Life Cycle Analysis and Sustainability in Resource use: A case for Governance reforms in water delivery in Delhi, India

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INTRODUCTION

The provision of safe and universal water supply in an equitable, efficient and sustainable manner is the vision of most of the urban water utilities in developing countries. In most developing countries water as a common pool resource has been in domain of public entities of the national and local governments. The public sector model has led to excessive wasteful use of water, poor treatment of water sources and an unsustainable demand usage pattern resulting in water crises in urban center of South-East Asia especially India. Reforming the sector is the urgent need for maximizing water beneficial use. The reforms are to be driven based on the key postulates of Dublin environmental and economic principle. Sustainability and Conservation of resource are the key drivers of such governance reforms in water management sectors The shift is reflected in strategies of city governments and water supply utilities that are gearing for reforms for sustainability, both environmental and economic.

This sector reform of service arrangements objectifies improvement in performance criteria – equity, efficiency and sustainability that are often conflicting. Scientific approaches to facilitate decision-making in conflicting criteria in the context of sustainable development are scarce. Life-Cycle Analysis and aggregation of choice through multi criteria analysis can be a tool for the scientific basis for public decision making and in changing of governance patterns based on opinion of stakeholders, experts and society. An emerging direction about new governance and public policy discourse is the role of scientific measurable indicators in decision-making by generation, transmission and distribution of knowledge through life cycle analysis for transparent, decentralized and collective scientific decision-making.

This paper incorporates life cycle method and multi criteria analysis based on opinion of experts and stakeholders on important indicators with particular emphasis on sustainability, equity, efficiency and overall performance of the water utility of Delhi. Life Cycle Assessment (LCA) based on Sustainable Development Indicators (SDI) has been attempted to assess the sustainability of an urban water system in the city of Delhi, the national capital of India. It also addresses the issue of simplified LCA and suggests how this method can be used as a framework for selecting indicators of environmental sustainability of an urban water system and reforming the institutions and governance by scientific analysis of decisions.

The paper is divided into three parts. In part one, the situation analysis in of water supply in Delhi with focus on resource and environmental issues of water cycle and its components are described briefly to set the first level of reference. In part two, theoretical concept of life cycle analysis and sustainability in urban water is discussed with reference to the application and synthesis. Opinion of experts and stakeholders in Delhi is taken up to assess water supply situations vis-à-vis performance and sustainability criteria. Finally an assessment and empirical analysis on urban water sustainability is attempted through indicators covering equity, efficiency and sustainability criteria in a multi criteria framework using perceptional opinion of experts.

LIFE CYCLE ASSESSMENT AND SUSTAINABILITY OF URBAN WATER SYSTEMS

Life Cycle Assessment is defined as 'an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying energy and materials used and wastes released to the environment, and to evaluate and implement opportunities to affect environmental improvements" (Society of Toxicology and Chemistry, SETAC, Code of Practice, 1991). The standardization of these methods has been promoted by the ISO (The International Organisation For Standardisation). According to the ISO standard LCA can be used for; identification of improvement possibilities, decision making, choice of environmental performance indicators and market claims and learning (Baumann, 1998). Life Cycle assessment (LCA) offers a potential to take on broader, life cycle thinking and incorporate it into corporate strategic planning and policy development. LCA is a tool that aims to analyze and evaluate the environmental impacts of products or services. LCA can briefly be described as a four-step procedure (ISO/DIS 14040, 1997). These steps include Goal and Scope definition, Life Cycle Inventory & Life Cycle Impact Assessment based on which interpretations are made by scholars.

Several studies have used LCA to estimate the environmental impacts from urban water systems (Lundin et al., 2000). LCA has also been used for learning purposes e.g. for the supply of drinking water in order to find 'hot-spots' where potential for improvements are high (Wallén, 1999).For the different LCA studies made on urban water systems, very different choices have been made for system boundaries (Lundin et al., 2000). One difficulty in assessing sustainability of urban water systems is the definition of a functional unit, since several services are supplied by the system. In different LCA studies a variety of units have been chosen as a basis, making comparisons complicated. One choice would naturally be supply or disposal of a quantity of water. These choices lead to different conclusions. But in terms of sustainability it is important to have a holistic perspective and to include the whole system as well as its parts (Hardi and Zdan, 1997).

