Proceedings of the Seminar
on
Statistical Accounting of Water Resources
24-25 June, 2005

Organised in Collaboration with
Institute for Social and Economic Change
Bangalore

Central Statistical Organisation
Ministry of Statistics and Programme Implementation
Government of India

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Seminar
on
Statistical Accounting of Water Resources
24 - 25 June, 2005

<u>Programme Schedule</u>

Date and Time		**Programme**	
Friday June 24, 2005			
9.00 – 9.30 a.m.	:	Inauguration	
		Welcome:	Prof. Gopal K. Kadekodi, Director, ISEC
		Inaugural Address by Chief Guest:	Shri. P.S. Rana Secretary to the Government of India Ministry of Statistics and Programme Implementation
		Overview of the Seminar & Vote of Thanks:	Prof. K.V. Raju Head, Ecological Economics Unit, ISEC
9.30 – 10.00 a.m.	**:**	*High Tea*	
10.00 – 10.15 a.m.	:	Registration	
10.15 – 1.15 p.m.	:	**Session 1: Water Resources** **Chairman: Prof. P.S. Rao,** **Rapporteur: Sarbani Mukherji**	
10.15 - 11.00 a.m.		1. Sustainable Water Use in India: A Way Forward *Prof. K.V. Raju, ISEC, Bangalore*	
11.00 - 11.45 a.m.		2. Methodologies for Valuation of Water and Linking with Resource Accounting *Prof. Gopal K. Kadekodi, Director, ISEC, Bangalore*	
12.00-12.45 noon		***Tea***	
12.00 – 1.30 p.m.		3. Issues in Statistical Accounting of Groundwater Resources *Prof.M.G. Chandrakanth, University of Agriculture Sciences, Bangalore*	
1.30 – 2.15 p.m.	**:**	*Lunch*	
2.15 – 4.45 p.m.	**:**	**Session 2: Urban and Rural Water Supply** **Chairman: Prof. R.S. Deshpande, ISEC, Bangalore** **Rapporteur: K . C. Smitha**	
2.15 - 3.00 p.m.		1. Rural Water Supply in India: In Search of Institutional Alternatives *Prof.K.V. Raju, ISEC, Bangalore*	
3.00 – 3.45 p.m.		2. Issues of Unaccounted for Water in Urban Water Supply *Dr.G.S. Sastry, ISEC, Bangalore*	
3.45 – 4.00 p.m.	:	*Tea*	
4.00 – 4.45 p.m.		3. *Issues of waste water resources* *Shri..M.N. Thippeswamy, Chief Engineer (Retd) ,*	
Saturday June 25, 2005			
9.30 – 1.30 p.m.	**:**	**Session 3: Water Quality** **Chairman: Prof.Paul Appaswamy, Madras School of Economics, Chennai** **Rapporteur: Geetanjoy Sahu**	
9.30 - 10.15 a.m.		1. Water Quality Indices *Prof.A.K. Thukral, Guru Nanak Dev University, Amritsar*	
10.15 - 11.00 a.m.		2. Drinking Water Quality *Shri. S.K. Panda, Director, Central Water Commission,, New Delhi*	
11.00 – 11.15 a.m.	:	*Tea*	

11.15 - 12.00 noon.		3.	Safe Water Options against Arsenic Problems in West Bengal: An Awareness and Socio-Economic Study *Prof.Ranjit Chakrabarty, Calcutta University, Kolkata*
12.00 – 12.45 p.m.		4.	Physical Accounting of Water Quality Parameters – Understanding Water Quality Accounting Through Case Study of Bhoj Wetland of Bhopal *Prof.Madhu Verma, IIFM, Bhopal*
12.45 - 1.30 p.m.		5.	Lake Characterisation & Classification *Prof.Renu Bhardwaj, Guru Nanak Dev University, Amritsar*
1.30 – 2.15 p.m.	:	*Lunch*	
2.15 – 4.15 p.m.	**:**	**Session 4: Environment and Conservation** **Chairman: Prof. A. Damodaran, IIM, Bangalore** **Rapporteur: Poulomi Bhattacharya**	
2.15 - 3.15p.m.		1.	Protecting Environment through Promotion of Water Resources: Challenges and Strategies *Prof.M.M. Adhikary, Bidhan Chand Krishi Viswavidyalaya, West Bengal*
3.15 – 4.15 p.m.		2.	Environmental Accounting for Pollution Damages: The Monetary Approach *Dr. L. Venkatachalam, ISEC, Bangalore*
4.15 – 4.30 p.m.	:	*Tea*	
4.30 p.m. – 5.30 p.m.	:	**Valedictory**	
		Chair:	**Prof. Gopal K. Kadekodi, Director, ISEC**
		Chief Guest:	**Prof.S. Bisalaiah, Former Vice-Chancellor, University of Agricultural Sciences, Bangalore**
		Observation by the CSO:	Shri J. Dash, Dy. Director General, CSO, Govt. of India
		Participants' Observation:	
		Overview of the seminar and Vote of Thanks:	Dr. G.S. Sastry Seminar Co-ordinator

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List of Resource Persons and Articles

1. A.K.Thukral, Professor Department of Botanical & Environmental Sciences Guru Nanak University, Amritsar : Water Quality Index

2. B. Purkayastha, IAS, Secretary to Government of India, Government of Meghalaya, Shillong : A Statistical Accounting of Water Resources

3. G.S.Sastry, Assistant Professor, ISEC, Bangalore : Issues of Unaccounted Water in Urban Water Supply

4. K.V.Raju, Ecological Economics Unit, ISEC,Bangalore :
   (i) Sustainable Water Use in India: A Way Forward
   (ii) Rural Water Supply in India In Search of Institutional Alternatives

5. L.Venkatachalam, Assistant Professor, Economics Unit, ISEC, Bangalore : Environmental Accounting for Pollution Damages: The Monetary Approach

6. M.G. Chandrakanth, University of Agricultural Sciences, GKVK, Bangalore : Issues in Statistical Accounting of Ground Water Resources

7. M.M. Adhikary, Professor of Agricultural Extension & Former Dean, Faculty of Agriculture Bidan Chandra Krishi Vidalaya, West Bengal : Protecting Environment Through Promotion of Water Resources Challenges and Strategies

8. M. N. Thippeswamy, Chief Engineer (Retd). , BWSSB, Bangalore : Issues of Waste Water Resources

9. Madhu Verma, Associate Professor, IIFM, Bhopal : Physical Accounting of Water Quality Parameters- Understanding Water Quality Accounting through Case Study of Bhoj Wetland

10. O.P.Singh, Reader, NEHU, Shillong : Appraisal of Water Resources of North Eastern Region of India,

11. Ranjit Chakrabarty, University of Calcutta : Safe Water Option Against Arsenic Problems in West Bengal: An Awareness and Socio-Economics Study

12. Renu Bhardwaj, Reader & Head Department of Botanical & Environmental Sciences Guru Nanak University, Amrisar : Lake Characterstics and Classification

13. S.K.Panda, Director Central Water Commission, New Delhi : Drinking Water Quality

PREFACE

Environment Statistics occupies an important place in the national statistical system. It seeks to present human activities in relation to environment especially water, soil, forest, atmosphere and other resources that are available in the nature. There is a growing concern on the deterioration of the environment and the need to improve its quality. Sound database on all aspects of environment is a prerequisite for formulation of various policies and plans to protect and conserve our environment.

The Ministry of Statistics and Programme Implementation has been organizing Workshops/Seminars on Environment Statistics which act as a common platform for academicians and experts for sharing their individual experiences and knowledge to bring about improvement in environment statistics. The Seminar on 'Statistical Accounting of Water Resources' is fifth in this series and was organised in collaboration with the Institute for Social and Economic Change (ISEC) during 24-25th June at Bangalore.

The Seminar deliberated upon many relevant issues relating to Water Quality, Water Pollution and Measurements, Economic Accounting of Water, Policy and Programmes and came out with many recommendations. This volume is the outcome of the deliberations in the Seminar. I am very thankful to the Institute for Social and Economic Change, particularly Prof Gopal K Kadekodi, Director and his team for organizing and giving full logistic support for the Seminar.

I wish to record my special appreciation for the Officers and Staff of the Social Statistics Division of this Ministry headed by Shri J.Dash, Deputy Director General for organizing the Seminar and bringing out the proceedings in this form.

P.S.Rana

Secretary to the Government of India

November, 2005 *Ministry of Statistics and Programme Implementation*

Inaugural Session Report

The seminar began with the welcome address by Professor Gopal K Kadekodi, Director, Institute for Social and Economic Change, Bangalore. Professor Kadekodi while cordially welcoming the chief guest Shri P S Rana, Secretary, Ministry of Statistics and Programme Implementation, Government of India, Resource Persons, invitees, media people and staff of ISEC highlighted the theme of the seminar as timely and emphasised need for appropriate accounting of all natural resources in general and water resources in particular for their sustainable use. Prof. Kadekodi highlighted the importance of statistics in achieving good planning, governance and development and the national income accounting research by late Prof. VKRV Rao as early as in 1933. In addition, Professor Kadekodi stressed the importance of efficient management of water resources in the context of scarcity and increasing demand, and competition among the various sectors of the economy and institute's long history in conducting research and training on the issues relating to environment and natural resources.

The inaugural speech of Shri Oscar Fernandes, Hon'ble Minister of State (Independent Charge) for the Ministry of Statistics and Programme Implementation, Government of India, in his absentia was circulated to the participants, resource persons, invitees and media persons. The Hon'ble Minister in his inaugural speech clearly highlighted the problem of current method of computation of GDP and underlined the need for the revised methodology for GDP computation by taking resource depletion into consideration to reflect the real GDP. The CSO has promoted such studies to cover methodologies on land, air, water, forestry, mining and energy. The Minister mentioned that although CSO is the nodal institution responsible for data base for all the sectors of the economy for efficient planning and development, its quality has to be maintained for meaningful analysis, interpretation and use. In this context, the minister highlighted the Rangarajan Commission's Report on Statistics and its recommendations for establishing National Statistical Commission to review the quality, quantity, coverage, standards, and methodology of statistical data base. The Hon'ble Minister indicated the main issues of water resources as sustainable use and management in rural and urban areas; appropriate technology for exploitation, distribution and use; pricing of water resources and institutional management. He attributed the current problem of scarcity and mismanagement solely to the fact that water has not been recognised as an economic good. The Minister expected the seminar to deliberate on these issues and wished the seminar all success .

The seminar was inaugurated by Shri P S Rana, Secretary to the Government of India, Ministry of Statistics and Programme Implementation. In his inaugural address, Shri Rana highlighted the emerging issues of environment and development and need for common framework for their analysis. Environment accounting is the first step towards such methodological approach. Such a methodology would systematically analyse the issues of environment, economics and development which provide concrete inputs for efficient policy decisions. However, the main issue which remains is the development of the appropriate methodologies for accounting of various natural resources and creation of adequate supporting data base needed for the analysis. In this context, CSO being the nodal agency, has been attempting to meet these requirements through promotion of environmental accounting studies covering land , air, water, forestry, mining and energy. Towards the generation of the supporting data base for these studies, CSO has been compiling and publishing "Compendium of Environment Statistics" covering key parameters like biodiversity, atmosphere, land/soil, water and human settlements. The CSO is also organising theme based seminars periodically to address the issues of data base and methodology on the said themes. The earlier seminars were focused on the themes pollution and human health, status of data base on different types of pollution and human settlements. The current seminar was unique in the sense that it would focus on the most important issue of water resources and its related aspects. This seminar was organised as a follow up of the recommendations of the earlier seminar. Shri Rana expected that the two days deliberations would address the issues of physical and economic accounting, water quality, water pollution and conservation. The main benefit of accounting of water resources was that it reflected the available resource stock in terms of quality, quantity and seasonality. He wished all the success for the seminar.

Dr K V Raju, Professor and Head, Ecological Economics Unit thanked profusely Shri P S Rana for identifying ISEC to conduct the seminar on such an important theme and guiding the seminar deliberations by raising several basic issues of water resources accounting and management, and thanked all the resource persons, participants, invitees and media for accepting invitation and for their gracious presence. Prof. Raju thanked Prof Kadekodi, Director ISEC for his constant encouragement in conducting this seminar and the Registrar and the Accounts Officer for their all-out support in organising the important national seminar.

<u>Speech of Shri Oscar Fernandes, Minister of State (Independent Charge), Ministry of Statistics & Programme Implementation on the ocassion of inauguration of Seminar on 'A Statistical Accounting of Water Resources' on 24th June, 2005</u>

Venue: Institute for Social and Economic Change, Bangalore

It gives me immense pleasure to be with you all in this beautiful campus of the Institute for Social and Economic Change on the occasion of the seminar on statistical accounting of water resources. Water being the most precious resource for the existence of life, the topic of the seminar is of critical importance and Bangalore is the most ideal location for discussing the subject as it is already having water scarcity.

2. The Ministry of Statistics and Programme Implementation has always been measuring the economic growth of the country in terms of Gross Domestic Product and other related aggregates. GDP measure, however, does not take into account the depletion of various natural resources. For example, if we extract more minerals, the GDP increases. However, the crust of the earth gets damaged and we deprive the future generation of their precious wealth. Similarly, if we draw more sub-soil water, the water levels get depleted though the GDP goes up. It is, therefore, important to account for such depletions to measure the net economic growth. Keeping this in view, the Central Statistical Organisation has taken up a few studies for environmental accounting or natural resource accounting, with an outlay of about Rs.1.33 crores. These studies cover, land, air, water, forestry, mining and energy.

3. It has been the endeavour of the Ministry of Statistics and Programme Implementation to maintain statistical standards and reorient the processes and priorities in the realm of official statistics, in tune with the changing technological and economic environment and needs. The objective of the Ministry is to collect, coordinate, collate and disseminate credible and timely statistics for informed decision making as well as to promote human resource development in official statistics. The Ministry is also responsible for monitoring the progress of implementation of major infrastructure projects and facilitate the operation of the Member of Parliament Local Area Development Scheme. On the statistics side, the Ministry has to re-engineer the statistical system of the country to produce reliable and timely data on all important aspects to guide the development strategy of the country. For example, the system should provide reliable data for estimating the incidence of poverty and un-employment in different regions of the country to formulate policies and programmes for eliminating poverty and un-employment. The Ministry is thus making all the efforts to make the statistical system responsive to the needs of the country.

4. In line with the current requirements and the recommendations of the Rangarajan Commission on Statistics, the Government has recently notified the setting up of a National Statistical Commission through a resolution. It is expected that the Commission would be made a statutory Commission within a period of one year. The National Statistical

Commission will, among others, identify the core statistics which are critical to the development of the economy and lay down national quality standards on the core statistics, evolve national policies and priorities relating to the statistical system and develop strategies for human resource development to meet the needs of the statistical system. The Commission will also monitor and review the functioning of the statistical system in the light of the laid down policies, standards and methodologies and recommend measures for enhanced performance.

5. Now let us come to the theme of today's seminar. The subject of water is very close to my heart as it is a common denominator for all sectors of the economy. The rapid changes in living standards, population growth and economic development have increased the demand for water at an alarming rate. On the top of it, the mismanagement of existing water resources and its unsustainable use has created acute scarcity of water in several parts of the country. The basic reason for such a situation is the fact that water has not been recognized as an economic good.

6. The major issues relating to water are (i) Sustainable use and management (ii) Appropriate technology for exploitation, distribution and use (iii) Pricing of water resources and (iv) Institutional arrangement .

7. **The necessity of Sustainable use and efficient management of water resources has been recognised by the policy makers:** No doubt water is a natural good, but even in this era of acute scarcity and shortage, it is being treated as free and abundant. In **urban areas**, inefficient urban environmental planning has resulted in the loss of available potential water resources and poor management of urban water distribution systems has led to higher share of water loss. Consequently urban water supply utilities have to augment water resources quite frequently to meet the increasing demand on account of rapid urbanization and industrialization by drawing water from distant sources at a huge capital cost. The loss of water has been a very serious issue especially in developing countries with losses being around 40 percent. In urban areas, almost 80 percent of the consumed first quality water will come back as waste water. This potential, precious waste water resource if used after proper treatment would meet almost 2/3rds of urban water demand thereby reducing the pressure on the first quality water to a very great extent. Further, the efficient use of waste water will also save the environment. However, most of the urban areas lack under- ground drainage (UGD) facility for efficient disposal of waste water and also lack its treatment facility. In addition, by letting the urban waste water flow into fresh water bodies, the urban local authorities have not only polluted the fresh water bodies, but also damaged the entire ecosystem. The problem is aggravated further by indiscriminate discharge of untreated industrial effluents into fresh water bodies.

8. Non-availability of **economically feasible technologies** for water distribution and waste water treatment along with the use of inappropriate technology in agricultural operation has led to huge wastage of water resources. Use of sprinkler irrigation or drip irrigation systems for agricultural activities in water stress regions would ease the problem of water scarcity. Similarly in urban areas, use of water conservation technologies, rain water harvesting and water efficient technologies in household use (kitchen, bath rooms

and toilets) and use of treated waste water in the non- potable water use activities like cleaning, gardening, etc, would reduce the cost of treatment of huge quantity of first quality water to a very great extent.

9. **Pricing of water** has been a most crucial issue. Especially, in both rural and urban areas of developing countries, inefficient pricing of water resources has led to excessive use of water in agriculture, industry and household sectors. In addition, improper cost recovery on the supplied water resource has spoiled the financial health of utilities responsible for water supply which in turn has resulted in huge government subsidies. Hence, appropriate pricing of water resources with social justice is the only way to meet the challenges of the water sector.

10. **Institutional structure** specially existing at the distribution level is not efficient as they have been developed with top down approach by imposing supply-based norms. With the given stratified societal structure with differential consumption behaviours of urban population, this system may not suit in urban areas. For efficient distribution, it is better to have demand based options with appropriate people's participation. The non-serious implementation of the available legislation and poor monitoring have led to improper use and huge wastage of water resources. The models like, privatization or public-private partnership in water supply system, which is successful in other countries in efficient use of water resources, may be an alternative solution for efficient management of water resources In fact people's participation in the water management would solve many of the crucial administrative problems due to good understanding between government and beneficiaries.

11. Finally, the major issue of water sector is the need for proper accounting of water resources for its sustainable use and management. Since, all aspects of water supply have attracted global importance as a top priority issue for its immediate action, the UNO has declared 2005 - 2015 as International decade for action: Water for Life. It has begun from the World Water Day on 22 March 2005.

12. I hope you will discuss not only the accounting part of water resources but also issues of quality of water, water pollution management of water etc. which are important issues. I am confident that the two days' deliberations in this seminar will identify the data gaps and throw up pragmatic suggestions for development of a framework for natural resource accounting of water resources.

I wish the Seminar all Success

KEY NOTE ADDRESS BY SHRI P. S. RANA, SECRETARY TO THE GOVERNMENT OF INDIA, MINISTRY OF STATISTICS AND PROGRAMME IMPLEMENTATION

Prof. Gopal K.Kadekodi, Director, ISEC, Dr. G. Raveendran, Additional Director General, CSO, Shri J. Dash, Deputy Director General, CSO, distinguished participants , ladies and gentleman.

I consider it as my proud privilege to address this august gathering on the occasion of inauguration of fifth Seminar on Statistical Accounting of Water Resources in Bangalore. The Central Statistical Organisation, Ministry of Statistics & Programme Implementation being the nodal agency, which is responsible for the development of statistical system in India, has been acting as the coordinating agency on the environment statistics since 1996. In order to assist in the creation of data base on Environment Statistics, the CSO is bringing out an annual publication entitled "Compendium of environment Statistics" containing the data on five key parameters viz. Biodiversity, Atmosphere, Land/soil, Water and Human Settlements. My Ministry is responsible for capacity building of Statisticians from Central and State Government through organising training programme on environment statistics on regular basis.

Evironment is a new emerging area. With its unlimited scope, Environment Statistics seeks to present human activities in relation to environment which constitutes water, soil, forest and other resources that are available in nature. There is a growing concern on the deterioration of the environment and need to improve the quality of environment. Sound database on all aspects of environment is a prerequisite for formulation of various policies and acts to protect and conserve our environment.

The protection of environment and conservation of natural resources have emerged key national priorities in India after 1972 Stockholm Conference on Human Environment. There is a new emphasis on sustainable development heralded by the U.N. Conference on Environment and Development (UNCED) held at Rio in 1992. The main agreement to emerge from the UNCED was Agenda 21, which to date serves as a guidelines document for pursuing the goal of sustainable development and bringing about the concomitant institutional changes.

The economic development of a country or region is generally expressed in terms of the growth of its income. The value of the final product excluding the value of inputs used in the process of production is termed as the Gross National Product (GNP). However, these indicators of economic development do not take into account the use and depreciation of the renewable or non-renewable natural assets. But the growing scarcity of these resources has forced the policy-makers to develop the natural resource accounts. Following other countries, India too has given due thought to this phenomenon and outsourced eight studies to various research organisations on different sectors in selected States in order to develop sector wise methodologies for computing Green GDP. These studies are at various stages of completion.

I am happy that the present Seminar has been organised in the beautiful city of Bangalore This Ministry had organised four such Workshops on Environment Statistics earlier also. These workshops act as a common platform for academicians and experts to get together for sharing their individual experiences and knowledge to bring about the improvement in environment statistics. In earlier Workshops, technical discussions were focused on various aspects of environment such as pollution and human health, status of databases on different types of pollution, human settlements, etc. This Seminar is unique in the sense that it will focus Statistical Accounting of Water Resources and its related aspects. This has been decided as a follow up of recommendation made in the forth Workshop which stated that Workshop/Seminar should be organised sector wise to firm up specific guidelines for developing methodology in that particular sector.

These two days, we will discuss about Statistical Accounting of Water Resources with reference to Physical Accounting of Water Resources, Physical Accounting of Water Quality, Water Pollution and Measurements, Economic Accounting of Water, Policy and Programmes. As you all know, water is a prime natural resource, a basic human need and precious national asset. It is one of the most crucial elements in development planning. There is need to develop, conserve, utilise and manage this important resource in a sustainable manner. A well developed water statistics is prime requisite for resource planning, standards for coding, classification, processing of data and methods/ procedure for its collection should be adopted. Special efforts should be made to develop and continuously upgrade technological capability to collect, process and disseminate reliable data in desired time frame.

The Statistical accounting comprise of stock and flow accounts in physical terms as well as quality accounts. The use to which water can be put depends crucially on its quality. Water used in hydroelectric power generation, industrial purposes and transportation does not require high standards of purity, whereas other uses like drinking, recreation, habitat for aquatic organism etc.rely on higher levels of purity. There is need to define water accounting to the level of pollution with organic matter such as BOD (Bio Chemical Demand), COD (Chemical Oxygen Demand) or by measures such as ammonium ion concentration. So it is important to construct water quality accounts in physical terms with quality. Water valuation is also crucial for water management decisions, in particular for those related to allocation of water to different uses in the presence of increasing demands for fresh water and limited supply.

There are many benefits of water accounting which offer an integrated view of water supply and uses by industry and by purpose. They include measures of water pollution, protection and management and describe water quality in physical and monetary accounts. The accounts help to understand the interaction between human activity and the environment. They help to identify water availability for various uses, stress on water, and qualitative and quantitative water scarcity. I hope this Seminar will address such issues and come out with specific recommendations. I wish the Seminar all success.

SUMMARY OF TECHNICAL SESSIONS

Session 1: Water Resources
Chairman: Prof. P.S. Rao
Rapporteur: Sarbani Mukherji

Paper Title : Sustainable Water Use in India: A Way Forward
Author : Prof. K.V. Raju

The speaker highlighted the macro view of water resources in India. The critical issues pertaining to water resources were identified as follows: efficiency of water use; existence of vicious circle in the irrigation system and complexity of problem: deprivation of tail-enders, improper regulation, and governance constrains, poor monitoring system, etc; growing financial crunch, declining budgetary support, high gestation period, low water fee etc; pricing and competitive demand, low water price and revision is irregular, conflicts between industrial and agriculture demand, impairment of water quality through industrial pollution; unused wastewater: inadequate technology; water disputes: difficulty in defining enforceable property rights to water.

The speaker then suggested a few reform strategies, which include:
Refinement in reliability and accessibility to data; Enhancement of independent assessment of sources of irrigation; Promotion or autonomous river basin/ sub-basin boards; Community based rejuvenation of traditional sources like tanks which recharge groundwater and provide critical needs of community; Roof water harvesting and reuse of waste water to meet growing urban and rural drinking water. However, capacity building, institutional reforms and promotion of coherent policy and legal framework are essential for moving towards the reforms.

Discussion
Shri P.S. Rana commented that the speaker had flagged issues, which should be deliberated in the seminar. Dr. Raveendran mentioned that general economic theory deals with demand and supply and the primary assumption was that both could be adjusted using fiscal and non-fiscal parameters. However, natural resource theory involved a third dimension of total availability of the resource, which in fact determined the supply of the resource. Therefore, efficient use of the finite resources should be ensured (sustainable development concept). The sources and availabilities of natural resources should also be identified appropriately. Dr. Thippeswamy pointed out that efficiency in irrigation sector was rather poor and therefore it had to be improved and made financially viable. Besides, impairment of water quality through industrial pollution was a major issue, which should be addressed appropriately. Sustainability of water should be ensured both in qualitative and quantitative terms. He further commented that sustainable water use should be made mandatory for all governments. Dr. Thukral referred to the problems of implementation of the strategies on the part of the government. He suggested the deliberations to be forwarded to government. Sri. S.K.Panda mentioned about the need for a legal framework to account for the resources. Besides, inter-linking of rivers made it a national problem and hence the Central Government should come to the forefront. So efforts should be both from the Central

government as well as from the participatory agencies. Dr. Madhu Verma suggested that sustainable water use required not merely augmenting water supply but also controlling demand. Therefore, both demand and supply pattern must be looked into in totality.

Paper Title: Methodologies for valuation of Water and Linking with Resource Accounting Prof. Gopal K. Kadekodi

The speaker highlighted the importance of National Income Accounting as a statistical method of accounting for land, human, manmade and natural capital. Accounting for water is essential not only as a resource but also to trace the nuisance arising out of water use. Wastewater generates externalities, which are internalized by incurring defensive expenditures. Externalities affect both the consumption and expenditure sides of the accounting. To address the environmental component of natural resources, Augmented National Income Accounting System has been introduced, whereby the different components of water use are separated. National Income Accounting is essentially a flow concept, which accounts for the effect of a change in water quality or quantity. However, breaking up the data set at the national level is a rather complicated task. Basin-wise studies (like the study on Yamuna-basin) should therefore be encouraged. The speaker then referred to the concept of Satellite Accounting introduced by the United Nations (Satellite System of Integrated Environmental and Economic Accounting). This methodology was attempted in India in 1993 in a rather crude fashion. The summary of the major annual environmental costs in India reveals that on an average 5% of the resources remain unaccounted for. Precisely, an appropriate methodology is required for accounting water resources so as to develop proper sustainable development policies. A framework for physical accounting of water will also reflect the dynamic changes in the resource. Besides, valuation of the resource to different segments of the society is also essential. However, a number of problems may arise in valuation, since there exists a dichotomy between market situation and the actual willingness to pay for water. Individuals do not intend to pay for water even though they realize the immense importance of the resource in their life. It is in fact a social issue. This emphasizes the formulation of some legal framework to address the issue. The speaker then cited the example of Kumaon Valley Study that he conducted to substantiate the feasibility of accounting at a specified area. He concluded saying that in order to address physical accounting and valuation issues of water resources, basin level studies should be undertaken which can then be extended to state level and finally to national level.

Discussion

Sri. Dash raised the issue of dynamism in willingness to pay for water. Smt. Jain raised her query with regards to water accounting for industries that had their own pump sets and therefore it was difficult to measure how much water they were actually extracting. She also wanted to know how the price of water was reflected through the accounting method. Dr. Bhardwaj sought to know about the appropriate incentives that should be provided for water reuse and harvest. Sri. Panda asserted the necessity of disintegration of basin-wise data to state-wise data in monetary terms. Dr. Thippeswamy commented on whether water should be treated as a 'social' or an 'economic' good.

In response to the above queries, Prof. Kadekodi commented that the issues of incentives and subsides were policy subjects. If wastewater was dumped without treatment it imposed a societal cost by affecting the health of the people. A defensive expenditure had to be incurred to abate such societal costs. Therefore, in accounting terms they should come under the expenditure side. He agreed to Sri. Dash's view on dynamism of water price, which he asserted could be indexed through statistical methods. He also asserted that whether water was a social or an economic good was in fact a philosophical debate. However, social value of water might differ from economic value, as water price might not reflect the actual willingness to pay for water.

Paper Title : Issues of Groundwater Resources
Author: Prof. M.G.Chandrakanth
The speaker referred to the Dublin principle on water which reveals why water should be valued (water has an economic value). Use of water is the maximum for agriculture uses (about 80%). Besides, it involves consumptive use of water and hence the water used cannot be retrieved. Hence in terms of physical and economic scarcity agriculture water use is more expensive. The speaker asserted that linear extrapolation of water use for irrigation is irrational ad unscientific due to the existence of diminishing returns. He mainly focused on the groundwater resources, as the problems pertaining to groundwater are more complex as compared to surface water. This is because groundwater is invisible and hence both recharge and discharge are estimated. The speaker also pointed out that his field experience often contradicts official estimates (Karnataka Minor Irrigation Census, 2002). Therefore reliability of official statistics is rather questionable. He also posed the challenges in accounting groundwater. They are as follows; 1) Linear extrapolation beset with problems since demand for groundwater is derived from demand for crops; 2) groundwater markets improve efficiency and equity; 3) groundwater usage varies widely across crops; 4) well aquifer characters are to be accounted for. However, indirect accounting for groundwater is possible through electricity meter installation, quid-pro-quo with power sanction. Educating farmers is also an important aspect of the problem. The speaker finally highlighted the functions of the groundwater wing.

Discussion
Dr. P.S Rao raised the query about the role of CGWB in investigation; budgeting and accounting as per groundwater issues are concerned. In response to this query, Prof. Chandrakanth clarified that both CGWB and State groundwater Board maintain their own records, which are published periodically as research reports. The question that needs to be addressed is to what extent this statistic can help farmers. Dr. Raveendran pointed out to problems of obtaining estimates of the total availability of groundwater. He also highlighted the two different dimensions of the problem; 1) physical accounting and; 2) monetary valuation. Prof. Chandrakanth further added that groundwater use is more micro in nature and hence micro-level information is required to address the issue. Better data set should be made available to the users. 'Well law' can be promoted. Irrigation extension system should be introduced and promoted. He also touched upon the concept of 'virtual water' and commented that cultivating rice with groundwater is a criminal act. He referred to the use of optimal control theory for tracing the equilibrium path of water use. But, free

rider problem may limit the scope of this method. Prof. Kadekodi emphasized the role of conjunctive use of both groundwater and surface water. He asserted that physical accounting is necessary for certain purposes, whereas valuation is important to know the value or price of water. In case of lack of any physical measure, value of water gives a signal of individual response with respect to value of water. Dr. Rao added that the mixed use of groundwater and surface water is a function of economic access to the resources. Dr. Appaswamy commented that agriculture use value of water is relatively lower, but even then largest volume of water is used for agricultural purposes. This in fact is a puzzle.

The Chairperson, Dr. P.S. Rao summarized the discussion in the end by hinting at the valuation conflict over natural resources. He also referred to the increasing complexities in water management (scarcity and quality impairment). Finally, he emphasized the importance of research and capacity building in addressing the issues of accounting and valuation of water resources.

Session 2: Urban and Rural Water Supply
Chairman: Prof. R.S. Deshpande, ISEC, Bangalore
Rapporteur: K . C. Smitha

Paper Title : Rural Water Supply in India: In Search of Institutional Alternatives
Author: Prof.K.V. Raju, ISEC, Bangalore

The presentation begins with the due emphasis on the general and over all scenario on Investment patterns on water supply. It is identified that the investment pattern is largely concentrates on physical components; as such there is need for Institutional alternatives. There is a increasing global population exertion. Even in India scenario there is a need nearly 7 billion dollars investment needs. This phenomenon puts enormous constraints on sources and technology. Meanwhile, five-year plans also reiterated the need for strategic planning and investment in rural water supply. Particularly the 8th and 9th FYP (Five Year Plan) have laid due stress on need of technology and piped water sources.

- The 8th FYP was basically Demand Driven Approach focused on Integrated Water Management and Decentralization. Though the emphasis was on the conservation of water but less attention was paid towards this.
- The 9th FYP focused on community participation and was basically a Demand Driven Approach with due stress on private sector participation. But this would again depend on choice of available and suitable infrastructure and institutions for RWS (Rural Water Supply) to tackle at the rural level. But these aspects could not succeed as due limited policy and design alternatives.

In Gujarat

Basically the state presents a picture of visible and viable alternatives, as there is visible collaboration between civil society and public institutions (with due emphasis of Panchayati Raj Institutions). But the situation is not the same in Karnataka, as there are no visible and workable alternatives available. The policy makers must duly address this aspect. In Gujarat, the availability of water supply is very poor. Its only 17 per cent as across the large population in the state. Nearly ¾ of the state face drinking water scarcity.

But there exist an active coordination between civil society and NGOs for monitoring and evaluation of water supply facilities. Here basically, the recharging is not possible due to persistent drought situation and geographical feature.

In Karnataka

The availability of water supply varies. But the general situation is that there are consistent problems of accessibility and quality of water. Sustainability of quality and resources has become a fixed problem. Meanwhile, there is a general trend of lack of involvement of civil society groups and NGOs. There is also trend of resource depletion at uncontrollable feet; water quality problems in rural areas; contamination has crossed the permissible limits in both the states as such the number of habitations affecting is alarming in both the states. **These problems are due to** Undue emphasis on surfaced water; Revival methods of recharging is not visible;. Particularly in Karnataka the efforts towards rechargeable methods are in small scale; This study presents 40 case studies covering both the states.

Initiatives

Some conservation techniques of rain water is undertaken. Meanwhile the HHs contributions are not prominent towards O&M in both the states; even user committees are less functioning and cooperating in this aspect at rural areas; decisions lacks planning affecting programs and during scarcity of water situation, private sector invention is inevitable making enormous business.

Gujarat

More emphasis is on pipeline water supply than traditional supply of water. There are number of rural and regional water supply schemes. Roof water harvesting if picking up but not in Karnataka. There is a well-planned centralized pipeline system with enormous investment covering 3,800 villages.

Karnataka

The technology is overemphasized leading to the defunct of traditional methods of water supply. Basically there is poor coordination between agencies like NGOs and civil society groups and Panchayati Raj institutions resulting in ineffectiveness.

Arguments for Change

There must be effective enforcement mechanism in ground water extraction or management in both the states; Roof harvesting must be promoted; Bette methods must be practiced; there must be clarity on rights and responsibilities between agencies, NGOs, public institutions.

Discussion

The following Questions were posed. i) What extent the irrigation well has alleviated drinking water needs? ii)What do you feel on the transfer of responsibility to decentralized institutions particularly for collecting tariff and taxes? iii) Basically there are institutional differences such as public institutions, NGOs etc who intervene in water markets in selling and supply of water. How do they contribute towards sustainability and quality of water supply? iv) Since mutuality of these institutions are inevitable, how inefficient and viable are they? Whether there is any rural water supply database available accounting for rural water supply?

Responses

Transfer of responsibility involves designing problem. Usually planning is done at central level but imposed on local institutions without considering local variations. The constructions executed are profit orientated not looking into the quality of construction. Moreover, local users do not take the responsibility of paying for damages of constructions. There lacks central guidelines to involve the local people. No finances generated for O&M leading to dependency on other sources. Good water sources are overused. NGOs and civil society groups are not coming up with long term institutional alternatives. Traditional methods are not sustained. The database does not reflect the excessive amount spent on droughts at central, state and taluk levels.

Paper Title : Issues of Unaccounted for Water in Urban Water Supply
Author : Dr.G.S. Sastry, ISEC, Bangalore

With specific context of Bangalore two studies are prepared one with comparison with Paris. Here the prime issue is the water loss that is unaccounted for water particularly in urban areas in developing countries. Its impact in enormous in terms of quality, quantity, inequality etc on urban water utilities. Basically, UFW is non-revenue water loss and its alarming issue irrespective of levels of development and its magnitude is very high. Definition of UFW was presented as the difference between water supplied and water consumed. This definition is basically broad one. Moreover its random factor, not reaching consumer that is not recorded. This aspect as the problem of accountability and assessment of water supply. The causes are numerous and linked to each other. Some classification has two components i.e., Real losses and Apparent losses. Specific causes are presented for these two components. Metering and awareness is very vital in tracing and monitoring the UFW. Economic distinction exists between two losses. The argument of groundwater recharging by UFW is not valid and logical. Share of UFW is present of both developed and developing countries. The present situation is dismal regarding pricing, institutions, awareness etc.

Remedies suggested

Efficient Management system contributes to prevention of UFW; Rigorous water management is required; the OECD countries has low UFW due to Public-Private Partnership approach; water auditing presenting input and output scenario is a must. In particular to the situation of Bangalore excessive expenditure on power and pumping do not give adequate attention to solve the problem of UFW. Meanwhile the BWSSB has developed vision plan with the help Australian aid program that has categorically emphasized on the reduction of UFW. Now BWSSB has initiated a pilot program that looks into the issue of UFWin pilot project area in the old city and now recommended for its extension to the entire city area.

Discussion
Paper Title : Issues of Waste Water Resources
Author Shri Ravishankar, BWSSB, Bangalore

He made a general presentation on sources of water supply to Bangalore. He elaborated on the term Waste Water Treatment and its reuse. He emphasized on wastewater treatment. He emphasized on alternative methods of wastewater treatment for conservation and its reuse. He stress that waste water is the only product that has capacity to be used for many purposes. But generally he points that there is lack of interest on WWT (waste water treatment). He identified some the big industries are promoting and installing small wwt plants there by saving water like BHEL, Golf association etc. and even forthcoming international projects like international airport, arkavathy layout etc do emphasis on WWT and its construction.

Presentation by : Sri..M.N. Thippeswamy, Chief Engineer (Retd). BWSSB
He started off with the due emphasis on WWT is inevitable consequence of increasing demands of infrastructure, and growing populations and unmet demands. As such water supply and WWT is treated as synonymous. Even the instances of both developing and developed countries for sustainability and future mankind waste water reuse is inevitable. He presented a slides of proportion of Water supply availability in both developing countries and developed countries. Particularly in India the picture of drinking water supply is dismal. He also categorized them as water stressed; water starved; Absolute scarcity countries. He then presented how Bangalore city is a privileged city with treat plants (740 million capacity) of 14 plants for WWT. Its unique in the country and next 2 years drainage water will be treated fully. He also presented the situation of other mega cities like Chennai, Bombay, Calcutta, and New Delhi.

Bangalore
Recycling is inevitable as next decade is the decade of recycling and reuse. Dual water supply system is the day of the order both in developing and developed countries. As the population is growing alarmingly, the issue of sustainability of water reuse must be examined. Water conservation methods and resource management must be duly emphasized and must be made mandatory at the Household levels. Decentralized waste water system i.e., mini waste water treatment projects must be emphasized for urban requirements. Lots of economics must be worked out for next generation.

Discussion
Dr. Madhu Verma: How do you make sure for addressing the issues of UWF particularly unaccounted wastewater? Do you advocate dual water supply system in the future? How viable is the DWS and its replication in other cities?
Responses: At present there are attempts made at sector level like BWSSB, BDA collaborating for Dual Water System. Its very feasible and due regulations and rules must be created for its effectiveness implementation and its must be made mandatory in all the urban areas.

Session 3: Water Quality
Chairman: Prof.Paul Appasamy, MSE, Chennai
Rapporteur: Geetanjoy Sahu

Paper Title : Water Quality Indices
Author: Prof. A.K.Thukural

The speaker gave a brief overview of different water quality indices with special emphasis on WQI developed by National Sanitation Foundation, USA in 1970. These indices can be used to assess water quality on the basis of several characteristics, each of which beyond specified limits may render the water quality. Each parameter was scaled from 0 to 00 for given range of values. For each test value, a Q value was assigned and then standard Q value curves were drawn for each parameter. The speaker also commented on WPI, which could be better understood and widely used for all water use purposes and water pollution management. He asserted that the proposed WPI would give a number as to how many times water used to be diluted with the best quality water in the acceptable range to bring the water with in the permissible limit.

Discussion
Sri Dash suggested that the statistical information on water pollution level should be made available to other scholars. According to Sri Panda the aforesaid indices did not capture a few water pollution characteristics, which also need proper attention.

Paper Title : Drinking Water Quality
Author : S.K.Panda

The speaker emphasized the use of BIS standard limit to monitor the drinking water quality. However, it has its own limitation because it involves a few numbers of chemicals. Therefore, the general suggestion of the speaker was to extend the basket to chemicals in BIS standards to include all chemicals of USEPA standards. He also suggested various methods of treating drinking water and protecting ground water supply. According to him, WHO formulation of guidelines for drinking water qualities should be taken care of. In GDWQ it is often emphasis that the guideline values recommended are not mandatory limits. Finally, he presented a brief overview of statistical accounting of drinking water quality.

