WATER RESOURCE ACCOUNTING AS A TOOL FOR URBAN WATER MANAGEMENT: AN ILLUSTRATION IN NCT-DELHI

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Abstract
Water is an important resource as well as a constraint to urban development. Given variation over space and time, urban water resource management often calls for an integrated approach toward it. Resource accounting is such prudent method of water management in the urban context. This paper argues for using water accounting as an appropriate tool for decision-making in water resource management through an illustrative case study of NCT-Delhi. This framework of resource accounting shall be adopted by the urban water authority (or the urban local government authority) and implemented to achieve the goals of water management cost effectively. An institutional framework for policy and decision making using water resource accounts is also delineated.

Key Words: Water Resources Accounting, Urban Water, Water Resource Management, Policy making, Institutional Framework

1. INTRODUCTION

Water is an important element of human life in several ways. Fresh water deserves a special mention, as it supports most of the human needs and it is unevenly distributed on surface of earth as well as in atmosphere. River water is an important and dominant form of fresh water that needs particular attention, as, historically, human concentration (in what we see them as current cities) and the development of human societies has been along the sources of water (and, river water, in particular); they flourished where water was available in plenty. The emergence of urban areas also led to industries, trade and commerce services concentrating in the cities, which also began to discharge a good amount of waste water. As urban growth has been accentuating by the expansion of industrial and service sector activities, the demand for water has also began to
exceed its availability in the nearby water resources; this, in turn, needed its
drawal from distant places as well as diversion from other uses. However, the
diversion of water from one sector to another, and one area to another, is
although essential, became a contentious issue due to the fact that original rights
have made livelihoods dependent upon them. Moreover, importing water from
other basins through long distances comes at high economic, social and
environmental costs. Over and above these costs, we find ourselves in a situation
wherein intense conflicts are taking place, across the sectors of water use as well
as over geographical areas. All these compel the adoption of new regional and
local approaches to the planning and management of the resource within a
sustainable development framework\(^1\) (Paredes 1997).

Although it has been argued elsewhere (Tortjada and Biswas 1997) that crisis
situations themselves lead to crafting of solutions, even in the case of conflicts,
the public authority cannot take such risks. Essentially, water resources
management needs to blend the means of combining technical, economic and
legal solutions in solving the conflicts that arise between various users. Local
Government, which is often the manager of water quality as well as quantity,
needs to formulate policies and implement strategies, which influence the user
consumption, and use the principles of private sector management in the
management of a public good like water. However, formulation of water policy
requires information on water parameters, evaluation criteria and behavioral
models. Often, this kind of information is not easily available; it needs to be
created while making use of conventional data collection methods.

In this paper, we emphasize upon how urban water management can be based
on policies with the goals of effective water allocation, and its quality and
quantity management, by making use of a water resource accounting framework.
We do not discuss here too much of strategy, organization and implementation
structures of the public authority, which was discussed in another paper (i.e.,
Ramakrishna 2001). The current paper essentially focuses on illustrating how
urban water management can be achieved through water accounting through a
case study of NCT-Delhi. We will discuss natural resources accounting in the
context of national/regional policy first, and then place water resource
accounting within it. Subsequently, the methodology as well as study
framework adopted for resource accounting are discussed. The findings of the
case exercise on water accounting in NCT-Delhi are presented thereafter and an
institutional framework for water resource management is drawn and discussed
finally.

\(^1\) Sustainable development, as defined by Brundtland commission (WCED 1987), is ‘the development that
meets the needs of present without compromising the ability of future generations to meet their own needs’.
2. NATURAL RESOURCES ACCOUNTING

Natural Resources Accounting (NRA) is considered as an important environmental economics and policy tool for achieving sustainable resource management from national to regional levels. NRA is quite useful in decision making at policy level, because, national/regional accounts consist of information directly useful to policy making; they can be formed using existing data generation methods; they are based on set evaluation criteria that have theoretical foundation and open for questioning by policy maker before accepting; lastly, they are not an end in themselves, but a means to decision making. Likewise, water resources accounting, in particular, aids in policy and decision making for water resource management at regional/national level.