The water is changing character (from raw water to drinking water, via Households and industry to wastewater, which is further mixed with storm water, and Groundwater, finally treated to some degree and released to receive water. The urban water system may be considered as an interconnected set of subsystems. The services or the needs that the urban system should meet include three main functions: to supply safe water to users, take care of the resulting wastewater, and collect and treat storm water. A fourth function, important, is recovery of resources for reuse or recycling. A simplified LCA approach can guide the selection of Sustainability indicator by identifying the Parameters that are most disturbing or typical for the sector. The impact assessment is useful since it aims to identify and quantify the most important resource uses. The related processes causing that impact can thus be identified. The main idea is to identify the most important processes and to find indicators relevant for environmental aspects of sustainability.

WATER SITUATION ANALYSIS IN DEVELOPING CITY OF DELHI

In India urban water supply systems and practices have evolved in direct relation to the physical, social, economical and institutional environment of the cities. Cities in most of the developing countries have followed different paths of spatial and demographic growth. Water distribution networks have typically followed the emerging patterns of urban development with lack of long-term planning based on scientific indicators. The capital city's water utility – the Delhi Jal Board (DJB) is the primary provider of piped water supply and sewerage services. It serves a total population of nearly 14 million through 1.47 million water connections. The Municipal Corporation of Delhi (MCD), which has over 94% of the NCTD area (1400 sq. km.) under its Jurisdiction is the study framework of analysis. The Level of consumption is very low. The average water consumption in Delhi is generally cited at being 240 lpcd, but, according to the sources, the average consumption per household is low.

Reliance on groundwater amongst both planned and unplanned dwellers is high. Despite the existence of a piped water system at least 36% of the planned population meets 90% of its water need from personal tube wells. The large-scale extraction of groundwater is a result of widening gap between the demand and supply of water. The groundwater table is Delhi has depleted to 20 –30 meters in various areas across the city. This has disturbed the hydrological balance leading to decline in the productivity of wells, increasing pumping costs and more energy requirement. The quality of underground water is deteriorating and in several places it is unfit for human consumption. Salinity and over exploitation has contributed to depletion and drastically affected the availability of quality water in different parts of the city.

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Wastewater is not properly conveyed and treated. Around 90 % of the wastewater produced is collected in the sewer system but of this amount, only 60 % is conveyed to treatment works. Around 40 % (600 million litres/day) of the collected wastewater is discharged as raw wastewater into drains and Nallah's, flowing ultimately in the Yamuna River. This results in severe pollution and nuisance. Currently the effluent quality at most treatment works does not consistently meet the current 20 mg/litre BOD and 30 mg/litre SS effluent standards, with limited coliform reduction.

There is a trend of High non-revenue water (NRW) depicting wastage of the precious resource. According to DJB the percentage of UFW is as high as 50% (Table). The real losses comprising transmission and distribution losses are 37%. Total water billed is estimated to be 300 MGD while the total production of filtered water for supply is 650 MGD and the rate of recovery on revenue demanded is about 57%.

Non Revenue Water (NRW) In Delhi City

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td rowspan="8">System Input Volume</td><td rowspan="4">Authorised Consumption (60%)</td><td rowspan="2">Billed authorized consumption (50%)</td><td>Billed meter consumption</td><td>14%</td><td rowspan="2">Revenue water consumption (50%)</td></tr>
<tr><td>Billed unmetered consumption</td><td>36%</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption (10%)</td><td>Unbilled meter consumption</td><td>1%</td><td rowspan="6">Non Revenue water (50%)</td></tr>
<tr><td>Unbilled unmetered consumption</td><td>9%</td></tr>
<tr><td rowspan="4">Water losses (40%)</td><td rowspan="2">Apparent losses (3%)</td><td>Unauthorised consumption</td><td>2.5%</td></tr>
<tr><td>Metering in accuracy</td><td>0.25%</td></tr>
<tr><td rowspan="2">Real Transmission and Distribution Losses (37%)</td><td>Leakage on transmission main</td><td>14%</td></tr>
<tr><td>Leakage on distribution of mains and service connections to the point of metering</td><td>23%</td></tr>
</table>

FRAMEWORK OF ANALYSIS

The present research uses multi-criteria analysis using LCA indicators for stakeholder's consultation for achieving a consensus evolving solution for institutional reforms. The environmental indicator and impact categories chosen for this study were reduction in non revenue water, sustainability in resource besides efficiency and equity indicators. These were chosen on the basis that they were most relevant to the particular systems undergoing comparison. Life Cycle Assessment (LCA) has been used as an analytical tool to examine various management options for restructuring of delivery of urban water. The possibility of incorporation and implementation of LCA based approaches in decision-making is analysed.