Discussion
Dr. Venkatachalam has raised the issue of physical accounting with respect to different polluters. Prof. Kanbur mentioned about the different indicators of water quality and Prof.Appaswamy proposed the need to integrate data base so as to design appropriate methodology for measuring water quality.

Paper Title: Safe Water Options against Arsenic Problems in West Bengal: An Awareness and Socio-Economic Study
Author : Ranjit Chakravarty

The author highlighted the arsenic contamination problem in ground water in West Bengal due to drilling deep tub wells that contain geological deposits of arsenic. Inspite of abundant surface water it is hardly being used due to poor management and improper investment. To study the effect of arsenic contamination and to explore the possibility of using surface water, in particular the use of Pond Sand Filter method. For mitigating this problem a study is carried out in North 24 Pargana District of WB. He concluded that the awareness about the Pond Sand Filter method it is seen that increase in income or education don't increase the level of awareness. Thus the speaker suggested that an attempt should be made to aware the unaware people about the effects of the polluted water.

Discussion
Dr.Thukural enquired about the working of pond sand filter method. Dr. Sastry intended to know about the arsenic problem in detail and Prof. Appaswamy raised clarification about the presence of arsenic in the rock strata.

Paper Title : Lake Characterisation and Classification
Author : Renu Bhardwaj

The speaker presented the gaps in Morph metric study pertaining to lack classification and characterization. She emphasized the role of classification of lakes as per the scientific norms for their effective management. She vividly presented characterization and classification of lakes based on depth, surface area, littoral area, shoreline, shape, tropic status, etc. She also asserted that Osgood index, Shoreline Development factor and Tropic Indices are some important indices for lake classification and characterization. Finally, she proposed the lake interface of air and soil in relation to lake value. The speaker commented that there is a need to work on tropical lakes since most of the work on the lake classification pertains to temperate climate.

Paper Title : Physical Accounting of Water Quality Parameters Understanding Water Quality Accounting through Case Study of Bhoj Wetland of Bhopal.
Author : Madhu Verma

The speaker highlighted the functions of multilateral ecosystems in providing substantial benefits to society. However, she asserted all wetlands in India are endangered by lack of appreciation of their role. Hence, the proposed study attempted to analyze the factors causing Bhoj Wetland loss. She also presented an estimate of extent of the injury to the wetland thereby quantifying the impact of degradation on benefits and cost borne by stakeholders. Therefore, participation of community should be envisaged to address these issues as per the speaker. She presented a precise ecosystem modeling for Bhoj wetland based on water quality parameters. The elasticity matrics of ecological parameters of pre-restoration state were also explained. Finally, she gave an overview of the valuation exercise.

Discussion

Prof. Kadekodi emphasised the system of data collection and maintenance for appropriate application of economic modeling. Prof. Appaswamy showed his reservation on modeling water quality parameters are non liner. The chairperson finally concluded by emphasizing the importance of valuation of water resources. In this regard, he also suggested consideration of tanks for valuation apart from lakes.

Session 4: Environment and Conservation
Chairman: Prof. A. Damodaran, IIM, Bangalore
Rapporteur: Poulomi Bhattacharya

Paper Title : Protecting Environment through Promotion of Water Resources: Challenges and Strategies
Author : Prof.M.M. Adhikary, Bidhan Chand Krishi Viswavidyalaya, West Bengal

This paper highlighted out the major issues related to water and environment. Sources of water contamination and drinking water quality issues were described in details. Gynogenic and anthropogenic act ivies causing contamination and the severe problem of drinking water were stressed. Another major focus of the paper was the issue of irrigation and the need for promoting environment friendly irrigation systems. Given the scarcity and importance of water a few strategies for water conservation were put forward. These include recycling of used water especially by industries, reducing evaporation, rainwater harvesting etc. The author also suggested a few possible remedial measure for promoting water conservation like optimal conjunctive use of water, traditional water conservation practices, promoting participatory approach in water conservation etc.

Discussion

Prof P. Appaswamy emphasized on the necessity of building up systematic databases for fertilizer and nitrate contents of the soil by agricultural universities, because these are not available. *Dr. Damodaran* informed about existence of scatter data bases on the above mentioned parameters with mining and geology department, which can be used but also agreed with active participation of agricultural universities in building such databases.

Urban Water Issues:

Scheduled paper could not be presented, because of unavoidable reasons. In this session a good number of discussions came up on the urban water issues. ***Dr. Thippaswami*** spoke on the various aspects of conservation and recycling of water and alternative uses of recycled water taking Bangalore as an example. The issues of discussion are as follows: Rejuvenation of lakes, treatment of waste water; Reuse of waste water in different types of agriculture (e.g. grapes) as followed in countries like Australia, Mexico etc; Reuse of water in city specific activities like construction of multistoried buildings, maintenance of golf clubs, lawns etc; Importance of government intervention and proper regulation regarding waste water use; Decentralization of waste water treatment.

Discussion

Discussion of this session unfolded a few important aspects on urban waste water treatment. *Dr. Venkatachalam* raised a question on the use other economic instruments rather than depending upon the scarcity factor in urban areas. One of the participants highlighted the importance of demand side factors in waste water reuse. Consumer's decision and preferences between the choices of water use could play an important role especially when the use of waste water is costlier. *Dr. Thakural* pointed out the promotion of waste water reuse at the household level by introducing cost effective technologies. *Dr. Damodaran* reflected upon the opportunity cost of reuse. If freshwater is plenty, then it is less likely that the people will go for recycled water. He also emphasized the question of reuse of industrial waste water. In order to promote the reuse of water discharged by industries the Pollution Control Board (PCB) have to be more stringent on the quality of water and also careful about setting the standards of quality parameters

Paper Title : Environmental Accounting for Pollution Damages: The Monetary Approach
Author: Dr. L. Venkatachalam, ISEC, Bangalore

The basic rationale of this paper is to provide a simple framework for the CSO to utilize the information of micro level studies for a macro level environmental accounting. First part of the presentation dealt with the key features of natural resource accounting (NRA), the omissions and commissions of the national income accounting systems. In order to take into account the environmental damages caused by economic activities data is not available at the national level. To have an idea about say, water pollution damages, micro level water physical accounting systems should be done on a 'satellite' basis. But environmental damage in quantity terms does not take care of the actual level of damage to the people affected by it. There comes the role of economic valuation. Among the different valuation techniques the replacement cost approach and the production function approaches are the most users friendly. The paper attempts to provide damaeg figures for a river basin as a whole based on information provided by a micro study, using abatement cost approach. The mitigation of degradation of land due to water pollution is captured by amount of expenditure on gypsum. The figures finally arrived are said to be the maximum limit of the damage cost.

Discussion

Shri. *Dash* emphasized on the need for consensus between the academicians on methodologies before jumping into the conclusions. *Dr. Verma's* comments highlighted the implications of these kinds of valuation studies for emphasizing the damage to the poor people and drew the attention of policy makers for poverty eradication. *Dr. Appaswamy* discussed about the difficulties of quality accounts and advised to go for physical quality account on a sector by sector basis. Measuring the levels of crucial quality parameters produced by each sector and how much are released in environment would be a reasonable option. *Dr Kadekodi* expressed his opinion on the need for making a compendium of case studies from which a set of parameters of importance should come out on the basis of which CSO can design its surveys.

Recommendations of the Seminar

RESEARCH STUDIES

1. Physical accounting and valuation of surface and ground water resources at basin level, agro-climatic regions, state and national levels.

2. Develop water quality and water stress index of water bodies (sea shores, Rivers, lakes, tanks).

3. Water quality of drinking water supplied based on ground water resource in urban and rural areas.

4. Waste water reuse in agriculture, industry and households in urban local bodies.

5. Characteristics of Lakes and Wetlands in the country

6. Demand, supply and pricing of water in agriculture, industry and households sectors.

7. Institutional arrangements for ground and surface water management at urban and rural areas

8. Methodologies for carrying out the water audit at gram panchayat level and urban local bodies

Generation of DataBase.

Centralised systematic data base with good periodicity at the national level on-

1. Water quality and water quality index of all water bodies.

2. Lake and wetland characteristics.

3. Unaccounted for water of urban water supply system.

4. Urban waste water quality and its reuse in agriculture, industry and households

5. Centralised database of all projects sponsored by the CSO.

6. Addition of the variables associated with the pollution abatement cost incurred by industries in the Annual Survey of Industries schedule to get pollution abatement cost data on industries at the national level sample.

7. Various characteristics of water like source, availability, demand, supply, quality, infrastructure and institutional arrangement for water supply in gram pancayat and urban local bodies.

Summary of Valedictory Session

The valedictory session of the seminar began with a welcome address by Professor Gopal K Kadekodi, Director, ISEC, Bangalore. In his welcome address Prof. Kadekodi introduced the chief guest as 'We are fortunate to have Professor S Bisalaiah a distinguished agricultural, economic environment and development scientist and former Vice-Chancellor of University of Agricultural Sciences, Bangalore as our chief guest to address the valedictory session on the theme Natural Resources Accounting and Sustainable Development'. Prof Kadekodi welcomed Mr J Dash, Deputy Director General, CSO, and resource persons and participants of the seminar and ISEC faculty. Prof. Bisalaiah in his valedictory address highlighted the importance of efficient use of natural resources and drew the attention of the participants how the violation of cropping pattern in the Tungabhadra command area had led to loss of precious agricultural land as early as in 1970 and hence, underlined the need for efficient input pricing(water pricing) and output pricing mechanisms for proper regulation for irrigation. He also mentioned that such problems do exist even to this day. Prof. Bisaliah indicated that `irrigation induced land degradation' is a very serious environmental externality emerging out of inefficient irrigation process. While referring to the issue of pricing of water resources, he mentioned that the problem was contemplated as early as in 80s in several of his studies as he was looking for conceptual basis for pricing of water resources, and in the process he cautioned the researchers that pricing of water was a multi-disciplinary issue and needed involvement of agronomists and soil scientists in addition to economists, statisticians, sociologists etc. With regard to physical accounting of water resources, he mentioned that it involved more complex parameters like stock and flow, in addition to cost and benefits. Prof Bisaliah highlighted the problems of water quality in the context of pervasive pollution. Finally, he argued that irrigation subsidy was negligible when compared to subsidies being enjoyed by the urban people. Mr J Dash in his suggestion expressed the possibility of adding a few questions in Annual Survey of Industries Schedule relating to the pollution abatement cost in order to get better cost estimate on the basis of larger sample and addition of a few questions into the National Sample Survey Schedule about the willingness to pay for water for better pricing policy for water resources at the national level. The participants of the seminar suggested on the maintenance of national level data base on the water quality at a single source. Prof. Kadekodi highlighted the multi-disciplinary approach to accounting of water resources as a very valuable suggestion made by the chief guest and underlined the need for generation of systematic data base at the national level on the lake characteristics of the country.

Dr G S Sastry, the seminar coordinator in his overview and vote of thanks, summarised the two- day deliberations of the seminar and highlighted that in addition to the traditional issues of water resources like resource availability, distribution, management, conservation and quality, the emerging issues of water resources are valuation of water resources and associated methodologies; urban wastewater and its reuse, and water loss or unaccounted for water in urban water supply system.

Dr Sastry thanked the Chief guest Prof. S Bisalaiah for accepting the invitation to deliver the valedictory address and raising very important issues of natural resource accounting and sustainable development;. Shri Oscar Fernandes Hon'ble Minister (independent charge), Ministry of Statistics and Programme Implementation, Government of India for his inaugural address presented in absentia which raised the basic issues of water resources management, and Shri P S Rana, Secretary, Ministry of Statistics and Programme Implementation, Government of India for his well designed inaugural speech which guided the seminar deliberations in terms of the main dimensions like resources, distribution, quality and conservation; the Institute for Social and Economic Change, Bangalore for conducting the seminar on such an important issue of water resource ; the chairpersons, paper contributors and the participants for their significant contribution towards the deliberations of the seminar; Professor Kadekodi, Director ISEC for his constant encouragement in conducting the seminar the Registrar and his supporting staff (Mr Sadanand, Mr Shivanand, Mrs Margaret Dawsan, Mr Amarnath); the Accounts Officer and his supporting staff (Mr Jagadish, Mr Amaranath) for their full support without which the seminar would not have reached such a successful stage; Mr J Dash DDG, CSO and Mr R C Aggarawal, Jt Director CSO who had been responsible for conducting this seminar smoothly. Dr Sastry mentioned that Ms Padmavathy shouldered the major responsibility of various aspects of the seminar like correspondence, preparation of seminar materials, internal circulation, registration and thanked her for the over all support. Finally, Mr J Dash DDG, CSO and Mr R C Aggarwal, Jt. Director CSO thanked Prof Gopal K Kadekodi, Director, ISEC for giving an opportunity to conduct the seminar in the ISEC and to Dr G S Sastry for successful completion of the seminar.

Annexure-I

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ANNEXURE-II

Sustainable Water Use in India: A Way Forward[1]

K.V.Raju[2]

"Of all the social and national crisis we face today, the water crisis is the one that lies at the heart of our survival, and that of our planet earth".

Stated by the United Nations Report presented to the international community at the third World Water Forum, held in Kyoto, Japan, in March 2003.

1. Introduction

Water is fundamental to the development of India's development. The ambitions set out in the India Vision- 2020 by the Planning Commission (GoI, 2003) are closely linked to the efficient utilization of available water resources. India is moving towards "water scarce" country. With the increase in population, and the economic growth will only demand for greater stress on the water sector. The water challenges for the country and particularly for its states[3], are manifold: a) improving and safeguarding the existing drinking water supplies, b) managing the water demand across the competing sectors, and c) determining environmental requirements and prevention of pollution. These challenges are true for any state in India, as it is clearly stated e.g, in case of Andhra Pradesh (GoAP, 2003). This paper illustrates the availability of water resources, its historical development, growing constraints, reforms attempted in recent years. Towards the end, the paper argues for required policy modifications and effective implementation arrangements to achieve the millennium development goals.

2. Water Resources Availability

Over the years, there have been many estimates of the water resources available to India. The most recent (as shown below) are those given in the Report of the high-level National Commission for Integrated Water Resources Development Plan (hereafter NCIWRDP) set up by the Government of India, Ministry of Water Resources, (September 1999) (Figures in cubic km[4]).

Precipitation over the Indian landmass	4000
Available surface water resources	1953

[1] This paper, to be presented in the CSO training seminar to be held in ISEC on 24-25 June 2005, is based on a larger paper commissioned by NCAP-ISEC and supported by ADB as part of the Policy Research Networking to Strengthen Policy Reforms in Agriculture, Food Security, and Rural Development. The author is highly thankful to Prof.A. Vaidyanathan for his detailed comments on the earlier version of this paper and participants of the technical workshops held in Delhi and Bangalore for their suggestions and comments.

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[3] Since development of water resources for any purpose and its allocation and utilisation is a state subject in India.

[4] Cubic Kilometers. Also referred to as Billion Cubic Meters or BCM. 1 BCM = 1 km^3.

Available groundwater resources	432
Usable surface water resources	690
Usable groundwater resources	396
Total usable water resources	1086
Present quantum of use	around 600

There are some definitional and conceptual points here[5], but the crucial fact to note is that the above are national annual figures. There are wide variations, both temporal and spatial, in the availability of water in the country. Much of the rainfall occurs within a period of a few months during the year, and even during that period the intensity is concentrated within a few weeks. Spatially, there is a wide range in precipitation – from less than 200 mm (or even 100 mm) in parts of Rajasthan to 11000 mm in Cherapunji in the north-east of the country. This has (or is felt to have) implications for water-resource policy and planning and leads to certain responses. We shall revert to this in the last section of this paper.

As against the above figures of availability, there are projections of water demand for various uses. Many variables and assumptions enter into these estimations, and multiple projections may have to be made with reference to different assumptions and estimations in regard to some of the factors involved. In addition, there can be different expectations (`scenarios') as to the likely course of future developments. Some of the studies on the subject try to project water needs under three scenarios: (a) things go on as before and no significant changes are made in policies and practices (the `Business As Usual' or BAU scenario): (b) some incremental improvements are attempted in policies, procedures, patterns of use and technologies (`Improved Management' scenario); and (c) significant and radical changes are brought about with a view to ensuring economy in water–use, resource-conservation and long-term environmental `sustainability' (`sustainable water world' scenario). Some others adopt BAU, High Growth (HG) and Sustainable (SS) scenarios. Based on their respective assumptions and scenarios, different studies give their projections of future water requirements (for all uses):

(i) The Working Group (WG)[6] of the NCIWRDP and NCIWRDP itself: 973 to 1180 BCM in 2050.

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[5] `Precipitation' includes rainfall and snowfall; `available surface water resources' are measured in terms of annual flows at sites close to the terminal points of the river systems; `available groundwater resources' means `dynamic' groundwater or `groundwater potential', i.e., the quantity that can be extracted annually, having regard to the rate of annual replenishment (`recharge') and economic considerations; `usable water resources' means that part of the notionally `available' water resources which is actually available for use through impoundment or other means. (There is a view that the quantum of available surface water resources of 1953 BCM includes the groundwater availability of 432 BCM, as much of `dynamic' groundwater eventually joins surface water flows into the sea and the quantum of groundwater that independently flows into the sea is not significant; but this view is not accepted by all.) Water is also available in the form of atmospheric and soil moisture, and as stored in wetlands; there are also possibilities of local augmentation of availability through rainwater-harvesting or additional runoff-capture. However, these availabilities are not generally taken note of (at any rate not adequately) in the conventional estimations of water engineers; similarly, `usable' water resources can also have a wider meaning than the conventional engineering sense.

[6] For these three studies see References.

(ii) India Water Vision (IWV) of India Water Partnership: 1027 BCM in 2025.

(iii) Study by Kanchan Chopra and Biswanath Goldar of the Institute of Economic Growth (KC/BG): 920.92 BAU, 1004.72 HG, and 964.9 SS in 2020.

WG and NCIWRDP assume that certain steps to ensure economy, efficiency and conservation will be taken, and predict a fragile balance between supply and demand on that basis. IWV and KC / BG also seem to adopt a similar position of a cautious but not an alarmist view of the future. Is such a position warranted? There are two divergent views on this question. One is that this is a complacent view and that a crisis is imminent. The other view, questioning the prediction of a crisis, is that of the Centre for Science and Environment (CSE): they argue that if there is proper water management, and if local, community-based water-harvesting is undertaken extensively all over the country (wherever it is feasible), there will be no crisis[7]. (We shall revert to this in the final section.)

3. Irrigation Development in India

Historical Background

Through most of its history, India has been an agricultural society. The earliest evidence of irrigation in India is provided by the Indus Valley civilization. Medieval India saw the creation of diverse and locally appropriate water management regimes. The diversity of agro-climatic zones, soils and topography resulted in the emergence of a number of traditional institutions of different kinds for collectively managing water, many of which are still extant though not fully active. Apart from the small village-centred irrigation works, some large irrigation structures were also constructed in medieval times. The colonial era marked the beginning of an accelerated development of irrigation works throughout India. In the nineteenth century, a number of canal systems were renovated and modified, and some new canals were also constructed. It must be noted that with the advent of the colonial era control over natural resources including water and the management of the irrigation structures tended to pass from the community to the state. The emergence of large state-built irrigation works gathered pace and became the norm after Independence. The brief synoptic picture given above is filled out to some extent in the ensuing paragraphs.

Tank Irrigation

Surface structures or formations collecting and storing rainwater, runoff and seepage from the surrounding areas are known as tanks or ponds. Over the centuries, locally built water storage systems (e.g, tanks in South India, *Johads* in Rajasthan), have acted as insulation against droughts, helped in recharging groundwater, provided crucial irrigation for crop production, functioned as a source of multiple uses for the village community (drinking water, washing, bathing, water for livestock and wildlife, fishing, water for cultural and ritual purposes), and played a role in the maintenance of a good

[7] Paper circulated at the World Water Forum, The Hague, March 2000.

natural environment. Because of these benefits, the Indian kings, *Jagirdars*, religious bodies and philanthropists built large numbers of tanks all over their domains. These rainwater-harvesting structures in various forms were known by different names in different parts of the country, e.g., k*ere* in Karnataka, c*heruvu* in Andhra Pradesh, *erie* in Tamil Nadu, *johad* and *bund* in Rajasthan, *ahar* and *pyne* in Bihar.

Tanks were meant not only for agriculture, but also served as a resource-base for many other activities such as the collection of fodder, fuel, the making of bricks, pots, baskets, etc, with women offering their assistance in these processes. Tanks were also part of the socio-religious and economic system in villages. The location of the tank and its physical conditions were a matter of much significance to the people, particularly women, in carrying out their economic activities. The tank and its surroundings used to be the common property of the village and its people. The reverence for water as a life-sustaining element and the tradition of respect for water-sources ensured the proper maintenance of tanks for use by all, mitigating to some extent the prevalent caste-discrimination in work and access to and control over tank-based resources. The maintenance of natural resources through a continuous process of use and conservation meant not merely the assurance of livelihoods to the people of the village, but also the preservation of the ecological balance. While the given social framework might have restricted women's participation in community matters, their role in the conservation and maintenance of natural resources was implicitly acknowledged.

The years after Independence witnessed the abolition of *Inamdari* landholding patterns and hereditary village offices, and there were also changes in the land-use patterns affecting the catchments of the tanks. These processes, whatever their other merits, had negative effects on tanks. In the post-Independence era there was a decline in the tank-irrigated area and the emphasis shifted to major and medium irrigation projects. The share of net irrigated area under tanks declined in the country from 17.3 per cent in 1950-51 and to 6.8 per cent in 1990-91 (GoI 1994). The decline of tank-irrigated area is common throughout the country. The reasons for this will be gone into later.

Major and Medium Irrigation[8]

Reference was made earlier to the shift from the community to the state and to the emergence of large state-built irrigation works. In pursuance of the recommendations of the first Irrigation Commission, a number of projects on a truly large scale began to be constructed. Table below shows the trend of area irrigated in undivided India. In the early 20th century, the aim was to provide protective rather than productive irrigation works (Reddy, 1998).

Area irrigated in undivided India (in Million hectares)

Year	Public Sector (Govt-	Private Sector (Zamindar-controlled)	Tota l

[8] In India, irrigation schemes and projects are classified as `major', medium and minor in terms of culturable command area covered (major: having more than 10000 hectares of CCA; medium: 2000 to 10000 hectares of CCA; minor: below 2000 hectares of CCA).

	controlled)		
1900	7.6	5.7	13.3
1920-21	10.4	8.9	19.3
1945	13.5	10.0	23.5

Source: Reddy, 1998.

After Independence, the Government of India launched an ambitious programme to improve agricultural production through the extensive development of the irrigation infrastructure. Development works in irrigation were taken up in all five-year and annual plans. Aside from China, the irrigation system in no other country is as extensive as in India.

Table below gives the numbers of major & medium projects introduced in each Plan. Passing over the earlier Plans and confining ourselves to the recent ones, the position is that from the Sixth five-year Plan onwards, emphasis has been laid on the completion of on-going projects and consolidation of gains, rather than on `new starts'. However, new projects continued to be undertaken. As shown in Table below, the Seventh five-year Plan (1985–90) envisaged 12 major and 33 medium projects.

Number of Major and Medium projects introduced in each Plan

Plan Period	Major	Medium
First Plan (1951-56)	44	169
Second Plan (1956-61)	33	102
Third Plan (1961-66)	32	44
Annual Plan (1966-69)	11	30
Fourth Plan (1969-74)	32	73
Fifth Plan (1974-78)	70	300
Annual Plan (1978-80)	13	52
Sixth Plan (1980-85)	30	91
Seventh Plan (1985-90)	12	33
Annual Plan (1990-92)	1	-
Eighth Plan (1992-97)	14	50
Total	292	944

This impetus for new construction was continued in the next two Annual Plans (1990–92). The Eighth Plan (1992–97) emphasized the completion of on-going projects rather than undertaking new ones (Planning Commission, 2001b). The ongoing Ninth Plan (1997–2002) has a comprehensive strategy regarding irrigation development and management. The strategy stresses the promotion of programmes for Participatory Irrigation Management, rational pricing of irrigation water, conjunctive use of surface water and groundwater, and strengthening of CADP. It lays particular stress on the improvement of water-use efficiency by progressive reduction in conveyance and application losses (Planning Commission, 2001c). For the forthcoming Tenth Five-Year Plan (2002–2007), the Planning Commission recommends a major revival of public investment in irrigation capacity and water management and suggests the Accelerated Irrigation Benefit Programme as a potential means of providing resources to State Governments to support ongoing projects (Planning Commission, 2001a).

Minor Irrigation

Much of what goes by the name of `minor irrigation'[9] is based on groundwater, though some of it also based on water from other sources. There has been a dramatic increase in groundwater-based irrigation in the last several decades. This is further referred to in the next section.

[9] As explained in the last footnote, the definition of `major', `medium' and `minor' irrigation is by culturable command area. However, the term `minor' has the unintended effect of belittling the importance of this category. This is unfortunate, as minor irrigation accounts for a significant part of the total irrigation potential, as will be seen from Table 4 below.

4. Present Status of Irrigation

The gross irrigated area (GIA) of the country increased from about 23 million hectares (mha) in the triennium ending (TE) 1952–53 to about 72 mha in TE 1996–97, an increase of 2.62 percent per annum. During the same period the net irrigated area (NIA) had increased from 21 mha to nearly 54 mha, an increase of 2.16 percent per annum. By 1999-2000 NIA increased to 57 mha (IASRI, 2004). This is elaborated below in terms of category of irrigation.

Canal irrigation: In absolute terms, the net canal-irrigated area increased from about 8.61 mha in TE 1952–53 to about 17.25 mha in TE 1996–97 and to 17.55 mha by year 1999-2000 (see table below on source-wise irrigated area). This increase was not commensurate with the magnitude of the investments on the `major and medium' irrigation sector in the Plans. The rate of growth of the area under canal irrigation tended to decelerate after the Sixth Plan despite increased investments mainly because of three reasons. First, the relatively easier potential had already been utilized, and further development was more difficult, with the result that there was inevitably a decline in the rate of growth of the area under irrigation. Secondly, the investment costs of the irrigation projects that were taken up from the Seventh Plan onwards were much higher, and a given order of investment could create only a lower order of irrigation potential than was possible in earlier Plan periods. Thirdly, budgetary allocations could not be made in adequate measure for the large number of major and medium irrigation (MMI) projects taken up, and this inevitably resulted in the slower completion of projects and therefore the slower creation of irrigation potential. There is every possibility that the growth of canal-irrigated area may decelerate further in future for these reasons. Further, while the area under canal irrigation did increase in absolute terms in almost all the States, the share of canal-irrigated area in the net irrigated area either declined or did not increase very much between the early sixties and late nineties, because of the significant role played by groundwater irrigation during the last 40 years.

Source-wise irrigated area

(in million ha)

Source	1980-81	1990-91	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00*
Govt. canals	14.45	16.97	16.80	16.56	16.87	17.11	17.20	17.55
	(37.3)	(35.3)	(31.7)	(31.0)	(30.6)	(31.11)	(30.22)	(30.66)
Private canals	0.84	0.48	0.48	0.56	0.48	0.50	0.50	0.45
	(2.2)	(1.0)	(0.9)	(1.0)	(0.8)	(0.91)	(0.88)	(0.78)
Tanks	3.20	3.25	3.28	3.11	3.34	2.74	2.94	2.71
	(8.2)	(6.1)	(6.2)	(5.8)	(6.1)	(4.98)	(5.15)	(4.73)
Tube wells	9.53	14.21	17.19	17.91	18.43	18.91	20.40	20.95
	(24.6)	(29.7)	(32.4)	(33.5)	(33.4)	(34.39)	(35.64)	(36.60)
Other wells	8.21	10.00	11.72	11.79	12.39	12.68	12.75	12.68
	(21.1)	(21.7)	(22.1)	(22.2)	(22.5)	(23.06)	(22.38)	(22.15)
Other sources	2.58	3.08	3.53	3.46	3.62	3.05	3.27	2.91
	(6.8)	(6.1)	(6.7)	(6.5)	(6.6)	(5.55)	(5.73)	(5.08)

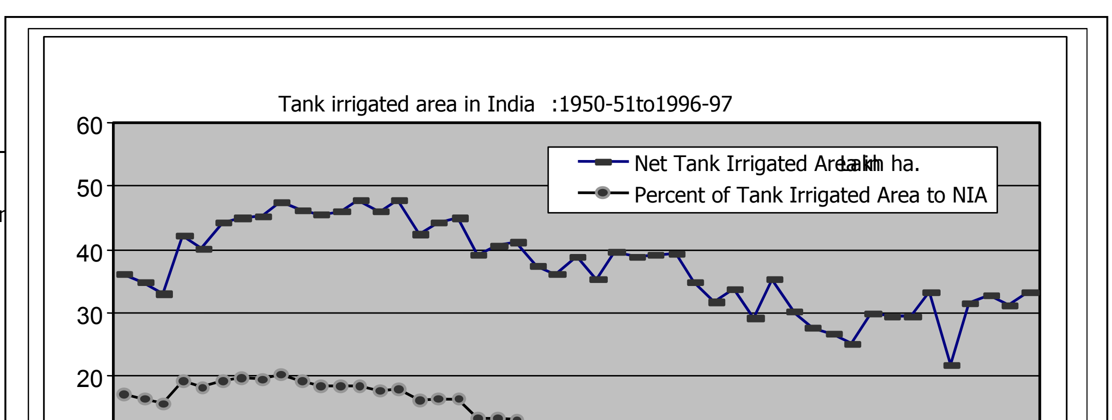
Net irrigated area	38.81	47.99	53.00	53.39	55.13	54.99	57.05	57.24
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Note :1. Figures in parentheses indicate percentage of the total area, 2. * Provisional.

Source : a) Fertiliser Statistics, 2002-03, The Fertiliser Association of India, New Delhi.
b) Agriculture Research Data Book – 2004

Tank Irrigation: Tank irrigation has gradually declined over the last 50 years both in absolute terms and also in relation to NIA. Among the three major sources of irrigation, the tank is the only source where this phenomenon is observed. Tank-irrigated area started declining continuously from the 1960s, though some improvements have been noticed during the nineties (see Figure below). Interestingly, this reduction in area under tank irrigation happened despite the construction of thousands of new tanks during this period (Vaidyanathan, 1994 and 2001). Tanks are mostly concentrated in areas where other sources of irrigation are limited or absent. The worst affected group because of the continuous decline of tank irrigation is that of poor farmers (small and marginal) for whom an alternative source of irrigation is costly or not available.[10] Studies (Janakarajan, 1993; Narayanamoorthy, 1993; Palanisami et al. 1996; Sivasubramaniyan, 1997; Dhawan, 2000; Palanisami and Easter, 2000; Vaidyanathan, 2001; Raju et al., 2001) have identified many reasons for the decline of tank irrigation:

a) encroachments in the tank foreshore and along the feeder channels have reduced the supply of water to the tanks;
b) the accumulation of silt in the tank basin/bed has reduced the water-holding capacity of the tanks;
c) the construction of dams/reservoirs in the upper watershed or catchment area has prevented the water supplies from reaching downstream tanks;
d) the rapid development of groundwater irrigation in the tank command areas has reduced the participation of farmers in tank-related works, which ultimately reduced the area under irrigation;
e) the poor design of new tanks has resulted in low levels of performance;
f) there has been a breakdown in village institutions because of caste and other conflicts, while community participation which was part and parcel of tank irrigation development has declined drastically; and finally (but importantly)
g) there has been inadequate attention on the part of the government.



[10] As
percen

The reliability of official data showing a decline in area irrigated by tanks has been questioned on the basis of field studies of a large number of tanks in Tamil Nadu – in most of the tanks of surveyed the effective command area is more or less the same or even increased in some cases, compared to the figures recorded in the tank memoirs.

The effect of spread of well irrigation is to weaken the collective activity in maintenance and regulation of tank water distribution; not necessarily to a reduction in area irrigated directly or indirectly by tank water.

there is a strong presumption that the decline reflects misclassification of areas getting well irrigation in the tank commands as well irrigated area.

There is no mention of demographic pressure leading to increase in number of ayacutdars or of the shift in focus of land control and changes in the configurations of local power structure.

The literature on the tank irrigation points to a far more complex and nuanced picture than suggested by the author)

Several research studies have indicated reduced focus of government agencies to rejuvenate tank systems (Vaidyanathan, 1994 and 2001; Sivasubramaniam, 1995; Palanisami, 1990; Palanisami and Easter, 2000, Raju, et al, 2001). Considering its cost and other advantages, adequate attention needs to be given to the improvement of the performance of tanks. A few southern states – Andhra Pradesh, Karnataka and Tamil Nadu have indicated new projects to revive tank systems on community-based management.

Other factors that have been identified (Raju et al, 2003) include: (a) the abolition of *zamindari* and the tanking over the rights of ownership of *zamindari* or other private tanks by the government, (b) the involvement of multiple governmental agencies and a lack of coordination among them, (c) political interference compounded by poor technical capabilities in the location and construction of new tanks and their size, (d) which hampered the water regulation and capacity of centuries-old upstream/downstream tanks in recent decades, (e) a widening conflict of interests between tank-bed cultivators (including unauthorized ones) and command farmers, (f) especially in the absence of institutional mechanisms to safeguard the interests of the resource, (g) increased control by the government agencies without accountability, (h) the absence of accountability to, or control by, local communities, and (i) the lack of governmental policy and programme support for traditional water management institutions.

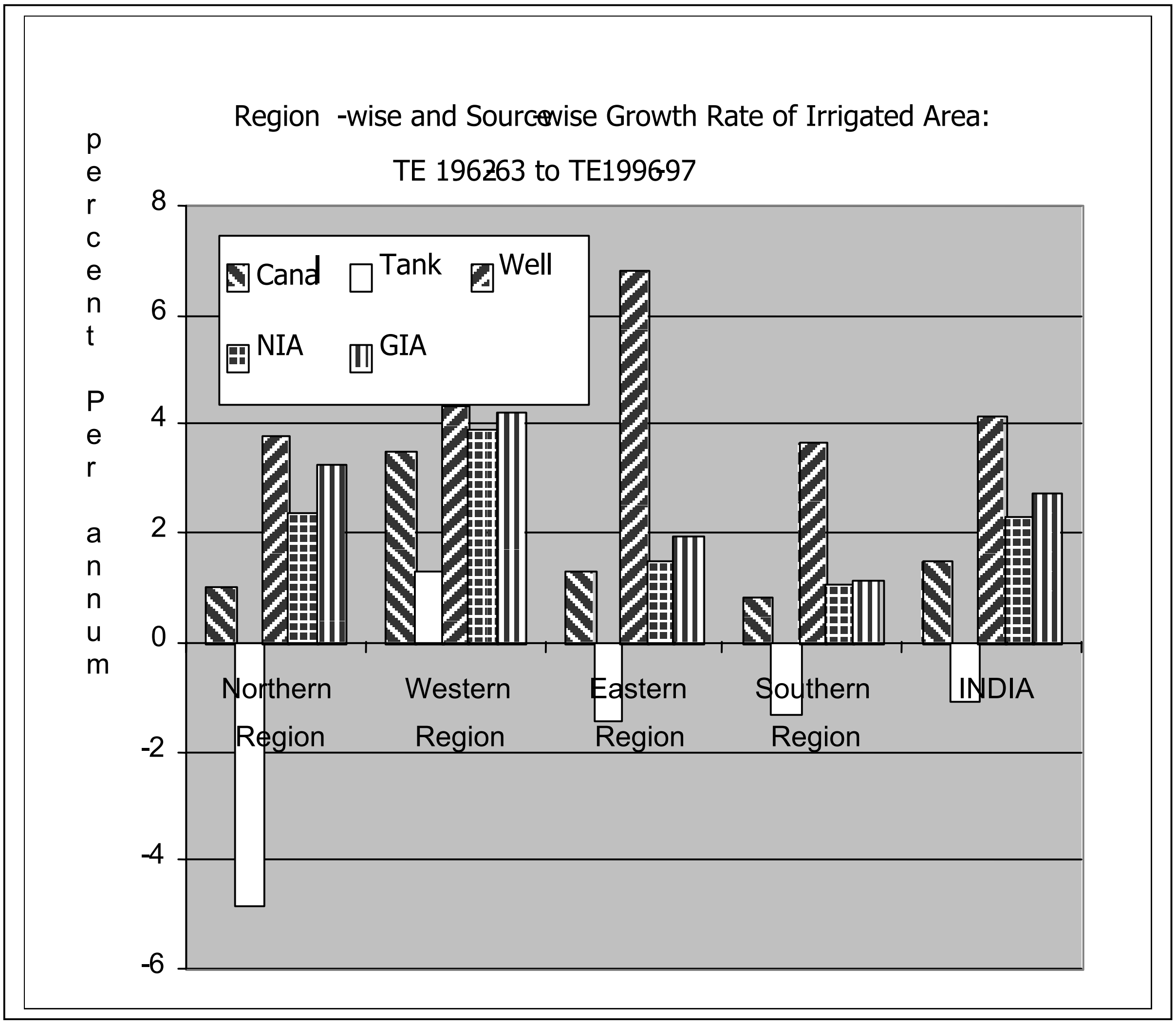
<u>Groundwater Irrigation</u>: The importance of groundwater in the national life is evident: around 59% of irrigated agriculture, and 85% of rural drinking water comes from groundwater. Even after all the major and medium irrigation projects (under construction or contemplated) are implemented, a substantial part of irrigation (not far below 50%) will still depend on groundwater.

One of the biggest developments that have taken place in Indian irrigation after Independence is groundwater irrigation. This source is predominantly owned and managed by farmers (Shah, 1993). Groundwater-irrigated area has increased to 34 mha in 1999-2000. It was about 29.81 mha in TE 1996–97 from 6.39 mha in TE 1952–53, its share in

NIA increased 59 percent by 1999-2000. Unlike tank and canal irrigation, the area under groundwater irrigation grew at a rate of 3 to 5 percent during different sub-periods from the 1960s onwards. The main factor in the growth of groundwater irrigation is tubewell irrigation, which grew at an impressive rate of 9.90 percent per annum during the period 1960–61 to 1996–97. The area under tubewell irrigation, which accounted for less than one percent of NIA up to 1960, increased to about 37 percent by 1999-2000. The development of the rural electrification programme and the availability of credit at highly subsidized rates have helped the farmers to increase the area under groundwater irrigation significantly (Shah, 1993; Vaidyanathan, 1994). The rapid development of groundwater irrigation not only helped the well-owning farmers but also the non-well-owning farmers through water markets (Narayanamoorthy, 1994; Saleth, 1996; Shah, 1993; Shah and Raju, 1987). However, there are problems associated with tubewell/borewell irrigation and with water markets, which will be referred to later.

Irrigation by Other Sources: Over the last 40 years, changes have also taken place in areas under other sources of irrigation. While the share of this category in the total net irrigated area declined consistently in the majority of the States between TE 1962–63 and TE 1996–97, the absolute area has increased moderately in many States during this period. During TE 1962–63 and TE 1996–97, Madhya Pradesh registered the highest growth rate of over 9 percent per annum, where its share of NIA also increased impressively from 6.31 percent to 12.95 percent during this period. At all India level, other sources contributed five percent of the net irrigated area during 1999-2000.

Regional Variations: The development of irrigation is not the same across different States and sources of irrigation from TE 1962–63 to TE 1996–97. Between TE 1962–63 and TE 1996–97, the highest growth in the area under irrigation, whether from canals or from other sources, was registered in the western region as compared to the other three regions (see Figure below). This was because of the higher irrigation potential and the higher level of investments on irrigation development made by the States forming part of the western region. The growth rate of irrigation (both NIA and GIA) is found to be very low in the southern region as compared to other regions during the period mentioned above. There are two reasons for this: first, most of the surface irrigation potential had been harnessed before Independence by the southern region and therefore further growth was bound to be low; secondly, tank irrigation, which is an important source in the southern region, declined at a rate of 1.31 percent per annum between the sixties and late nineties, which affected the growth of both NIA and GIA. For state-wise variations in area irrigated see table in Annexure-1.



Agro-Climatic Zones: From an agro-climatic perspective, India is divided into 15 zones. Water-resource availability and the circumstances of water-utilization vary considerably in the different agro-climatic zones. The area of irrigated land varies from 64% of the net sown area in the Trans-Gangetic Plain zone (States of Punjab and Haryana) to 6.3% in the Western Dry Region. Broadly, the level of irrigation (and consequently the use of water) is high in the Gangetic Plain region and in the Eastern Coastal plain zone.

A related point is the unquestioning reliance on canal/groundwater-based irrigation for all areas and regions and the tendency to assume that in the absence of this no `development' is possible. Many areas in the country practise types of irrigation (usually classified in statistical tables under the category `Other Sources') that are suited to the local terrain and conditions. It would be myopic to dismiss these systems as anachronistic. They have their place. Modern knowledge and technology can be utilized for improving and modifying the traditional systems so as to make them more relevant to present conditions (Sengupta, 1985). Institutional means of reviving those systems by synthesizing traditional technology with modern knowledge could rejuvenate the development of irrigation in these areas.