Resource accounting methods vary in their form and structure due to the differences in framework adopted. They vary from variants of satellite accounts, followed by several countries\(^2\), to flow resource accounting of natural resources that consists of inflows and outflows of products and services (e.g., Hannon 1990). There exist several case studies applying environmental economics and valuation techniques in preparing national environmental-economic accounts\(^3\). In the Asian context, Parikh et al (1997b) present a series of such case studies in environmental accounting from Asian countries for different sectors. A beginning towards outlining NRA in a sectoral framework for national policy making was made in India by Parikh et al. (1992). However, there have been few application studies carried out using this framework, as it requires data collection efforts, on one hand, and knowledge of applying evaluation methods to the specific areas and problems, on the other. Water Resource Accounting (WRA) per se did not receive the attention of researchers and policy makers in India. The current study of applying WRA in the NCT-Delhi is a beginning, which makes use of the NRA framework provided by Parikh et al (1992), but its implications are different from that of the NRA in sectoral economic accounting.

3. STUDY FRAMEWORK

National Capital Territory (NCT) – Delhi is formerly the Union Territory of Delhi, which is a conglomerate of the Delhi city and its urban environs. Yamuna river is a major tributary of river Ganga that passes through NCT-Delhi. Rapid population growth, accompanied by increasing urbanization and development of agriculture and industry, have led to an increase in water consumption, on one hand, and so also an increase in wastewater discharges into the river, on the

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\(^2\) For example, see Pearce et al (1989) for review of international case studies and Parikh et al 1997a&b for developing country case studies

\(^3\) For example, see Pearce et al (1989), Ahmad et al (1989) and Munasinghe (1993) for such detailed country case studies under different methodologies
other. Moreover, in the recent past, the demand for water has exceeded the amount of surface and ground water that can be sustainably extracted. The knowledge of these facts helped us to conceptualise a framework for carrying out water resource accounting in NCT-Delhi, which is shown in figure 1.

4. METHODOLOGY

![Flow Diagram of Methodology for Water Resource Accounting in NCT-Delhi](Figure 1: Flow Diagram of Methodology for Water Resource Accounting in NCT-Delhi)
Water resources accounting in NCT-Delhi essentially aims at accounting for water use in the backdrop of its inventory and the wastewater discharges. It begins with the delineation of physical accounts to depict the status of water resources – both quantity and quality - first, followed by description of economic valuation of water uses, quality and quantity, and, finally, monetized accounts of water use, decline and degradation are presented. These are explained further in the respective sections below.

4.1 Physical Accounts of NCT-Delhi

4.1.1 Water resource inventory

Water resource inventory consists of source wise total available water resources in the region. It is based on surface runoff from normal rainfall after accounting for interception and evapo-transpiration losses, and another 25% for infiltration in case of surface water, and the quantity status monitored and observed by the Central Ground Water Board (CGWB) in case of ground water.

4.1.2 Water use accounts

Water use accounts comprise of water uses in various sectors, namely, domestic, livestock, industrial, agriculture, and transportation and are based on either estimates using standards or norms of consumption or actuals based on observations. As NCT-Delhi is also an industrial center with the presence of a wide variety of industries accounting for a good amount of water consumption, a primary survey was carried to account for water consumption in various categories of industries.

4.1.3 Wastewater discharge accounts

Wastewater discharge accounts comprise of discharge quantities of wastewater that were estimated to have been generated from various sectors, namely, domestic, livestock, industrial, agriculture, and transportation. These estimates are based on either observations or follow norms consistent with water use.

4.2 Economic Valuation of Water Resources in NCT-Delhi

The physical accounts give a detailed account of source-wise quality and quantity status of water resources in the region. However, the economic importance of these status indicators needs to be brought about through economic valuation in order to provide the importance of the specific actions towards water resource management. We do not provide here a detailed account of the appropriate choice of valuation method vis-à-vis the resource component, but suffice it to outline these approaches and then provide a summary of their
application to the current study. There are three major approaches taken towards valuation of resources in general and water resources in particular, and these include (Turner 1978):

(i)  *Avoidance and/or damage costs approach* to valuation of physical uses;
(ii) *Market methods* for ascertaining farm demand for water quality and quantity; and,
(iii) *Survey methods* in measuring non-use e.g., aesthetics and recreation, benefits.