In undertaking the LCA, two key comparative assessments were made - a comparison of efficiency, equity and sustainability criteria and a pair wise comparison of delivery mechanisms. Indicators have been used for assessing temporal changes of an urban water system towards sustainable development (Lundin et al., 1999), modeling (Parkinson and Butler, 1998) and for communication (Stockholm Water, 1998). Finally a decision-making framework based on life cycle analysis (LCA) of the water production to disposal has been attempted.

Sustainability and issues relating to resource in urban water systems of Delhi has been illustrated in the resource flow diagram (CHART 1) It is broken down in the three sub-systems for the different services it is assigned to fulfill. The three different systems (drinking water, wastewater and storm water) interact with each other. The changes that are done to any of the systems will inevitable affect the others. The typical urban water system of Delhi city divided into various sub systems consisting of various processes from extraction/exploration of resource – surface and sub-surface, treatment of water, transmission, disposal, recycling are defined in resource accounting framework for city in Delhi in the diagram. The resource flow from the life cycle analysis is completed from various secondary sources for defining the losses within the system processes. This has been done so as to develop life cycle indicators for soliciting the opinion of exports, stakeholders and customers for decision making.

In doing Life cycle analysis, we have considered following type of indicators

1. Efficiency indicators : Quantity, Quality, and Reliability of services
2. Financial aspects: Adequacy of cost recovery for operation
3. Equity aspects: Affordability, Equitable access and participation in Decision making
4. Sustainability and Environmental aspects

While determining the criteria, we considered the different and at times conflicting objectives of the various stakeholders such as government, the management, the employees and the different types of consumers. The dimensions that overlay the assessment criteria are Achievement of sustainability Objectives that the option fulfils and the Risks/Costs that it entails. Overall, we considered the following criteria for options assessment:

- Improved service (water and sewerage), e.g.
- Quality
- Reliability
- Coverage
- Customer responsiveness
- Concern for the environment through study of losses and non revenue water
- Concern for poor and equitable service
- Efficiency in operations (higher productivity & lower costs)
- Increased future investment and capacity
- Financial self-sufficiency
- Long term sustainability

In order to assess various options across a common platform, we developed the framework of criteria, which we then applied to the various institutional options. . At the conceptual level one has to first identify the main channels and policy instruments through analyzing a series of case studies cities of India where different institutional instruments have been adopted for improving the services. Models of various institutional mechanisms experimented in various sectors, Corporatisation, Management contract, Concession contract AND Divestiture has been applied for assessing impact. The measurement of perception of sector performance through a set of indicators of efficiency, equity and sustainability is the key area of perception measurement based on expert and stakeholder survey on a likert scale.

DIRECTION OF RESULTS

The methodology used combines qualitative and quantitative approaches of analysis both from primary and secondary sources. The primary sources here include expert opinions and stakeholder opinions besides semi-structured interviews with resident welfare associations. In modeling expert stakeholder perception for assessing impacts on sector performance, it is important to consider the variables / components affecting the performance. In the present study, these have been analytically decomposed in terms of efficiency, equity and sustainability criteria. In designing indicators the family of criteria has been chosen in such a way that all major concerns about sustainability of water and institution have been taken care of .

Empirical evidence from the expert and stakeholder opinion carried out on 44 experts and stakeholders modeled indicated that coverage in terms of quantity, quality, reduction in water losses, cost of services, lifeline rates, affordability, level of satisfaction, ease of implementation, management of risks, political acceptability and sustainability of resource use were the important attribute which needs to be considered for evaluating the best option. The choice task with 5 most important attributes of quantity, quality, cost of services, reduction in water losses, social acceptability, were found statistically significant. (**Table 1)**

The direction of findings recommends a introduction of mechanism to reduce losses in water delivery system so as to decrease in over extraction of water and allows the industry to save resources by postponing investments in new supply capacity and is resource friendly. The indicators and the institutional options compliment each other in terms of viability and sustainability of reforms in the long run. The empirical results suggest broad contours for designing institutional and regulatory framework for achieving sustainability and distributional objectives. In policy terms the implementation of reform shall attempt discouraging wasteful use and efficiency enhancement by reduction in water losses, which can help in sustaining resource use.