Finally, there are regions with modest or limited irrigation development. These are classified as `rainfed'[11] areas. Rainfed agriculture is usually associated with images of deprivation and underdevelopment. However, recent research conducted on the divide between irrigated and rainfed agriculture has provided some unexpected results. Fan and Hazell have conducted an analysis on the productivity of irrigated and rainfed districts in the country from 1970 to 1995 (Fan and Hazell, 2000). They utilized Indian Council of Agricultural Research classification of 20 agro-ecological zones for their analysis. They categorized the districts (the ultimate unit in this method) into irrigated and rainfed areas with reference to the level of irrigation in the districts. Districts with irrigation levels greater than 25% were denoted as irrigated and those with levels less were rainfed (Fan and Hazell, 2000). Districts with poor irrigation development (hence `rainfed' according to this nomenclature) were further defined as having poor or high potential depending on whether the zones within which these districts lie, have poor or rich soils, low or high rainfall and short or long growing seasons. Their analysis by considering a number of factors such as public and private irrigation, high-yielding varieties of crops, fertilizer application, literacy rates as well as rural markets, reach the conclusion that investment in rainfed areas including many low-productivity regions is at least as productive as in irrigated areas, and also has a much larger positive impact on poverty (Fan, Hazell and Thorat, 2000).

5. Irrigation: Problems and Deficiencies

Irrigation development in India has undoubtedly brought many benefits, but it has also been characterized by many problems, weaknesses and failures. Canal irrigation, groundwater irrigation, tank irrigation and rainfed agriculture: there are problems in relation to all of these. A synoptic account of these will be given in this section. (Some of these issues have been referred to in passing in the foregoing overview. Some will be discussed in greater detail in the section on reforms).

Canal irrigation

(i) Canal-irrigation efficiency in India (around 35 to 40%[12]) is very low. But "efficiency" of water use has to be assessed in at least three ways: (a) "Irrigation" efficiency, (b) "Productive" efficiency, and (c) "Economic" efficiency (for details see Vaidyanathan and Subramaniyan, 2004). It is true that what is lost from canals through seepage is partly recovered as groundwater recharge and as `return flows' further down, but that is not a reason for

[11] The distinction between `irrigated' and `rainfed' agriculture is not as sharp as may be imagined. If by `irrigation' we mean the artificial application of water as distinguished from natural rainfall, then rainwater-harvesting and watershed development, mostly undertaken in `rainfed' areas, convert those areas into partially irrigated areas, even if the irrigation is limited. However, such areas continue to be classified as rainfed; the term `irrigated' is confined largely to canal-irrigated and groundwater-irrigated areas.

[12] Source: National Commission on Integrated Water Resource Development Plan.

inefficient conveyance. (In any case, it is the actual application of water on the ground in irrigation that contributes more to recharge and return flows than seepage from canals. This depends on the size of the command and the distances over which water has to be transported and whether or not the distribution network is lined? That again is not a justification for the excessive use of water in irrigation).

(ii) Injudicious canal-irrigation without regard to soil conditions, over-application of water, failure to take the groundwater table into account, and inadequate attention to drainage, have led to the emergence of conditions of water-logging and salinity in many areas, resulting in valuable agricultural land going out of use. The reclamation of such lost lands is not always possible, and where feasible, it often requires large investments. A 1991 Report of a Working Group of the Ministry of Water Resources estimated the extent of waterlogged land in the country at 2.46 million hectares (mha), and that of salt-affected land at 3.30 mha.

On an average, the yields of irrigated agriculture in India have been relatively low in comparison with what has been achieved in other countries, or even in some parts of this country; and there has been inadequate attention to increasing productivity in rainfed areas. Even the NCIWRDP's projections for the future seem fairly modest as shown in Table below.

NCIWRDP's projections of yields (tonnes per ha)

Average Yield (projected)	Year 2010	Year 2050
Irrigated Foodcrop	3	4
Unirrigated	1.1	1.5

Higher yields, which ought to be achievable, will mean a reduction in the demand for water.

(iii) The source of canal irrigation is generally a major project, and the cost of creating irrigation potential through such projects has been steadily increasing: from Rs. 1200/ha in the first Plan (1951-56) to Rs. 66570/ha in 1990-92 in current prices; and from Rs. 8620/ha to Rs. 29587/ha in constant 1980-81 prices[13]. The figures today must be much higher. (Rough figures of Rs. 80000/ha to 100000/ha (in current prices) have been mentioned.)

(iv) Further, there is a persistent gap between the irrigation potential[14] created at such cost and the extent of its utilization (Table below). This problem, which was earlier presumed to occur only in the case of major and medium projects, was later found to be present in the context of minor irrigation also.

[13] Source: Ninth Plan Working Group on Major/ Medium Irrigation Sector.

[14] `Irrigation potential' is a problematic concept inasmuch as it involves the translation of the water storage created by a project into the area of land that can be irrigated, on the basis of assumptions in regard to cropping patterns and watering needs and practices; nevertheless, the `gap' between created and utilized potential cannot be dismissed as unreal.

Gap between irrigation potential created and utilized (end of 1995-96) (in mha)[15]

Category	Ultimate	Created	Utilized	Gap	Actually irrigated (land-use statistics)
Major/medium	58.46	32.20	27.45	4.75	
Minor (surface)	17.38	12.10	10.72	1.38	
Minor (groundwater)	64.05	44.42	40.83	3.59	
Total	139.89	88.72	79.00	9.72	70.64

The Command Area Development programme which was formulated as the answer to this problem is considered in the ensuing section on reforms.

(v) Resource constraints, an unsound Plan/Non-Plan distinction, and an in-built preference for new construction over the efficient running of what has been built, have together resulted in the under-provisioning and neglect of maintenance. Systems built at great cost fall into disrepair, and there is a failure to provide the planned service. Canal irrigation is thus dependent on an inefficient and unreliable supply.

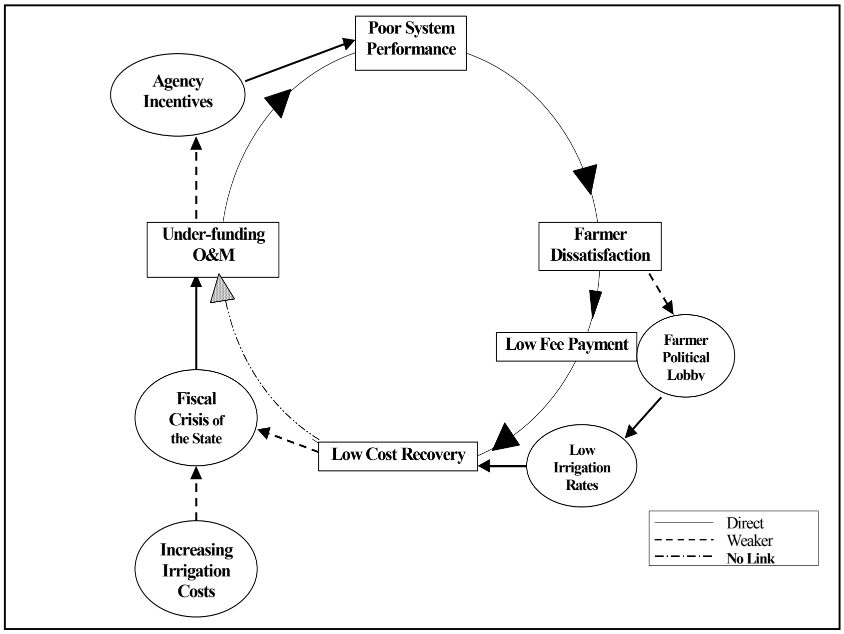
Signs of improper operations and inadequate upkeep of systems are plentiful. Canals are silted up or eroded, and breach. Water is unevenly distributed between head and tail of distributaries, minors, and even field channels, with tail-enders often receiving no water, while areas adjacent to the canals are becoming waterlogged. Where water is supplied, timings are often unreliable. The contrast between public surface systems, over which farmers have little control, and private groundwater systems that provide water virtually on demand, makes the situation more acute.

Although farmers spend considerable amounts to invest in private wells and pump groundwater, they have not been willing to pay as much for the less adequate service from surface systems. Those who do not receive irrigation “opt out” of paying, driving cost recovery lower still, thus feeding into a vicious circle of poor maintenance and growing financial crisis in Indian canal irrigation.

While parts of this analysis are certainly accurate, it is not complete or fully accurate. First, it assumes a structural relationship between fees and operation and maintenance funding that does not, in fact, exist. It is only in the context of fiscal deficits and declining indirect revenue from irrigation that low irrigation charges have become a serious factor in underfunding operation and maintenance. Moreover, it is not clear that more funding would necessarily improve performance because of the incentive structure

[15] Source: National Commission on Integrated Water Resource Development Plan.

within irrigation agencies. Indeed, most analyses have neglected the role of farmers' political opposition to irrigation fees (which stems, in part, from dissatisfaction with service as well as from populist appeals by politicians). Thus, a more complete analysis of the "vicious circle" would include the elements in Figure below (Gulati, Meinzen-Dick and Raju, 2005).



Political economy analysis of irrigation-system problems

(vi) Canal irrigation in India has been marked by a number of inequities. As waters begin to rise in the reservoir, and canal systems for taking them to the tail-end are not yet ready, the head-reach farmers have plenty of water available and tend to plant water-intensive crops. This establishes a pattern of water-use that cannot easily be changed at a later stage. It is also a matter of unwillingness and inability of managements. by the time the full canal system is ready, much of the water stands pre-empted in the head-reach areas and there is little left for conveyance to the tail-end. This is a familiar problem in most project commands.

(vii) Irrigation water from canals is supplied to farmers at very low prices in most States. This leads to the wasteful use of water and is not conducive to the promotion of resource-conservation. Even at the prevailing low rates, the collection of irrigation charges is poor in most States. The result is that the revenues accruing to the government from the provision of irrigation do not even cover the operation and maintenance costs of the systems, and there is no contribution towards capital-related charges, much less any generation of resources for further investments. This subject is dealt with further in the section on reforms.

(viii) Finally, most of the inter-State river water disputes arise in the context of canal irrigation (existing or desired) from major projects. Examples, among others, are the Ravi-Beas, Telugu Ganga, Alamatti and Cauvery disputes.

Sharing of interstate waters was handled reasonably smoothly in the initial phases but have become more acute and contentious in more recent times reflecting the growing demand for water and limited scope for expansion of supplies. Unfortunately, that such disputes are rampant even within states and that there are hardly any institutions or due process to resolve them on the basis of clear principles).

Groundwater irrigation

(i) There has been over-extraction (mining) of groundwater leading to depletion in some areas, and salinity ingress in coastal zones (e.g., in Gujarat). On the other hand, there is a situation of rising water tables and the emergence of water-logging and salinity in other areas (e.g., in the Sharda Sahayak command in Uttar Pradesh).

(ii) Water markets tend to emerge in the context of groundwater extraction through tubewells and borewells, and they serve some useful purposes, but there are dangers of unsustainable extraction as also of inequitable relationships between sellers and buyers. Water markets are not limited to tubewells and borewells; that apart, their extent is relatively limited except perhaps in the deep alluvial aquifers of the Gangetic plain and north Gujarat. Free or highly subsidized pricing of energy has become major reason for groundwater over extraction.

(iii) The answer to both (i) and (ii) above may be claimed to lie in regulation, but this has so far not been found feasible because of political factors and the legal problem of easement rights. Under the directions of the Supreme Court, the Central Groundwater Authority has been established, but it is not yet clear how it will evolve and operate, what kind of regulation it will attempt, and with what success.

Tank irrigation

This has already been dealt with in earlier sections. In brief, the problems in relation to tank irrigation are mainly physical decay and institutional decay arising from the passing of ownership and management into the hands of the Government followed by inadequate attention on its part, the increasing dominance of other forms of irrigation, and a decline in interest on the part of the farmers.

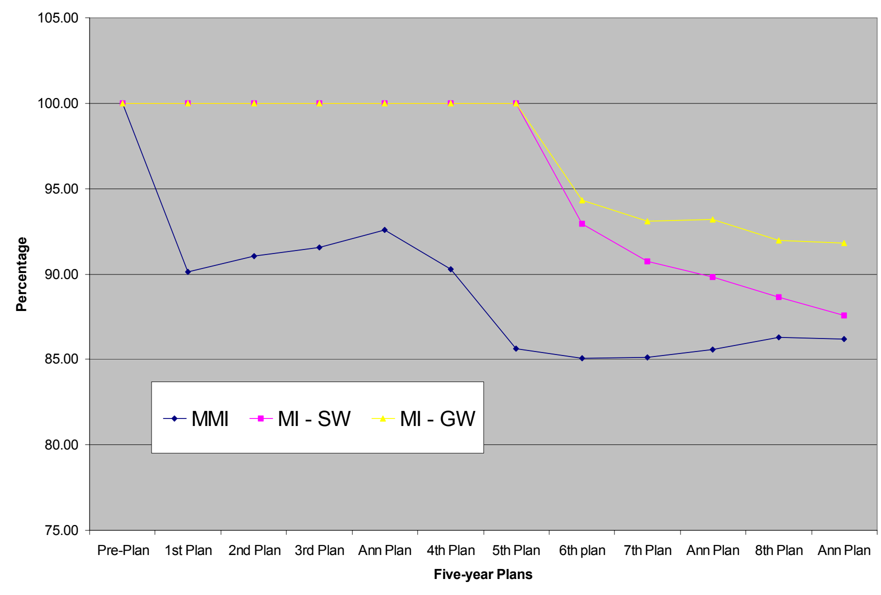
6. Reforms in recent years

Over the years, many reforms have been attempted in answer to the problems and weaknesses identified above. These combined in varying degrees policy changes, institutional reforms, administrative and procedural changes, new laws, and attitudinal changes. The following paragraphs outline some of the major areas where reforms were felt to be needed and have been attempted.

The Utilization Problem

While the creation of `irrigation potential' (a problematic concept as mentioned earlier) is doubtless a good measure by which to judge sectoral progress, the actual utilization of that potential is a better indication of the speed and effectiveness of accessibility of irrigation to farmers (Vaidyanathan, 1999). At the national level, the utilization of the potential is 86% in the case of major/medium irrigation projects, while for minor irrigation as a whole it is 91% (92% for groundwater irrigation and 88% for minor surface irrigation (CWC, 2000). Figure below shows the variations in utilization in the different categories of irrigation in different Five-year Plan periods.

Utilization levels vary considerably among the various States. Some states such as Tamil Nadu and Punjab consistently record levels of utilization of nearly 99%, while other States such as Assam, Maharashtra, Madhya Pradesh and Bihar record significantly lower levels.



Variation in utilization across Plan periods.

The under-utilization of surface-water irrigation potential has been attributed in large measure to the delay in the construction of field channels and the establishment of water distribution systems (Saleth, 1996). The phenomenon of poor distribution infrastructure in the command area has given rise to two serious problems in Indian irrigation – excessive conveyance losses and tail-end deprivation. Seepage and other conveyance losses are high in some commands with the result that a sizeable portion of the water below the outlet is lost through seepage[16] (Gulati, Meinzen-Dick & Raju, 2005). The World Bank notes that deterioration in distribution infrastructure has also contributed to reduced utilization and increased seepage (World Bank, 1999a). Increasing incidence of waterlogging and salinity can be attributed to the increased seepage.

Data on irrigation potential developed and utilized contain significant discrepancies. The discrepancies occur both across States (i.e., in data relating to different States) and within the same State (i.e., in data reported by different agencies). Data regarding irrigation area developed and utilized are reported by two distinct agencies at the national level, namely the Ministry of Agriculture (Land Use Statistics) and the Ministry of Water Resources (Sengupta, 1993). The Land Use Statistics data on irrigated area by canals are collected through various sources – village-level officials in some states, Irrigation Department officials in some and sample surveys in others – while data for the Ministry of Water Resources are collected by the State Irrigation Department officials (Sengupta, 1993; Vaidyanathan, 1999). There are substantial differences between the data reported by the two sources. Further, definitions and methodology of collection show variations across States, which further add to the discrepancies. In addition, the conjunctive use of groundwater and surface water is not reported by any of the data- compiling agencies, resulting in double-counting errors in the data (Raju and Brewer, 2000). A major problem is the failure to distinguish between areas which use both surface and groundwater and those which use only groundwater; mis classification of area under conjunctive use as area under wells rather than the surface source which is the source of groundwater recharge in such area.

Discrepancies notwithstanding, the gap between the creation and utilization of irrigation potential is a real problem and has been causing concern. The Command Area Development Programme was conceived essentially as an answer to this problem. This was one of the earliest `reforms' undertaken in the irrigation sector.

Command Area Development

The Command Area Development Programme (CADP) started in 1974, mainly focused on-farm development works in the irrigated command areas, and the utilization of the created irrigated potential. By 1997, CADP covered 203 projects, with cultural command area of about 21 million ha in 22 states.

The physical progress achieved in respect of construction of field channels has been very high but in case of rotational water distribution, it has been moderate viz, about 60% of the area covered by the field channels. Farm roads, included in the CADP package, are

[16] It has been estimated that of the total water let in the outlet, about 45% is lost through seepage by unlined field channels while 15% is lost due to excessive water application (from Rath, 1989) as reported in (Saleth, 1996).

not a part of the Centrally-Sponsored CADP, and the Ministry of Water Resources is therefore not monitoring this activity. This is now being undertaken through the State sector.

The survey of relevant legal provisions in the existing Irrigation Acts in various States shows that most of the States do not have on-farm development works included in their Acts. In the absence of a statutory provision, the CADP is being implemented by obtaining possession of land from the farmers concerned without any payment of compensation. In such a situation, several difficulties arise, such as field channels being undone after sometime without any check, field channels being generally aligned on field boundaries resulting in a zigzag alignment and causing higher costs of implementation and higher conveyance losses. The consolidation of holdings is another activity which needs attention by the States. For all these matters, a legal backing to the CADP is needed (Iyer, 2003).

There have been several evaluations of the CADP By and large the finding is that while CADP has undoubtedly improved the utilization of the created irrigation potential, it has failed to achieve some of the larger objectives behind the undertaking of the programme. The main emphasis has been on physical works such as the construction of field channels, OFD works, land-levelling, etc. Organizationally, the unification and integration of different functions has not come about to the desired extent. Departmental compartmentalization and lack of coordination continue in most places. Some crucial disciplines such as agronomy, social sciences, etc, have not been inducted into the management. Extension services and the management of demonstration farms are areas that need attention. The promotion of agro-industries has not been marked. The CADP has not brought about significant improvements in water-use efficiency or in agricultural production. Several studies have also indicated that the weakest aspect of CADP is the failure to involve the farmers in the programme. The general `top-down' approach of the State Water Resources Departments continues (NCIWRDP, 1999).

Participatory Irrigation Management

If the `utilization gap' problem led to the CAD Programme, the failure of the major and medium projects to provide satisfactory irrigation service to the farmers led to the idea of PIM. The dysfunctionality of the system and a growing feeling even within the government that it could not really run these huge, far-flung irrigation networks efficiently and render proper service, combined with the dissatisfaction of the farmers, led to the idea of transferring parts of the system to the farmers themselves for management. It became fashionable to talk about "farmers' participation", though the `participation' envisaged was limited, was being reluctantly invited under the pressure of circumstances, and at a late stage in the operation of projects earlier planned and executed by the state in an essentially non-participatory manner. (Underlying this line of thinking in recent years has also been the ideological consideration on the part of some, particularly the international financial institutions, of reducing the role of the state.) Be that as it may, the entrustment of the management of the system below a certain level to the users themselves was a necessary and desirable proposition in the given circumstances, and PIM has become an important measure of reform in the major / medium irrigation sector.

There were early anticipations of what is now called `PIM'. Passing over earlier history we may note that the National Water Policy 1987 stressed the involvement of farmers in various aspects of the management of the irrigation system, particularly in water distribution and the collection of water rates. The Committee on the Pricing of Irrigation Water (Government of India, 1992) recommended not merely the revision and rationalization of water rates but also improvements in the service as a necessary accompaniment, and for bringing this about, it strongly advocated farmers' participation in the management of irrigation systems. The Eighth Plan, recommending "greater user participation in major and medium projects both at system level and the local level", observed: "Local initiatives by users or non-government organizations to set up users' organizations to manage water below government outlets will be actively supported by the Government." The Working Group on PIM for the Ninth Five-Year Plan identified legal, institutional, and financial aspects as being crucial to the effective implementation of PIM programmes. It concluded that the efforts made so far had been tentative, and that in the absence of clear legal provisions Water Users' Associations (WUAs) remained weak. It suggested that legislative backing for PIM should be provided as early as possible. By the beginning of 2002, several States - Andhra Pradesh (which played a pioneering role in this regard), Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, and Rajasthan - had enacted laws to promote PIM and the formation of WUAs. Turnover 'below a certain level' will not accomplish much unless the users representatives were on decision making and monitoring bodies at all levels right upto the system level with power to decide, through mutual consent, matters relating to allocations and delivery schedules. This was the thrust of the recommendations of the pricing committee (1992). And a view voiced in several other writings.

Turning to actual implementation, fourteen States have pilot or full-scale PIM programmes: Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, and West Bengal (Navalawala 1995; Raju and Brewer 1996; INCID 1996a). These ranges from minimal changes proposed in Haryana to more ambitious programmes in Maharashtra and Gujarat. The proposed WUA functions include O & M functions in seven States, dispute-settlement in only one State and the collection of water charges in seven States. Perhaps the most dramatic changes are proposed in Bihar, where farmers are to assume maintenance responsibility for distributary commands of up to 10,000 ha, and can retain 70 percent of the irrigation charges. Here again, severe fiscal crises which precipitated a clear breakdown of the Government's ability to deliver irrigation service has been responsible for the most sweeping changes (Brewer *et al*. 1997). Several NGOs, over the years have demonstrated successfully, on how to build up water users associations linking them with critical functions, in different parts of the country. Some of them are, SOPPECOM in Maharashtra, DSC in Gujarat, IRDAS in Andhra Pradesh.

Andhra Pradesh is the first and leading state in India to bring about overall institutional reforms in the irrigation sector at the state level (Peter, 2000; Raju, 2000). The main components of the reform process are: (a) introduction of a suitable policy and legal framework; (b) formation of Water Users' Associations across all types of irrigation systems in the state; (c) implementation of large-scale training on the issues related with the irrigation reform programmes both for farmers and the staff of the irrigation department; (d) bringing in significant financial reforms to influence quality performance of Users' Associations.

Despite the range of policies, cases can be classified according to two critical dimensions: level of water users' organizations and changes in the collection of irrigation charges. The first is important because some form of farmers' organization is necessary if users are to take over O&M activities, thereby contributing to the objectives of improving efficiency of management and/or reducing government costs. The second is aimed at reducing financial deficits, either by increasing the collection of charges or reducing state expenditure on collecting water charges.

The level of organization indicates the level at which users are expected to take on an active role. Haryana proposes to have water users' organizations only below the outlet (as is currently found in most States).[17] A number of States (Andhra Pradesh, Madhya Pradesh, Karnataka, Rajasthan, Bihar, Gujarat, and Maharashtra) propose transferring O&M responsibilities to WUAs at distributary or minor level. This approach implies a somewhat greater degree of change, as it generally requires the formation of new organizations to co-ordinate between outlet-level groups, and a greater level of responsibility for farmers in O&M. This could reduce marginally the fiscal deficits of the States if the State agency withdraws from O&M at the distributary level, and it can improve performance if farmers do the work more effectively than the government agency had done. However, in many cases the Government does not fully withdraw, so any `farmer involvement' often becomes a supplement to the agency. The transfer of O&M responsibilities to a three-tiered structure of WUAs and joint management committees (JMC) with the Government is proposed in Tamil Nadu, Andhra Pradesh and Kerala. JMCs are committees made up of farmers' representatives—often selected by WUAs—and government officials. Participation in the JMCs gives farmers a somewhat stronger voice in management and allocation.

In regard to irrigation charges, the earlier situation in most States was for the Revenue Department or a special wing of the Irrigation Department to collect charges from individual farmers. Plans to involve WUAs in the collection of irrigation charges are a response to the recognition that state agencies are failing to collect even the relatively low level of charges assessed. Bihar, where government expenditures on collection have exceeded the revenues collected (Bhatia 1989), proposes to involve WUA in the collection of charges. Several States (Gujarat, Maharashtra, Karnataka, and Rajasthan) are experimenting with volumetric wholesaling (i.e., bulk supply and billing by volume) of water to mid-level WUAs.

[17] Some will question whether the Outlet WUA policy proposed by Haryana is a transfer policy at all since the pre-transfer policy in Haryana (and in all of the other States) is that farmers are collectively responsible for O&M below the outlet. The only features that qualify it as a transfer policy are that some maintenance now done by the State will be transferred to the WUAs and there will be formal registered organizations of farmers rather than informal groups below the outlet.

Whatever the organizational structure, most PIM policies focus primarily on shifting responsibilities from the state to farmers. Only volumetric wholesaling proposes to change the basic allocation principles and to give farmers more control over decisions about water. Under this approach, mid-level WUAs pay for water by volume and assume responsibility for allocating it among their members and for collecting the charges. As the user group pays for water by volume, it has an incentive to conserve water collectively. However, individual farmers are the ultimate water users, and this approach depends on the group to motivate individuals to use water efficiently.

The success of PIM policies must be measured not in the number of recommendations or programmes, or even in registered associations, but in the level of constructive involvement of farmers in improving the performance of irrigation systems. The critical question is whether and how farmers respond to government overtures to increase their participation. Pilot projects show that much can be achieved, but whether these pilot activities can be scaled up to cover large areas remains a question. There is a need to identify factors that tend to affect farmers' willingness to participate in irrigation systems.

Training

Eleven major States in India have established Water and Land Management Training Institutes (in some states Irrigation Management and Training Institute). These were envisaged as important agents of change. Over the years, for a number of reasons, these institutes have failed to play a key role in most of the States. On the whole, the WALMI idea has not been a successful reform measure and seems to have run out of steam. The idea needs to be thought through afresh at both State and Central levels and re-formulated or re-energized.

Pricing of Irrigation Water

This is essentially a problem relating to the pricing of irrigation water supplied from public major/medium projects. In general, irrigation water rates in this country (for water supplied by the state from canals) are unduly low, and even charges at those rates are not fully or always collected. Rates for irrigation water supplied from canals are fixed at the State level on a crop-area basis in nominal rupee terms, and remain unrevised for years, sometimes for decades. The rates in Tamil Nadu have remained unrevised for over 25 years. Towards the late 1990s, there was an effort to raise water rates: Andhra Pradesh has tripled its irrigation water charges in 1997, Maharashtra has announced a gradually rising rate for the next five years, and may other States are contemplating similar moves. However, the overall the picture during the period 1960 to 1997 is not a reassuring one (Svendsen, Gulati and Raju, 2005).

Poor revenues from public irrigation systems created at great cost are among the many factors responsible for the severe resource constraint faced by most State Governments. The result is poor maintenance of systems, which tend to fall into disrepair, and an unreliable and unsatisfactory service. That leads in turn to poor revenues, thus setting in motion a vicious cycle. If even maintenance suffers there can hardly be any resources for further investments in this sector. Apart from this, the low pricing of irrigation water encourages an extremely wasteful use of this precious and scarce resource. There is also an equity consequence: the profligate use of water by the head-reach farmers results in the no-availability of water for the tail-end farmers. The tail ender issue is more complex. Though the issue encompasses significant variations in different systems and regions. The recent study (DSC, 2003) focusing on six states (Gujarat, Haryana, Karnataka, Maharashtra, Orissa and Tamil Nadu) ranked the specific causes for tail-enders problems: (a) unauthorized drawing of water (13 projects); (b) absence of outlet gates/structures (in 10 projects); (c) poor maintenance, seepage and reduced carrying capacity due to weeds (8 projects); and (d) design/construction faults and unlined canals (7 projects).

It is now well recognized that there is a substantial under-recovery of costs in the major / medium irrigation sector, and that most of these projects are loss-makers in financial terms. (It must be noted that from the fifties onwards, financial return has ceased to be a criterion for the approval of major / medium irrigation projections. The investment decision in such cases is based on a `benefit-cost ratio'.) The Committee on the Pricing of Irrigation Water (GoI, 1992) estimated that the total unrecovered costs on account of major and medium irrigation projects had increased fivefold in a ten-year period from Rs. 2800 million in 1977-78 to Rs. 15250 million in 1986-87. Irrigation subsidies were nearly 47 percent of total non-merit economic services in 1993-94 in Karnataka as compared with 36 percent for all states taken together (Srivatsava and Sen, 1997). Even the water fees collection (revised in 2002) in Karnataka would generate only 9.6 percent of the current expenditure (Raju and Amarnath, 2003).

Successive Commissions and Committees (Irrigation Commissions, Finance Commissions) have stressed the importance of recovering at least the O&M costs if not the capital-related charges, but these have not been acted upon. The National Water Policy 1987 stated that irrigation water rates should be such as to cover the O&M costs fully and make a partial contribution towards capital-related charges (the extent of this was not specified) but this too, like many other principles laid down in the NWP, remained non-operationalized. The National Water Policy 2002 makes a similar observation.

A crucial question in this regard is whether irrigation water rates are a tax or a `user charge'. If it were a tax, there need be no connection between that tax and the cost or quality of the service rendered, and the budget provisions for O&M would have nothing to do with the tax: the latter would be part of the general revenues, and the former would be independently provided. This question was gone into by the Committee on the Pricing of Irrigation Water (the Vaidyanathan Committee) in its Report (GoI,1992). The Committee came to the firm conclusion that the benefit of canal irrigation went to an identifiable group of beneficiaries; that it was therefore not a public good available to all; and that irrigation water rates were clearly not a general-purpose tax but a user charge recoverable from the beneficiaries.

The Vaidyanathan Committee recommended a two-part tariff, in the first phase, comprising a fixed charge of Rs. 50 per ha for the entitlement arising from membership of the command area and a variable charge to recover the annual O&M cost and one per cent interest on the capital cost (adjusted to remove the costs attributable to inefficiency). The objective was to move towards full cost recovery. The change was to be brought about in three phases, ultimately leading to rates on a volumetric basis, linked to an improvement in the service, and the creation of autonomous, financially self-reliant entities at the system level, with participatory management by users. The Committee also suggested that while the change to fully volumetric charges would take time, a beginning could be made by shifting from the present crop-specific area-based rates to rates related to area irrigated in each season (irrespective of the crop grown) so that differences in irrigation requirements between seasons are taken note of. Unfortunately, ten years after the Report, it remains largely unimplemented because of the lukewarm response from the State Governments. This was doubtless due to the fact that the implementation of the recommendations would have meant a substantial (more than fivefold) increase in rates even in the first phase. However, as mentioned earlier, some States have revised their water rates to varying degrees. Indeed, the required increase in rates would be much less forbidding if steps were taken to ensure proper assessment and full and prompt collection of dues. Also the Irrigation Pricing committee (1992) had recommended that pricing and their revisions be subject to review and approval by an independent regulatory authority rather on the lines of other public utilities.

The subject was gone into again by the NCIWRDP in its Report (1999). It broadly followed the Vaidyanathan Committee's recommendations but made a few modifications and refinements. It also laid down some broad guidelines and principles. The NCIWRDP's recommendations do not seem to have received serious consideration so far.

The question might be raised whether poor farmers would be able to pay increased water charges. The short answer to that question is that irrigation increases productivity and production, and the resulting increase in income will enable the farmer to pay the water charges which will be only a small fraction of the value of the output (as pointed out in the Vaidyanathan Committee's Report). Irrigation-water rates are essentially user charges and not a tax, they will necessarily have to cover running costs and eventually capital-related charges. Poverty is not to be taken as an unalterable given and accommodated through subsidies on water or electricity, but reduced through income-generating measures, of which the extension of irrigated agriculture is an important one. Also since irrigated land produces three to five times more than rainfed land, those who have access to public irrigation get much higher incomes than unirrigated farms across all size classes.

Financing of Projects: Bonds, Privatization

The paucity of funds for new investment is forcing State and Central Governments to explore alternative sources of financing for developing and rehabilitating irrigation projects, such as the tapping of the capital of private investors, private borrowing through revenue-backed instruments, and the mobilization of local capital through investments by farmers in the systems that serve them (Svendsen, Gulati and Raju, 2005).

The raising of resources from the market through the issue of bonds was initiated with the sale of Narmada Bonds in the mid-1980s. Bonds were also sold to support the

Upper Krishna Project in Karnataka. Under both of these schemes, secured, redeemable, non-convertible bonds were offered at a fixed rate of interest guaranteed by the respective State Governments. A pre-requisite for this is the establishment of corporate bodies for managing specific projects. Examples are the Krishna Bhagya Jala Nigam Limited (KBJNL) in Karnataka, Sardar Sarovar Nigam in Gujarat, and Maharashtra Krishna Valley Development Corporation (MKVDC) in Maharashtra.

The rates of interest on such bonds are very high, as high as 17.5% in some cases. This makes it a very costly source of credit. No irrigation or even multi-purpose project can service such a debt. The liability necessarily falls on the Government, and constitutes an addition to its already heavy burden of debt-service. It is a delusion to think that this is an `innovative' resource-raising method. The debt will sink either the project or the Government's budget. If such capital- and resource-intensive projects are to be undertaken at all, the proper course would be for the Government to do so out of the budget. This would clearly call for a very selective approach and a most stringent scrutiny with reference to hard criteria. There are no soft options.

Private sector participation in irrigation financing is an idea that has been favoured by both the Planning Commission and the Ministry of Water Resources. The revised National Water Policy (GoI, 2002) advocates private sector participation in the planning, development and management of water resources projects wherever feasible. Private sector participation is expected to help in introducing innovative ideas, generating financial resources, speeding the construction process, introducing corporate management modes, and improving service efficiency. However, there are questions as to the likelihood as well as the desirability of this course.

Taking likelihood first, even the most pro-business States such as Gujarat and Maharashtra have not been able to elicit much private sector interest in irrigation projects. State Governments have not asked for expressions of interest from potential bidders, nor has any State Government formally declared willingness to sell stakes in irrigation projects. In practice, private sector participation is likely to encounter several problems (Svendsen, Gulati, and Raju, 2005): large investments, long gestation periods, modest or low returns, high financial risks, likely political interference in project management and water-rate assessment, the political influence of farmers' lobbies, the difficulties in raising water rates and collecting them effectively, and so on. The much-advocated idea of private sector participation has made hardly any headway in power projects, and there is no basis for thinking that it would be more successful in irrigation projects.

Turning to desirability, privatization can mean allowing a private entity to build dams and reservoirs on rivers, or exploit surface water bodies (e.g., lakes) or an underground aquifer for commercial purposes. Even assuming that the private sector is interested in investing in such capital-intensive, long-gestation, modest-return projects, how are the environmental and social impacts (which have presented serious difficulties to the state in past projects) going to be handled by the private entrepreneur and manager? Supply may match demand but resource conservation may receive scant consideration; resettlement and rehabilitation aspects are likely to be given grudging attention only to the extent that resistance by those affected and public opinion compel such attention; and it is naïve to imagine that market forces will obviate conflicts or provide a magical route to their resolution. Further, there are questions not merely of equity and sustainability but also of control over natural resources. That does not mean that one is arguing for a dominant role for the state; but merely that the alternative to the state is not necessarily the corporate sector.

There is also the basic conflict between regarding water as an `economic good' in which tradable rights can be created (which is a pre-requisite for private corporate investments) and regarding it as a life-supporting element and therefore a basic right (now recognized as a human right in the UN context). Many would argue that water is more appropriately treated as a common pool resource to be managed by the community, than as a tradable commodity. It is not easy to reconcile those two conflicting approaches to water. But, there is a more fundamental issue of whether it is possible to define enforceable property rights in water.

One important question that will need consideration in this context is whether allowing the domestic private sector to exploit national natural resources, particularly water, will make it difficult to deny a similar right to foreign investors in terms of the WTO regime and the principle of `national treatment' of foreign investors, and if so, whether there is a danger of our losing control over our own natural resources, as some have argued.

Revival of Traditional systems

A significant reform that is still to realize its full potential is that of revival of traditional systems. Over the years, a few leading NGOs (e.g, Dhan Foundation in Tamil Nadu) have made strenuous efforts to mobilize local communities in restoring the role of traditional systems such as tanks. Some State Governments (e.g, Karnataka, Andhra Pradesh, Rajasthan, Tamil Nadu, and Madhya Pradesh) have also initiated large-scale programmes to rejuvenate tanks. Karnataka State has taken a much-needed initiative to rehabilitate the minor irrigation tanks. The proposed project has plans to rehabilitate some 5,000 tanks on a pilot basis all over Karnataka through a community-based approach. A somewhat similar approach, supported by SIDA, was designed for 4,100 tanks in Rajasthan. The European Economic Commission and others have supported the NGO-initiated approach in various parts of Tamil Nadu. DHAN Foundation has taken up this programme mainly in Madurai and Ramnathapuram districts. This programme is also supported from rural development funds of the State Government. Their main focus has been on small tanks (below 40 ha) with a view to improving the livelihoods of marginal and small farmers, besides landless families.

The utilization of local knowledge systems enables the communities to participate with the feeling that it is their project, and they take pride in designing the rehabilitation plan and implementation. In the proposed community-based tank rehabilitation project in Karnataka, emphasis has been on local people's perceptions of the tank and its structures and the sustainability of their efforts and contributions. The local farmers believe that if tank rehabilitation is carried out with their active participation, then the design and structures will not require an ISI mark, and the tank will be as clean as a temple. However, experience during the past few decades has been that the design and strategies are evolved elsewhere with little concern for local needs and situations. This being the case, the people evince no interest in such projects. Consequently, the tanks in most Karnataka villages lost their importance in the everyday life of the rural population whom they were meant to serve.

As part of the initiative, the Government of Karnataka has set up a separate organization called Jala Samvardhane Yojana Sangha (JSYS) as a special purpose vehicle and as an autonomous society. JSYS can make decisions faster and simplify procedures for the effective implementation of the World Bank projects. JSYS has initiated some tank-user associations on a pilot basis, and launched different studies to appraise the current situation and to suggest strategies.

Water- Harvesting Movement

Tanks can be subsumed under the wider heading of water-harvesting, to which we now turn. India has a long history and tradition of rainwater-harvesting. Recognising the importance of capturing the transient and variable rainfall[18], our ancestors had learnt to harvest water in a variety of ways (Agarwal, 2001):

- They harvested the raindrop direct. From rooftops, they collected water and stored it in *tankas* built in their courtyards. From open community lands, they collected the rain and stored it in artificial wells called *kundis*.
- They harvested monsoon runoff by capturing water from swollen streams during the monsoon season and stored it in *zings* in Ladakh, *ahars* in Bihar, *Johads* in Rajasthan and *eris* in Tamil Nadu, to name a few.
- They harvested water from flooded rivers in places like north Bihar and West Bengal. This is also the case with the system tanks of Tamil nadu.

Considering the enormous land and water resources, and variability of rainfall, the calculations carried out by Agarwal et al (2001) show that the potential of rainwater harvesting is enormous and undeniable. There is no reason whatsoever for thirst in India. The strategy for drought-proofing should be to ensure that every village captures all the runoff resulting from the rain falling over the entire land and the associated government revenue and forest lands, especially during years when the rain is normal, and store it in *tankas* or ponds or use it to recharge the depleting groundwater. It would then have enough water in its tanks or in its wells to cultivate substantial lands with water-saving crops like millets and maize. Apart from the well-known efforts of villagers in Ralegan Siddhi in the drought-prone Ahmednagar district of Maharashtra (under the leadership of Anna Hazare), the poor, low-rainfall villages in Alwar district of Rajasthan (under the leadership of Rajendra Singh and the NGO Tarun Bharat Sangh), and the villages of Sukhomajri and

[18] India's average annual rainfall is 1,170 mm. It varies from 100 mm in the deserts of western Indian to 15,000 mm in the high rainfall hills of the Northeast. Nearly 12 percent of the country receives an average rainfall of less than 610 mm per annum while 8 per cent receives more than 2,500 mm. But more than 50 per cent f this rain falls in about 15 days and less than 100 hours out of a total of 8,760 hours in a year. The total number of rainy days can range from a low of five days in a year in the desert regions of Gujarat and Rajasthan – though on some of these days there can be high-intensity rainstorms – to 150 days in the Northeast. (Source: Making Water Everybody's Business. (ed) Anil Agarwal, Sunita Narain and Indira Khurana. Centre for Science and Environment. 2001).

Dhamala in the degraded Shivalik hills in Haryana (under the leadership of the late P. R. Mishra), there are numerous other efforts taking place in India and elsewhere to revive the old water-harvesting practices. The above-mentioned examples have clearly shown that rainwater-harvesting is not merely a means of locally augmenting the availability of water but the starting point of an effort to eradicate rural poverty, generate rural employment and reduce distress migration from rural areas to urban areas. However, this calls for a new approach to governance itself: a participatory form of governance rather than a top-down bureaucratic one. So far, these have been scattered local initiatives. What is called for is a national campaign on these lines. The Prime Minister emphasized this strongly in his Address to the National Water Resources Council on 1 April 2002, while commending the National Water Policy 2002 for adoption.