We applied all these three major approaches to valuation of the respective component of the water resource i.e., ground water, irrigation use and functional uses of river water. We provide a brief summary of how these exercises were carried out, and these ultimately led to the preparation of monteized accounts of water resources in the region.

**4.2.1 Economic valuation of the costs of groundwater mining**

The withdrawal of ground water exceeding its recharge has led to depletion of ground water as evident by decline in ground water levels, which can be referred to as groundwater mining. Ground water mining is conspicuous by decline in water table in various parts of the city and it amounted to an estimated 2962 MCM over 15 years, or an annual loss of 227.85 MCM. Ground water mining not only results in water depletion but also degradation of its quality, rendering it unfit for direct consumption. Mining has led to the decline of water level, thus leading to water quality problems like fluoridation and salinity associated with deep underlying stratum of aquifers. The ground water quality degradation is evident from results of water samples tests of the CGWB, with the salinity, nitrates and fluorides exceeding the permissible levels. The economic cost of ground water mining was estimated using avoidance and replacement costs methods, which are summarized in Box 1. A detailed discussion of valuation and its results are presented in another paper (Rambabu et al 2004).

**Box 1: Valuation of the costs of ground water mining in NCT-Delhi**

**Avoidance costs of Ground water quantity decline**

The ground water mining taking place in the region was well established in the physical accounts. As ground water is a replenishable resource that needs to be consumed at the sustainable levels, it is imperative to avoid its excessive use. The costs of the excessive use or mining was evaluated in a hypothetical manner i.e., how much it would cost to provide a similar amount of water to cater to the drinking water needs, which are the dominant use in NCT-Delhi. As already
there existed proposals for construction of dams in the upstream areas to bring water to Delhi, we looked at the nearer and economical dam proposition. The capital costs of dam construction were apportioned to the drinking water use through the allocation made for this out of the total water supply and then to the proportion of replacement to be made. Similarly, the conveyance costs were calculated for the given flow speed and conveyance rate using the distance to be covered and the pipeline unit costs. A similar method has been used to arrive at the costs of water detention in the storage tanks and water supply distribution using a hypothetical distribution network. These capital costs were then annualized using a physical capital depreciation rate of 10% and different life times of the structures.

Replacement Costs of Ground water quality degradation

The ground water mining has not only resulted in quantitative decline but also quality degradation, the avoidance costs of which also need to be estimated. The treatment costs of water to bring back to the desired water supply quality standards using reverse osmosis treatment method was done with the help of unit capital costs of treatment of water and the unit operation and maintenance costs. The annualized costs and annual operation and maintenance costs gave rise to the avoidance costs of ground water quality degradation for the quantity of ground water depletion in NCT-Delhi.

4.2.2 Contingent valuation of functional uses of river Yamuna

Yamuna river water, which flows through NCT-Delhi, has several functional uses associated with it. These can be classified under use and non-use values in economic literature (Munasinghe 1993; Pearce et al 1989). Although use and non-use functions vary throughout traverse of river, as also disutility of river water viz. pollution, people attach some value with regard to several functions of river water quality and quantity. Pollution of river water reduces the value of river water and the demand for its treatment reflects the preference for water quality i.e., functional uses. As river Yamuna had already been polluted by wastewater discharges of point and non-point sources, people had strong perceptions about bringing down pollution (or, improving water quality).

An attempt was made to measure the preference for water quality or functional uses. Contingent Valuation Method (CVM) is an economic valuation method, in which, elicitation of value of goods and services, including water quality, is

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4 Both are also interlinked. It is the water flows in the case of river water and recharge rate in case of ground water that determines the quality of water as well.