The paper argues that it is the institutional change and benchmarking competition incorporating public-private partnership through LCA, which can give a fillip to the overall sustainability of resource use and utilization of precious resource. The improvement in service delivery indicators needs to be compared in performance benchmarking and evolving of a regulation in a competitive framework. The paper argues for application of the LCA as an information-generating tool for planning and decision-making related to resource, environment and policy development by developing a matrix for decision-making

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Anand Prakash Tiwari has a Bachelor in Civil Engineering and Masters in Planning from Centre for Environmental Planning and Technology and currently he is a PhD candidate of public policy at TERI University, New Delhi. His doctoral work is on infrastructure reform focusing on institutions and delivery mechanisms. His major research interest areas are Public Policy, Water Resources and Management, Environmental Engineering and Institutional Economics. He has widely presented and published his research work both in India and abroad and represented India on various International delegations. He is a member of Institution of Engineers, Institution of Planners, Institution of Public Health Engineers, International Water Association and International Society for Ecological Economics (ISEE).

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INDEX OF PERFORMANCE VARIABLES USED IN EXPERT OPINION AS PER LIFE CYCLE ANALYSIS OF WATER USE

NRW	=	Reduction in Non Revenue Water
FRR	=	Expectation of financial rate of return
Polacc	=	Political and Social acceptability
SRU	=	Sustainability of Resource use possibility
AFF	=	Affordability
AOB	=	Accuracy of Billing
LLR	=	Life Line rates
MOR	=	Management of Risks in transition
ICB	=	Institutional Capacity Building
LOS	=	Level of Satisfaction
TR	=	Technological Reliability
EOI	=	Ease of Implementation
CPM	=	Community participation in Management
USO	=	Universal Service Obligations

Table	Experts views on important attributes of selection for delivery of water			
Log likelihood function		-196.9037		
Restricted log likelihood		-249.4629		
Pseudo R- Squared		0.21069		
Corporatisation (Y=1)				
	Coeff.	Std.Err.	T-ratio	P-value
Constant	-1.36482	1.27214	-1.07286	0.283336
OVERALL	0.620843	0.598087	1.03805	0.299248
NRW	-0.493934	0.52012	-0.949655	0.342288
FRR	0.647484	0.452555	1.43.073	0.152507
POLACC	0.295025	0.27925	1.05649	0.290744
SRU	-0.862509	0.615996	-1.40019	0.161458
Management Contract [Y=2]				
CONSTANT	-0.156391	1.19611	-0.13075	0.895973
QUANTITY	0.945469	0.675358	1.39995	0.161527
QUALITY	-0.671042	0.553099	-1.21324	0.225038
NRW	1.20052	0.6296681	1.90656**	0.0565781
FRR	1.06133	0.655566	1.61896	0.105456
LLR	-0.623031	0.62242	-1.00098	0.316835
AFF	-0.75867	0.807503	-0.939526	0.347461
AOB	0.636392	0.641645	0.933612	0.350504
ICB	0.851054	0.742093	1.14683	0.251452
SRU	-0.664657	0683549	-0.972362	0.330871
Concession [Y=3]				
Constant	0.34109	1.15793	0.29457	0.768322
QUANTITY	1.2168	0.730643	1.66538	0.0958373
QUALITY	-1.08256	0.611351	-1.77077**	0.0765995
NRW	0.863003	0638485	1.35164	0.17649
FRR	1.36601	0.649431	2.10339*	0.0354317
AFF	-1.70269	0.835067	-2.03899*	0.0414513
ICB	0.612573	0.674953	0.907579	0.364101
SRU	-0.752075	0.681093	-1.10422	0.269499
Divesture (Y=4)				
Constant	-0.102992	1.25111	-0.0823206	0.934392
QUANTITY	2.02519	0.781119	2.59268*	0.00952321
QUALITY	-1.1051	0.589891	-1.8734**	0.06101138
NRW	1.23363	0.675376	1.82658**	0.0677623
FRR	1.38802	0.644428	2.15388*	0.0312495
AFF	-1.93769	0.858452	-2.25718*	0.0239965
LOS	-1.22238	0.98141	-1.24553	0.212937
TR	1.17481	0.970947	1.20996	0.226293
EOI	-1.33653	0.780983	-171134**	0.0870179