The most beautiful thing about water harvesting, as Agarwal (2001) argues, is that there is a human-rain-land synergy (see table below). This table clearly shows that rainwater harvesting is possible in all human-land-rain scenarios. India receives most of its rain in just 100 hours a year.

The hidden link

Synergies exist between rainfall, human population density and land availability

Region	Annual level of rainfall	Rain yield potential from one hectare of land (*)	Human population density	Land availability for water harvesting	Surface quality for water collection efficiency	Number of people whose water needs can be met at 100 litres per person per day from one hectare of land
Rural-arid	100 mm	1 million litres	Low	High	-	27
Rural-humid	2,000 mm	20 million litres	High	Low	-	553
Urban	-	-	Very high	Very low	More roof tops and built-up surfaces available with high runoff	

Note: (*) Assuming rainwater collection efficiency of 100 percent

Source: Adopted from Agarwal, 2001.

Reforms in relation to Groundwater

The problems in relation to the exploitation and use of groundwater have already been referred to earlier. Broadly speaking, these relate to equity, resource conservation, protection of quality, and environmental sustainability, and these are what reforms in relation to groundwater need to deal with. Difficulties arise essentially in two inter-related contexts: the prevailing law governing the ownership of groundwater, and the emergence of water markets.

Under Indian law, the ownership of land carries with it the ownership of the groundwater under it, subject to regulation and control by the state. It has been said that "groundwater is attached, like a chattel, to land property", and that "there is no limitation on how much groundwater a particular landowner may draw" (Chhatrapati Singh 1991). It follows that only those owning land can have rights over groundwater; the landless (including communities, tribal and other, who may have been using certain natural resources for centuries) can have no such rights. Further, this legal position leads to inequities of various kinds: a rich farmer can install power-driven tubewells or borewells in his land and their operation can make dugwells in the neighbourhood run dry; he can sell water so extracted to his poorer neighbours even though the water may come from a common aquifer running under their lands; and he can deplete the aquifer through excessive exploitation. The easement right makes regulation difficult.

Easement right is not only problem. In principle a well owner who is adversely affected by deepening or other action by a neighbour has the legal right to seek restraint or compensation from the latter. That this right is not easy to enforce makes its empty.
Even if you dissociate rights to extract underground resources from ownership of land, the task of monitoring compliance and enforcing regulation to ensure equitable sharing and sustainable use is far too difficult in terms of effort and cost. That is the reason for emphasizing economic incentives to check over extraction and introducing some form of lcommunity regulation of groundwater extraction and use at the local level. That too is fraught with many difficulties. Available literature on India context is inadequate in dealing with (a) different people (gender, class, caste) perceptions on groundwater rights, (b) bundle of rights, (c) how rights are acquired, maintained, transmitted or lost and what types of laws support or hinder them.

Attempts by government agencies to regulate water use by different users by means of state law have often not succeeded in decreasing conflicts and may in fact have led to uncertainty about water rights for the traditional rights holders. As many studies have show, in the process of negotiation for water rights, power relations are very important: the elites are more likely to negotiate better water rights for themselves than the less powerful (Hammoudi 1985; R. and U.Pradhan 1996; R. Pradhan and F. and K. von Benda-Beckmann 2000; Bruns and Meinzen-Dick 2000). "Water tends to flow away from the poor and powerless toward those better endowed politically and economically" (Ingram and Brown 1998: 119). This is because the elites control the decision-making processes that legitimize the rules for allocation and distribution of water (Adhikari and Pradhan 2000).

It is against that legal background that water markets have emerged in the context of groundwater extraction through tubewells and borewells. Groundwater markets exist in various forms in many regions of India. They are truly spontaneous institutional responses to emerging and variegated needs in different areas (Shah, 1993). According to Shah (1993) and Shah and Raju (1987) the following factors influence the pace of development of water markets: availability of water resources, scale and quality of adoption of irrigated farming technologies, progress of rural electrification, quality of power supply, and extent of land fragmentation. Nearly 18 of the total 47.5 million hectare metres (mhm) of India's groundwater potential were used to irrigate about 28 mha of land in 1992. Ultimate groundwater irrigation potential is put at around 80 mha. In States like Uttar Pradesh, the presence of public tubewells which dominated the groundwater scenario until the early 1960s has long since declined to insignificance. At the national level, of the over 21 million groundwater structures less than 50,000 were State-owned tubewells and fewer still were NGO-induced group tubewells. Thus, 95 percent of the area served by groundwater in India is in all likelihood commanded by privately owned tubewells. Undoubtedly, the emergence of water markets helps farmers who cannot afford to invest in tubewells or borewells to buy water and practise irrigated agriculture, and they are not necessarily or always over-charged (Saleth, 1996; Shah and Raju, 1987).

Two case studies presented by Dubash (2002) indicates that the two villages have moved on from subsistence agriculture and poverty to production for the market and prosperity. However, there has been no great gain in equity or social justice; in fact inequities and inequalities appear to have been accentuated in some ways. The growing commercialization of life and relations benefit some but affect others (poorer people, small and marginal farmers) adversely. There has been an alarming depletion of groundwater aquifers. Much damage has already been done, and even if effective regulation is now undertaken, past damage cannot be wholly undone. In fact, the introduction of effective regulation is enormously difficult, and it is by no means clear that further damage can be arrested. Many farmers expect that the resource will be irretrievably run down and are preparing for the inevitable abandonment of agriculture in the not too distant future.

Efforts to regulate groundwater extraction have been going on for a long time. The Gujarat Government has an Act in place for the regulation of groundwater, but it applies only to nine districts, and even that limited law seems to be moribund: there is a difference of opinion as to whether it is in fact in force. Maharashtra and Madhya Pradesh have Statewide Acts, but only for the regulation of drinking water sources. Tamil Nadu has an Act applicable only to the Madras Metropolitan Area; for the rest of the State, a Bill has been introduced. Andhra Pradesh has an Act of 1996, and an Ordinance of wider scope is under consideration for promulgation. Largely, we are still in the realm of intentions rather than actualities. There is no concerted, nation-wide effort to treat groundwater as a scarce and precious natural resource to be protected and conserved. In the light of the foregoing, reforms in relation to groundwater have to be two fold: (i) the legal position on the ownership of groundwater needs to change, with aquifers being regarded as common pool resources in which only limited use rights (and not property rights) are conferred on individuals or institutions; and (ii) water markets need to be carefully regulated with reference to equity, resource conservation and environmental sustainability.

Power subsidy to groundwater extraction: Emerging groundwater resource problems are closely related to high governmental subsidies in the agricultural sector. The subsidy on power supplies is perhaps the most significant, since in most of the states electrical energy is provided either free of charge or on a flat rate basis. The power tariff policy is a critical factor in achieving efficiency and sustainability of groundwater use and management since the pace of groundwater withdrawals is intimately tied to energy prices. During 1976-78, the Government of India decided to promote electricity supply for agriculture by strengthening Rural Electrification Program and energizing agriculture pump sets. This led to a spurt in groundwater irrigated area as additional electricity driven pumps began to get installed. This was followed by another spurt in 1980-83, when power tariff was converted from metered supply to a flat rate so as to minimize administrative costs involved in metering, billing, and collection from agriculture consumers scattered in remote areas (Mukerjee, 2005). Consequently, the low marginal cost of pumping induced farmers to drill more wells and install electric pumps. Groundwater levels began to fall and diesel-operated pumps became economically less feasible in many parts of the country. Number of farmers investing in bore wells with electric pumps began to increase at high rate. This is indicative of the fact that electricity tariff structure is a principal drive for increase in pump population (22 million by year 2005) and groundwater extraction.

Increased cost of extraction: Subsidization of electricity for pumping groundwater reduces the marginal cost of extraction to near zero and thereby encourages farmers to use the resource inefficiently. This in turn has resulted in increased drilling and extraction costs for farmers as well as complete abandonment of some wells (negative externality issue). On the other hand, reduction in electricity subsidy alone may not bring in significant changes in the existing pattern of groundwater use. Mainly owing to consumption of groundwater for agriculture is also dependent upon: pump capacity, irrigation intensity, proportion of groundwater irrigated area to total irrigated area, energy efficiency of pump sets, etc. Therefore, one needs to look into this complex of issues in a more pragmatic way.

Impact on Farmers' livelihood: Subsidization of electricity for pumping groundwater also has far-reaching social and economic implications (i.e., impact on living conditions of farmers, agricultural wage and employment structures, etc.). It has led to significant growth in the market for pumped water. This has enabled even those farmers who could not buy a pump to benefit from subsidized power supply. It is important to appreciate that access to power subsidies requires pump ownership. However, non-pump owning farmers can also benefit from the power subsidies through the market for pumped water. However, the actual flow of subsidy would depend upon the characteristics of the pumped water market (Dubash, 2000). Precisely, power subsidy facilitates the development of groundwater markets thereby enabling the small and marginal farmers to access the scarce groundwater resource through water purchase from large farmers (equity issue). Moreover, availability of power subsidy has also made substantial contribution in terms of raising agricultural productivity and farm incomes through irrigation.

Drinking Water Supplies

The proportion of urban population has increased from last 5 decades from 17 percent to 28 percent. Of the present 1.02 billion population, 285 Million (27.8% of the total population) live in urban areas, which comprises of 5161 towns an increase of 2.1 per cent over the proportion of urban population in 1991 census. Table 4 shows the increase in urban population. Over a period of time, the proportion of population having access to drinking water has been increased considerably. The improvement has been significant to 90% in 1997 from 75 % in 1981 (GOI, 1999). Table below indicates the states receiving the supply for more than 85% and less than 75%.

Decadal growth in urban population

Year	Increase in urban population (%)
1961	17.97
1971	19.91
1981	23.34
1991	25.71
2001	27.78

Population provided with water supply (in %)	States
High: more than 85%	Andra Pradesh. Arunachal Pradesh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Madhyra Pradesh, Maharastra, Meghalaya, Nagaland, Rajasthan, Uttar Pradesh, West Bengal
Medium: between 75 to 85%	Bihar, Goa, Manipur, Punjab, Tamil Nadu, Tripura
Low: less than 75%	Assam, Kerala, Mezoram, Orissa, Sikkim

Source: India's 10th five year plan (GoI, 1999)

These statistics are a matte[illegible]ate supply of safe drinking water is very fuzzy and the reporting is suspect. The suspicion is strengthened by the fact the these proportions keep going up and down over time.

Groundwater Quality: In India's Gujarat and Rajasthan States, groundwater overuse is causing fluoride contamination of drinking water supplies, creating a major public health crisis. In coastal India, overexploitation of groundwater has resulted in high levels of salinity in the water, making it unfit for human consumption or farming. Increasing levels of arsenic in West Bengal and parts of Uttar Pradesh are posing serious health problems.

Water quality problems have been on the increase with groundwater depletion as water is being procured from deeper depths and contamination. Efforts to curb quality impacts have been taken up lately. In Karnataka, the Rural Development and Engineering Department had taken up the testing of drinking water samples in rural areas on a massive scale. The sample test completed for 37,776 sources in 45 taluks out of which 21,088 had quality problems (see table below).

Status of Quality Affected Habitations in Karnataka

Contamination Beyond Prescribed Limits	Number of Habitations Affected	In Per centages
Excess Fluoride	5,838	10.3
Excess Iron	6,633	11.7
Excess Nitrate	4,077	7.2

Brackishness	4,460	7.9
Total	21,088	37.1

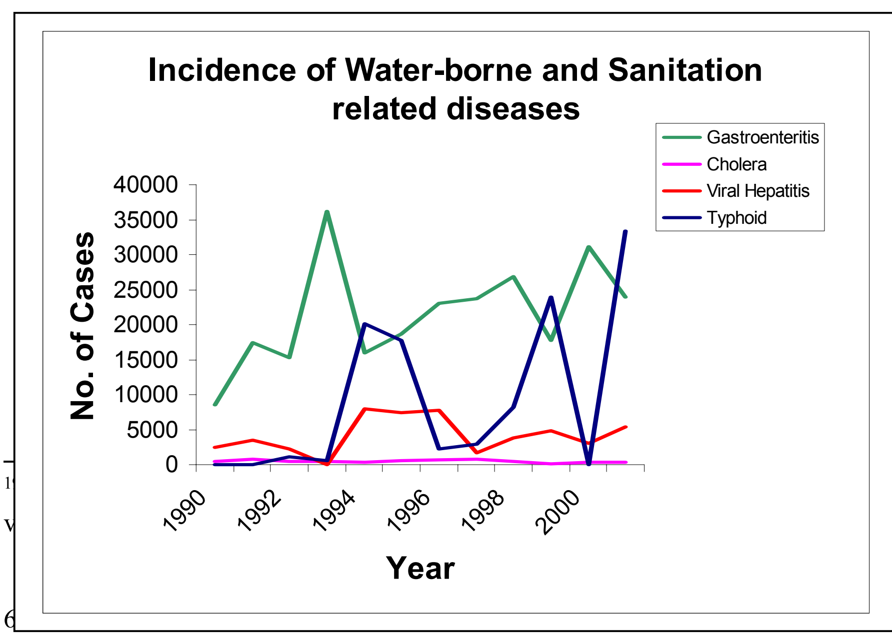
Source: RDPR document 2003

Recently, in 2001-02, the Karnataka Rural Water Supply and Sanitation Agency commissioned a geographical information system approach based study to develop spatial information and knowledge base on the groundwater quality in the State. The study[19] indicates that water quality problems in the state are Fluoride, total Dissolved Salts, Iron, total Hardness, Nitrate and Bacterial contamination. Higher concentration of fluoride in drinking water was high in arid and semi-arid zones in the state. Drinking water sources in more than 10 per cent villages in the state were permanently affected by poor quality – mainly excess Fluoride, Iron, Nitrate and TDS.

Degradation in water quality as in many regions, Karnataka also has similar reasons. Contamination of groundwater sources due to disposal of untreated sewage, disposal of industrial effluents without treatment, disuse of wells, extensive usage of pesticides and chemical fertilizers, overexploitation of groundwater and poor sanitation and hygiene is rampant. The extent of quality decline has increased over time which is being addressed by the government.

Unsafe and poor quality water adversely affects health status of people. For instance, presence of chemicals like fluoride in excess quantity (more than 1.5 PPM) causes dental and bone hazards, while skin rashes result from consuming water with excess brackishness. Sixtysix million people in India are estimated to be consuming groundwater with unsafe levels of fluoride. Nearly 30 million people in the eastern states are estimated to be at risk of consuming water with higher than acceptable arsenic levels (Kolavalli and Raju, 2003). Microbial contamination is the more important and frequent cause of ill health, with 20-30 infectious diseases (viral, bacterial, protozoan and helminthic) being transmitted through water.

Incidence of Water-borne and Sanitation Related Disease



19 ... ut of the total 56,682
v ... meters, (GoK, 2002)

For example, of the 208 urban local bodies under the Karnataka Urban Water Supply and Drainage Board, 151 depend on river water whereas 47 depend on ground water. Groundwater in the state are fast declining with 34 taluks considered critical due to over exploitation. (This is not only or even primarily due to overextraction for domestic use) Besides, maintenance, poor distribution systems have also added to the problem. In the early 1970s, Karnataka's rural population, which constituted about 42 million of the total population of 53 million, could meet its drinking water needs largely from open wells as ground water levels were at an average depth of three to five meters. Presently about 64 percent of rural habitations are covered with more than 55 litres per capita per day of water supply. However nearly 34 percent of the habitations are yet to attain the level of 55 litres per capita per day. One estimate suggests that about three lakh wells dug in the 1970s have gone dry, and shallow open wells have been replaced by deeper tubewells. At present (GoK, 2003) there are about two lakh drinking water tubewells in the State and 12 lakh irrigation tubewells as against about two lakh irrigation wells in the 1970s.

Groundwater serves 85 percent of the rural population's requirement of drinking water and nearly half of the urban and industrial requirements in Karnataka. Over the years, groundwater utilization in 21 taluks of the state has exceeded 85% limit and 22 taluks between 65 to 85% and 29 taluks has exceeded by 50% causing rapid depletion of aquifers. However, the concept as well the basis for estimates of potential, utilization are highly contested. The National Family Health Survey indicates that only 3 percent of households in 1998-99 made use of surface sources compared with 11 percent of households in 1992-93. In Punjab, Haryana and Western Rajasthan, the main consequence has been salinity; in North Gujarat and Southern Rajasthan, it is fluoride contamination of groundwater; in hard-rock Southern India, it is declining well yields and increasing pumping costs arising from competitive deepening of wells. In West Bengal and western Bangladesh, the consequence is arsenic contamination. In West Bengal and western Bangladesh, the consequence is arsenic contamination. In coastal areas, the most serious consequence of intensified pumping of groundwater for irrigation is saline ingress into coastal aquifers. All these problems will impair the region's capacity to feed its growing population. In South Asia, the urban groundwater scene is reaching a melting point: large cities like Ahmedabad and Jodhpur in Western India and Chennai in the South Indian state of Tamilnadu support thriving private groundwater businesses that draw water from tube wells in the neighboring hinterlands for supplies to high-income residential areas because groundwater tables in the cities are falling at a rate of 7–10 ft/yr.

Urban areas and industrial hubs in our part of the world are now putting greater pressure on water resources. Cities across the country need more water. They are powerful.

Their elected masters work overtime to source water from far, and further, away (Narain, 2005), Delhi will get water from the Tehri dam, over 300 km away in the Himalaya; Hyderabad, from Nagarjunasagar dam on the Krishna river 105 km away; Bangalore, from the Cauvery, about 100 km away; Udaipur used to draw its water from the Jaisamand lake but is drying up, and so the city is desperately seeking a way of this new thirst. Add to all this industrial growth.

Rural Water Supplies

Rural Water Supply is one of the major challenges that has been addressed by the Indian government and attempts made towards tackling the crisis in providing safe and adequate water to the rural people. Lately, the problem has become particularly severe in rural areas. A review (Raju, Das, and Manasi, 2004) of the government's efforts in implementing various programs, policies adopted has shown that there has been progress but has not been successful in providing adequate quantity of potable water to all persons. Several factors like, increased urbanization leading to negligence of traditional water sources, poor water management, resource depletion due to over exploitation of existing resources, poor co-ordination between departments and poor institutional setup in addressing the problem have led to the severity of the problem over the years.

Considering the bare situation, since the First Five-Year Plan (1952-57), \$6.5 billion have been invested in India by the central and state governments to provide potable drinking water in rural area. However, according to latest survey (NSSO, 1998), 69 per cent of the households have access to modern sources of potable water, (see Table below) and much less in case of rural area. According to the National Family Health Survey (1998-99), 74.5 per cent of urban and 25 per cent of rural households have access to piped water supply. Hand pump as a source of drinking water figures after piped water. 18.1 per cent of urban households and 47.3 per cent of rural households depend on it. The remaining household still depends on unsafe water sources. Thereby, the problem of rural drinking water supply and sanitation has not been fully resolved.

Access to Principal Sources of Drinking and Domestic Use of Water
(Per centage Distribution of Households - 1988, 1993 and 1998)

Source	Principal source of drinking water			Principal and Supplementary for different purpose 1998					
	1988 (44th round)	1993 (49th round)	1998 (54th round)	Cooking		Bathing		Washing utensils	
				PS	SS	PS	SS	PS	SS
Modern	54.3	63.4	69.0	69.6	45.1	60.1	43.3	64.9	44.7
Traditional	45.1	36.5	30.7	30.0	53.3	39.2	55.5	34.7	53.9
Others	0.6	0.3	0.2	0.4	1.6	0.4	1.2	0.3	1.3
All India (rural)	100	100	100	100	100	100	100	100	100

Source: Computed from 44th, 49th and 54th Round of NSSO data.
PS: Principal Source, SS: Supplementary Source

Picture is unclear about coverage of villages. Agencies indicate contradictory figures. For instance, NCAER (1994) survey concludes that about one-half of all villages in India do not have any source of potable drinking water which is contrast to the official claims that in 1994 more than 80 per cent of villages were provided with adequate potable water. The Eighth Five-year plan (1992-97) had set a target of achieving 100 per cent coverage in providing safe drinking water by the turn of the century. At the end of Eighth Five-year plan (1997), the approach paper to the Ninth Plan (1998-2002) claims "efforts will be made to provide access to safe drinking water facility to the entire population in urban and rural areas in the next five years". Besides, puts the requirement of funds at a staggering sum of Rs 40,000 crore; Further, it recommends for involvement of the private sector on the lines of Sri Satya Sai Trust of Puttaparthy in Andhra Pradesh. This change in policy argument is due to resource constraint and magnitude of the problem; for instance, the estimates (Pushpangadan and Murugan 1998) based on expenditure data, indicate that if the present rate of budget allocation is followed, the amount is just enough to meet the expenses on replacement of old systems, operation and maintenance activities.

The seventh five-year has identified the strategies followed in the existing modes and indicated two factors contributed to the failure: One, it was essentially a supply driven, top-down approach that did not take into account the pattern and intensity of demand for this service. Second, the lack of community participation in provision of this service rendered it inefficient and unsustainable. To overcome these problems, it was suggested making beneficiaries share a portion of capital cost and pay for services to maintain the assets. In support of this, the eighth five year plan policy paper stressed the need for devolution of responsibility to grass roots levels and recommended a change in mind set, through four stages of intervention; viz., a) creating awareness; b) developing action plan to ensure the decision making management and financial autonomy; c) strengthening the institutions and; d) improving monitoring, accountability and transparency of the sector (World Bank 1999). Further providing logical support, policy instances were cited from worldwide experiences showing a positive correlation between beneficiary involvement, on the one hand, and the efficiency of implementation and the effectiveness of the project sustainability on the other (David Hymer and Ashok Mody, 1997, Pushpangadan and Murugan, 1998). Forty-eight per cent of the recent World Bank projects have included community participation in their design as a way to increase project efficiency (Churchill 1994) and reduce cost. Recent literature on water supply systems shows that, proper institutional framework and collective action improve the efficiency (Narayan, 1993). In state led planning, old paradigm of centralized decision-making and bureaucratic allocation is fading fast to pave way for a decentralized allocation and stakeholder participation (Saleth and Dinar, 1999).

A recent study on Rural Water Supply in Karnataka (Raju, Das and Manasi, 2004) indicated following reasons for poor performance: (a) poor coordination between the departments, (b) planned approaches but poor implementation, (c) poor sustainability of the schemes, (d) intricacies of the problems were not identified, (e) political intervention, (f) institutional inadequacies, (g) lack of alternatives, and (h) social attitude.

The problem of providing drinking water in the rural areas has been an arduous and complex challenge to the State government. Evolving appropriate systems, structures, and policies for effective water supply to rural areas has been adopted in different ways, but the problem remains in new forms. Every year there are contradictory statements on the coverage of villages as reported by the NCEAR survey and official and department figures. Huge investments have been made right from the beginning of the First Five-Year Plan, although progress seems visible, the target of achieving 55 lpcd has not been achieved in all the villages. The problem is complex because it is multidimensional in nature and balancing the situation seems too complicated. The Central, State and external funding agencies have adopted various approaches towards achieving quality and adequate quantity of water.

Traditional arrangements through which rural communities secured their water supplies—community and private wells, tanks, rivers—have gradually declined partly with the spread of modernity and rising expectations and partly because of the government efforts to deliver piped water supply. The RWS problem has two dimensions. One is of choice of appropriate infrastructure/institution combine; this is essentially a question of designing for service provision in a viable, sustainable manner. The second is the issue of water-security through better planning and management of water resources; that is of meeting basic household water requirements during droughts and dry spells, when the so-called no-source villages are in dire straits and contribute to a politically surcharged atmosphere.

There exists limited organized literature on policy and design alternatives in RWS. According to civil society institutions, these capital-intensive schemes have done little to meet the RWS challenge; instead, they advocate locally constructed and managed water sources, including roof water harvesting. The government as well as scientists argue that these can at best be supplemental and cannot be a substitute for a ‘proper’ RWS. One reason why we see not much common ground emerging is paucity of analyses.

Strategy for Future

The global challenges of sustainable development also reflect India’s sustainable water use. The challenges are also faced by the governments- both at national and state level, and institutions concerned with developmental assistance. Thereby, in future, the policies, programmes and investments should support, not only economic development, but also: a) distribute the gains of development in a more equitable manner, with a particular focus on reducing poverty, b) avoid sacrificing the interests of future generations to meet the need of the current generations, c) build on emerging global consensus that natural resources and other valuable environmental assets must be managed sustainably.

1. How much water will be needed in the coming decades and to what extent and in what ways they can be met is therefore an issue of critical importance. Assessments of the future water scenario (Vaidyanathan and Subramaniyan,

2004; NCIWDP, 1999) depend critically on: (a) the technically feasible and economically liable augmentation and surface and groundwater; (b) the quantum of water needed to meet consumptive use of both agricultural and non-agricultural use; (c) the ratio of consumptive use to gross utilization in different uses, the scope for and prospects of increasing this ratio; and (d) increasing the productivity per unit of consumptive use of water.

2. State governments need prioritise investments to renovate/modernize/ complete the existing systems which account for nearly 40 percent of the irrigated area from the major and medium irrigation projects (Rao, 2003). The rate of return from such investments would be very high when compared to the projects that create new irrigation potential. Modernization of the delivery systems and the distribution channels for the existing projects would have a high pay-off, as they would facilitate a clear definition of property rights or entitlements of farmers and their effective enforcement.

3. The price and procurement policy of the government has an important bearing on the efficiency and productivity of water use through its impact on the cropping pattern. A glaring illustration of this is the price policy for rice and what in the recent period which has resulted in the accumulation of over 60 million tonnes of foodgrains – nearly thrice the actual requirement with the Food Corporation of India (Rao, 2003). It has been estimated that for each hectare of rice raised under irrigated conditions, as much as 16,000 tonnes of irrigation water is applied in the semi-arid North-Western Indian States (Dhawan, 2001), from where a bulk of rice is procured by the Food Corporation of India.

4. Savings in irrigation water need can be promoted (upto 25-40 percent) through intermittent submergence and transplanting rice seedlings at about the time of onset of monsoon rains. Experiments in various parts of country has also shown that 'Madagaskar Method' (also known as SRI method) of rice cultivation would help to save water (20-30 percent) and enhance yield levels (30-40 percent). Similarly, water savings from drip irrigation (upto 50 percent) and sprinkler irrigation (upto 25 percent) is possible, as shown by several studies (Dhawan, 2001; Murthy and Deshpande, 2004; Sivanappan, 2001). Only one percent of the irrigated area in the country is presently covered by the drip and sprinkler methods of irrigation.

5. Water conservation need to be brought into mainstream debate in the country, alongwith water rates. A system of rationing water supplies in water-scarce regions even with moderate charges can induce farmers to increase water productivity, provided supplies are reliable in terms of quantity and timings (Berkoff, 1990; IWMI, 2001).

6. Water Users' Associations and Panchayats should be fully empowered and induced to charge and collect irrigation fees from farmers on the basis of actual

water consumed (Rao, 2003; Raju *et.al.* 2004). The water fee collection can still be made by the Revenue Department but should be accountable to and funds should be transferred to local Water Users' Associations.

7. In future years, stress should be more on institutional reforms, which hold key to raising water productivity by bridging the vast gap that now exists between the knowledge and its application. Recent studies (Gulati, Ruth & Raju, 2005; Shah, 2005, Rao, 2003, Vaidyanathan, 2003; World Bank, 2004) have emphasized the need and scope for understanding the institutional reforms in Indian water sector.

8. Rationing in electricity supply, improving pump efficiency and fixing differential rate of tariff may bring about the desired improvement in efficiency. However, this needs to be supported by improved quality in electricity supply and farmers' awareness about the effects of over-exploitation of the resource. In order to optimally exploit groundwater, policies concerning groundwater should consider the role of surface water bodies like irrigation tanks, canals, reservoirs, and watersheds. Workable programs and policies should be specific to each condition**.** Policies of isolation distance, power pricing and subsidies to adopt water saving technologies are sine-quo-non-for conservation of groundwater resources. Cropping pattern and pricing support also plays a significant role in groundwater use and conservation.

9. Need to reverse the usual approach of proceeding from projects of demand to supply-side answers in the form of 'water-development' projects; start with a recognition of finite supply and learn to live with it; shift the focus from 'water resources development' to 'water resources management' (Iyer, 2003).

10. We need to intensively promote water harvesting as a strategy to meet human needs. In management terms it means (based on Agarwal, 2001): (a) making water everybody's business. Every household and community has to become involved both in the provision of water and in the protection of water resources, (b) making water the subject of people's movement, (c) re-establishing the relationship between people and their environment. Turning water into a sacred element of nature, (d) empowerment of our communities to manage their own affairs with the state playing a supportive role and civil society playing a critical role in encouraging equity and sustainability in the use of water.

The strategy has to cover interrelated objectives like

a) Improving livelihood systems both in rural and urban areas through
    a. better management and improved productivity of water resources
    b. support for institutional reforms, incentive structures, and improved governance, particularly decentralization efforts
    c. improved infrastructure, including access to safe and adequate drinking water, and access to adequate and timely supplies for agriculture.

d. Improved access to efficient and adequate energy sources and alternative renewable fuels
e. Enhance support to initiatives to eliminate the gender gap and foster inclusive institutions.

b) Reduce environmentally related health risks by
  a. Providing access to safe and reliable drinking water supplies both in rural and urban areas
  b. Institutional reforms to improve service delivery, fiscal sustainability and public-private partnerships.

c) Reduce vulnerability to natural and environmental disasters through
  a. Changes in land use planning,
  b. Disaster preparedness
  c. Community involvement and awareness creation,
  d. Water conservation and management
  e. Social protection measures to protect people who are vulnerable to natural disasters.

d) Improving the prospects for and the quality of growth through
  a. Integrating water resources availability and access into all developmental plans and programmes at all levels
  b. Mainstreaming sustainable water use in all developmental sectors
  c. Enhancing water resources projects quality through strengthened implementation of safeguard policies

e) Protecting the quality of the regional commons through
  a. The management of shared river basins across states – e.g., between Punab and Haryana, Tamil Nadu and Karnataka, Maharashtra, Karnataka and Andhra Pradesh.
  b. Enhance cooperation among riparians on other internationally shared river basins- e.g India and Bangladesh.

As part of the implementation arrangements it is necessary to adopt the following steps:

a) Prioritise the investments and project components. Need to focus on mainstreaming water resources use into sectoral development plans.

b) Promoting participatory and community-driven development approaches (in watershed, irrigation and drainage, wastewater treatment, groundwater use, rural water supplies, rain water harvesting and roof water harvesting – both in rural and urban areas), private sector participation, particularly in urban water supplies.

c) Enhancing water resources project implementation, operation, maintenance and monitoring quality through.
  a. Establishment of an independent safeguard review and compliance monitoring team.
  b. Systematic upstream review and input into project design beginning with the project concept stage.
  c. A project risk management and compliance monitoring system.

d. Thematic joint social and environment reviews focusing on groundwater, surface water, and traditional sources.
e. Periodic skills enhancement for all state, river basin and project level staff.
f. Enhancement of local ownership and consensus building.
g. Continuous policy dialogue and training.

d) Intensify the use of sectoral-regional environmental and social assessments by building on the experience of the past three years in the water sector.

e) Strengthen analytical and advisory activities through
a. Filling critical gaps in knowledge and information by undertaking new analytical work. e.g., impact of declining groundwater table, potential of roof water harvesting both in rural and urban areas, rejuvenating traditional sources across the country, promoting community-driven approaches in water sector.
b. Addressing institutional priorities by focusing on helping build state level water resources department staff and users capacity in critical areas such as policy, incentives, and monitoring and enforcement
c. Promoting techniques that foster cross-sectoral integration, such as improved monitoring and evaluation of impacts and spatially based analysis of projects and policies.

Vision

At the outset, the water vision should be a shared vision. Separately at the national level and for each state. The vision has to be locally evolved and shared with the people, their communities, government agencies, non-governmental organizations, and civic groups. But first, there should be a thorough review of the water sector both at the national level. Clear examples are available both at state level prepared by the government agencies (e.g, Andhra Pradesh), and by the Area Water Partnerships[20] at the river basin level (e.g, Bhima river in Aurgangabad and Tampraparani river in Tamil Nadu). These vision documents have been designed locally after wider public consultations and taking care of emerging demands from the competitive sectors. The shared water vision of all stakeholders should indicate:

- clean, hygienic, accessible, affordable and secure drinking water supplies for the entire population.
- Sustainable levels of water extraction from rivers, tanks and groundwater – without jeopardizing their future use of vital ecosystem functions.
- Conservation of rainwater and its efficient use for agriculture, plantations, livestock and groundwater recharge.
- An efficient, well-managed and sustainable irrigated agriculture sector-enhancing value and ensuring farming livelihoods, but also avoiding wasteful

[20] Area Water Partnerships were set up under the Global Water Partnership through India Water Partnership.

use of water. Of great importance is the efficient use of water in agriculture – maximizing the return on water and the social benefits of efficient water-use.
- Mitigation of the effects of droughts, with short-term emergency responses and long-term planning.
- Prevention of the pollution of water resources used by people and livestock, agriculture and industry.
- Integrated governance of water- reflected by effective legislation, efficient government services that work in a coordinated manner, sound water information and data sets, adequate monitoring and applied research – so that we know where we are and what options are available to us.
- Participatory water management through effective institutional arrangements. Greater concern for water management at every level- individual, community, and government. Special emphasis on the participation of women and landless persons in decision-making.

But unfortunately, government agencies are yet to consider these vision documents (of Bhima and Tambraparani river basins) for policy dialogue and implementation.

Key Challenges in the water sector

- The water needs for drinking and domestic use are relatively insignificant load on the available resources, but the availability or quality of drinking water is often jeopardized by overuse of pollution in other sectors.
- The demands for municipal and industrial needs are on the increase, and these will have to be met from the present allocation to the agriculture sector. Agriculture is by far the largest water consumer in India. More efficient use of water in agriculture is therefore a top priority.
- Equally important, the harvesting and efficient use of rainfall is necessary to augment and retain an adequate freshwater resource base, including roof water harvesting both in rural and urban areas for drinking water.
- Rapid contamination of water supplies – due to increasing municipal, industrial and other uses (including aquaculture) – is reducing the amount of already scarce and good-quality water supplies. Proactive measures are therefore a priority to control or contain such pollution threats.

Water actions are therefore urgently required in many critical areas – improving the efficiency of irrigation water use, and removing the incentives that encourage wasteful water use (with special attention to rice, which is a high-water-requirement crop); protecting drinking water sources; preventing water pollution; controlling water logging and soil salinity; reducing the over-exploitation of groundwater; stopping the deterioration of water quality in rivers and in coastal areas; improving the use of rainfall for agriculture; protecting the water bodies in urban areas, and improving the management of tanks of various sizes in rural areas.

The sustainable development of water resources in the country will depend on four key activities, as listed out by the water conservation mission in Andhra Pradesh: a) securing drinking water demands in terms of quantity and quality, b) development of water planning, river basin management and prioritizing for sustainable water extraction, c) water resources development with respect to other state priorities in Vision –2020 of the India and of respective states, d) the development of an efficient and well-managed water sector. This approach to sustainable development requires a significant change in governance, involving policy development, organizational reform, use of economic measures, strengthening of legal frameworks and development of monitoring and regulation procedures. This approach needs to be supplemented with research and development, and capacity building (both community and government) through education and training.

Integrated Water Resources Management (IWRM)[21] is the preferred approach to water management. But IWRM requires a range of inputs like:

a) State-level policy decisions,
b) Initiatives at the district level,
c) Legal and institutional frameworks,
d) Capacity building, research and development,
e) Engaging wider society.

Central to IWRM is the coordinated development and management of water, land and related resources to maximize social development and economic growth while safeguarding important ecological values. The preferred approach for using IWRM includes:

- Managing all available water and determining sustainable limits of use.
- Using stakeholder participation at all levels of decision-making.
- Reorienting government services to deliver coordinated action at district and village levels.
- Moving water to its most efficient use.
- Developing water policy and a state IWRM plan.
- Facilitating resources for research and development.
- Improving water information in order to achieve effective water management.

As part of the action plan strategy requires to design:

a) short-term recommendations
    a. constituting water conservation missions at state level
    b. developing a state-level action plan for the next one/two years
    c. initiating several district level pilot projects
    d. initiating river basin level pilot projects
    e. establishing a monitoring and learning procedures to assess the implementation of water vision.
b) Long-term recommendations
    a. Develop
        i. State water policy

[21] Global Water Partnership has developed a toolbox to evolve IWRM plans and practice, available in www.globalwaterpartnership.org.

ii. Integrated water resources management plan
iii. River basin management plan

b. District action plans
c. Water research programme

Institutional strengthening

For the Institutional strengthening of the actors in water management and planning, Vaidyanathan and Oudshoorn (2004) suggest the following as essential to enhance research on:

a) the existing legal framework, and its underlying concepts; interpretations thereof, reflected in case law and tribunals awards, and implementation of judicial decisions;
b) the elements of a framework of laws and institutions to facilitate and promote negotiated settlement among claimants for water;
c) the structure and functioning of existing irrigation and water management institutions in selected systems, the perceptions of concerned interests (different user groups, managers, those adversely affected) regarding defects and their attitudes to alternative ways of organization;
d) a critical assessment of the experiments with user participation and their lessons;
e) collate and evaluate experiences of participatory, integrated management in other countries and their lessons for design of better institutional arrangements in India.

Further, based on the performance of the river basin boards in the Netherlands and France, India can take up action research studies of the legal, institutional, and operational aspects of participatory planning and management of water along the lines of the Water Boards of the Netherlands and the French River Basin Planning Authorities.

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Annexure-1

State-wise net area irrigated by source 1999-2000 (provisional)

(in 000' ha)

Zones / States	Canals			Tanks	Wells		Other sources	Total net irrigated area
	Govt.	Private	Total		Tube wells	Others		
North	**5990**	**141**	**6130**	**99**	**12972**	**473**	**388**	**20031**
Haryana	1441	-	1441	1	1432	1	14	2888
Himachal Pradesh	3	-	3	0	10	3	85	102
Jammu & Kashmir	139	140	278	3	1	1	21	303
Punjab (r)	1296	-	1296	-	2995	10	3	4004
Uttar Pradesh	3109	-	3109	95	8797	458	233	12692
Chandigarh (h)	-	1	1	-	1	(a)	-	2
Delhi	2	-	2	-	36	-	2	40
South	**3584**	**5**	**3589**	**1682**	**1639**	**2609**	**686**	**10307**
Andhra Pradesh	1634	(m)	1634	651	1000	900	199	4384
Karnataka	994	-	994	245	282	477	350	2548
Kerala	81	5	86	53	122	-	119	380
Tamil Nadu	867	1	868	633	222	1231	18	2972
Pondicherry	8	-	8	-	13	-	(a)	22
A & N Islands (k)		-	-	-	-	-	-	-
Lakshadweep	-	-	-	(a)	-	1	-	1
East	**2896**	**298**	**3193**	**728**	**2998**	**647**	**902**	**8468**
Arunachal Pradesh (k)	-	-	-	-	-	-	35	35
Assam(b)	71	291	362	-	-	-	210	572
Bihar	1136	-	1136	155	2008	85	241	3625
Orissa @ (i)	949	-	949	305	299	537	-	2090
West Bengal (p)	717	-	717	263	689	23	219	1911
Manipur (j)	-	-	-	-	-	-	65	65
Meghalaya	-	-	-	-	-	-	48	48
Nagaland	-	-	-	-	-	-	63	63
Sikkam (c)	-	-	-	-	-	-	16	16
Tripura (d)	21	-	21	5	2	2	6	35
Mizoram	2	7	8	-	-	-	-	8
West	**5080**	**2**	**5082**	**286**	**3145**	**8951**	**961**	**18434**

Gujarat (r)	602	-	602	25	868	1542	25	3082
Madhya Pradesh	1802	2	1804	193	1310	2547	887	6740
Maharashtra (est) *	1051	-	1051	-	-	1921	-	2972
Rajasthan	1619	-	1619	78	947	2920	47	5612
Goa	4	-	4	-	-	18	-	22
Daman & Diu (g)	-	-	-	-	-	1	-	1
D & N Haveli	2	-	2	-	(a)	2	2	5
All-India 1999-00	**17550**	**445**	**17995**	**2706**	**20953**	**12679**	**2905**	**57238**
1998-99	**17205**	**503**	**17708**	**2939**	**20404**	**12754**	**3272**	**57077**

Note : 1. 'a' below 500 hectares, 2. 'b' relates to the year 1953-54, 3. 'c' relates to the year 1984-85, 4. 'd' relates to the year 1992-93, 5. 'e' relates to the year 1996-97, 6. 'f' relates to the year 1988-89, 7. 'g' relates to the year 1989-90, 8. 'h' relates to the year 1987-88, 9. 'i' relates to the year 1993-94, 10. 'j' adhoc estimates, 11. 'k' relates to the year 1994-95, 12. 'p' relates to the year 1985-86, 13. 'q' relates to the year 1995-96, 14. 'r' relates to the year 1997-98, 15. @ relates to major, medium and minor for canals, tanks and wells, 16. 'm' Included under Govt. canals, as separate break up for private canals is not available, 17. * relates to surface irrigated area, 18. est. estimated.

