and analyzing them according to their determined weight.

- As regards groundwater resource charging, a necessary first step is to put in place a registry of groundwater users and rights (**Briefing Note 5**). The second step is to determine the feasibility of direct abstraction metering or an alternative technique to determine groundwater use. In accordance with local conditions, groundwater user groups should be consulted on the decision and how to enforce it. Similarly, indirect charging for groundwater abstraction via energy pricing also needs to be analyzed in relation to its potential effect on the poorer groups in society and compensatory measures defined and implemented.

- Finally, agricultural and food policy is usually set at the highest political level and will typically be analyzed within the macro-socioeconomic context of the country concerned. Here, the critical step will be for groundwater resource managers to establish a dialogue with macro policy-makers in order to clarify the impacts of current policies. Making this link should lead to more effective groundwater management by placing this vital resource more centrally in the context of national socioeconomic development policy.

What economic instruments are available to aid groundwater pollution control?

- The instrument usually prescribed to decrease water pollution is the polluter-pays-principle, by which an industry is charged for the amount of pollution it produces. The less it pollutes, the less it pays. This approach is not directly applicable to aquifer protection because of the special characteristics of groundwater, notably the time-lag of impacts, the persistence of some groundwater contaminants, and the potential cost of some pollution episodes. Instead economic incentives are required for industry and water utilities to invest in adequate wastewater treatment and recycling (Table 2), especially where aquifer vulnerability assessments suggest high risk of groundwater pollution (**Briefing Note 8**).

- Another important issue is the control of non-point pollution from agricultural cultivation. Crop subsidies tend to lead to monocultures over large land areas, sustained by excessive use of fertilizers and pesticides (themselves sometimes subsidized), regardless of soil and climatic suitability. This can have a major negative impact on groundwater quality due to agrochemical leaching, the cost of which is not initially taken into consideration. There is a pressing need to re-target such subsidies and thereby provide an incentive to reduce agrochemical leaching (Table 2). There sometimes may be an argument for going further and putting an 'environmental tax' on fertilizers and/or pesticides to generate funding for water quality monitoring.

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Publication Arrangements

The GW•MATE Briefing Notes Series is published by the World Bank, Washington D.C., USA. It is also available in electronic form on the World Bank water resources website (www.worldbank.org/gwmate) and the Global Water Partnership website (www.gwpforum.org).

Funding Support

GW•MATE (Groundwater Management Advisory Team) is a component of the Bank-Netherlands Water Partnership Program (BNWPP) using trust funds from the Dutch and British governments.