5 A detailed discussion of CVM surveys is reserved here. Mitchell and Carson (1989) provide a detailed account of how to conduct such surveys to measure willingness to pay.
done by survey instruments. Normal surveys of CVM use instruments like openended questions, bidding games, pay card etc (Navrud 1985). In current exercise, bidding games method was chosen alongwith pay card. A willingness to pay survey was conducted with an intention to capture value attached by people, intuitively, to pollution abatement of river water. The survey questionnaire was designed to collect information on, river water functional uses, water consumption, WTP for pollution prevention through treatment of wastewater flowing to river, Maximum WTP for the same, WTP for river water purification to acceptable levels (standard). Using the information from the survey, analysis was made using methods that allow for the choice e.g., logistic regression, to estimate the expected willingness to pay.

4.2.3. Irrigation use valuation using Hedonic pricing method

Hedonic pricing method is an economic valuation technique with potential to value the resources which form the functional component of the goods/services traded in market. Land prices and house rents represent such traded value in markets. In current study, market values of agricultural land have been used to evaluate the implicit values of irrigation water use. Farmland prices in and around NCT-Delhi and the descriptives of factors affecting land prices were observed in the field surveys carried out. After giving due considerations for intensity scores of these factors, the factor component value of irrigation facility per unit area of land was derived.

The method involved linear regression analysis for building a mathematical model that describes factor variables and their relation to farm prices, as well as, gives due allowance to market exigencies. The analysis yielded average annualized values of irrigation facility (for improvement of average irrigation facility in a year) at Rs. 34,086 and Rs. 17,043 per hectare irrigated area in NCT-Delhi in the case of surface and ground water resources.

4.2.4 Defensive expenditures of wastewater discharges

The physical accounts also accounted for wastewater discharges, most of which reach either the river water or percolate down, causing water quality problems in the river or ground water. This can be avoided if the wastewater is treated and then released, the costs of which are termed as ‘defensive expenditures’. The treatment costs, when they are recorded, would serve this purposed. However,

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6 A detailed account of measurement of willingness to pay is explained in another paper (Nallathiga and Ram Babu, 2004), and the evaluation of functional uses from bids is explained in another paper (Nallathiga and Paravasthu 2005).

7 Incidentally, these were also used to assess the value of land mass degradation, which is explained in Paliwal et al (1999). This paper also provides a technical discussion of the hedonic pricing methodology and its application to resource component valuation.
in the absence of booked treatment costs, we estimated the costs by estimating the treatment costs. For this purpose, the costs of unit wastewater treatment were first arrived at by making use of the information on existing treatment plants i.e., the capacities, capital costs and maintenance costs, and then used for the volumes of wastewater generated in NCT-Delhi. The annualized capital costs and annual maintenance costs then essentially contributed to the total costs and with known capacities, the unit costs were derived.

4.3 Monetized Accounts

The valuation methods described above enunciate the methods utilized for arriving at the economic values of the water resource whose physical status was depicted in the physical accounts. The monetized accounts make use of the physical accounts and economic valuation principles to summarize the water resources status in monetary terms.

4.3.1 Monetised accounts of ground water decline and degradation

The avoidance costs of ground water decline were estimated for the decline observed over a period of 13 years. These avoidance costs per annual decline were then converted into the unit costs for annual decline and adjusted to the price levels of 1992 and 1995. These unit costs were then used along with the physical accounts of ground water decline to estimate the monetised value of ground water decline in NCT-Delhi.

The replacement costs of ground water quality degradation were estimated for the amount of water that was mined by making use of the unit costs that were calculated earlier in the economic valuation. These unit costs of treatment of water were used to calculate the replacement costs of ground water quality degradation.

4.3.2 Monetised accounts of river water functional uses and irrigation

Functional uses of water in river Yamuna are important as they range from basic human needs to modern industrial needs of society. The total willingness to pay for functional uses of water (quality as well as quantity) constitutes willingness to pay for pollution prevention as well as water purification. The total Willingness to Pay (WTP), thus obtained, was disaggregated for each functional use based on the preference structure shown by the respondents in the interviews. This per capita WTP was extrapolated to the entire population in order to estimate the functional use values of river water.
The monetized values of irrigation use in NCT-Delhi have been estimated making use of revealed willingness to pay through hedonic valuation method explained earlier. The WTP for irrigation use of water is arrived after deducting costs of irrigation infrastructure services from revealed willingness to pay.