Source : Fertiliser Statistics, 2002-03, The Fertiliser Association of India, New Delhi.

ISSUES IN STATISTICAL ACCOUNTING OF
GROUNDWATER RESOURCES

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The need for accounting of water resources in general and of groundwater in particular arose from the DUBLIN PRINCIPLES (1992) on WATER which enunciated that

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment;
- Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels;
- Women play a central part in the provision, management and safeguarding of water;
- Water has an economic value in all its competing uses and should be recognised as an economic good."

Of these the recognition that water has an economic value in all its competing uses is in order. However its application in different countries and regions depends upon the synergies between policy makers and users of water, since even before realization of water as an economic good, its proper accounting matters the most.

The accounting of water also depends upon how the derived demand for water can be estimated. It is to be appreciated that more than 85 percent of water resource in India is used for agriculture through irrigation of crops. Thus, water accounting plays a prominent role in agriculture rather than in domestic and industrial use. It is relatively easier to estimate the balance of 15 percent, while it is difficult to measure the water use in agriculture where it is accounted as ‘consumptive use’. By consumptive use, once water is applied, it cannot be recovered. While in ‘non consumptive use’ such as domestic and industrial or municipal uses, water used can be accounted both as input (through water meters) as well as though output (of used or sewage water). The Following diagram indicates the demand for water for various uses, where its uses in food production dominates over all other uses. While the use of water in food production is the highest, its economic and social benefits generated are lower in comparison to its use in industrial an domesticuses.

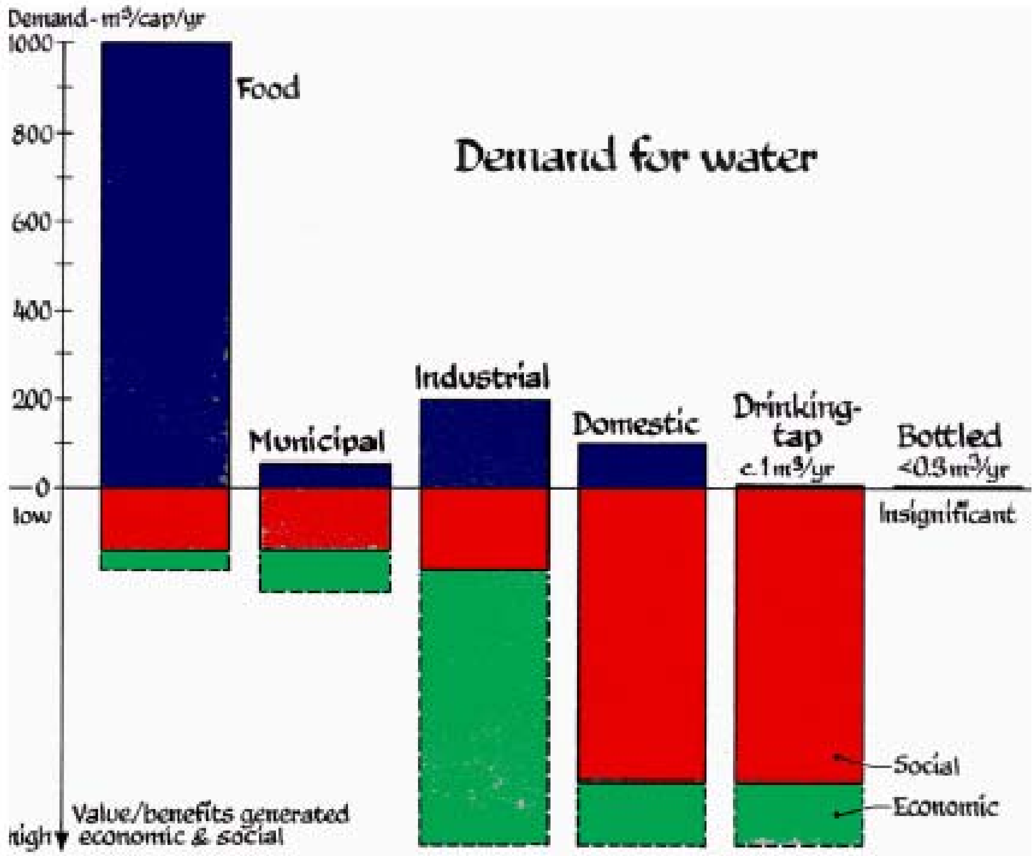

Figure 2.2 *Demand for water (indicative for semiarid circumstances) in m^3/cap/year.*

In Karnataka, as on March 1998, the **a**nnual Natural Recharge of groundwater is 1.6175 million ha meters. With the provision for drinking and industrial use being 0.2418 MhaM, the available recharge is 1.3757 MhaM. The utilisable recharge is 1.3265 MhaM and the net draft is 0.44198 MhaM. The balance groundwater available is 0.93372 MhaM. The utilisable irrigation potential is 2.44268 MhaM for development. These show that the stage of groundwater development is only 33 percent. This situation is the same for the country also. This explicitly means that both in the country and in Karnataka, 67 percent of groundwater is yet to be extracted and utilized presenting a rosy scenario. However the nuances of properties between surface and groundwater and the associated externalities render the resource not easily amenable for extraction and use.

The surface water is a visible resource, hence surface flow measurements are available at the basin / dam / reservoir level. However the micro measurements at farmer level not available. Thus, top down measurement (from dam to farmer) is possible, while bottom up is not. Checks by environmentalists have prevented expansion of surface water. Thus, surface water contribution is below that of groundwater in India. Currently surface water irrigation forms only 44 percent of total irrigation while groundwater is 56 percent.

The groundwater on the other hand is an invisible resource, hence both recharge (input) and discharge (output) are to be estimated. Here, macro estimates for State/watershed level made, while again micro level estimates at farmer level are not available. The top down estimate of groundwater use from watershed to farmer level is impossible and bottom up estimate of groundwater use from farmer to watershed level is also impossible due to problem of linearization. Further, unlike the role of environmentalists in surface water, there has been no check on extraction by anyone including farmer regarding its extraction and thus, it contributes to more than 50 % of total irrigation.

In Karnataka, according to the Minor irrigation census of 2000, there were 851331 wells of which 39 % were dug wells, 61 % were borewells. There were **859770 electrical pumpsets of which** 61 % were fitted to borewells, 33 % to dugwells. There were **31795 diesel pumpsets of which** 91 % were fitted to dug wells, and 9 % to lift irrigation.

Considering the pattern of ownership of wells (Table 1), it is apparent that 80 percent of the dug wells as well as borewells are owned by small and marginal farmers in Karnataka.

Table 1: Pattern of ownership of wells in Karnataka (2000)

Farms	Dug wells	Shallow tubewells	Surface flow	Surface lift	Total

Marginal farmers < 1 ha	46	42	47	22	42
Small farmers 1-2 ha	33	39	23	28	36
Medium farmers 2-10ha	21	19	24	44	21
Large farmers > 10 ha	03	0.002	06	6	1
Total	327410 (100)	529301 (100)	1754 (100)	59579 (100)	918044 (100)

Considering the proportion of wells in command area of surface water bodies, about 8 percent of dug wells and 5 percent of borewells were in the command area of surface water bodies. Thus 92 percent of dug wells and 95 percent of borewells were constructed / drilled outside the command area of surface water bodies. Accordingly most of the wells suffer from low recharge.

The 2000 Census however indicates that even with this predicament of locating outside the command area largely of irrigation tanks, only 4 percent of dug wells and 4 percent of borewells were not functioning, while the rest were functioning. The Cenus further indicates that there were 859770 electrical pumps of which 33 percent were fitted to dugwells, 61 percent to borewells. There were 31795 diesel pumps. About 70 percent of dug wells pump upto 4 hours / day, 29 % of dug wells pump 4-8 hrs / day, 36 % of borewells pump upto 4 hours / day and 61 % of borewells pump 4-8 hrs /day. Considering the Horse power of the pump sets, it is reported that 32 % of dug wells have 4-6 HP pumps, 46 % of dug wells have 6-8 HP Pumps. Thus, around 80 % of dugwells have below 8 HP pump sets. Around 11% of borewells have 4-6 HP pumps, 63 % of borewells have 6-8 HP pumps. Thus, 75 % of borewells have below 8 HP pump

Challenges in accounting groundwater

The linear extrapolation of groundwater resource extraction is always beset with problems, since groundwater demand is derived from demand for irrigation. Further, not all farmers have similar economic response to groundwater use as some grow vegetables (as in Kolar), paddy (as in Madhugiri), Areca (as in Channagiri), Jowar, cotton (as in Bellary). Further, not all crops have similar water requirement and the same crop uses different volumes of water in different seasons on different soil types differing with different methods of irrigation. For instance, Paddy uses 40 acre inches, Sugarcane 80 acre inches; Ragi, Groundnut – 8 acre inches. Now paddy can even be grown with 30 acre inches of water under System of Rice Intensification / aerobic rice methods of cultivation. Thus, groundwater utilization varies widely with soil type, crop cultivated, potential evapotranspiration, drainage, extent of leveling, frequency of irrigation / method of irrigation (flooding, ring basin, drip/sprinkler), number of rainy days, intensity of rainfall, availability of electricity, time of availability, well / aquifer characters, type of the well, age of the well, horse power of the pump, Number of stages, pump quality, pipe quality, whether overground storage structure built (coping mechanism for vagaries of electrical power), depth of the well and other dimensions of the well, whether isolation distance maintained, the number of initial / premature failures already suffered by the farmer, financial capability of farmer, effective demand for the crop/s cultivated using irrigation, water markets (have potential to improve efficiency of water use) and so on.As on 1998, Karnataka had 13 grey blocks, 8 dark blocks and 6 overexploited blocks. However by 2000, the definition of dark, grey and white teshils is replaced by the groundwater situation in watershed context.

Solution for proper accounting for groundwater

The installation of electric meter measures only the electricity used in lifting water, which is an indirect measure, since depth of irrigation well has no relation with the yield of groundwater. Thus, installation of water meter is though vital but expensive, unless farmers take initiative to install. There is further quid-pro-quo with power sanction. Water meters usually cost

Rs. 6000 – 8000, have 3-4 years life, hence need to be changed periodically. Groundwater regulation is in order at least to the extent of educating farmers regarding water budgeting and hence in facilitating groundwater accounting / measurement. This will educate farmers in prudent water use

Rural Water Supply in India:
In Search of Institutional Alternatives[22]

K.V.Raju[23]

1. Background

Rural Water Supply is one of the major challenges that has been addressed by the government and attempts made towards tackling the crisis in providing safe and adequate water to the rural people. Lately, the problem has become particularly severe in rural areas. A review of the government's efforts in implementing various programmes, policies adopted has shown inadequate progress in providing sufficient quantity of potable water to all persons (Das 2001; and Rajashekar and Veerashekarappa, 2002, Hirway, 2004; Jaldisha, Durgaprasad). Several factors like increased urbanization leading to negligence of traditional water sources, lack of water management, resource depletion due to overexploitation of existing resources, ineffective co-ordination between departments and inadequate institutional setup in addressing the problem have led to the severity of the problem over the years.

Various dimensions of the problem have been addressed for the effective implementation of rural water supply schemes, which is dependent on a number of factors - Social, Technical, Economic, Institutional, Environmental, Legal and Political. It is important to understand the existing situation and the complexities in order to address the problem in the context of project design and implementation and factors affecting sustainability of Rural Water Supply (RWS) programmes. One of the major causes seen is the reversal of environmental quality, supply-demand relationships in just a few years. This is mainly due to economic growth accompanied by population increases, over-exploitation and mismanagement of natural resources, and urbanization and their cumulative effects are resulting in decreasing supply of clean water and other environmental goods.

Since water resource size is shrinking, several issues are being seriously addressed such as water management in a holistic way, through water quality maintenance, water allocation to different sectors, decentralization in water allocation, sustainable use of water, improvement of sanitation, water pricing, institutional set-up, technical solutions and awareness creation. Conserving water and using it judiciously has come about only with increasing shortages, depletion of water resources and extremities in weather conditions causing disparity in water availability. In this context, the present paper makes a comparative analysis of Karnataka and Gujarat through an analysis of the existing situation, identifying key issues, describing major approaches adopted, understanding field realities, implications for future action and arguments for change.

2. Existing Situation

[22] This paper is based on a larger study supported by IWMI-TATA.
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Considering the bare situation, since the First Five-Year Plan (1952-57), \$6.5 billion have been invested in India by the central and state governments to provide potable drinking water in rural areas. However, according to the latest survey (NSSO 1998), 69 per cent of the households have access to modern sources of potable water (Table 1) and much less in the case of rural areas. According to the National Family Health Survey (1998-99), 74 per cent of urban and 25 per cent of rural households have access to piped water supply. Hand pump as a source of drinking water figures after piped water. Eighteen per cent of urban households and 47 per cent of rural households depend on it. The remaining households still depend on unsafe water sources. Thereby, the problem of rural drinking water supply and sanitation has not been fully resolved.

Access to Principal Sources of Drinking and Domestic Use of Water

(Per centage Distribution of Households - 1988, 1993 and 1998)

Source	Principal source of drinking water			Principal and Supplementary for different purpose 1998					
	1988 (44th round)	1993 (49th round)	1998 (54th round)	Cooking		Bathing		Washing utensils	
				PS	SS	PS	SS	PS	SS
Modern	54.3	63.4	69.0	69.6	45.1	60.1	43.3	64.9	44.7
Traditional	45.1	36.5	30.7	30.0	53.3	39.2	55.5	34.7	53.9
Others	0.6	0.3	0.2	0.4	1.6	0.4	1.2	0.3	1.3
All India (rural)	100	100	100	100	100	100	100	100	100

Source: Computed from 44th, 49th and 54th Round of NSSO data.

PS: Principal Source, SS: Supplementary Source

We have yet to get a clear picture of the coverage of villages. Agencies indicate contradictory figures. For instance, NCAER (1994) survey concludes that about one-half of all villages in India did not have any source of potable drinking water, which was in the contrast to the official claims that by the year 1994 more than 80 per cent of villages were provided with adequate potable water. The Eighth Five-year Plan (1992-97) had set a target of achieving 100 per cent coverage in providing safe drinking water by the turn of the century. At the end of the Eighth Five-year plan (1997), the approach paper to the Ninth Five Year Plan (1998-2002) claimed "efforts will be made to provide access to safe drinking water facility to the entire population in urban and rural areas in the next five years". Besides, put the requirement of funds at a staggering sum of Rs 40,000 crore; Further, it recommended for involvement of the private sector on the lines of Sri Satya Sai Trust of Puttaparthy in Andhra Pradesh. This change in policy argument has due to resource constraint and magnitude of the problem; for instance, the estimates based on expenditure data, indicated that if the present rate of budget allocation has followed, the amount would be just enough to meet the expenses on replacement of old systems, operation and maintenance activities (Pushpangadan and Murugan 1998).

The Seventh Five-Year Plan identified the strategies followed in the existing modes and indicated two factors which contributed to the failure: One, it was essentially a supply-driven, top-down approach that did not take into account the pattern and intensity of demand for this service. Second, lack of community participation in the provision of this service rendered it inefficient and unsustainable. To overcome these problems, it was suggested making beneficiaries share a portion of the capital cost and pay for services to maintain the assets. In support of this, the eighth five year plan policy paper stressed the need for devolution of responsibility to grass roots levels and recommended a change in mind set, through four stages of intervention; viz., a) creating awareness; b) developing action plan to ensure the decision-making management and financial autonomy; c) strengthening the institutions and; d) improving monitoring, accountability and transparency of the sector (World Bank 1999). Further, providing logical support, policy instances were cited from worldwide experiences showing a positive correlation between beneficiary involvement, on the one hand, and the efficiency of implementation and the effectiveness of the project sustainability on the other (Harmeyer and Mody, 1997, Pushpangadan and Murgan 1998). Forty-eight per cent of the recent World Bank projects have included community participation in their design as a way to increase project efficiency (Churchill 1994) and reduce cost. Recent literature on water supply systems shows that, proper institutional framework and collective action improve the efficiency (Narayan, 1993). In state led planning, old paradigm of centralized decision making and bureaucratic allocation is fading fast to pave way for a decentralized allocation and stakeholder participation (Saleth and Dinar 1999).

The recent bilateral and multi-lateral rural drinking water supply and sanitation programmes have incorporated in their project designs most of the strategic points mentioned in the Eighth-Five Year Plan. Based on these experiences, government initiated reforms and the states were provided incentive in the form of additional funds for initiating reforms with the following broader elements:

- Adoption of a demand-driven approach based on empowerment of villagers to ensure their full participation in the project through a decision-making role in the choice of schemes design and management arrangement.
- Focus on village level capacity building (Village Water and Sanitation Committee);
- Ensuring an integrated service delivery mechanism by streamlining the functions of the agencies involved in project implementation and;
- Ten per cent (at least) capital cost sharing and 100 per cent sharing of O&M cost by users. The proportion of capital cost shared should increase proportionately with increasing service demand. This contribution can be in the form of cash or kind (labour, land or material)
- Taking up of conservation measures for sustained supply of water through rainwater harvesting and groundwater recharge structures.

According to the guidelines set by the Union Government, 20 per cent of the outlay will be earmarked under ARWSP to those states, which implement reforms, and the share of the states, which do not introduce the reforms, will be transferred to the states, which have implemented the reforms.

3. Front line Issues

3.1. Resource Depletion - an Uncontrolled Arena

Groundwater forms one of the important sources of water for drinking and irrigation. Groundwater serves 85 per cent of the rural population's drinking water requirement and nearly half of the urban and industrial requirements in Karnataka. The National Family Health Survey indicates that only 3 per cent of the households in 1998-99 made use of surface sources compared with 11 per cent of the households in 1992-93. With the gradual decline of traditional sources, people started extracting groundwater not only for drinking but also for agriculture and industrial purposes. The overexploitation of groundwater has resulted in the failure of existing wells used for irrigation and drinking water.

In Karnataka, groundwater depletion has been occurring since three decades while in Gujarat, it has witnessed a whopping 104 per cent increase in its groundwater extraction during the two decades. It was a combination of situations where Departments of Mines and Geology had discovered the groundwater potential, Land Banks lent loans while both the states were providing heavy subsidies on electricity tariff to enable the farmers to extract water from deeper aquifers. The resultant effect was the booming of wells and farmers shifted to growing rice and sugarcane, neglecting open wells. It was during the 80s that groundwater was utilized to the maximum and the department classified areas based on levels of extraction and no loans were given but the situation could not be reversed.

a) Impact on rural livelihoods - Severe water scarcity during dry seasons lead to grave consequences both in Karnataka and Gujarat. It is commonly highlighted in the media on the effects of drought on rural livelihoods during the summer seasons. The number of borewells with hand pumps are becoming defunct due to depletion of groundwater source, as a result of indiscriminate drilling of bore wells, non-availability of acquitters, water quality problems, non-availability and technical solutions on building artificial recharge structures (GoK, 1996). Migration to other villages and urban areas is another common feature where the children and the old are left behind leading to psychological and physical stress to the whole community. In Gujarat, in the last three years (2000-02 - largely drought years) and over the last 76 years, the state has faced droughts in 28 years. In the drought years, on an average, some 6,000 villages are supplied with drinking water by tankers. Even during normal periods some 1,500 to 2,000 villages are provided water with water tankers.

b) Coping interventions during scarcity – In Karnataka, while water supply is affected during severe drought it has been substituted mainly with tankers while migration during summer is left as the only alternative in some regions. In Gujarat, as per the government estimate, about 9,500 villages confronted the severe water scarcity situation that resulted in massive loss of livelihood opportunities, threatened household food security and forced large-scale out-migration. Water was supplied through tankers to 3,000 villages and rail wagons in Jamnagar. In some coastal villages, people evolved their own solution to tackle the drinking water problem by constructing 'Bandhara'.

c) Major changes - Following severe depletion, laying a pipeline from Narmada river was initiated in Gujarat, but in Karnataka no such massive projects were undertaken. Presently, the current water charges are very low and recovery rates are even lower. The estimates of the capital and running costs of Narmada pipeline are not known but plans to charge on a litre basis through distribution network to be taken over by Panchayats and village water committees are on. Regional water supply schemes[24] are commonly found in Gujarat. However, multi-village schemes[25] are often adopted in certain parts of Karnataka and Gujarat.

d) Groundwater control measures There are a number of complex legal issues when matters regarding integrated development of utilisation of groundwater, water rights and people's participation are considered. The property based groundwater rights and the rights claimed by the state in respect of all surface water are unsuited to conditions in which water resources are scarce and fierce competition among various uses exists. All groundwater existing and found beneath private property is fully under the control of the owners of the land. Inadequate regulatory restrictions on the exercise of private property rights in groundwater result in excessive withdrawals in many areas and participatory process in the groundwater management is recommended in which the role of the state could be that of a facilitator and empowerer and the prescribing regulator and the role of the community organization is an implementing regulatory agency of the scarce resource.

Legal regulatory mechanism for groundwater development and control in Gujarat does not exist while the government of Karnataka has now introduced groundwater control measures to protect drinking water sources. The Karnataka Groundwater Act of 1999 imposes restriction on sinking of wells within a distance of 500 metres from a public drinking water source without the permission of an appropriate authority. The authority is authorized to avert withdrawal from existing wells or even a watershed area by declaring any area as water scarce to protect drinking water wells (Kolavalli and Raju, 2003). The Act also empowers the local authorities to close down a private borewell, if it is affecting drinking water source. Thus, indirectly making farmers to shift to less water intensive crops. With no stringent regulations on groundwater, the groundwater resources have been overexploited. State government's plan to come up with a comprehensive legislation prohibiting sinking of new borewells Bill in 45 drought taluks of the state till the groundwater table is replenished was reported (Deccan Herald 2003). Lately, there is increased compulsion to bring about legislative reforms in groundwater control.

3.2. Deteriorating Water Quality - Serious Cause for Concern

Both Karnataka and Gujarat face severe water quality problems. The coastal areas face severe salinity ingress, while large sections are affected with Fluoride, TDS and Nitrate contamination. In regions like North Gujarat, which is underlain with deep alluvial aquifers, uncontrolled exploitation of groundwater has resulted in mineralization of

[24] A number of villages are connected through a pipeline with one or more sources
[25] Pipeline laid from a source belonging to neighbouring village or area

groundwater. High levels of TDS and salinity in groundwater have affected large parts of Central and North Gujarat (CGWB, 1998). The concentration of TDS ranging from 3,500 and 4,000 ppm as against permissible limit of 15,00 ppm while chlorides from 1,200 and 1,500 ppm as against 500 ppm. Out of the 18,594 villages in Gujarat, over 2,500 villages are affected with the problem of excessive fluorides in groundwater. Nearly 800 habitations in 19 districts face excess nitrate in drinking water supply.

Number of Habitations Affected with Quality Problems

Quality affected	Karnataka (habitations)	Gujarat (villages)
Fluoride	5,838	1,867
Nitrate	4,077	657
Salinity	NA	773
Iron	6,633	NA
Brackishness	4,460	NA
Total	21,088	3,279

Source: RDPR Document, 2003 and GJTI, Gandhinagar

a) Bacterial contamination: Bacterial contamination in Gujarat depicts the seriousness of the problem while similar data for bacterial contamination are not available in Karnataka. Hence, the incidence of water contaminated diseases have been taken as a proxy to arrive at the intensity of the problem. Though it is difficult to confirm how many persons were affected by these diseases as many cases are not treated in the government hospitals and the cases treated outside the hospitals are not reported, thus the incidence is under reported. Accordingly, the incidences of Gastroenteritis and Malaria cases are increasing. In fact, these diseases are becoming a major problem in the rural areas.

b) Negative Health impacts: People in both the states, Gujarat and Karnataka, are encountering with serious health impacts due to high mineral containing groundwater for human consumption resulting in widespread problems of kidney stone, indigestion, arthritis, affecting the rich and the poor alike. Unsafe and poor quality water adversely affects the health status of the people. For instance, presence of chemicals like fluoride in excess quantity (more than 1.5 PPM) causes dental and bone hazards, while skin rashes result by consuming water with excess brackishness. Microbial contamination is the more important and frequent cause of ill health, with 20-30 infectious diseases (viral, bacterial, protozoan and helminthic) being transmitted through water.

c) Reasons for quality decline: Degradation in water quality has been observed due to various reasons. Groundwater sources are contaminated due to disposal of untreated sewage, disposal of industrial effluents without treatment, disuse of wells, extensive usage of pesticides and chemical fertilizers, over-exploitation of groundwater and poor sanitation and hygiene. Whereas the aforesaid problems are common to both the states, in Gujarat the predicament of excess fluoride and nitrate is particularly acute in the entire Saurashtra and Kutch districts. Parts of Kheda and Banaskantha are also affected by such deterioration in water quality. In most parts, the TDS content can be observed to be much higher than the permissible limits. Further, the entire coastal belt, stretching from the north western point of Kutch through Saurashtra districts to the southern part of Kheda has been affected by saline ingress rendering the groundwater unsuitable for drinking.

d) Role of Agencies: There are no defined roles in the RDPR for maintaining water quality by any particular segment. However, RDED is supposed to test water quality in rural areas. The usual procedure followed is that the RDED tests the water quality in the newly dug borewells before supplying it but no regular monitoring is followed upon. In Gujarat, so far as testing and determining the nature and extent of water quality at the village level is concerned the sole authority rests with the GWSSB, which has a fairly well-developed specialised body called the Gujarat Jalseva Training Institute (GJTI). In addition to regional water quality testing facilities, the GJTI houses both the hardware and software for quality analysis and training for curbing the problem at the micro level. In Karnataka, the Rural Development and Engineering Department has taken up testing of drinking water samples in rural areas on a massive scale. The sample test has been completed for 37,776 sources in 45 taluks, out of which 21,088 have quality problems. Out of the total 20,929 (39 per cent) habitations affected a large number of them are affected by iron excess, followed by excess fluoride, excess TDS and nitrate in descending order[26]. According to the survey conducted by GOG (1996), there are 1,048 villages affected by high TDS and salinity in groundwater from the point of view of drinking water supply. The Departments have relaxed the permissible limits because a majority of the water supplied for drinking purposes by public bodies like panchayats and municipal corporations are non-potable and may raise public outcry otherwise.

e) Inadequate functioning of Laboratories: Huge investments were made in installing laboratories in some districts of both Karnataka and Gujarat. Laboratories initiated in both the states are not functioning effectively in respective districts. Lack of skilled staff, cost factors, poor co-ordination have been some of the reasons resulting in lack of systematized conducting of testing on a regular basis. A major reflection of such poor and ineffective functioning of the laboratories is the absence of comprehensive and regular collection and analysis of water samples and dissemination of the results and steps taken to rectify the same. As often such tests are carried out on demand, rather than a routine responsibility, stymies their utility.

In Karnataka, only 11 out of the 19 District level laboratories set up at the ZP level are functioning due to inadequate trained staff. Public Health Institute and District level Public Health Laboratories of the Health and Family Welfare Department have 28 laboratories. Each of the above have their own specific roles with limitations as PHD conducts test for chemical and bacteriological contamination, Divisional laboratories conduct only food testing and 19 District laboratories are devoid of necessary equipment and trained staff for chemical examination. The Department of

[26] Among the districts, Tumkur has a large number of habitations with quality problems, followed by Kolar, Mandya and Bangalore rural. The fully covered habitations affected with quality problems are estimated to be 5,810 (GoK, 2003).

Mines and Geology conducts water quality testing in observation wells twice in a year and do not have the facility to test bacteriological contents (State of Environment report and Action Plan - Karnataka 2003).

f) Treatment methods ineffective: Major intervention that the state governments have undertaken has been installation of defluoridation units, desalinization plants. Defluoridation and desalination plants have uniformly failed owing to reasons other than technical/engineering feasibility; some of them being lack of skilled manpower, improper selection of plant size and membrane, lack of proper attendance of the system and poor investment in maintenance and repair accompanied by poor recovery charges for O and M resulting in defunct schemes.

g) Additional costs: The RDPR is burdened with additional costs in tackling declining water quality problem. Till 2004, 99 projects costing Rs.420 crores have been cleared under Sub-Mission programme. Out of these, 45 projects costing Rs.100 crores have been taken up and 9 projects completed while the remaining 36 projects are in different stages of progress. It has been observed that the funds allotted from the Central government under the ARWSP are inadequate to address the quality problems. An additional requirement of Rs.100 crores per year is required for the implementation of Sub-Mission projects for providing safe drinking water to these partially covered and fully covered habitations through distant bore well sources / surface sources / treatment plants / artificial recharge measures (RDPR 2003).

h) NGO efforts in controlling quality: In Gujarat, NGOs have resorted to alternatives like lined ponds in saline areas, check dams and other water harvesting and groundwater recharge systems and roof-top rain water harvesting systems. In Gujarat, NGOs have taken a lead role and are extremely active and have influenced policies at the state level, which is comparatively insignificant in Karnataka and is in the beginning stage. In Gujarat, some villages have installed their own Reverse Osmosis system, unlike Karnataka, for quality drinking water supply. The cost ranged around 10 to 15 paise per litre.

j) Awareness: Quality of water is highly affected and people are unaware of the serious consequences. Systematic and effective awareness creation programmes are not undertaken at the ground level to initiate people to use treated water and to inform them about the negative consequences. However, with serious health impacts, a few instances captured by the media were industrial effluents penetrated into tube wells, water supplied had Fluoride, Nitrate contamination in North of Bangalore, thousands of farmers from Kolar marched to the State capital for demanding permanent solution to drinking water crisis due to deterioration in water quality due to excess fluoride was their main concern. (Vijaya Karnataka, May 30th 2003). In Gujarat, especially in the Saurashtra, Kutch and northern regions, the villagers are often at odds to relate water quality to physical ailments, as the *taste* of water finally sends the signal of potability. Moreover, in the absence of an alternative good quality source, people are forced to use such water which is accessible. This is particularly obvious in parts of Amreli district where excess fluoride in water has resulted in bone deformities.

3.3. Negligence of Traditional Sources

The traditional sources of water are significant in the form of open dug wells, step wells, tanks, ponds, lakes and other sources. With increase in population, people had to spread to other places and need for water storage was imminent. Karnataka has been a pathfinder of traditional water harvesting structures named locally as *arakere, holakere, devikere, katte, kunte and kolla.* Tanks formed the majority in number out of which 40,000 exist even to this day (CSE 1997). Traditional structures are different from state to state and even between region to region because of varied patterns of the monsoon in the country.

The state of Gujarat has traditional water harvesting structures galore in Gujarat, as in most Indian states. Despite a wide variety of locally designed systems, talavs (tanks) and vavs (stepwells) are the most prevalent forms of such rainwater harvesting systems. In Kutch and parts of Saurashtra regions, in particular, household level underground storage tanks are very common. Unlike in most other states, traditional systems largely catered to drinking (both human and livestock) and cooking purposes. As newspaper reports often suggest and academic exercises (see, Das 2003; Mahajan and Bharwad 2003) have established, there has been large scale neglect of traditional sources, including those in urban areas. Although such sources have limited capacity, given the increase of rural population, these still have great potential to be effective supplementary sources if scientifically and institutionally revived.

In Karnataka state, tanks formed one of the significant means to conserve water resources and was particularly prominent in Karnataka. Traditionally, lot of activities revolved around the Tanks for providing water for irrigation, domestic usage, water for livestock, washing clothes, supporting livelihoods of the poor, protecting local environment and sustaining water resources. Tanks are seen as one of the earliest expressions of indigenous knowledge systems in rainwater harvesting practices. This system was prevalent till the 60's which gradually saw the decline. The consecutive effects (Raju *et al* 2003) are attributed to factors like decline in the social values attached, inefficiencies in the government in tank management like financial crunch, poor accountability, political interference, increased access to alternative source of water, changed user expectations from the tanks owing to the increase in emphasis on food production and state's emphasis on major and minor irrigation.

Traditional sources like tanks were the principal source in rural Karnataka for 19 per cent of the households during 1998. The traditional sources were significantly concentrated in the western ghats and hilly areas, whereas in the plain areas the traditional water sources dried up due to lower rainfall and extraction of groundwater for agriculture and industrial use. Further, the traditional sources, such as tanks and ponds gradually filled with silt, thus affecting the storage capacity of these sources, which indirectly affected groundwater levels. Thus, over the years the traditional sources declined.

3.4. Technological Constraints

Technology forms one of the major factors in determining effective water supply in rural areas. Adopting the right type of technology to suit the local conditions has been a challenge to the government as various problems are encountered in the process. The three main ways of distributing water in the rural areas adopted by the RDPR has been through installing borewells with handpumps, water pumped to small cylindrical shaped tanks fitted with taps under the mini water supply programme and piped water supply where water is pumped using power pumps to overhead or surface tanks and distributed through public taps. The rural water supply programme is implemented through Zilla Panchayat Engineering Divisions. Villages are chosen based on the extent of water problems faced while the technology is decided based on the population of the village. Apart from these, in Gujarat, more advanced measures like regional water supply schemes are taken up while laying a pipeline from Narmada is on and roof top harvesting has been quite popular. In Gujarat, 254,000 BWHP out of 459,887 are defunct, 26 per cent of all piped water schemes need repair, 278,000 of the 1,528,000 standposts need repair, GWSSB spends 10 crores annually on the 343 rural regional schemes covering 3,453 habitations, spends Rs.450 per handpump and it had almost 70,000 of them in 1998.

Number and Type of Technology Coverage

	Karnataka	Gujarat	
Technology type		Installed	Defunct
Borewells with handpumps	183,058	459,887	254,000
Mini water supply scheme	20,867	1,528,000*	278,000*
Piped water supply scheme	16,223		
Total	214,743		

* Public StandPosts

Source: RDPR 2004 Handout

<u>a) Technical constraints</u> - Technical constraints in the area of rural water supply highlight the causes of scarcity of drinking water due to indiscriminate drilling of borewells, non-availability of acquifers, water quality problems, inadequate suction depth resulting in lowering water table, non-availability and technical solutions on building artificial recharge structures (Rural Development Department, 1986). It is evident that there are predominant problems in different areas in procuring water resources (like desert area, salinity, hilly area etc) and adequate measures have to be taken for the same by methodical steps through identifying problems, identifying sources, water quality monitoring and quantity and quality to be sustained on a long term basis to ensure ecological stability.

Insufficient machinery, lack of planning and inadequate priority for maintenance coupled with poor response of implementing authorities leads to abuse and defunct of technologies adopted. In the planning stage, community involvement for siting standposts to ensure adequate coverage, access, security and safety of users are normally overlooked apart from neglecting the finer details of design aspects.

b) Choosing appropriate technology and low cost technologies are absent in a majority of the cases resulting in the failure of the schemes. It would be beneficial in terms of reduced costs, relative simplicity and also in lower maintenance costs if location specific technology is chosen while effective operation of the systems is another important criteria.

c) Consumer's acceptance is an important aspect lacking in the targeted sector as the users are directly involved and work with the devices introduced, such as hand pumps and standposts. Good maintenance is related to and very much dependent upon consumer's acceptances as it affects people in daily life. The role of women, in particular, deserves ample attention.

d) Unaccounted - for water is one of the major constraints faced in the rural areas. Major reasons can be attributed as loss - leaks in pipes and univalves, unmetred public uses, excessive time to repair broken mains, nonfunctioning or under registering of metres. Although data for the developing countries are both scarce and unreliable, the facts are incontrovertible: un-accounted for water losses are high and constitute a gross capital and social cost (Bourne, 1984).

e) Residential demand - Until recently, literature on residential demand in developing countries has been at best scarce and based on unreliable data. The generally accepted 'requirements approach' for forecasting, long recognized but replete with in-accuracies, has tended to render future demand estimates inaccurate (Hirshleifer *et al.,* 1969; Warford, 1966). That is, the estimates are based on incomplete assumptions because they do not account for actual capacities to finance projects. More recently, attention has focused on a different mix and weighting of variables, rather than just considering price to be the single most important factor in determining consumer demand. Consumer's liquidity and income appear to be much more influential underlying determinants. Their interplay affects client capacity to afford service, and hence, generate income for the system.

f) Standposts are seen as immediate option and least costly to provide water to the low-income groups and as infrastructure that can be upgraded when affordable, mindful of budget constraints. Recent data challenge this assumption. In some cases, Standposts have cost more than it would have to provide the same people with individual house connections. Standposts, however, have not been subjected to a rigorous analysis as other water supply alternatives. In practice, Standposts are generally considered a part of the overall distribution system, without separate financial evaluations, capital, and recurrent expenses - all assumed, arbitrarily, to be the lowest cost because services are at their lowest levels. This latter assumption is one of the most important aspects of the analysis. Because expectations of cost recovery are low and operating expenses are not accounted for, the rest of the costs of standpipes are not scrutinized; instead they are regarded as being an essential public service.

g) Regional schemes in Gujarat – The GWSSB provides resources for construction of tube wells, overhead tanks at village and a pipeline for connecting villages. Rest of the expenditure towards capital investment is borne by individual village panchayats. Huge amounts are being spent on the maintenance of these schemes. People are not able to get potable water. In this system of drinking water the issues pertaining to recovery charges, poor operation and maintenance do exist along with the conflict between head and tail villages. A study of one of the villages that came under regional water supply scheme indicated that the investment cost was as high as Rs. 9.25 crores with O and M of Rs. 95 lakhs, government subsidized rate of Rs. 14/person/year, while the cost recovery was only 1 per cent and about 70 per cent of O and M cost went towards power and establishment charges. Other problems include, unreliable and inadequate water supplies to tail end users, illegal tapping of water and lack of appropriate action towards the offenders, poor involvement of the community in planning and other stages, all related to single source supply.

h) Roof water harvesting – a success story in Gujarat- The co-ordinated effort by the government and the NGOs have resulted in major takeoff of roof water harvesting in more than 12,500 households. The programme has been promoted with 70 per cent assistance from the GWSSB. The programme depicts demonstration of demand-driven approach and of active community participation and management, particularly by women. VWSCs take care of 13,000 roof top harvesting structures.

i) Rain water harvesting – vehement in Gujarat – The state has taken efforts by investing in several methods of rainwater harvesting and recharging structures all over the state. NGO's community groups have received assistance from GWSSB as well as CAPART, to revive traditional technologies in areas affected with water quality problems. The Sardar Patel Participatory Water Conservation Programme is symbolic perhaps of the paradigm shift, which many in the sector, both within and outside government, see as essential to a sustainable future. The original target was building of 2500 checkdams but the target was exceeded four times, 10,500 check dams were built (8000 in Saurashtra and Kutch). Contribution of 40 per cent by the communities with complete decision making handed over to the communities at every point of decision-making proved successful. However, strengthening is required with respect to building capacities through training. Monitoring was haphazard, hampered involvement of all the members in VWSCs.

3.5. High investments - Low performance

Financing for rural water supply has been one of the most important dimensions that needs immediate attention. Providing safe and potable drinking water to nearly 230,000 thirsty habitations covering more than 50 per cent of country's rural population has meant huge investments. States have also spent a large amount under the MNP. Sizeable amount of money is being spent on drought management over and above the normal funds. Funds are also allocated for development of village water schemes under the decentralised planning at the district level. The MLAs and MPs also attach priority to this sector while distribution of funds from the special grants are also available to them. External aid from donor countries and the World Bank have also made huge investments.

Some projects which started in the 1950s have still not been completed. Cost and time overruns have become endemic and chronic and spillover costs are increasing with every plan. Financial returns are negligible as a result of highly subsidized pricing of water and substandard modernization. The returns are not even adequate to cover costs of operation and maintenance. Maintenance has been sadly neglected and systems are deteriorating. The application of financial resources has not been optimal and there is little regard in the entire system for prudential norms and accountability. Despite repeated statements in the plan documents and in other writings and reports, the situation has deteriorated over the years. Internal revenue mobilization by panchayats is poor because of their poor capacity of mobilizing funds due to various reasons like poor staff support, no adequate guidance, deprived viable size of local frontiers etc. Added to the above dependence on inadequate and uncertain flow of funds from the state government adds on to the existing problems of management.

Since the First Five-Year Plan (1952-57), $6.5 billion have been invested in India by the Union and State governments. Apart from these governments, the external agencies provide the finance for rural water supply. The Union and State governments provide finance in the form of grants. As Zilla Panchayats and Taluk Panchayats do not have tax base or power to levy tax, they depend on grants for provision of service in their jurisdiction. The Gram Panchayats have power to levy property tax and the user charges on water supply for maintenance of the existing systems. In addition, part of property tax they derive is from water cess.

As mentioned, the funds for water supply is provided under the various programmes from the centre and as well as the states. From Table shown below, it can be observed that, according to the budgetary documents, there is a shift in funds flowing to the rural water supply. There is fluctuation in the share of funds allocated by different agencies. From the data, it emerges that the funds flow to the water supply programmes based on schematic programme or special programme during the drought situation. However, the funds flown to the RWS under bilateral agencies are not included totally.