* Acceptability above 99% confidence level; ** Acceptability above 95% confidence level

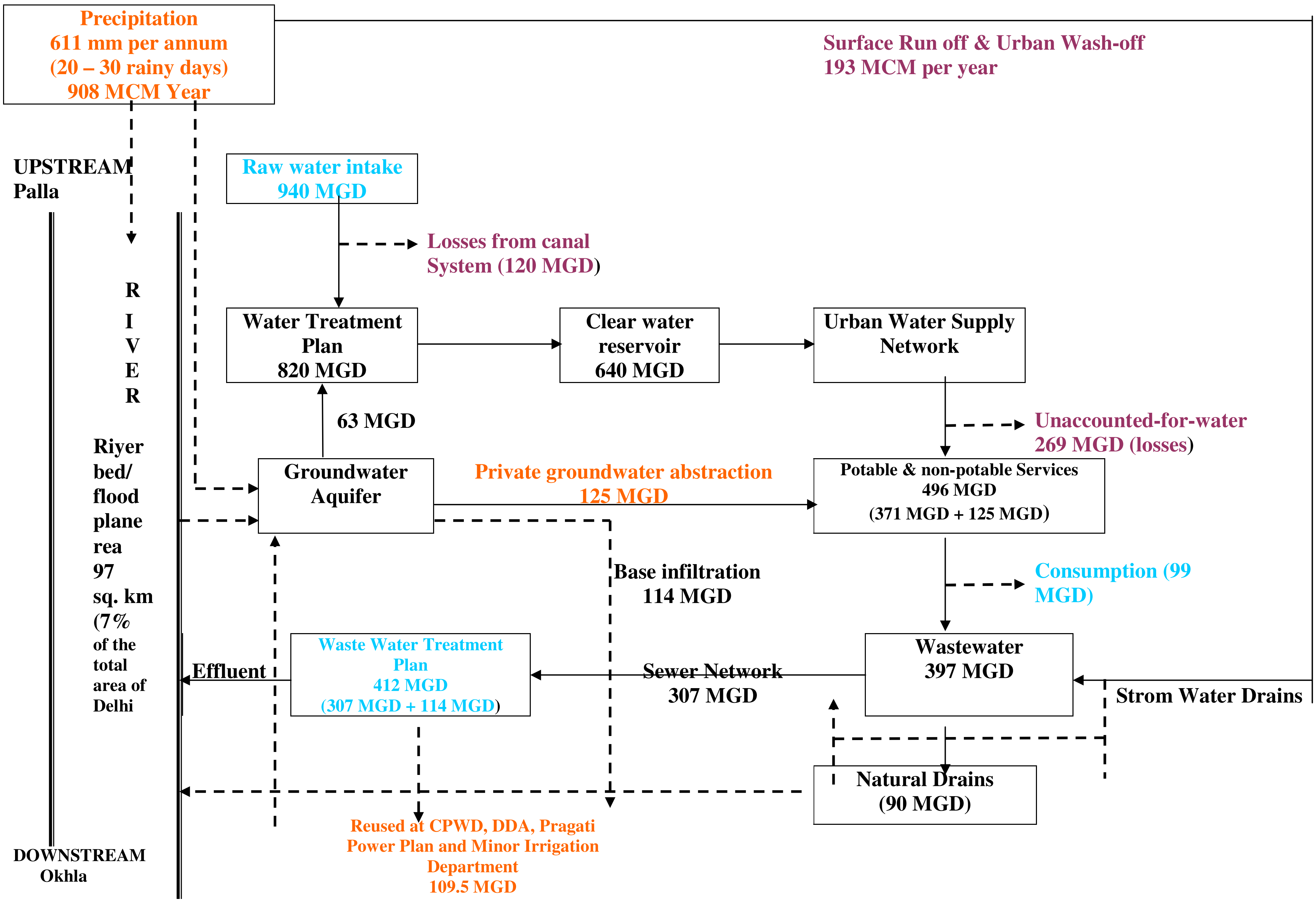

Chart 1 : Water Resource Flow Diagram in the City of Delhi