### 4.3.4 Monetised Accounts of Wastewater Discharges

As mentioned earlier the treatment costs per unit discharge have been arrived at in the valuation and the annual wastewater discharges were then considered for arriving at the costs in NCT-Delhi.

### 5. STUDY FINDINGS AND DISCUSSION

The study findings are summarized under the summary accounts for water in NCT-Delhi for the accounting years 1992 and 1995 respectively in the tables 1 (a) and (b). Water resource accounts in NCT-Delhi – both physical and monetized accounts – above clearly reflect a few points. The balance of water resources, particularly of ground water, indicates a deficiency, which has been rising and may further increase in future. Large wastewater discharges resulting from industrial sources like industries have affected river water quality. The high WTP for water uses implies greater acceptance to compensate against damages, and thus the damage to water resources would have been large when compared to the avoidance costs. This gets reflected in the costs of ground water mined. Ground water assumed a critical status due to excessive drawal of water in NCT-Delhi, which resulted in huge costs on society at large, particularly when it resulted in the degradation of water quality. There exists a WTP for conserving various functional uses of water. The unsustainable trends in water resource management noticed through water accounts emphasize the need for addressing it in an operational framework comprising water budgeting, policy making and institutional mechanisms.

#### 5.1 Water Budgeting

Water Resource Accounts provide a good framework to operationalize the water budgeting in quantitative terms as well as qualitative terms. As water availability is itself limited, efforts need to be made to conserve rain water through roof-top as well as surface water harvesting practices, which will augment both surface and ground water. Moreover, in the wake of rising demands coming from domestic and industrial sectors, effective demand management measures need to be set in pace. The physical accounts are particularly helpful in targeting the focus sectors of demand management.
Likewise, water quality balancing is required given the very low levels of water quality of surface and ground water sources. In particular, the ground water needs a good amount of improvement given the costs imposed on society are very large as compared to the consumption benefits. There is a willingness to pay for the water quality improvement in the case of river water, which needs an attention in terms of reviving its functional uses and allocating resources into those uses which are valued more in economic terms. Essentially, maintaining the minimum flows in the river will lead to such desirable change, which however requires both quantity balancing and quality tradeoff.

5.2 Water Policy Planning

Water policy planning involves determining significance of water in socio-economic context, preparing a matrix of problems and critical issues, quantifying and ranking pressures on water resources, and identifying options for mitigation viz., legal and institutional, economic policies, projects and programmes (FAO 1995). A variety of policy instruments, like direct controls, market processes, government investments, can be used to ensure that the outcomes meet with policy objectives (Baumol and Oates 1979).

Water resource accounts also reveal appropriate policy instrument, although the agency may choose based on several other principles. For example high pollution abatement costs and low willingness to pay may present different set of instruments e.g., financing mechanisms, as compared to the vice-versa. The long term water resource policy in the case of river Yamuna water would be to maintain the minimum water flows and maintain the water quality of designated uses across the river stretch, which can be achieved through design of alternative methods of water supply and distribution, efficient water utilization and demand management through effective pricing of water (Ramakrishna 2001). Whereas, water policies that discourage abstraction of deeper water and that encourage shared water use are essential in the management of ground water.

5.3 Water Resource Management Institutions

The policy objectives laid down involve designing of institutions and mechanisms, such as new management structures through public-private partnerships, which lead to improved efficiency of service delivery and reduced costs. The organizational structure aspects are discussed in Ramakrishna (2001). Several kinds of management structure changes can be envisaged that range from franchising arrangements like contracting out, management contracts, lease contracts and related systems to Concessions and related systems (e.g., BOT) to Joint public-private arrangements (Lee and Jouravlev 1997). Adoption of one or combination of above arrangements requires an analysis of economic, political,
and social environment, and evolutionary state. These institutional changes shall result in better water management.

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References:


Ram Babu, P., Ramakrishna, N. and Sribalakameswari, K., Economic Valuation of Natural Resource Damages: An application to Groundwater Mining in NCT-Delhi, Paper being prepared for submission to a journal, 2004.


### Table 1a: Summary Accounts of Water in NCT-Delhi (1992)

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