Utilization of Funds under Various Schemes (Amount in Rs. Lakhs)

Years	Hand pump		Mini water supply		Piped water supply	
	Allocation	%age	Allocation	%age	Allocation	%age
1998-99	3,201.5	80	3,601.87	100	5,487.49	95
1999-2000	2,832.14	50	2,283.97	65	3,861.52	75
2000-01	2,622.23	53	3,174.96	89	4,534	76
2001-02	2,680.12	47	3,278.11	88	5,317.34	83
2002-03	2,525.33	78	3,315.29	93	5,066.36	87

In fact, of the amount allocated under the budgetary allocation, a major portion goes for operation and maintenance. As indicated in the table below, the amount spent on operation and maintenance comes around 30 to 64 per cent with variation across the year. Thus, as mentioned by various studies, if the budgetary allocation continued in coming years, it may be enough only for O&M and providing new services will become a constraint.

Expenditure on Operations & Maintenance (Rs in Crores)

Year	Total RWS Exp.	Expenditure on Operation and Maintenance	
		Actual	per cent .
1993-94	89.41	31.38	35.10
1994-95	100.52	42.20	41.98
1995-96	135.81	64.94	47.82
1996-97	150.56	61.16	40.62
1997-98	190.24	97.73	51.37
1998-99	179.99	115.89	64.39
1999-2000	370.38	110.81	29.92

Visualizing the budgetary constraints, as part of sector reforms, the cost of operation and maintenance needs to be shifted to the users/beneficiaries. Under the Karnataka Panchayat Raj Act 1993, the responsibilities relating to drinking water supply has been demarcated among the three tiers of rural local bodies (RLBs). Even with the assignment of all operational and maintenance responsibilities to the lower two tiers (Taluk and Gram Panchayats) the user charges are levied and collected by Grama Panchayats. The data shows that 20 per cent of the GPs do not levy any user charges and another 42 per cent of GPs levy between Rs. 5 and Rs 10 only. Considering the GPs' inability to levy the user charges, the Government of Karnataka has issued an order to all Gram Panchayats to levy a minimum of Rs. 25 per private household connection and Rs. 5 per household on use of public taps. The revised rates come closer to the estimates made by Infrastructure forum 2001, World Bank. The Forum estimated a maintenance cost of $1.2 per capita per year for MWS and $3 per capita per year for PWS in 1998. Using the Forum's exchange rate of Rs. 35 in 1998 and an average household size of four, the monthly water rate per household is around Rs. 14 for MWS and Rs. 35 for PWS. The Government of Karnataka order, though do not cover the maintenance cost, is closer to the estimates made by the World Bank (Amarnath 2003). The Government of Gujarat has invested 127,898 lakhs in the last 17 years apart from spending 84,375 lakhs for providing drinking water during scarcity.

It has been observed that, from the experiences over the decades, foreign assistance can act only as a mechanism for financing and it is important that the developing countries depend largely on their own initiative and resources. Continuously the developing countries seem to be heading towards escalating indebtedness; hence, there are constraints with respect to lending even with official commitments. Further, as the developing countries are unable to raise their own internal finances towards water supply and sanitation, the flow of funds through external aid from international agencies also decreases. All this adds on to the pressure upon the local governments to find their own solutions. Hence, the stress towards generating finances internally towards water supply and sanitation seems evident.

Some data gaps in the Rural water supply are:

Non-availability of requisite data makes it difficult for making any financial assessments and to understand the situation. Also, access in obtaining data specific to Rural Water Supply falls into the category of what is mentioned as 'core functions', is not only inadequate, not maintained and also incorrect most of the times.

- the available relevant data are mostly 'guess estimates'.
- Nature of data available - Where the data are made available, the same are deficient in several respects. There is no common format or method of data maintenance in different districts. Apart from this, there is no functional classification of expenditure items in different districts.

A number of measures are suggested for immediate adoption to instill a measure of financial discipline in the system. These include project-wise funding, proper preparation of cost estimates including possible escalation, timely revision of such estimates, clear definition of commencement and completion of projects, insistence on preparation of completion reports and limitation on the change of scope of a project and on establishment costs (Ministry of Water Resources, Sep 1999).

3.6. Unclear and Overlapping Roles of Different Agencies

PRIs, particularly the intermediate and district panchayats, are relatively of recent origin. The state governments transferred some of their own functions, powers, authority and responsibilities to the newly created intermediate and district panchayats. As PRIs are perceived to be the units of local-self government, the scope and extent of their functional and financial domains had to be decided by the state governments. The search for identifying certain specific responsibilities of the state governments, which could be assigned to the PRIs thus, began.

a. RWS in the three-tier system

The organizational structure of Rural Water Supply and Sanitation in India and in Karnataka/Gujarat is a complex one. It involves many organizations at national, state and local levels, often with unclear or overlapping responsibilities, and typically overstaffed and under skilled, which hampers them from effectively carrying out their responsibilities. As explained above, the 73rd Constitutional Amendment and the subsequent State Acts created a policy environment conducive to decentralized governance and management of rural development. The constitutional amendment and policy changes contributed an increase in multiple number of local organizations in the management of rural development. However, evidence clearly demonstrates that this multiplicity of actors have created confusion and some conflict within the local institutional landscape, which have affected in effective delivery of services.

Rural water supply is one of the core functions operated at different levels after the funding is received from the Central and state governments under various schemes. Funds from the Central Government are allocated to the State through various schemes. Each of these schemes follow different approaches and different means of funding. The funding is based on certain criteria and conditions that the respective state has to fulfill, devoid of which, the funding will be withheld. The state government is responsible for allotting the funds under the schemes allocated from the Central as well as allotting funds from its own budget to the Zilla Panchayat.

Role of external agencies in funding RWS needs special mention (World Bank, Danida and Netherlands). Funds received from the externally funded projects flow through the Rural Development and Panchayati Raj institutions where a separate agency is set up to deal with the externally funded projects. The approaches vary with respect to addressing the problem at every stage. The focus of attaining the same problem is tackled to attain the same objective and improve sustainability. At the outset, roles assigned to the ZP, TP and GP are clear, however, at the ground level, the reality is too complex.

In Gujarat, the complexity is easily surmised by the fact of the operation of a variety of important state or state-supported institutions/agencies including the GWSSB, GJTI, GWIL, Gujarat Water Resource Development Centre (GWRDC), Sardar Sarovar Narmada Nigam Limited (SSNNL), Water and Sanitation Management Organisation (WASMO), Gujarat Infrastructure Development Board (GIDB) and major region specific projects as sponsored by the central government, World Bank, Dutch Government and International Water Management Institute (IWMI-India). Additionally, with a strong tradition of functioning of the parastatal bodies (NGOs, to be specific) in the state, provision, conservation and management of water have formed a vital share of activity for many of these. The collective and individual (member NGOs and activists) efforts of the group called PRAVAH[27] have been significant in both the field level intervention and substantive contribution to policy formulation at the state level and beyond.

The state government implements the Rural Water Supply Programme under the state sector Minimum Needs Programme (MNP). The central government, through the Rajiv Gandhi National Drinking Water Mission (RGNDWM) supplements the efforts of the state by providing financial assistance under the Accelerated Rural Water Supply Programme (ARWSP) and the Drinking Water Supply component of the Prime Minister's Gramodaya Yojana (PMGY).

The programme to distribute drinking water to the rural areas is implemented in the state since 1961. It consists of the following:

- Regional Water Supply Schemes
- Individual Village Water Supply Schemes
- Installation of handpumps
- Digging of simple wells

[27] It is a platform working on drinking water issues in Gujarat. It is a unique forum where the state's most active NGOs and individuals working on drinking water issues engage in debate, research and policy advocacy on drinking water problems in the state.

Role of Different Agencies at Governance Levels

Zilla Panchayat RDED:	the first tier in Panchayat Raj institutions, is responsible for planning, implementing and monitoring all the developmental programmes in the district which are being carried out by the Zilla Panchayat Engineering Subdivision.
District Project Monitoring Unit	Responsible to oversee the activities at district level programme of WB. It has technical, administrative personnel and also a social scientist. In fact, these units are phased out after the completion of 1st phase of WB implementation
Taluk Panchayat:	Taluk Panchayat liaisons between ZP and Grama Panchayat, and responsible for implementing and monitoring developmental works at taluk level. It takes the responsibility of O&M of BHP.
Grama Panchayat:	*As* the lowest tier of Panchayat Raj institution it prepares its own plan and implements after getting approval from Taluk Panchayat. It is also responsible for collecting water charges, operations and maintenance of water supply schemes such as MWS and PWS.
Village Water and Sanitation Committee (VWSC	VWSCs are developed to involve the local community participation in the project villages of the World Bank assisted Integrated Rural Water Supply and Sanitation. VWSCs play a crucial role in planning, implementation and operation and maintenance of the assets created.
Institutions in Water Quality Monitoring	Public Health Institute (Sheshadri raste). District level Public Health Laboratories of the Health and Family Welfare Department has 28 laboratories Public Health Institute at Bangalore, conducts test for chemical and bacteriological contamination Three Divisional Laboratories Nineteen District Health Laboratories (before formation of new districts), one at each district – 19 laboratories do not have necessary equipment and trained staff for chemical examination of water. Do not have the facility for bacteriological testing of water

Note: Compiled from various documents of the Government of Karnataka and based on discussions with senior officials of the various organisations.

The GPs are finally water providers, the VWSC are functioning in the villages, where external agencies are involved during implementation. The World Bank programmes created village level organizations under their programmes while local elected bodies represented the line departments at various levels. The organizations were assigned functions and were provided assets to undertake the functions. Recent studies have observed the various lacunae in the institutional arrangements like duplication of mandated functions, selection of villages based on political pressure, poor operation and maintenance, lack of co-ordination and establishment of linkages with development actors. Performance of functions varied across the local organizations with non-mobilization of capital costs from contributions, lack of participation in choosing technology, wrong choice of technology. It was also observed that the achievement levels of success was achieved with difference in ability to provide water while the assets and processes were affected by village characteristics, household characteristics influencing the development outcomes. The local organizations preferred to have PHCs and MWS and Public standposts were neglected. It was highly politicized having an adverse impact on equity (Rajasekhar and Veerarshekharappa, 2003). Though there are innovative approaches to address local water scarcity problems by several organizations, they are very uneven and localized, and are not implemented at scales where they can make an overall impact on the water situation at a regional level. There are multiple authorities including GWSSB who have yet to act in a synergistic manner, so as to be more focused and productive; networking between stakeholders outside the government sector, and between NGO's and state authorities, is now a major strength in Gujarat and needs to be fostered.

Although the focus has been to evolve the most effective and sustainable institution at village level for delivery of RWSS services, it has also been observed that there is a complex relationship between these two village-level organizations and it may not be an 'either-or' situation but rather a 'both'. Even with decentralized implementation of rural water supply taken up by the state, complexities remain due the above mentioned factors. Three major constraints for improper resource management are pointed out as - failure to recognize scarcity in the natural world, failure to ensure that the institutions managing natural resources are accountable, and failure to mobilize knowledge for managing environmental problems (Saleth 1996).

3.7. Sustainability Crisis: Sustainability has to be addressed in the context of various aspects of RWS - supply, source, quality, technology, finance and institution. With the acceptance and establishment of norms, people expect regular supply of water throughout the year. This necessitates adequate arrangements for ensuring sustainability of the system.

a) Need for technological sustainability: The sustainability of handpumps and intermediate technologies depends upon a number of components, viz., identification of proper sources, using local knowledge and scientific methods, drilling and constructing the proper bore up to the required depth, installing the handpump of the right type at the right length to pump water, creating aesthetically agreeable environmental platform, drainage facility and regular operation and maintenance of each of these items are not complex in themselves if properly integrated.

In case of PWS, a number of classifications can be made depending upon the sources and the type of distribution system and the type of treatment, sustainability of design period because it can fail with failure of source, poor quality of material used, poor O and M etc. Important issues are appropriate systems to be placed for various hydro-geological conditions and it is possible to give such region-wise classification for feasible options.

The dominant issues in all these systems are: (i) Sustainability of the sources with respect to quality and quantity; (ii) Quality of material used; (iii) Quality of construction and supervision; (iv) Quality of operation and maintenance; and (v) Financial resource for construction and maintenance of a system. It appears that the centrally managed operation and maintenance have failed to sustain the water supply systems in the villages. The new panchayat raj institutions have a very dominant role in mobilising the people, their knowledge and resources in ensuring the sustainability of the system.

b) Financial viability - User financing, contribution by users in cash or in kind individually or as a group to the capital and or recurrent cost, in the provision of basic services has been considered. Several reasons are suggested in justifying such a policy change. Most important among them are (a) efficiency (b) equity (c) sustainability. The increase in efficiency, it is argued, comes from both sides of supply and demand. The user fee imposed for a hitherto free good restricts the overexploitation of resources thereby enhances the demand side efficiency. The supply side efficiency is attributed to the likely quality and quantity improvement arising out of the accountability on the part of the providers. The equity argument is centered around the increased availability of services with better quality at a subsidized rate for users belonging to the group exempted from cost recovery. Sustainability is attributed to the better maintenance of the system and timely replacement of old system using the resource generated from user charges.

In the context of sustainability and relevance of user financing, it was estimated that the system is sustainable along with additional coverage and improvement in quality of drinking water supply only if user financing is introduced (Pushpagandan and Murgan 1996). Studies on willingness to pay for water and sanitation services is to assess the usefulness of the technique, its role as a tool within economic decision-making and its ability to inform choices for project planning and implementation. The major findings show that income, education, price and quality of service delivery are the key determinants affecting the sustainability of a public service system. WTP is enhanced with increasing income, education levels and reliability of service both in terms of quality and quantity supplied (Gupta and Alison 1997).

c) People's participation – major component in sustainability – There are many lacunae in involving people at the ground level. People also seem to agree to put in their efforts and money if water supply is available on a sustainable basis. This leads to the issues of cost of projects, resource mobilisation and resource sharing. In real terms, water is not made available to all according to their needs. Its availability is a function of many factors, economic and social position, political forces and technological feasibility (i) Should we recognise water as an economic good and hence should we encourage people to share the cost? (ii) If cost sharing is accepted, when do we start? Should capital cost be partly or fully borne or should we start with sharing O and M cost? (iii) If costs are to be shared, who should decide on the technology and its cost? (iv) While transparency is the focus at every stage, achieving transparency in the present existing system is a crucial challenge.

d. Undefined norms – Norms are fixed with equity view for all, the questions that still remain unanswered are (i) What is the minimum norm for supply through handpumps and standposts? (ii) What are the supplementary sources and how to provide it? How to regulate the norms about the supplementary sources (iii) Is the present norm of 1 handpump for every 250 population adequate? If now, what is the reasonable norm? (iv)

What is the reasonable distance in defining the norm? How is the habitation, the lowest geographical unit for defining coverage, related to the distance norm? (v) Should they be in the same form for every region? (vi) How much water is to be provided for cattle, and on what basis?

4. Key Approaches Followed by Study States

It is obvious that hardly any attention was paid to the demand side management until the recent past. Water demand management implies optimizing utilization of water for drinking, agriculture or industry. The efforts of all the projects were to increase the supply, irrespective of sectors, drinking water, irrigation or industry. The approach had always been to increase the water supply. This increase was to be obtained broadly from two types of sources, the surface structures and the groundwater. The common approach whether by the government or by the private individual has always been to tap into these sources. Lately, some efforts have been made towards water management. Although, presence of a policy instrument is the beginning point, but in real terms, providing a cordial situation for effective implementation and affiliation is challenging and critical.

There are different levels at which water resource management is carried out within the states of Karnataka and Gujarat. As drinking water comes under the State List, schemes for providing it to the rural habitations are being implemented by the state from its own resources. The central government supplements the efforts of the state by providing financial assistance under certain schemes that are taken up at the national level. Two distinct approaches towards ensuring sustainable drinking water supply can be identified. These are either supply-driven or demand-driven.

4.1. Supply-Driven Approach

For close to five decades now, both the states have assumed the responsibility of providing potable water to the rural population. As has been the practice all through, the predominant source of water has been groundwater in both Karnataka and Gujarat. This, however, involves massive paraphernalia of organisational arrangements wherein inter-departmental coordination holds the key for successful functioning. Nevertheless, the structure is complicated, the roles overlap, and there is no institutionalised manner of inter-departmental coordination.

The state government implements the Rural Water Supply Programme under the state sector Minimum Needs Programme (MNP). The central government, through the Rajiv Gandhi National Drinking Water Mission (RGNDWM) supplements the efforts of the state by providing financial assistance under the Accelerated Rural Water Supply Programme (ARWSP) and the Drinking Water Supply component of the Prime Minister's Gramodaya Yojana (PMGY).

The programme to distribute drinking water to the rural areas is being implemented in the state since 1961. It consists of the following:

- Regional Water Supply Schemes (only in Gujarat)
- Individual Village Water Supply Schemes or Piped Water Supply Schemes

- Multi Village schemes
- Mini Water Supply Schemes
- Installation of Borewells with handpumps
- Digging of simple wells

In reality, such a supply-driven approach has led to a certain kind of dysfunctionality affecting sustainable water supply, which was observed with groundwater as the vital source. Efforts at harvesting both rainwater and surface run-off is grossly neglected. A critical aspect of the water supply scenario in Gujarat and Karnataka are both the existence and emergence of defunct sources. A growing number of sources becoming or continuing to be defunct is a matter of concern as it involves the issues of management, possibilities for rejuvenation and a thorough re-evaluation of water supply schemes in the state. Several enquiries have been made into major causes of sources falling into disuse and the type of remedial measures that can be taken to reactivate them. These point to the possibilities through which augmentation of drinking water supply is feasible despite geohydrological constraints.

It is obvious that the most appropriate answers to the issue of rejuvenation of defunct sources could be provided by the concerned departmental personnel through detailed techno-economic evaluation. Whereas, in cases of permanent fall of water level there could be a need to set up new sources of water, only simple repairs could help rejuvenate many sources, which have gone defunct due to minor mechanical or electrical faults. As one study (Das and Kumar 1995) estimated[28], for the rejuvenation of three fourths of all the defunct sources, in nine districts (including Kutch and Saurashtra) the average expenditure would range between Rs. 1,00 and Rs. 5,00. It is important to note that the remaining quarter of defunct sources could be made functional with an average expenditure of less than Rs. 1,00, a majority of them requiring less than Rs. 500 to revamp the system. It was observed that a considerable proportion of defunct sources in the districts of Saurashtra could be revived by spending small amounts on the repairs. Among defunct sources handpumps were predominant, which were also the major sources of water supply in the districts.

In a typical supply-driven approach popular involvement in managing public water sources is often found relegated to the background. As reported by numerous studies, lack of participation has been noticed mostly in planning, site selection, maintenance and operation. Moreover, absence of active participation of the women in such matters is a pervasive problem in the state.

4.2 Demand-Driven Approach

Over the last few years in Gujarat, drinking water supply has received more attention from all walks of life. Two consecutive drought years have mainly contributed to this; also the growing realisation that present practices of the government playing the role of provider has to change to that of facilitator. Efforts are moving towards making a paradigm shift from centralised, target-based, government driven programmes to demand-driven, people's

[28] Das, K. and B.L. Kumar (1995), *A Validation Study of Habitations Not Covered Under the Rural Drinking Water Programme in Gujarat*, Report prepared for the Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, Government of India, p. 35.

participatory approach. New initiatives in the water sector include sectoral reforms, increased decentralisation through community participation, capacity building of local communities based on human resource development and information, education and communication campaign. Issues of equity, gender and community management are getting more and more attention in all programmes and schemes. There is also an increasing importance on the scarcity of drinking water in the state which can be taken care by adopting the right mix of local initiatives based on traditional knowledge and wisdom that represent changing vision of the government and also reflect new concepts in the field of participatory development. Further, to promote decentralisation and community participation in rural water supply sector and sanitation, the state government has constituted an 'autonomous' organisation, known as WASMO to facilitate the process through involvement of Panchayat raj institutions, civil society and local community based organisations.

As has often been noted, villagers make serious complaints about government agencies for their not attending to sources for long period and also not taking action during acute needs. There have been occasions when the priorities for sources to be maintained were vitiated due to political interference. This resulted in non-attendance to sources requiring immediate attention. Besides, villagers in many cases, did not report about problems to the concerned department; either they would not know whom exactly to contact or would not hope for any positive outcome despite their request. Especially in case of handpumps no caretaker would be found in the village who could bear the responsibility of informing the concerned departmental agencies whenever required. The non-availability of spare parts or expertise locally has also been described as a cause for the delay in the maintenance of the sources. At a certain level of praxis, much could be described as poor management and upkeep of the sources as also careful use of the otherwise scarce resource.

Considering the frequent incidence of the aforesaid problems, a substantive change in approach is called for. Largely influenced by the imperatives of a liberalizing economy and also experiences from a host of similar countries, assigning a larger role to the local community in managing water supply has come to be emphasized. Hailed as a paradigm shift, from a grossly supply-driven to an essentially demand-driven approach, the nationwide launching of the Sector Reform Programme (SRP) in 1999, marks the beginning of a strategy that no longer potable water to be considered a free good, making available of which should be the responsibility of the government. In principle, SRP is aimed at improving the sustainability of water supply systems and sources, besides ensuring effective implementation of the schemes.

7. Arguments for Change

- Groundwater depletion, a matter of serious concern will lead to irredeemable consequences unless planned efforts are undertaken. Borewells have dried up even though it is drilled upto 1,000 feet in the dry areas. Ten villages in Karnataka among the case study villages witnessed depletion. This was mainly due to excessive drilling of borewells and lack of efforts taken towards water conservation. Legal restraints have to be more stringent and clear. Although Karnataka has passed the groundwater bill and taken the first step towards regulation, implementation is still not effective. Bore well owners thrive making roaring business, in Kolar town (Karnataka), alone they make a profit of 120.25 million annually. Understanding groundwater markets in this context needs urgent attention. Role clarity needs specification in departments. Alternatives to improve water conservation are extremely poor in terms of implementation in Karnataka unlike Gujarat.

- Quality problems and its effects on health are taking their toll in both Gujarat and Karnataka. Water-borne diseases in rural areas have affected 1,08,907 lakhs people. In Karnataka 21,088 habitations and in Gujarat 3,279 villages are affected with quality problems. Among the case study villages, 31 per cent and 21 per cent faced quality problems in Karnataka and Gujarat respectively. Samples collected in 4 villages indicated quality contamination by nitrate, unknown to RDPR nor the public. Huge investments were made in installing laboratories in some districts of both Karnataka and Gujarat. Laboratories initiated in both the states are not functioning effectively in respective districts. Lack of skilled staff, cost factors, poor co-ordination have been some of the reasons resulting in lack of systematized conducting of testing on a regular basis. There is absence of holistic approach and lack of planningin involving the people at every stage before installation of the Defluoridation and Desalinization plant. Awareness creation campaigns are not intense. Fluoride in water would cause long-term harmful effects, which the people haven't realized. Need for trained local personnel in maintaining and managing the treatment plant is a must. Quality problem as a whole should be addressed with a planned approach beginning with identification to completion.

- Emerging coalitions between the government, researchers (social and physical sciences) NGOs' and people towards water management needs attention. A common platform to exchange and delegate plans in recharging water can be undertaken. This would form the basis for identifying issues to be resolved through action research, technology, promotion and networking. Alternative options that can be adopted should become a debatable issue at the local level. For instance, efforts taken at Huligaru village, Karnataka have borne significant results mainly because water conservation was taken up at the local level. Negligence of traditional sources in the case study villages of Karnataka was 42 per cent. Revival of traditional sources (dried up open wells, ponds, lakes) through conservation of rainwater would work out to be simple and cost effective in solving scarcity and quality problems. Effective results in Gujarat are on and should be replicated more intensely in Karnataka too.

- Rainwater harvesting although seriously discussed at the department level has not been implemented at the field level in Karnataka compared to Gujarat. The urgent need to harvest rainwater cannot be promoted effectively unless right approach is adopted. Campaigns and Awareness creation although discussed have not been effective, therefore needs further improvement in terms of design in imparting knowledge. This should be done in phases, beginning at the local level and then taken forward at various levels.

- Alternatives adopted in solving the crisis have been short-term and temporary meeting immediate crisis whereas long-term vision is completely absent among various actors, politicians and officials. In Karnataka, immediate solution sought has been drilling of borewells to meet the requirements or supplying water through tankers. The coverage in the Department is seen as number of borewells drilled but with groundwater depletion, borewells have failed miserably. However, the efforts taken by Gujarat is worth considering where the Narmada pipeline laid is a major step in terms of providing water and also in terms of investment, but needs appraisal in terms of cost recovery and equity problems. Need for thinking beyond immediate solutions has to be sought.

- High investments have resulted in low performance specifically with respect to operations and maintenance and wrong technical designs. Understanding Financial dimensions needs immediate attention. Non-availability of requisite data makes it difficult for making any financial assessments of the situation. Data is not maintained, incorrect and limited. Limited access to information was witnessed in 80 per cent of the case study villages in Karnataka. Although people were WTP was high as 80 per cent in Karnataka and 85 per cent in Gujarat, collection varied from 45 to 90 percent in Gujarat. 13 villages in Gujarat and 14 villages in Karnataka paid water charges.

- Co-ordination between all departments working on water resources and need to understand the objectives of respective departments is the need of the hour. This would help in having a common vision in assessing and addressing the problem from different dimensions.

- Setting up effective institutions for water management is required given the present unclear designs in roles and approach. Strengthening institutions with adequate skills has to be done with more intense planning and participation.

- Changing the perceptions of various stakeholders through providing a common platform to highlight issues is needed. Presumptuous actions ignoring people and involving the elite in the villages should be avoided helping all sections of society to voice their opinion. Training at all levels is necessary, inclusive of implementers about ways to carry the idea forward to the masses.

- Awareness creation methods need to be researched and popular practices adopted in other states like Gujarat can be replicated in other states. Several examples at the field level have indicated that with poor community participation, projects have failed. In Karnataka, among the VWSC's initiated, 2 were dysfunctional, 5 functioned irregularly. Although the various approaches have opted for awareness creation and participation strategy, loopholes are, many are to be identified in the process.

- Attacking political interventions is a difficult task that can be tackled with more awareness creation among the people about their rights else they will not know what to fight for. Need for transparency and accountability is required at every level by formulating an effective system where information and data should be made easily accessible.

- Approaches were varied and results mixed thereby indicating complexity and location specific problems. Hence, common design does not apply to various villages. It is important to study the local situation keeping in view the broad criteria.

- Unplanned and unregulated powers without adequate supportive infrastructure in terms of finance and staff capacities have led to ineffective results. It is important to equip the GP's with the required strength to manage at the ground level. Reporting and understanding the problem goes by numbers at the official level focusing on coverage and not functioning and field level problems.

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ISSUES OF UNACCOUNTED FOR WATER IN URBAN WATER SUPPLY SECTOR

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INTRODUCTION

Water is the most precious natural resource available on this planet earth and has remained as a basic need for human existence.Water is a renewable resource, but subject to conservation and sustainable use. While, rapid population growth**,** economic development, changing living standards have all resulted in rapid increase in demand for water, mismanagement and deteriorating water quality have limited its availability. Rapid increase in demand and limited availability have led to acute water scarcity through out the globe and hence, demanded efficient water management to save the resouce.The prime reason for water problems is that water has been treated as a free good and abundance with out-of–sight is out-of- mind syndrom(Thornton,2002). Water is a common good for all sectors of an economy, and its scarcity has been imposing tough competition among the various sectors and urban sector in particular.

Urban water supply systems through out the globe are infected with innumerable problems of water supply irrespective of the level of development of a country. One such alarming issue is"unaccounted-for water (ufw)" and for obvious technological, financial and institutional constraints, the issue is more serious in developing countries. The ufw problem is so primitive that even during the world's first water supply system - Roman water system - attempts were made to reduce its share. This problem has emerged from the fact that not all water supplied by the water utilities reaches the consumers; and not all water that reaches the consumer is properly measured and billed for payment(Thornton,2002). Hence, unaccounted-for water (ufw) in simple terms, known as water loss or non-revenue water is defined as the difference between the quantity of water supplied to a city's distribution network and the metered quantity of water consumed by the customers. Hence, unaccounted–for water, which is primarily a problem of accountability is associated with the water distribution process.The occurrence of unaccounted–for water in a system has been attributed to three types of losses: leakage from pipes, improper recording of consumed water by meters, and illegal connections and under registration of water meters. Broadly, these water loss problems have been categorized into a) real losses, and b) apparent losses. While, real losses has been attributed to the technical problems involving physical escape of water from the distribution system which includes leakage and overflows before it reaches the end users, apparent losses to the administrative inefficiency which ooccurres at the end users point by way of improper recording of total water consumed due to metering error, incorrect assumption of unmeasured use and unauthorized consumption (Table.1). Similarly, the economic distinction between the two losses has been identified as while, real losses are valued on the basis of the marginal production cost of water, apparent losses are valued based on the retail cost (Thornton,2002). Though higher share of ufw in general and real losses in particular has been interpreted positively as it would lead to higher ground water recharge(AusInd,2002;Thornton,2002), it is not a logical justification for inefficiency of water utility as it involves huge resource and financial losses.

The main concern in ufw is the physical loss of precious natural resource and that to after huge investment involved in the entire process extending from drawing of water from its natural source, treatment and delivery to the distribution network for consumption, in addition to investment and revenue losses. Higher share of real losses impose extraction, treatment and transportation of higher volume of water than the previling damand and hence, requires extra cost and energy in addition to limited water supply to the consumers.Leakes and overflows which are the components of real losses cause considerable damages to the distribution infrastructure. While higher share of apparent losses would impose huge revenue loss on the water utility. In particular, the economic impact of apparent losses on the water utility is much greater than the real losses(Thornton,2002). Hence, higher share of ufw imposes higher financial burden on water utility, in addition to wide spread recognition for its inefficiency. In the context of increasing water scarcity and financial constraints, ufw acquires greater significance as a priority issue to be tackled to save scarce water resource, besides improvement in the efficiency and financial health of a water utility. The main issue involved in ufw is proper accountability of water resources through appropriate method of estimation. This requires comprehensive approach to address the whole gamet of technical, operational, institutional, planning, financial and administrative issues(Table.1).

Table.1: Causes and Solutions for Real and Apparent losses

Causes		Solutions	
Real losses	Apparent losses	Real losses	Apparent losses
Varying pressure in the distribution system	Impact of water quality on the water meter	Pressure Management and level control	Reduction of meter error by testing, sizing and replacement
Inefficient leak detection system, Corrotion of pipes in the distribution network	Lack of periodic testing of meters and maintanence of in-housedistribution netwok	Efficient leak detection system,rduced response time for leak repair	Reduction of human error by training,standerdising, reporting and auditing

Poor network materials, workmenship, periodic maintanence	Installation of incorrect and technically not approved meter,theft and illegal connections, Inefficient reading and billing methods	Improved system maintanence, replacement and rehabilitation of network system	Reduction of computer error by auditing, checking,routine analysis and upgradation
Environmental conditions	Environmental conditions	Adoption of appropriate environment friendly technologies	Reduction of illegal use by education, legal action, prepay measures, pressure control and flow contorl

Source: Thornton(2002)

The optimum level of ufw in a well-run water supply utility is 15-20%. Some estimates of unaccounted for water of urban water supply at the continental level have revealed that Asia (42%) and Latin America and Caribbean (42%) have the highest share of unaccounted for water followed by Africa(39%). While, North America (15%) has the lowest share(WHO and UNICEF,(2000) In particular, for obvious constraints, the cities of developing countries have been experiencing higher share of unaccounted-for water (Rarotonga (70%), Hanoi (63%), Phnom Penh (61%), Lae (61 %) and Mandalay (60%),. (Manila,55-65; Jakarta (50); Mexico(50) (ADB Website and Lee,1994). However, it has been demonstrated that efficient ufw management has led to lower share even in Asian cities of Singapore (6 %), Male (10 %), Penang (20 %) and Johor Bahru (21 %) (ADB Website). It has been identified that apparent losses are consistently higher than real losses. Singapore - the globally known city for its least ufw share - has reported that apparent and real losses as 7 percent and 4 percent respectively. Similarly, in Bogota, Colombia, the corresponding values were 26 and 14 percent.The higher share of apparent losses implies that the contribution of administrative inefficiency is more prominent. From the revealed share of ufw at the continental and country levels, it is evident that the main influencing factors for unaccounted for water are per capita GDP, literacy, appropriate technology for water distribution and efficient institutional structure. In this context, it may be noted that in most developed countries which account for lower share of unaccounted-for water, urban water supply has been either completely privatised or being provided by public-private partnership(**OECD, 1999a and UNSCEO (2004); Sastry, 2004).**

Methodology for Estimation of Unaccounted for Water

Water auditing methodology is involved in estimation of the quantem of ufw of a water supply utility. This process involves complete listing of all the relavent variables involved in the water distribution system;dividing the city into innumerable small areas called district metre areas(DMAs);instalation of bulk metres at several strategic points in a DMA to measure the water flow in a specific duration of a day; identification of leaks and damages in the network through traversing the entair DMA area with suitable leak detection instruments; recording of the bulk metre readings installed at different strategic points; testing of consumer metres for its correct measurement,identification of unauthorized connection and usage of water in each DMA area and finally, preparation of water balance charts for all DMAs(Table.2). Hence, water auditing methodology invariably involves highly technical skill and gadgets for complete water usage assessment.

Table 2 Water Balance Chart of DMA.

<table>
<tr><td rowspan="8">Water produced</td><td rowspan="5">Water accounted for</td><td>Residential/domestic</td><td rowspan="4">Water billed</td><td rowspan="4">Revenue Water</td></tr>
<tr><td>commercial</td></tr>
<tr><td>industrial</td></tr>
<tr><td>Institutional</td></tr>
<tr><td>Special /operational consumption</td><td rowspan="4">Non-billed water</td><td rowspan="4">Non-Revenue water</td></tr>
<tr><td rowspan="3">Water not accounted for</td><td>Illegal connection</td></tr>
<tr><td>leakage</td></tr>
<tr><td>Meter error</td></tr>
</table>

Source: BWSSB, 2004

Hence, the main diagoganistic methodology involved in identification and reduction of ufw is the filling up the said chart by implementing five tasks described in Table.3 This paper attempts to analyse the problem of unaccounted-for water and its emerging issues in a globally known software city, Bangalore.

Table 3 Tasks Involved in Water Audit

TaskNo.	**Task Details**
Task. 1	Measure the Supply • Identify and map sources of water • Measure the water from each source • Adjust figures for total supply
Task. 2	Measure Authorised Metered Use • Idetify metered usees • Measure metered uses • Ajust figures for metered uses
Task.3	Measure Authorised Unmetered Use • Identify unmetered use • Estimate unmetered use

Task.4	Measure Water Losses • Identify potential water losses • Estimate losses by type
Task.5	Analyse Audit Results • Identify recoverable leakage • Quantify the value of recoverable leakage • Quantify the cost of recoverable leakage • Calculate the cost of leak detection

Source: Thornton,2002

Study Area

Bangalore, the capital of Karnataka, India and a globally known software city has been experiencing rapid population growth more due to migration. The population of Bangalore in 2001 is very close to 6 million. The area and population of Bangalore in 1901 were 28.9 sq kms and 0.163 million which has increased to 595 sq kms and 6 million respectively. As a result, while, area has increased by 1958.8 percent the population by 3581 percent during 1901-2001. The main concern of Bangalore is its abnormal area expansion to accommodate the rapidly growing population. These abnormal increase in area and population of Bangalore is mainly due to it locational advantage for the growth of industries and commerce for which the city has been known since its foundation. It has a very strong production base as reflected by its highest share of workforce engaged in production activities (45.8%) followed by equal importance in trade(27.1%) and services(27.1%). By income, middle income households dominate the city (46.8%) followed by low income households(38.3%).(AUSAID,2002). Though the share of high income households is just 14.8 per cent, they contribute significantly to the future growth and development of the city. In recent decades, the city has been acclaimed for its Information Technology (IT) growth and development which has enhanced its rapid growth. As a result, Bangalore has been experiencing functional specialisation in terms of software development and distribution for the entire globe, in addition to high concentration of traditional as well as modern hi-tech manufacturing and commercial activities. This functional specialisation has attracted all sections of population for their assured livelihood and in particular, professionals and highly skilled workers from the entire country and abroad to meet the city's professional and technical requirements. The rapid in-migration process being experienced by the city and its associated `multiplier effect' have all led to very high demand for high quality functions and services. As a result, the city has been experiencing innumerable constraints in supplying the required functions and services of high quality. One such problem that the city has been facing is inadequate water supply.

Sources of Water Supply and Demand

Bangalore located on the ridge top at an altitude of about 900 metres from mean sea level is in the water deficit zone. Bangalore has no perennial water source in the vicinity except the river *Arkavathi*- a tributary to the river *Cauvery*. Hence, to provide drinking water to the city, the first piped water provision was commissioned in 1896 from the Hesaraghatta lake located at a distance of 18 kms from the city with water supply potential of 22.5 MLD. Later to meet the growing demand, Thippagondanahalli reservoir was commissioned in 1933 which is located at a distance of 28 kms with water potential of 143 MLD. These two sources originate from the river *Arkavathi.* Meanwhile, Bangalore had started gaining growth momentum on account of industrialisation process initiated by the Govt. of India and the state government. Hence, to meet the water demand of the growing population, a perennial water source from the river *Cauvery* was identified. Since, the river *Cavuvery*'s water has to be shared by several south Indian states, for assured water supply to the city, the Govt. of Karnataka in consultation with the Govt. of India has allocated 600 cucets (19 TMC) of water exclusively to Bangalore to meet its growing drinking water needs(AusInd,2002). As a result, the *Cauvery* first stage was commissioned to Bangalore in 1974 by bringing 135 MLD of the river water to Bangalore city from a distance of about 100 kms and against the head reach of 500 metres. This requires continuous pumping of water from its source to the city which obviously consumes huge power.In addition, the project cost itself has escalated due to higher input cost. Hence,unlike the *Arkavathi* source which works on natural gravity, *Cauvery* water has turned out as highly expensive(Table.4).This has obvious implications on the operation and maintenance cost which in turn on the tariff structureas as well. However, to meet the increasing water demand, periodical augmentation of water resources to the existing potentials from the river Cauvery (I,II,III and IV Stages) has been in progress from time to time (Table.4).

Table.4: Sources of Water to Bangalore

Source	Year of Establishment	Distance to Bangalore in kms	Water Potential (in MLD)	Water Received (in MLD) as on 2004	Average unit cost per kilo litre(in Rs)
Arkavathi River					
Hesaraghatta	1896	18	22.5	1.92	0.45
Tippagondanahalli	1933	28	143.0	0.75	
Aarkavathi	-	-	165.5	2.67	
Cauvery River	1974	98	135.0	840.28	7.10*

Stage -I Stage- II Stage -III Stage- IV Phase - I Phase- II	1982 1993 2001 2003 (planned)	98 98 98 98	135.0 270.0 270.0 500.0	(Cauvary I,II, III,IV stages, Phase-I only)	16.23* 24.35* 108.78* 185.37*
Cauvary		98	1310	840.28	
Total (Arkavathi & Cauvery)		-	1475.5	**842.95**	

Source: 1.AUSAID,2001; BWSSB Annual Performance Reports, 1997,1998, 2001&2004.

2. BWSSB has maintained 5850Borewells(1350 energised, 4500 hand pump)to meet the addition water demand of consumers(Annual Performance Report2001-02, BWSSB, Bangalore

The water demand for Bangalore is assessed on the basis of the fixed norms prescribed for various class of cities by the National Commission on Urbanisation, India,1988. Bangalore city has been experiencing water problem mainly due to rapid population growth. In fact, during 1971-81 the population of Bangalore grew by almost 76.8 percent thus claiming as the fastest growing city in Asia. As a result the demand for water which was 225935 million in 1991 has increased to 346020 million litres per year in 2004 thus recording 4.09 percent growth per annuam.While the potential created in 1991 was only 141375 litres which is only 62.5 percent of the demand.Efforts to augment the water resource to the city has been in place through additional potentials from the river *Cauvery* and maximum exploitation of the existing potentials from the river *Arkavathi*. As aresult, the potential created has increased to almost 93.45 percent during 2004(Table.4). However, supply and potential gap persisted. Similarly, while, demand and supply gap also reduced gradually during 1991-2004(1991:60.7%;2004:,88.8%) the demand and consumption gap has videned quite significantly and persisted during the same period (Table5) (1991:50.6%;2004:54%) (Fig.1)

Table. 5: Water Demand, Potential, Exploitation, Consumption, Un accounted for Water and Per Capita Consumption in Bangalore : 1991-2004

Year	Water demand in million litres (based on 150 lpcd)	Water potential (in million litres)	Water Produced (in million litres)	Water consumed (in million litres)	Percent UFW	Water Supplied lpcd	Water consumed lpcd	Percent Shortage	Percent shortage after adjustment for UFW
1991	225935	141375	137174	114341	16.65	91	76	39.29	37.64
1992	235790	141375	124654	108588	12.89	79	69	47.13	47.21

1993	245645	229125	148381	123402	16.83	90	75	39.59	37.76
1994	255500	229125	170536	132472	22.32	100	78	33.25	25.93
1995	265355	229125	200404	140414	29.93	113	79	24.48	9.55
1996	275210	229125	206818	146107	29.35	114	80	24.85	10.50
1997	285065	229125	201154	145134	27.85	106	76	29.43	16.58
1998	294920	229125	209605	145307	30.66	106	74	28.93	13.27
1999	304775	229125	224006	152396	31.97	110	75	26.50	9.53
2000	314630	235625	236420	157751	33.27	114	75	24.86	6.59
2001	318280	235625	247382	167074	32.46	113	76	22.27	4.51
2002	327405	235625	260036	168810	35.08	115	75	20.58	-0.50
2003	336895	323375	274877	176737	35.70	122	79	18.41	-2.29
2004	346020	323375	307680	186935	39.24	133	81	11.08	-17.08

Source: BWSSB, Handbook of Statistics 1997-98&1998-99; Annual Performance Report 2000- 01and 2001-02.

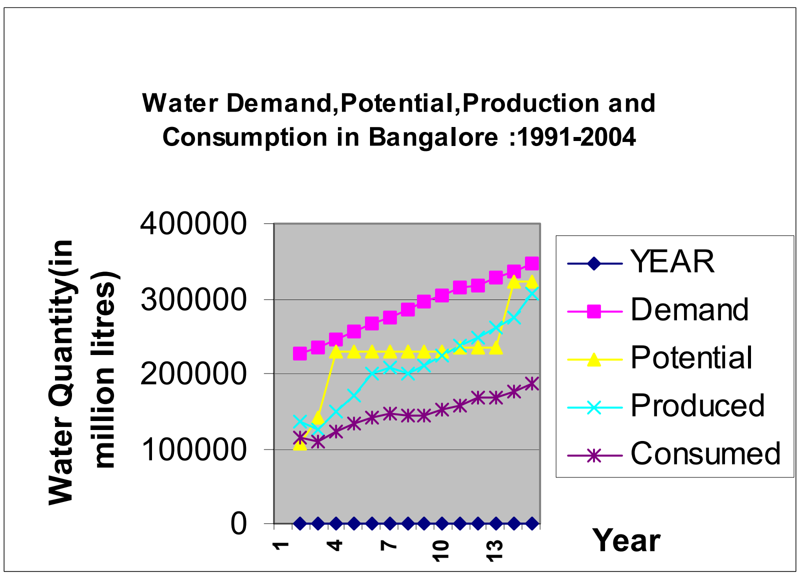

Fig.1

Meanwhile,another dimension of water shortage has emerged in the form of `unaccounted for water` arising out of the supply and consumption gap. As explained earlier, this is an universal issue and has been posing serious challenge in the management of urban water supply in developing countries. Bangalore is not an exception to this problem. In Bangalore, the percentage of unaccounted for water was slightly higher than the allowable limit(15%) in1991(16.65 %). However, during 1991-2004 this percentage has more than doubled from 16.65 in 1991 to 39.24 in 2004. thus compounding the issue of shortage. The most horrifying fact is that even in the case of highly expensive water form the Cauvery system, the quantum of un-accounted for water assessed using bulk meter installation is as high as 44 per cent (AUSAID,2002). As a result, the per capita water supply in the city which is already below (115) the prescribed standard of 150 lpcd has further reduced drastically due to ufw (81) during 1991-2004. Hence, the process of augmentation of water resources by the BWSSB with huge investment to meet the demand has ended up in gradual increase in the share of unaccounted for water instead of improvement in the percapita consumption thus turning the very costly exercise of additional potential building into a futile one.In fact, it has been demonstrated that the exising water shortage may be erased provided the share of unaccounted for water is reduced to a minimuml(Table.5). The situation in the other metro cities of India is also not that favourable.While, Mumbai(18%) had the lowest share of un-accounted for water with moderate levels in Chennai(20%)and Delhi(26%), Calcutta(50%)has recorded the highest share (Ruet, Saravanan and Zerah,2001). Even in the neighboring million city, Hydrabad, the water loss has been estimated as 51 percent (Saleth,1997).

On the basis of total water produced (247382 million litres) and the total cost incurred for production and supply (5722 million rupees) during 2001, the unit cost of production per kilo litre of water in Bangalore is Rs 23.13. This cost is as per the water received for distribution. The unit cost of production which was nominal in 1991 (Rs 5.98) has almost increased by four times(Rs 23.13) during 1991-2001 with an annual increase of 28.7 percent(Cost.1,Fig.2) This cost is derived based on the total quantity of treated water received for distribution without adjusting for the water loss. In Mumbai and Chennai the cost of production per kilolitre are Rs 2.17 and Rs 5.73 respectively (Charankar and Sahasrabudhe,2003) which is nominal as compared to Bangalore Two more dimensions are involved in the production cost : a) cost of production by excluding the share of un-accounted for water, b) cost of production by including the share of un-accounted for water with suitable adjustment.

The BWSSB has lost almost 80,308 million litres (32.46 %) of precious treated water as 'un –accounted for water' in 2001 and it has revealed an increasing trend during 1992-2001 which should be brought into our cost calculations to reflect the real cost. Hence, the unit cost of production and supply of drinking water to the city after excluding the share of un-accounted for water in 2001 is Rs 34.25.This cost was Rs 7.12 in 1991 and has recorded almost five fold increase which is much steeper than the simple production cost(Cost.3,Fig.2). Hence, the higher share of unaccounted for water has posed huge financial burden on the BWSSB to the tune of Rs 11.12 per kilo litre of water in 2001.This is in addition to restricted water resource to the consumers. During 1991-2001, this difference has magnified almost by ten times from Rs1.14 to Rs 11.12 which has obvious implication on the tariff structure which is subject to frequent revision. Hence, the BWSSB should take appropriate measures to reduce the share of water loss to an acceptable level. The cost calculations reworked by allowing for an acceptable level of 15 percent wastage has revealed the cost per kilo litre of water as Rs 27.50 (Cost.2,Fig.2)which is very close to the cost per kilo litre without the adjustment for water loss (Rs 23.13) as compared to the total exclusion of water loss (Rs 34.25). Obviously, all the three cost behaviours have revealed an increasing trend with the cost per kiloliter excluding water loss and including water loss with the cost trend with adjustment of water loss squeezing in-between.(Fig.2).

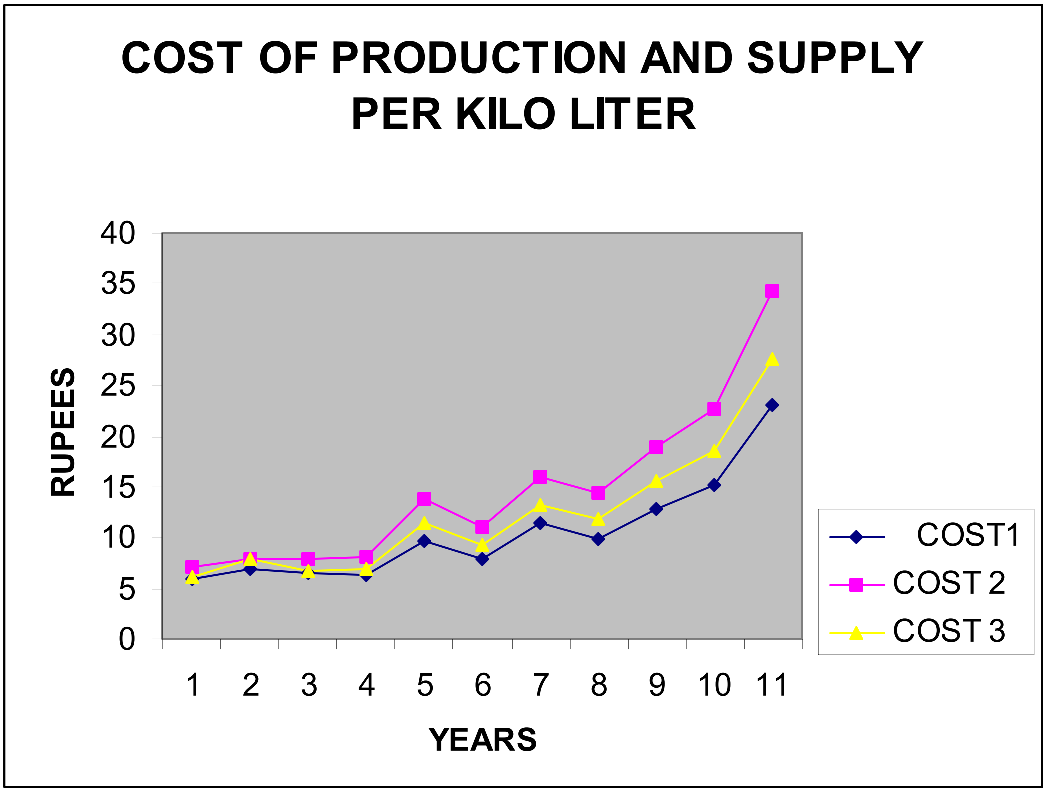

Fig. 2

In addition, there are differences in the cost of production per kiloliter of water among the various supply source as well as between various stages and phases of the river Cauvery (Thipeswamy, 2003, Table 4)).

Hence, efficient policy decision is imperative to achieve the minimum UFW level to save the precious natural resource in addition to huge investmentin and meeting of consumption requirements.However, in reality, limited water potential and higher share of unaccounted for water have made the water shortage problem to persist. This induced artificial resource crunch emanated out of management and infrastructure deficiencies could be the main reason for the most unpalatable policy decision by the Bangalore Water Supply and Sewage Board(BWSSB), to supply water to the consumers on alternative days.. This problem in turn has forced the various socio-economic sections of the population to adopt appropriate strategies to bridge their water shortage. As a result, affordable middle and high income households have gone for private water management to bridge the water shortage through indiscriminate digging of borewells in their residential premises with no regulation on the parameters like inter borewell distance, quantity of extraction of water, depth of the borewell and sustainability of number of borewells with respect to the ground water reserve and its recharge etc. A rough estimate about number of private borewells in the city is around 100,000 and it is increasing at the rate of 1000 borewells per year. Development of storage facilities in the form of sump and overhead tank and water lifting pump.An an average a middle of high income group household had to spend about one lakh to meet all these infracture requirements in addition to .spending on the energy for lifting the water from sump/borewell.This has turned out as a costly but inevitable exercise to meet the water demand. While, poor have to encourage water venders by paying huge amount to meet their water needs.

The share of unaccounted –for water has indicated an increasing trend since 1991 and reached almost an alarming level(39.24%) in 2004. Althpugh BWSSB has been active towards the reduction in the share of ufw, but it is in the form of only through passive leakage control measures like repairing visual leakes,and leaks reported by consumers. However, the need of the hour is the active leakage control measures such as establishment of DMAs,conducting leak detection serveys, reparing leakes quickly,inspecting and replacing defective metres, rehabilitating the water distribution network.By looking at the scarcity of the water resource and rapidly increasing demand for water in the city and the increasing share of ufw,the Bangalore water utility viz; BWSSB has recognized the seriousness of the issue and had initiated a pilot study in 2003 to diagnosis the causes for rapid increase in the share of unaccoted for water in the city. The study had covered the twin issues of unaccounted for water and distribution system rehabilitation. The pilot project area formed the city core area where water distribution network was laid in 1940.The area covered were johnson market, ulsoor service area, M G Road and hosure road,vasantha nagar, shivaginagar, coales park,lavelle road,cubbon park road and the areas surrounding the reservoyer existing in the study area. The study had a coverage of 32,833 service connections and 350 kms of distribution network.The scope of the study had covered the formation of district metre area to measure the bulk water supply to each DMA,and their leakage level,inspection of all revenue metres,fixing of new metres where unmetred water connection previles, metres are not working; testing of metres for its accurate recording, and to measur the difference between the inflow of water into DMAs and water supplied to consumers.

For proper recording of water flowes into DMAs and to identify the the problems of ufw, water balance chart was developed for each DMA.The DMA measurements are taken between 12.00 midnight and 04.00 am when consumption in the DMA is at a minimum and water flow is maximum.

The overall baseline leakage level of all DMAs derived on the basis of weighted average was 134 l/c/hr which has reduced to 72 l/c/hr as on november, 2004 with the implementation of pilet project activities.in the study area. The reduction in ufw at various DMA level with the implementation of project activities is significant during the project period in the study area (Table 6). Similarly, almost 31 percent of the consumer metres were found defective with improper recording of water consumed by the consumers. The major cause for the leakage has been attributed to problems in the main followed by service pipes and standpost. By exteding the ufw study to the entire city area, about 276 MLD of water can be saved (BWSSB, 2004). This ha sobvioous inplications specially on finance and water supply and percapita consumption level.

Table 6: Details of Sample DMA on supply duration, pressure, baselin, current and targeted leak levels

DMA	No.of connections	Supply duration(hrs/day)		AveragePressure (in metres)		Leak Reduction(l/conn/hr)		
		original	current	original	current	Baseline level	Target level	Current level
DMA-1	1364	12	24	11	13	87.26	28	38.57
DMA-3A	1680	8	8	6.5	10.5	96.42	31	38.48
DMA-3C	37	12	24	2.5	4.7	91.62	30	23.49
DMA-4	609	12	12	3.4	3.4	197.05	152	170.00
DMA-5	3209	24	24	1.4	6	108.36	89	29.90
DMA-6	996	8	8	3.1	4.6	106.56	34	43.00
DMA-7	1604	24	24	6.8	5.2	240.90	34	74.10
DMA-8	42	12	12	4.7	5.4	212.14	79	142.82

Source: BWSSB,2004

Table 7: Types of leakage and their Percent share in the pilot project area

Sl no	Type	Percent
1	Main	36.0
2	Service pipe	25.0
3	Standpost	24.0
4	Main valve	8.0
5	Meter joint	4.0
6	Ferrule	2.0
7	Stopvalve	1.0
8	Airvalve	0
9	Others	0

Source: BWSSB, 2004

Summary and Policy Issues

Rapid increase in demand,limited availability and detariorating water quality have all resulted in acute water shortage thus, calling for water conservation and sustainable use to save the precious water resource. Due to lack of required data base on the various componets of water resources the policy decision with regard to strict conservation measures and sustainable use has been posing a serious challenge.

In urban water sector, in addition to innumarable problems of distribution, quality and quantity, the most alarming issue is the rapid increase in the share of non revenue water or unaccounted for water. The increasing share of ufw has not only imposed serious problems to the water supply utilities in terms of finance, infrastructure, technology but has led to loss of huge precious resource that to after huge invetment towards it treatment and distribution. This is a global issue and the attempts are being made to reduce to a minimum level.

In Bangalore, the share of ufw has increased significantly to the the level of almost 40 percent thus calling for immediate measures for its reduction.Accordingly, BWSSB has initiated a study to identify the causes and its reduction. The study has identified the main causes for the ufw as leakage and metre recording problems as well as the unauthorised consumption..The strudy if extended to the entire city area would save the treated drinking water to the tune of 276 MLD per day. The BWSSB by looking at the cost escalation for the new projects is very keen on the reduction in the share of ufw to save both huge investment and precious water resource.

Since ufw is a very issue in urban water management, there is a need for proper data base with good periodicity at various regional and national levels to assess its possition for its planne dreduction.

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Issues of Waste Water Resources

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ABSTRACT

This paper mainly suggests suitable methodology for sustainable wastewater re-use for Bangalore city looking at the availability of fresh water resource – from both surface and ground water in the next two decades. It is imminent that wastewater re-use need to be supplemented for augmenting the water requirement for growing population

The world fresh water is finite and is threatened by pollution. Rising demands for water to supply to agriculture, Industry and water supply to cities are leading to competition over the allocation of limited fresh water resources. This paper examines how water re-use increases the available supply of water and enable human needs to met with less fresh water. This paper also illustrates with water reuse case studies in agriculture, Urban areas and industry, water resources supplimentation in different countries. Water conservation and water reuse produce instrumental environmental benefits, arising from water diversions and reduction in the impact of wastewater discharges on environmental quality. In addition wastewater reuse with reference to Bangalore city is also highlighted in the light of huge industrial and Urban requirement and non-availability of fresh water further augmentation to growing population.

1. Introduction

The natural water cycle

In nature water (like energy) is neither created nor destroyed but is converted from one form to another. In the water cycle, rain falling on the land is mostly transferred by vegetation. But some percolates to ground water and some run off the rivers and flows to the ocean to evaporate and return as rain. 97% of World water is in the Ocean, which is salt water of the raining 3%, two third occurs as snow and ice in polar region. Thus only about 1% global water occurs as fresh water source. Of this 1% 98% is in ground water rest 2% in streams and rivers and lakes. So the fresh water availability is finite and limited.

Mankind has significantly altered the natural water cycle by over laying new water cycle elements including

a) Extraction from rivers and grow water for urban industrial and agriculture use
b) For agriculture runoff.
c) Return of treated or untreated wastewater to streams.

In many parts of the world ground water is the main water resource and often rates of extraction exceeds rate of re-charges generated. So the ground water levels are declining.

Urban development also has significant impact on water cycle. Water drawn for urban water supply reduces the stream flow in rivers. At the same time storm water runoff and wastewater discharges which often carry high levels of pollution cause a decline in the water quality. Serious degradation has been observed in many rivers like Ganga, Yamuna etc., which have high levels of development in their catchment.

2. Emerging water shortages

World's supply of fresh water is finite and is threatened by pollution. Rising demand of water supply for agriculture, industry and water supply to cities are leading competition over the allocation of fresh water resources. In many countries the available fresh water resources are heavily committed and in some cases perhaps already over committed. To avoid the water crises many countries must conserve water to manage supply and demand, pollute less and reduce environmental impacts of growing population.

Bangalore city is also an example of such a situation. Non availability of fresh water from Arkavathi sources such as Hesaraghatta and T.G. halli and dependency on Cauvery water sources has already made situation vulnerable. Augmenting water from Cauvery source is very costly and has limitations. Probably beyond CWSS Stage IV Phase II further tapping from Cauvery is also not possible. This has really driven for looking at alternate sources like wastewater reuse. Scenario of water resource availability is same as Bangalore, in many urban areas of Indian sub continent. Many cities in India are looking for re-use of wastewater for urban requirements such as Industrial requirement and non potable use.

3. Source substitution

Source substitution is not a new idea. In 1958 the United Nations economic and social council enunciated policy that "No higher quality water unless there is surplus of it should be used for a purpose that can tolerate a lower grade" (United Nations 1958). With the growth and increased density of population, few cities can enjoy a surplus of high quality of water, if they do this surplus can be expected soon to be exhausted.

The use of reclaimed water for non potable purpose offers the potential for exploiting a "new" resource that can be substituted for existing sources. By source substitution replacing the potable water used for non potable purposes an increased population can be served from existing source.

Many urban residential, commercial and industrial uses can be satisfied with water of less than potable water quality. They are irrigation of lawns and industrial cooling, towers, parks, road way 'borders' and medians, industrial processing, toilets, air conditioning, cleaning including vehicle washing, functions and environmental and recreational purposes. Customary Public water supplies are designed to provide water of potable quality to reuse all these purposes.

4. Pollution abetment

While the need for additional water supply has indeed been the impetuous water reclamation and reuse programme in arid and semi arid areas rigorous and costly requirements of effluent discharge to surface water particularly the removal of nitrogen and phosphorous is taken up.

For most non potable reuse applications, nutrient removal is unnecessary and actually contradicted for irrigation.

The purpose and practice may differ between water re-use programme developed strictly for pollution abetment and those developed for water resources or conservation benefits.

Naturally, a wastewater re-use programme can easily serve both water conservation and pollution abetment purpose.

5. Water quality consideration for different uses.

The overriding consideration in developing a reuse system is that the quality of the reclaimed water be appropriate for its intended use. Higher level uses such as irrigation of public access and lands and vegetable to be consumed without processing require a higher level of wastewater treatment prior to reuse than with lower level uses such as pasture irrigation etc.

6. Dual water supply system

In many parts of USA, Australia and other countries parallel water supply system for potable / non potable system for distribution has been provided for meeting the requirements separately. In all such cases sufficient safe guards have been provided to prevent cross connections from reclaimed water. In case of reclaimed water generally separate colour code is given for pipeline valves, hydrants etc., to distinguish from potable water supply system. Other safe guards like back flow prevention devices are also installed.

7. Water recycling in action

The mission of water supplier is to provide reliable high quality services that meet customer needs and to protect environment. In the recent years many countries have implimented water recycling projects successfully. The experience demonstrates feasibility of water reuse on a large scale and its role in sustainable management of world's water. Few examples of agriculture, industrial and urban use are indicated below.

7.1 Reuse for agriculture

a) **Mexico City** : In Mexico nearly 90% wastewater is used for irrigation in the valley of Mexico and Mezquital Valley, an area of low rainfall and poor soil. About 45 m3/sec., (390 MLD) is transferred to Mezquital Valley where it is used for irrigating 90,000 hectares.

b) **Monterey California :** The Monterey regional water pollution control agency has constructed a scheme to reuse up to 20M m3/y of recycled water for adjoining town to irrigate 5000 hectares of land to grow vegetables in lower Salinas valley. Earlier excessive use of ground water has resulted in salt water intrusion to in aquifers.

c) **Virginia, Australia :** In South Australia a major scheme has been constructed to supply up to 30M m3/y recycled water from Bolivar Sewage treatment plant in Adelaide to the Virginia area of Adelaide for irrigation of horticulture crops. The scheme include 120,000 m3/d water reclamation plant that incorporates dissolved air flotation and filtration processes.

7.2 Urban Reuse

a) **Rouse hill, Australia :** In Australia water is recycled for residential uses at Rouse hill a new housing development area in the North Western sector of Sydney. The area is ultimately planned to have 3,00,000 people with the first stage of development catering for 1,00,000 people in 35,000 houses. The reticulation system is mainly installed for using recycled water for toilet flushing and gardens.

b) **St. Petersburg Florida :** The city of St. Petersburg in Florida has constructed an extensive urban water re-use scheme, which has been in operation since 1977 which now supplies approximately 10,000 properties including 9300 residential properties. Reclaimed water use, include urban and residential landscape use, industrial uses, air conditioner chillier water and have backup source for fire protection. The scheme supplies an average of about 80,000 m3/d of recycled water.

c) **Mawson lakes, Adelaide :** The Mawson lakes housing development in Adelaide, Australia will house 10,000 people in 3700 houses and also serve a university and a commercial and industrial estate. Wastewater from the estate will be treated and recycled for toilet flushing and landscape irrigation

7.3 INDUSTRIAL RE-USE (Steel production)

a) Recycled water is supplied to steel work for variety of process water including cooling water, water quenching for blast furnace slag and quenching at the coke ovens. It is currently planned to expand the water recycling systems at the port Kembia Steel Works in Australia to at least 35,000 m3/d and possibly to 50,000 m3/d.

b) Semi conductor manufactures : Singapore public utility Board has been conducting the Singapore NEW water project a 10,000 m3/d demonstration project to demonstrate the suitability of recycled water, which has received advanced treatment to supply high purity water for high technology and semi conductor industries. The demonstration project, which has been commissioned in May 2000 includes extensive health studies. A dual membrane process using micro filtration followed by reverse osmosis followed by ultrafiltration has been used.

c) Oil recycling, Australia : A 14,000 m3/d dual membrane water reclamation plant has been installed at luggage point sewage treatment plant in Brisbane to supply to BP Oil refinery.

8. Recycling to supplement water resources

Incidental or unplanned supplementation of water resources is widespread where treated wastewater is discharged to rivers, lakes that are subsequently used for drinking water supplies. Commonly quoted cases include the Thames and Rhine Rivers where multiple uses occur between source and the ocean.

South Africa : Waste reuse has played a major role in matching demands and available raw water supplies. The 1956 Water Act required treated wastewater flows to be returned to stream of origin unless applied to beneficial reuse, a requirement that encouraged the introduction of high standards of treatment. As a result, recycled water constitutes a substantial proportion of the base flow in many rivers. For example, recycled water is now about 50% of the inflow into Hartbeespoort Dam, which supplies water to Pretoria and Johannesburg (Odendaal et al., 1998).

Orange County, California : Since 1976, Orange county in California has operated Water Factory 21, a 57,000m^3/d water reclamation plant producing recycled water drinking water standard which is injected under pressure into a heavily used potable aquifer to prevent salt water intrusion. After more than 15 years of intensive groundwater monitoring, Orange County has observed no change in groundwater quality that would cause a public health concern. The plant is currently being expanded to 200,000m^3/d using a dual membrane process.

Windhoek, Namibia : Windhoek the capital city of Namibia, is situated in the central highlands of Namibia between the Kalahari Desert to the east and the Namib Desert to the west. The nearest perennial river is the Kavango, 750 km away. As a result of severe water shortages during drought, the world's first potable water reclamation plant of 4,800m^3/d capacity was constructed in 1968. The plant has consistently produced water of acceptable potable quality for 30 years. It has been upgraded on several occasions and is currently being enlarged to 21,000m^3/d using dual membrane technologies. Overall since 1968, recycled water has contributed 4% of the total water supply in Windhoek but has been up to 31% of the total supply during severe drought periods. The recycled water is blended with treated water from the Goreangab water treatment Plant before distribution, with the maximum blend being 1:1 during drought periods. The average blend since 1968 has been 1:3.5. The blend from Goreangab is mixed with water from other sources in the service reservoirs so that normally there is a maximum proportion of 25% recycled water in any zone in any period (van der Merwe and Menge, 1996).

9. Scenario in Bangalore

Bangalore is situated on the watershed of two principal river basins, the Arkavathi to the West and South pennar to the East and the general elevation of the city above sea level varies between 940 mtrs. The local topography is characterised by a series of well defined valleys which radiate from a ridge of high ground to the north of the city and fall in a gradual manner towards a wide belt of flat cultivated land extending beyond the limits of the metropolitan area to the South. The Configuration of the valleys and well graded side slopes of their tributary areas have provided Bangalore with a natural system of drainage without water flow by gravity beyond the city.

Unlike many other cities Bangalore is not blessed with a perennial river and this could be the reason for construction of many lakes across the seasonal streams. With the rapid urbanization of the city many of the lakes have been destroyed and converted into residential localities. These lakes, which were acting as source of ground water recharge, have gone consequently the water table is depleting rapidly.

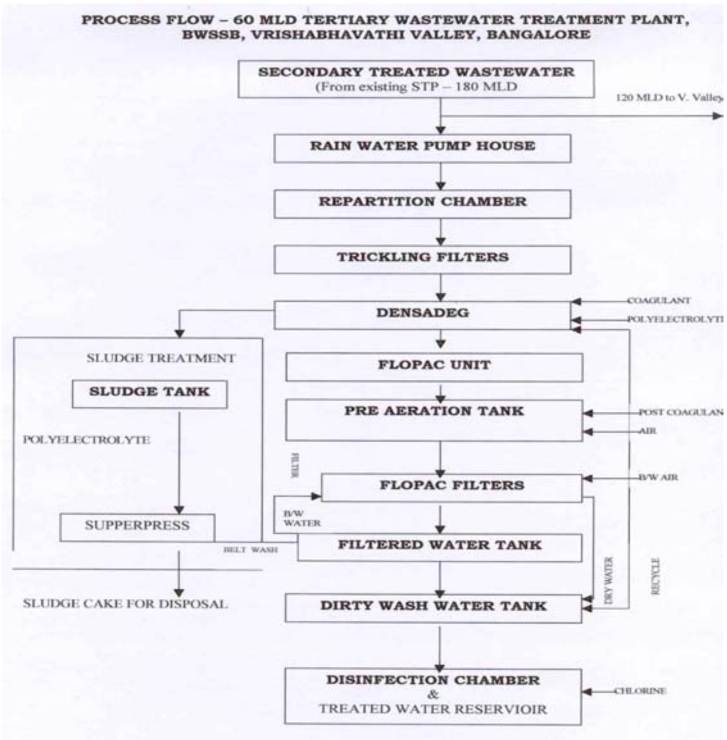
At present about 850 MLD of water is being supplied to the city from two sources and water is supplied every alternate days. The dependency of oldest surface resource, Arkavathi has dwindled over a period of time. Fresh water was recently augmented to an extent of 270MLD. About 80% of wastewater, which is being treated upto secondary levels before being discharged into natural valleys.

Since city gets fresh water from vary far off sources against high heads, the production cost of water is high due to high energy cost involved in pumping. The production cost after implementing CWSS Stage IV Phase I is estimated to be around Rs.18/-per Kilolitre. Further there are no nearby fresh water resources for augmentation. Therefore, wastewater generated in the city should be treated as a source for non-potable use.

In order to reduce the burden on fresh water resources for drinking purposes, BWSSB has set up a 60MLD recycling plant at V. Valley and 10 MLD recycling plant at Yelahanka under French Funding. Recycled water from V. Valley will meet the requirements of industries along Bangalore Mysore Road and Bidadi Industrial area for non-potable purposes. Recycled water from Yelahanka will meet the requirements of BEL, Wheel & Axle, Air Force and proposed international Airport at Devanahalli and other industries enroute.

10. V. Valley tertiary Treatment Plant

The existing plant is of 180MLD capacity and the wastewater is treated upto secondary levels through an activated sludge process. The quality of tertiary treated wastewater calls for a high level removal of organic & specific inorganic pollutants from wastewater. This is achieved by treating the secondary effluent in the following manner.



i. Treatment for removal of suspended and soluble biodegradable pollutant i.e. TSS, BOD_5 using a combination of biological and physio chemical treatment. Thus includes the treatment of sludge.

ii. Treatment for disinfection of treated water plant process

The treatment chain consist mainly

- Trickling filter
- DENSADEG high rate clarifiers.
- FLOPAC attached growth biological reactor
- Chlorine based disinfection


11. Yelahanka Tertiary Treatment Plant

The sewage effluent from the Yelahanka satellite town and its surroundings, which were earlier led into a nearby tank without any treatment is now treated up to tertiary levels in the 10MLD plant set up at Yelahanka.

The treatment unit consist of primary, secondary and tertiary treatment stages and the attached flow sheet indicates the process flow diagram.

11.1 Process description

Screening: Wastewater is screened through 2 automatic cleaned curve type screens that have a bar spacing of 10mm and is designed to handle a flow rate of $450m^3$ /h each.

Grit and Grease removal: Two combined Grit and Grease removal units are provided and volume has been sized to have necessary retention time to separate grit from organic suspended solids and to collect grease and oil. Grit is collected and removed from wastewater in an aerated grit chamber. The injected air by means of a submerged turbine induces fine bubble production, enabling oil removal. Velocity along the bottom allows the sand to settle while keeping sludge in suspension.

A grease separation zone is incorporated, as excessive amounts of grease and oil are harmful for activated sludge.

The floating waste extracted from grit and grease removal tank is mainly composed of grease and it will be scraped by a skimmer into a storage chamber for further disposal.

Primary settlings: This unit aims to remove maximum quantity of pollutants easy to settle such as suspended solids. Suspended solids removal particulate are collected by a sludge scraper and discharged to a sludge collection sump by gravity and pumped to the sludge thickener. A scum skimmer attached to the scraper bridge collects floating materials, while the supernatant is collected via an overflow weir plate at the top of the tank.

Aeration tank: After primary settling, wastewater is treated using a medium load activated sludge process. A large percentage of bio-degradable matter constituents in the wastewater is absorbed and broken down by bacteria in the ASP. The oxyzen required for the degradation process is supplied by means of OTV turbines, as surface aerator.

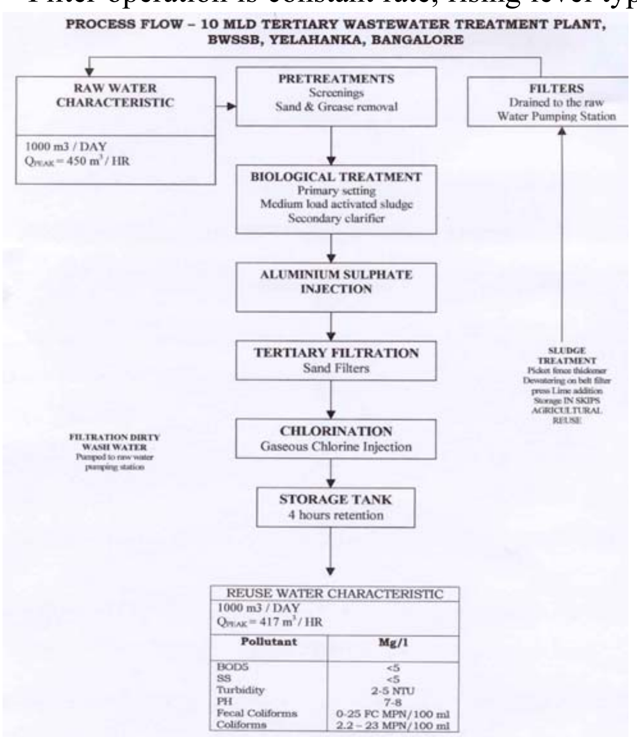
Secondary clarifier: Following the ASP, sludge must be separated from the mixed liquor in order to allow treated wastewater pass to the next step of the treatment. The separation is carried out by gravity in a circular secondary clarifier. Sludge being more denser than water, falls into the bottom of settler while supermatent is collected through an overflow weir plate at the top of tank.

Sludge at the bottom is collected by a scraper system discharged to a sump from where it is pumped. A percentage of sludge is recycled upstream to serve as a source of bacteria to enhance ASP while rest is pumped to sludge thickener. Floating matter is collected in a scum collection box by a surface skimmer fixed to the scraper bridge.

Aluminium sulphate is used to coagulated secondary treated water on the filter media to enhance suspended solids removal process

<u>Filters</u>: Aluminium sulphate coagulated water is introduced by gravity to the OTV F-filter with a nominal filtration rate of 10mtrs. / hr. Water is fed to front of each filter above a weir followed by a wall opening designed to obtain a mean water horizontal velocity of 0.8 – 1.00mtrs/second. This high velocity avoids the phenomena of an uneven settling of suspended particulates over the length of filter and lifting of sand below inlet opening.

Filter operation is constant rate, rising level type, in which water flow is controlled by the inlet and outlet weirs of filters.



Filter layer consists of 2000mm bed of sand above a 100mm layer of gravel designed to protect the nozzles. A layer of support gravel, 4 to 7mm in size is provided above the floor with the nozzle, beneath the filter mass. The support provides mechanical protection of nozzles and drains off the filter washing water over its entire surface.

The particle size of filtration sand is 2mm for a coefficient of uniformity of 1.3.

The OTV F filter consists of a rectangular concrete tank with standard type false nozzle flow used as a support for filtering media. Floor is made of pre cast reinforced concrete slab equipped with OTV nozzles. Nozzles are integrated in the supporting floor and provide even distribution of air and water during washing phase as well as filtered water during filtration phase.

Filter backwash is triggered through detection of filter clogging. Back wash water is chlorinated to prevent any biomass formation on the nozzles and therefore any clogging. Back wash water velocity is set at 30m per hour during rinsing phase to guarantee an efficient backwash. Backwash sequence consists of air only, air and water and water only.

12. Conclusions

Successful water recycling projects have been implemented in many countries. This experience has demonstrated the feasibility of water reuse on a large scale and its role in the sustainable management of the world's water. Both project experience and comprehensive health studies have demonstrated the potential to use recycled water to supplement drinking water supplies. An integrated approach to urban water, sewerage and stormwater planning can identify opportunities that are not apparent when separate strategies are developed for each service. The result is better-integrated, more sustainable solutions, and substantial cost savings for local communities. Water conservation and water recycling measures are key elements in integrated urban water planning.

Water conservation and beneficial reuse can reduce freshwater diversions from streams and improve downstream water quality. There are many direct and indirect benefits, which result from reduced diversions and improved downstream water quality. These benefits should be evaluated and taken into account when assessing the merits of implementing new water reuse projects. Water reuse increases the available supply of water and enables greater human needs achieved with less fresh water, thus lessening mankind's impact on the world's water environment. A move from the old "use once and throw away" approach, to a new sustainable "conserve, use wisely and recycle" water economy will benefit the whole world. There is still much to do to improve water recycling technologies and improve the evaluation of project economics and sustainability. While the World's water problems may seem great, we have seen enormous progress in water conservation and recycling in the last 20 years. There is cause for optimism that, with focused effort, mankind can reverse the degradation of the planet's water environment and meet the world's water needs in a sustainable way.

Bangalore city is growing abnormally, the population is already 6.0 million and it will be about 7.5 million by 2011. Providing water supply is a gigantic task, there is no fresh water source other than Cauvery River. There is also limitation for drawing Cauvery water beyond 600 Cusecs. In view of non-availability fresh water source, authorities should look at alternative sources such as rainwater harvesting, recycling of wastewater, reducing un-accounted water and other options. Next stage of Cauvery is going to cost Rs.3500/- crores for augmenting additional 500 MLD and so also the O & M cost. The authorities should seriously consider making rainwater harvesting compulsory. Similarly wastewater recycling should be thought of with dual water supply system for new layouts. Using recycled water for urban usage should be made compulsory. Reduction of un-accounted for water and water auditing should be a regular phenomenon. Since fresh water resource is absolutely scares and not available, serious measures for Demand Management should be considered.

Water Quality Indices

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Abstract

The quality of water may be assessed using the Water Quality Index (WQI) developed by National Sanitation Foundation, USA in 1970. The index takes into account nine water quality parameters: Dissolved oxygen, Faecal coliform, pH, BOD_5, Temperature difference (1 mile), Total phosphate, Nitrate, Turbidity and Total solids. Water is graded for its quality from the worst to best on a scale of 0 to 100. The quality of water for a given parameter is represented by 'Q' value. Each water quality parameter is assigned a value known as Weighting factor. The value of weighting factor for each parameter ranges from 0 to 1, such that the sum of weighting factors for all the 9 parameters is 1. The water quality index for each parameter is given as the product of Q value and weighting factor. Overall WQI is the sum total of all the 9 water quality indices. The Overall WQI ranges from 0 to 100, and the quality of water is graded into five classes. The WQI though widely used for in the US and developed countries, does not take into account many factors which account for water pollution in Indian rivers and streams. If assessed in terms of WQI, all river waters flowing in the planes would have poor water quality. Besides there are other factors, which account for water pollution in India, such as heavy metals, pesticides and chemicals originating from industrial, agricultural and domestic uses. In order to account for water quality in terms of individual parameters, a unit free index, Water Pollution Index (WPI) is being proposed.

$$WPI = (X - Min) / Range,$$

where, X is the value of the parameter, Min is the minimum acceptable limit, Range is the acceptable range. For dissolved oxygen water quality is defined as

$$WPI\ (DO) = [(Min - X)/Range] + 1$$

The WPI would take into account not only the upper limits of tolerance but also the lower limits, and may be used for classification of waters for specific purposes. The WPI may be defined as the dilution of water required to make the water acceptable with water having minimum value of the parameter in the acceptable range. The WPI can be used to compare the water quality of different sources.

Introduction

The 2005 Environmental sustainability index (ESI-2005) arrived at by researchers at Yale using intricate mathematical tools has put India at a rank of 101 among 146 countries (Esty et. al., 2005) (Table 1). The dismal performance on India with ascore of 23 out of 100 for environmental systems, vis-à-vis the first ranker, the Finland, with a score of 74 needs to be urgently looked into (Table 2). The most glaring difference between the two countries is with regard to water quality indicator value, -0.96 for India and + 1.61 for Finland, the largest difference among all the parameters assessed.

Table 1. Environmental sustainability index - 2005. Comparative statistics of India and Finland.

	India	Finland
Ranking out of 146 countries	101	1
ESI	45.2	75.1
GDP/capita, USD	2530	23700
Variable coverage	69	75

Table 2. Sustainability scores of India and Finland

	Score out of 100 each	
	India	Finland
Environmental systems	23	74
Reducing stresses	50	61
Reducing human vulnerability	46	81
Social and constitutional capacity	51	92
Global stewardship	66	68

Water pollution in India has taken epidemic proportions and the menace poses the biggest challenge to be tackled. Sporadic research on the water front has not yielded perceptible results. Water management requires monitoring water quality, pollution control and judicious management of water resources. In this paper we present a brief treatise of the Water Quality Index (WQI) as given by National Sanitation Foundation (NSF) of America (Brown et. al., 1970). Though WQI is extensively used in most of the countries with slight modifications, its use in India is rare (CCME, 2004; CPCB, 2001; Cude, 2004; Des Moines, 2004). In order to account for variables not included in the WQI, albeit extremely important ones under Indian conditions, we propose an index, Water Pollution Index (WPI), which will assign a number to the water under test as to how many times it has to be diluted with the unpolluted water of minimum limit so as to bring it within the permissible limits for specific use.

The quality of water can be assessed on the basis of several characteristics, each of which beyond specified limits, may render the water unfit for use for specific purpose (Stream Keepers Handbook, 2005). The properties of various hazardous substances have been given by Patnaik, (1999). In order to monitor the water quality level of stream waters, the NSF surveyed 142 scientists and managers engaged in water quality research and management, for 35 short listed water quality factors (BASIN, 2004; Five Creeks, 2004;

Path Finder Science, 2005). On the basis of this survey, finally nine factors were selected for water quality assessment. These are:

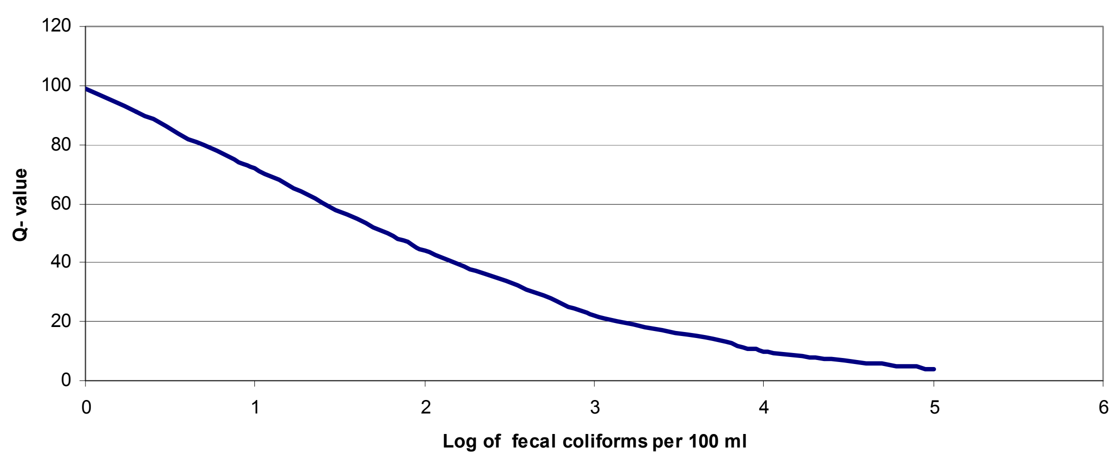
1. Dissolved oxygen (mg/L)
2. Fecal coliform (number/100 ml)
3. pH (standard units)
4. Biochemical oxygen demand – 5 day (mg/L)
5. Temperature change (1 mile, ^{0}C)
6. Total phosphate – P (mg/L)
7. Nitrates (mg/L)
8. Turbidity (NTU)
9. Total solids (mg/L)

Q – Values

Each parameter thus chosen was then scaled from 0 to 100 for given range of values for the parameter to grade water from the worst to the best. The data provided by the scientists were inputted to compute the average values. For each test value, a Q – value was assigned. Standard Q – value curves were drawn for each parameter. In the present communication Q – values were computed from the software available online and graphical representations made there from. Given below are the factors used for WQI:

Fecal coliforms: Fecal coliform bacteria are indicator of water pollution by human and animal excreta. Water contaminated by excreta carry harmful pathogens and are not fit for use. In general total coliforms are about ten times more abundant than fecal coliforms in water. Q- values for FC are given in Fig. 1 and table 3.

Fig. 1. Q- value for fecal coliforms (Q=2 for FC>100000/ 100ml)



Biochemical oxygen demand: Biochemical oxygen demand (BOD-5) measures the amount of oxygen consumed by microorganisms to oxidize organic matter inflowing water sources through death and decay, sewage, sewerage and industrial effluents. A high BOD value may create anaerobic conditions and detrimental to the growth of organisms. Q-values for FC are given in Fig. 2 and table 3.

Dissolved oxygen: Dissolved oxygen (DO) is vital for aquatic life. Percent saturation is defined as the ratio of DO to potential capacity of water to dissolve oxygen at given temperature and pressure. DO at 100 % saturation level is best suited for aquatic organisms. Both under and over saturation affect the growth and survival of organisms in water. Q- values for DO are given in Fig. 3 and table 3.

pH: pH measures the acidic or alkaline nature of water. Most of the aquatic organisms are affected by pH changes and survive best at 6 to 8.5 pH. The pH most suited to water plants and animals is 7.4. Lower or higher pH values decrease biodiversity. Q- values for pH are given in Fig. 4 and table 4.

Fig. 2. Q- value for BOD-5 (Q=2 for BOD>30 mg/L)

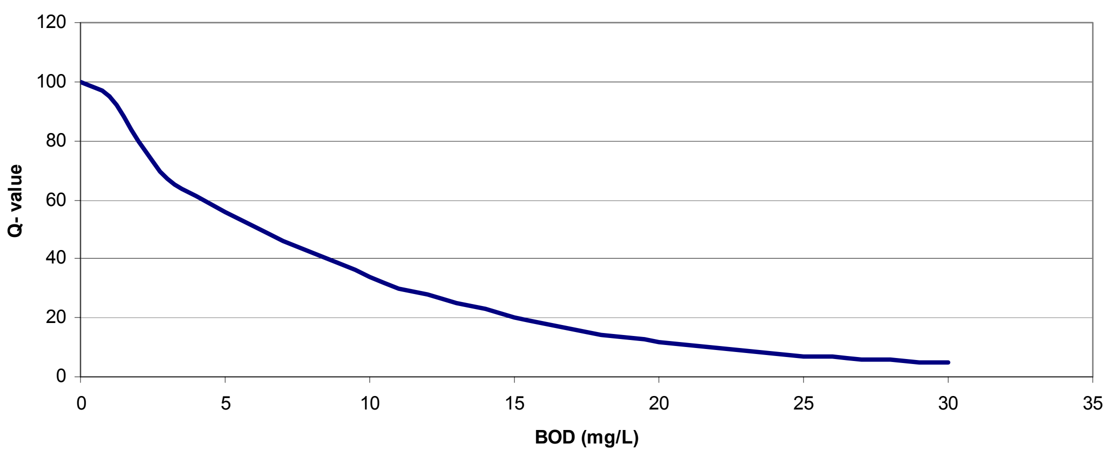


Fig. 3. Q- value for dissolved oxygen (Q=50 for DO>140%)

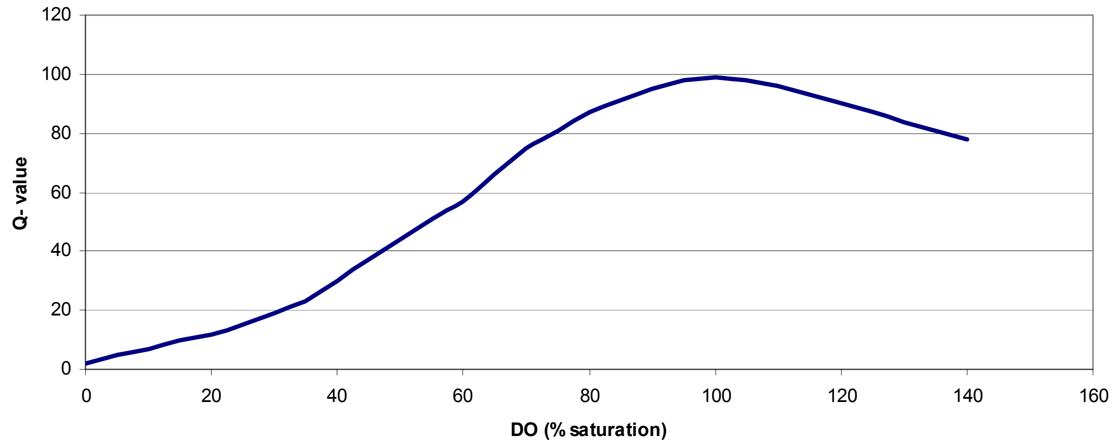
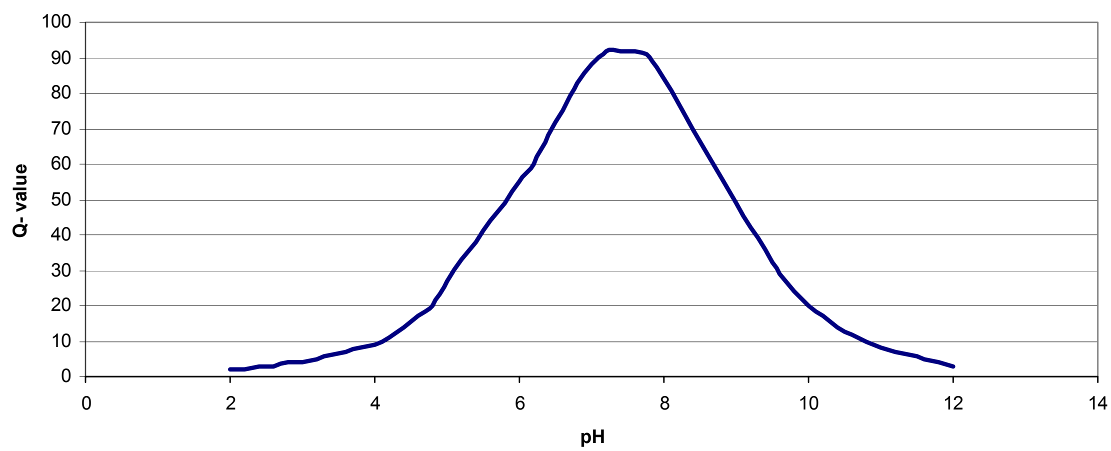
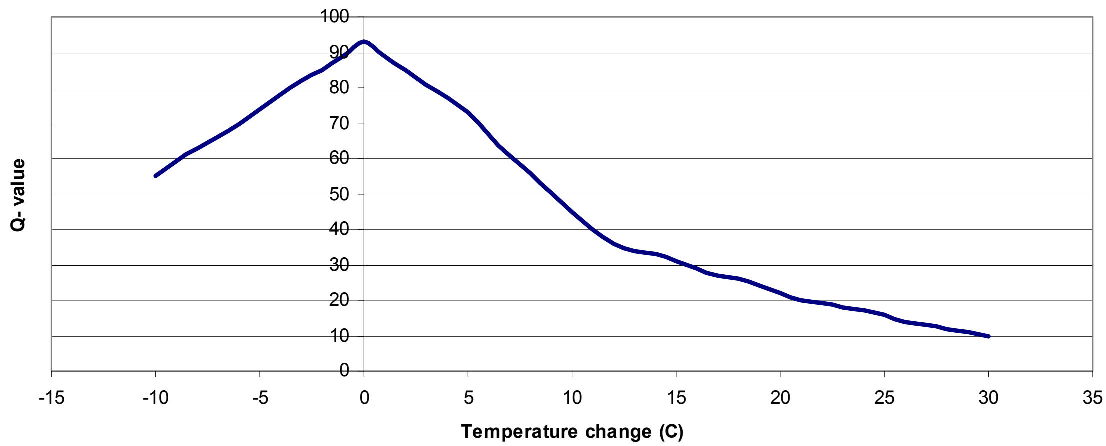


Fig. 4. Q- value for pH (Q=0 for pH<2 and pH>12)



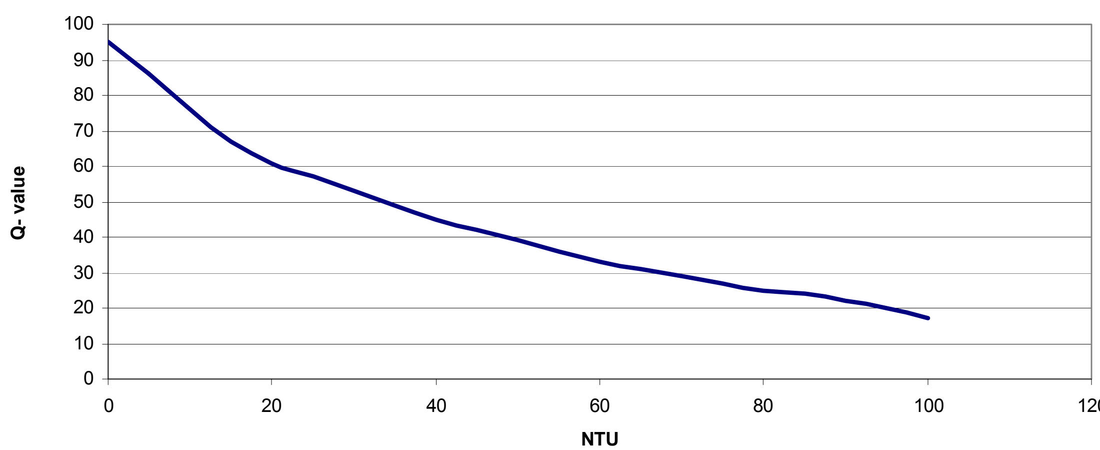
Temperature change: Since most of the organisms are cold blooded, they are quite susceptible to temperature changes. DO content decreases at higher temperatures as the rate of decomposition increases. The metabolic rates also increase at higher temperatures. Hot waters from thermal power plants and industries tend to increase water temperature. Removal of shading trees increases the diurnal variations in water temperature. Temperature change (TC) across points half mile upstream and half mile down stream is used as a factor affecting aquatic life. Q- values for TC are given in Fig. 5 and table 4.

Fig. 5. Q- value for temperature change



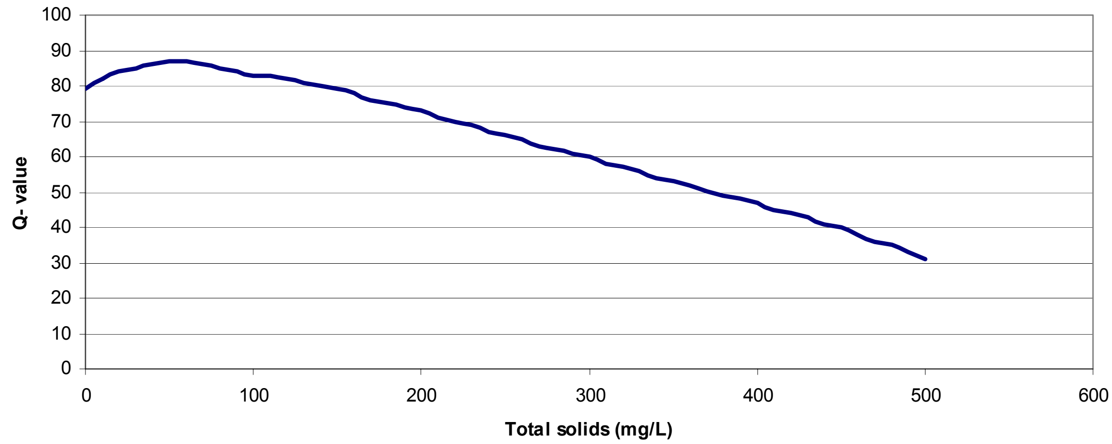
Turbidity: Turbidity measures the murkiness of water. It decreases the penetration of light in water, thus decreasing the growth of algae. Turbidity is caused by sewage disposal, industrial wastes, soil erosion etc. Q- values for turbidity are given in Fig. 6 and table 4.

Fig. 6. Q- value for turbidity (Q=5 for NTU>100)



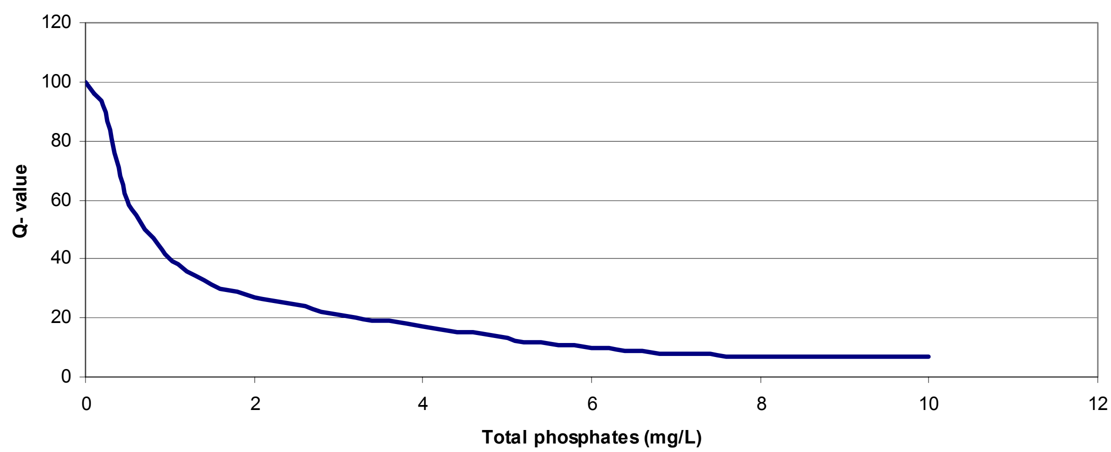
Total solids: Total solids (TS) include suspended solids and dissolved solids. At low concentrations dissolved solids are essential for organisms, but at higher concentrations TS limit the growth of organisms. The sources of TS are ash from thermal power plants, fertilizers, effluents, sewage, sewerage etc. Q- values for TS are given in Fig. 7 and table 5.

Fig. 7. Q- value for total solids (Q=20 for TS>500 mg/L)



Total phosphates: Total phosphates (TP) are the main cause of eutrophication which leads to chocking of streams and other water bodies. Main sources of TP are detergents, fertilizers and sewerage etc. Q- values for TP are given in Fig. 8 and table 5.

Fig. 8. Q- value for total phosphates (Q=2 for TP>10 mg/L)



Nitrates: Besides providing a source of nourishment to plants, nitrates may cause urinary disorders. The main sources of nitrates are fertilizers. Q- values for nitrates are given in Fig. 9 and table 5.

Fig. 9. Q- value for nitrate (Q=1 for nitrates>100 mg/L)

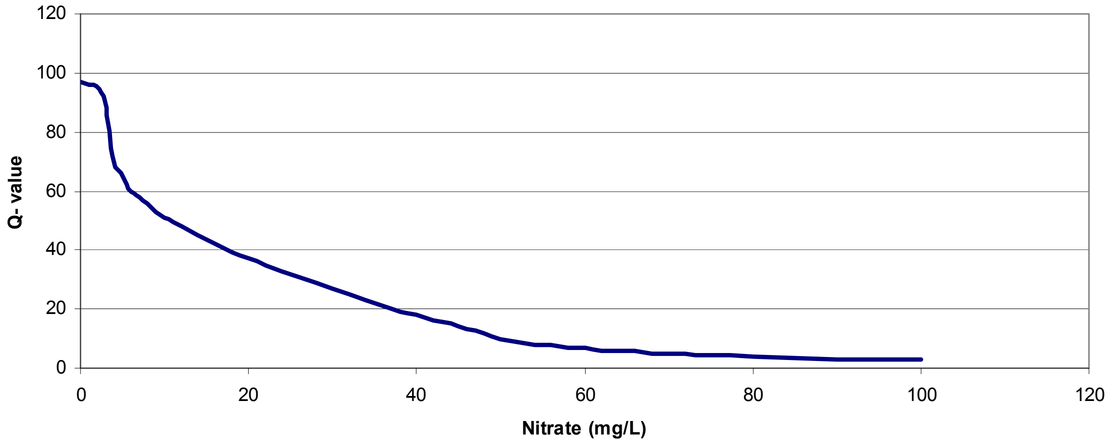


Table 3. Water quality values (Q- values) for Fecal coliform, BOD and DO

Fecal coliforms (per 100 ml)	Log_{10} FC	Q	BOD-5 (mg/L)	Q	Dissolved oxygen (% sat)	Q
1	0	99	0	100	0	2
2	0.30103	91	1	95	5	5
3	0.477121	86	2	80	10	7
4	0.60206	82	3	67	15	10
5	0.69897	80	4	61	20	12
6	0.778151	78	5	56	25	15
7	0.845098	76	6	51	30	19
8	0.90309	74	7	46	35	23
9	0.954243	73	8	42	40	30
10	1	72	9	38	45	37
20	1.30103	63	10	34	50	44
30	1.477121	58	11	30	55	51
40	1.60206	55	12	28	60	57
50	1.69897	52	13	25	65	66
60	1.778151	50	14	23	70	75
70	1.845098	48	15	20	75	81
80	1.90309	47	16	18	80	87
90	1.954243	45	17	16	85	91
100	2	44	18	14	90	95
200	2.30103	37	19	13	95	98
300	2.477121	34	20	12	100	99
400	2.60206	31	21	11	105	98
500	2.69897	29	22	10	110	96
600	2.778151	27	23	9	115	93
700	2.845098	25	24	8	120	90
800	2.90309	24	25	7	125	87
900	2.954243	23	26	7	130	84
1000	3	22	27	6	135	81
2000	3.30103	18	28	6	140	78
3000	3.477121	16	29	5	>140	50
4000	3.60206	15	30	5		
5000	3.69897	14	>30	2		
6000	3.778151	13				
7000	3.845098	12				
8000	3.90309	11				
9000	3.954243	11				
10000	4	10				
20000	4.30103	8				
30000	4.477121	7				
40000	4.60206	6				
50000	4.69897	6				
60000	4.778151	5				
70000	4.845098	5				

80000	4.90309	5
90000	4.954243	4
100000	5	4
>100000		2

Table 4. Q values for pH, temperature change and turbidity

pH	Q	Temp. change (C)	Q	Turbidity (NTU)	Q
<2	0	-10	55	0	95
2	2	-9	59	5	86
2.2	2	-8	63	10	76
2.4	3	-7	66	15	67
2.6	3	-6	70	20	61
2.8	4	-5	74	25	57
3	4	-4	78	30	53
3.2	5	-3	82	35	49
3.4	6	-2	85	40	45
3.6	7	-1	89	45	42
3.8	8	0	93	50	39
4	9	1	89	55	36
4.2	11	2	85	60	33
4.4	14	3	81	65	31
4.6	17	4	77	70	29
4.8	20	5	73	75	27
5	27	6	67	80	25
5.2	33	7	61	85	24
5.4	38	8	56	90	22
5.6	44	9	50	95	20
5.8	49	10	45	100	17
6	55	11	40	>100	5
6.2	60	12	36		
6.4	68	13	34		
6.6	75	14	33		
6.8	83	15	31		
7	88	16	29		
7.2	92	17	27		
7.4	92	18	26		
7.6	92	19	24		
7.8	90	20	22		
8	84	21	20		
8.2	77	22	19		
8.4	70	23	18		
8.6	63	24	17		
8.8	56	25	16		
9	49	26	14		
9.2	42	27	13		
9.4	36	28	12		
9.6	29	29	11		

9.8	24	30	10
10	20		
10.2	17		
10.4	14		
10.6	12		
10.8	10		
11	8		
11.2	7		
11.4	6		
11.6	5		
11.8	4		
12	3		
>12	0		

Table 5. Q values for total solids, total phosphate - P and nitrates

Total solids (mg/L)	Q	Total phosphate (mg/L)	Q	Nitrate (mg/L)	Q
0	79	0	100	0	97
10	82	0.1	96	1	96
20	84	0.2	92	2	95
30	85	0.3	81	3	90
40	86	0.4	71	4	70
50	87	0.5	60	5	65
60	87	0.6	55	6	60
70	86	0.7	50	7	58
80	85	0.8	47	8	56
90	84	0.9	43	9	53
100	83	1	40	10	51
110	83	1.2	36	12	48
120	82	1.4	33	14	45
130	81	1.6	30	16	42
140	80	1.8	29	18	39
150	79	2	27	20	37
160	78	2.2	26	22	35
170	76	2.4	25	24	33
180	75	2.6	24	26	31
190	74	2.8	22	28	29
200	73	3	21	30	27
210	71	3.2	20	32	25
220	70	3.4	19	34	23
230	69	3.6	19	36	21
240	67	3.8	18	38	19
250	66	4	17	40	18
260	65	4.2	16	42	16
270	63	4.4	15	44	15
280	62	4.6	15	46	13
290	61	4.8	14	48	12
300	60	5	13	50	10
310	58	5.2	12	52	9
320	57	5.4	12	54	8
330	56	5.6	11	56	8
340	54	5.8	11	58	7
350	53	6	10	60	7
360	52	6.2	10	62	6
370	50	6.4	9	64	6
380	49	6.6	9	66	6
390	48	6.8	8	68	5
400	47	7	8	70	5
410	45	7.2	8	80	4
420	44	7.4	8	90	3
430	43	7.6	7	100	3

440	41	7.8	7	>100	1
450	40	8	7		
460	38	9	7		
470	36	10	7		
480	35	>10	2		
490	33				
500	31				
>500	20				

Weighting factors

Each of the nine water quality factors is assigned a weighting factor which signifies its importance. Maximum weightage is given to DO, followed by FC. The sum of weighting factors is 1. Table 6 gives the weightings for different water quality factors.

Water Quality Index

WQI is computed for each factor as the product of Q-value and weighting factor.

WQI = Q-value x Weighting factor

The overall WQI is the weighted average of all Q-values:

Overall WQI = Σ(Q-value x Weighting factor) / Σ Weighting factors

If all the 9 factors are considered for computation of WQI, the sum of weighting factors is 1. Less than 9 factors (6 or more) may also be used for WQI. WQI worksheet is given in table 6.

Table 6. WQI worksheet

Factor	**Test value**	**Q- value**	**Weighting factor (W)**	**WQI=QxW**
DO (% saturation)			0.17	
Fecal coliform nos./100ml			0.16	
pH			0.11	
BOD (mg/L)			0.11	
Temperature change (^{0}C)			0.10	
Total phosphate – P (mg/L)			0.10	
Nitrates (mg/L)			0.10	
Turbidity (NTU)			0.08	
Total solids (mg/L)			0.07	
Overall WQI			Σ WQI =	

Water quality rating

On the basis of WQI, water quality is rated into 5 grades as given in table 7.

Table 7. Water quality rating

WQI		**Water quality**
>90-100		Excellent
>70-90		Good
>50-70		Medium
>25-50		Bad
0-25		Very bad

Water Pollution Index

Water quality indices with slight modification of the original are used throughout the world (Hallok, 2002; Veerbhadram, 2005). Though suitable for most situations, WQI does not take into account some of the extremely important parameters such as heavy metals and pesticides, most characteristic of Indian rivers and other water resources. Water quality criteria given Central Pollution Control Board, New Delhi, classify waters into 5 groups, A-E (MOSPI, 2003). Though, WQI serves the purpose for most of the cases, for countries like India, where rivers and streams are studded with garbage, heavy metals, pesticides, fluoride, cyanide indusrial organicals etc., especially in the thickly inhabited plains, agricultural and industrial areas. Further, river and stream waters in India are used for drinking purposes as well.

It is therefore ecologically warranted that we have an index which would give a relative number with respect to the minimum accepted limit for specific chemicals. Accordingly we propose an index, Water Pollution Index (WPI) which could be better understood, widely used for all water use purposes and easy to use for water pollution control and management. Guidelines values for some chemicals and pesticides as given by WHO (2004) are given in Tables 8 and 9.

Table 8. Guideline values for chemicals that are of health significance in drinking water (WHO, 2004)

Chemical	Guideline value (mg/L)
Antimony	0.02
Arsenic	0.01
Barium	0.7
Chromium	0.05
Copper	2
Lead	0.01
Manganese	0.4
Molybdenum	0.07
Nickel	0.01
Selenium	0.01
Uranium	0.015
Cadmium	0.003
Mercury	0.001
Boron	0.5
Fluoride	1.5
Cyanide	0.07
Nitrate	50
Nitrite (short term exposure)	3
Nitrite (long term exposure)	0.2

Table 9. Guideline values for some of the pesticides in drinking water (WHO, 2004)

Chemical	Guideline value (μg/L)
Alachlor	20
Aldicarb	10
Aldrin and dialdrin	0.03
Atrazine	2
Carbofuran	7
Chlordane	0.2
2,4 D	30
Endrin	0.6
Lindane	2
Methoxychlor	20
2,4,5 T	9

WPI for parameters for which limits are so defined as not to exceed maximum value: If the limit is defined not to exceed the maximum value, such as fecal coliform , total coliform, BOD, temperature change, total phosphate – P, nitrates, turbidity, total solids, free ammonia, conductivity, sodium adsorption ratio, boron, heavy metals, pesticides etc.

$$\text{WPI} = (X - \text{Min})/\text{Range}$$

where, X is the test value of the parameter, min is the minimum acceptable limit, and range is the range of acceptable limits for specific use. As for example,

Maximum limit of lindane in drinking water = 2 μg/L
Permissible range of lindane = 0 to 2 μg/L
Let the test value (X) for a water sample = 6 μg/L
WPI = (6 – 0)/(2 – 0) = 3.

This would imply that the sample water is 3 times polluted than the specified limit. Or in other words, 1 L of test water should be diluted with 2 L of water with a water having lindane 0 μg/L for make it suitable for drinking purpose.

If the water is assessed for a number of parameters (n), different values of WPI would be obtained for different factors, maximum of which would be crucial for water quality assessment.

$$\text{WPI (max)} = \text{Max } (\text{WPI}_1, \text{WPI}_2 , \text{WPI}_3 \ldots \text{WPI}_n)$$

Water quality grades are given in Table 10.

Table 10. WPI and water quality

WPI	Water quality
0 to 1	Acceptable for specific purpose
> 1	Water polluted n times. Should be diluted with water of best quality in the

	acceptable range.
< 0	Water deficient in factor

WPI for parameters for which limits are so defined as not to go below the minimum value: For DO the minimum limit is defined, below which the water is not fit for specific purposes. The WPI for DO value is defined as,

$$WPI\ (DO) = [(Min - X)/Range] + 1$$

For example

Minimum limit of DO in water (say) = 4 mg/L
Permissible range of DO = 4 to 8 mg/L
Let the test value (X) for a water sample = 2 mg/L
WPI = [(4 – 2)/(8 – 4)] + 1 = 1.5

That is, the test water is to be diluted with 0.5 L of water with DO value 8 mg/L to bring it to the minimum permissible level of 4 mg/L.
WPI worksheet is given in Table 11.

Table 11: WPI worksheet.

Parameter	Test value (X)	Minimum acceptable limit (Min)	Maximum acceptable limit (Max)	Range = (Max-Min)	WPI = (X-Max)/Range WPI(DO) =[(Min–X)/Range] +1
		WPI (Max) = Maximum value of WPI =			

The proposed WPI would give a number as to how many times water is to be diluted with the best quality water in the acceptable range so as to bring the water within the permissible limits. WPI is a unitless number and may be used to compare water quality from different water sources and for different parameters, and to rank them accordingly.

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DRINKING WATER QUALITY*

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Synopsis: In India, BIS standard limits are used to monitor the drinking water quality.But BIS involves a few no.of chemicals.However in USA,USEPA standard limits are used to monitor the drinking water quality.USEPA standards involve a large no. of chemicals.The basket of chemicals in BIS standards must extend to include all chemicals of USEPA standards.In some of the common chemicals,the USEPA limits are even larger.

1. INTRODUCTION

Domestic water supply is widely acknowledged as a key element in the fight against poverty and disease. Adequate drinking water supply is rightly seen as essential to human well being. From watering livestock to brewing beer, in rural, urban and semi urban environments, water is crucial enabler of economic activity – particularly for women and the poor.

Adequate knowledge of the existing nature, magnitude and sources of various pollutional loads in water bodies is necessary for any national formulation of water quality management and water-pollution control policies and programmes. For a vast country like India with varying meteorological, hydrological, and developmental conditions, the policies and programmes related to water quality management can be made effective only if taken up on a river-basin-wise approach. In the present study we will cover all river basins.

While proposing any policy and programme formulation for water pollution control, it is imperative to take into account certain predominant features of the country within which such programmes are to be implemented. Poverty, ignorance and lack of adequate socio-economic development are three abominable social realities that still continue to dominate the community life in India. The use of water courses by people, by and large, can not be viewed in isolation ignoring these factors. Thus, in any water quality improvement/protection programme, it must be recognized that such a programme has to be pursued amidst the overriding limitations prevalent in Indian communities, which are not likely to change radically. Over and above this, rivers have always been regarded in India from ancient days, as sacred water bodies which purge away sins, and being observed by such faith, people bath in these rivers with very little concern about whether the rivers are polluted or not.

* The views expressed in this paper are of the author and not of the organization to which he belongs.

Water is a prime necessity for human survival and for growth of agriculture as well as for industrial development. Effective management of water resource, monitoring and control of its quality are becoming increasing important for sustainable development and human welfare. Pollution of water has become a universal phenomena in present day world and for maintaining water quality at acceptable levels, Environmental Protection Act also includes, as one of its objectives, protection of water from pollution. Now-a-days, greater emphasis is also being given to water quality because of concern of environmentalist. Degradation of water quality is not only caused by increasing inflow of domestic and industrial waste water into water course, but also from the abstraction of water from rivers rendering them dry or with meager flow leading to concentration of pollution.

Some people are more vulnerable to contaminants in drinking water than the general population. People undergoing chemotherapy or living with HIV/AIDS, transplant patients, children and infants, the frail elderly, and pregnant women and their fetuses can be particularly at risk for infections. If someone has special health care needs, he should take additional precautions with his drinking water. Cost of making water safe continues to rise.

2. Common Sources of Pollution

a) Naturally occurring: Microorganisms (wild life and soils), radionuclides (underlying rock), nitrates and nitrites (nitrogen compounds in the soil), heavy metals (underground rocks containing arsenic, cadmium, chromium, lead and selenium), and fluoride.

b) Human Activities: Bacteria and nitrates, human and animal wastes –(septic tanks and large farms), heavy metals (mining construction, older fruit orchards), fertilizers and pesticides, industrial products and wastes, household wastes, lead and copper (household plumbing material) and water treatment chemicals (waste water treatment plants)

Actual events of drinking water contamination are rare and typically don't occur at levels likely to pose health problems. However, as development in our modern society increases, these are growing number of activities that can contaminate our drinking water. Improperly disposed of chemicals, animal and human wastes, wastes injected underground and naturally occurring substances have the potential to contaminate drinking water. Likewise, drinking water that is not properly treated or disinfected, or that travels through an improperly maintained distribution system, may also pose a health risk.

Water should be boiled to prevent microbial contamination while it should not be boiled for nitrate fertilizer and lead contaminations.

There is no such thing as naturally pure water. In nature, all water contains some impurities. As water flows in streams, sits in lakes, and filters through layers of soil and rock in the ground, it dissolves or absorbs the substances it touches. Some of these substances are harmless. In fact some people prefer mineral water precisely because minerals give it an appealing taste. However, at certain levels, minerals, just like man-made chemicals, are considered contaminants that can make water unpalatable or even unsafe.

Some contaminants come from erosion of natural rock formations. Other contaminants are substances discharged from factories, applied to farm lands, or used by consumers in their homes and yards. Sources of contaminants might be in the neighbourhood or might be many miles away. The local water quality report tells which contaminants are there in the drinking water, the levels at which they were found, and the actual or likely source of each contaminant.

Some ground water systems have established well head protection programs to prevent substances from contaminating the wells. Similarly, some surface water systems protect the watershed around their reservoir to prevent contamination. Right now, states and water suppliers are working systematically to assess every source of drinking water and to identify potential sources of contaminations. This process will help communities to protect their drinking water supplies from contamination.

Environmental Protection Agency (EPA) has set standards for more than 80 contaminants that may occur in drinking water and pose a risk to human health. EPA sets these standards to protect the health of every body, including vulnerable groups according to the health effects that they cause e.g. acute or chronic health effect from compounds in drinking water.

a) Acute effects occur within hours or days of the time that a person consumes a contaminant. People can suffer acute health effects from almost any contaminant if they are exposed to extra ordinarily high levels (as in the case of a spill). In drinking water, microbes, such as bacteria and viruses, are the contaminants with the greatest chance of reaching levels high enough to cause acute health effects. Most people's bodies can fight off these microbial contaminants the way they fight off germs, and these acute contaminants typically don't have permanent effects. Nonetheless, when high enough levels occur,they can make people ill, and can be dangerous or deadly for a person whose immune system is already weak due to HIV/AIDS, chemotherapy, steroid use, or another reason.

b) Chronic effects occur after people consume a contaminant at levels over EPA's safety standards for many years. The drinking water contaminant that can have chronic effects are chemicals (such as disinfection by products, solvents, and pesticides), radio nuclides (such as radium), and minerals (such as arsenic). Examples of these chronic effects include cancer, liver or kidney problems, or reproductive difficulties.

3. Treatment of Drinking Water

The amount and type of treatment applied varies with the source and quality of water. Generally, surface water systems require more treatment than ground water systems because they are directly exposed to the atmosphere and runoff from rain and melting snow.

Water suppliers use a variety of treatment processes to remove contaminants from drinking water. These individual processes can be arranged in a "treatment train" (a series of processes applied in a sequence). The most commonly used processes include coagulation (flocculation and sedimentation), filtration and disinfection. Some water systems also use ion exchange and absorption Water utilities select the treatment combination most appropriate to treat the contaminants found in the source water of that particular system.

All sources of drinking water contain some naturally occurring contaminants. At low levels, these contaminants generally are not harmful in our drinking water. Removing all contaminants would be extremely expensive and in most cases, would not provide increased protection of public health. A few naturally occurring minerals may actually improve the taste of drinking water and may even have nutritional value at low levels.

a) Coagulation (Flocculation and sedimentation)

Flocculation:- This step removes dirt and other particles suspended in the water. Alum and iron salts or synthetic organic polymers are added to the water to form tiny sticky particles called "floc", which attract the dirt particles.

Sedimentation:- The flocculated particles then settle naturally out of the water.

b) Filtration:- Many water treatment facilities use filtration to remove all particles from the water. Those particles include clays and silts, natural organic matter, precipitates from other treatment processes in the facility, iron and manganese and micro-organisms. Filtration clarifies the water and enhances the effectiveness of disinfection. Water passes through charcoal, sand and gravel layers in a filtration tank.

c) Disinfection:- Disinfection of drinking water is considered to be one of the major public health advances of the 20th century. Water is often disinfected before it enters the distribution system to ensure that dangerous microbial contaminants are killed. Chlorine, chlorinates, or chlorine dioxides are most often used because they are very effective disinfectants and residual concentrations can be maintained in the water system. However, sometimes the disinfectants themselves can react with naturally occurring materials in the waster to form unintended byproducts which may pose health risks. EPA recognizes the importance of removing microbial contaminants while simultaneously protecting the public from disinfection byproducts and has developed regulations to limit the presence of these byproducts.

Home treatment of water:

A home water treatment unit can improve water's taste or provide a factor of safety for those people more vulnerable to water-borne disease. There are different options for home treatment systems. Point of Use (POU) system treat water at a single tap. Point of Entry (POE) system treat water used throughout the house. POU systems can be installed in various places in the home. POE systems are installed where the water line enters the house.

POU and POE devices are based on various contaminant removal technologies. Filtration, ion exchange, reverse osmoisis, and distillation are some of the treatment methods used. All POU and POE treatment units need maintenance to operate effectively. If they are not maintained properly, contaminants may accumulate in the units and actually make water worse.

The table below shows the treatment device, water treatment and limitations.

	Treatment Device	**What it does to water**	**Limitations**
1.	Activated Carbon Filter	▪ Absorbs organic contaminants that cause taste and odor problems. ▪ Some designs remove chlorination byproducts. ▪ Some types remove cleaning solvents and pesticides.	▪ Is not efficient in removing metals such as lead & copper. ▪ Does not remove nitrate, bacteria or dissolved minerals.
2.	Ion exchange unit with activated alumina.	▪ Removes minerals like calcium & magnesium that makes water 'hard'. ▪ Some design remove radium & barium. ▪ Removes fluride & arsenate.	▪ If water has oxidized iron or iron bacteria, the ion-exchange resin will become coated or clogged and loose its softening ability.
3.	Reverse Osmosis unit with carbon	▪ Removes nitrates, sodium, other dissolved inorganic and organic compounds. ▪ Removes foul tastes, smells or colors. ▪ May also reduce the level of some pesticides, dioxins, chloroform and petrochemicals.	▪ Does not remove all inorganic and organic contaminants.
4.	Distillation Unit	▪ Removes nitrates, bacteria, sodium, hardness,	▪ Doesnot remove some volatile organic

		dissolved solids, most organic compounds, heavy metals and radio nuclides. ▪ Kills bacteria.	contaminants, certain pesticides & volatile solvents. ▪ Bacteria may recolonise on the cooling coils during inactive periods.

4. **Protection of Ground Water Supply**.

1. The exposed parts of the well must be periodically inspected such as: cracked, corroded or damaged well casing, broken or missing well cap, settling and cracking of surface seals.

2. The area around the well must be sloped to drain surface run-off away from the well.

3. A well cap or sanitary seal must be installed to prevent unauthorized use of, entry into the well.

4. Drinking water wells must be disinfected at least once every year with bleach or hypochlorite granules.

5. The well must be tested once a year for coliform bacteria, nitrates and other constituents of concern.

6. Accurate record must be kept for any well maintenance such as disinfection or sediment removal that may require the use of chemicals in the well.

7. A certified well driller must be hired for any new well construction, modification or abandonment and closure.

8. Mixing of using pesticides, fertilizers, herbicides, degreasers, fuels and other pollutants must be avoided near the well.

9. Wastes should not be disposed in dry wells or in abandoned wells.

10. Well casing should not be cut off below the land surface .

11. Septic systems must be pumped and inspected as often as recommended by the local health department.

12. Hazardous materials must not be disposed in a septic system.

5. WHO Guidelines for Drinking Water Quality (GDWQ)

In 1950, the requirements for safe and potable water supplies became particularly pertinent with the great increase in travel, especially global air travel. It became apparent that the traveler must be provided with potable drinking water. In 1953, WHO distributed a questionnaire to all member states to assess the status of water treatment plants and their production of acceptable water quality. The replies to the questionnaire clearly indicated the magnitude of the problem and the need for WHO to establish drinking water standards. Following a series of expert consultations culminating in a meeting in 1956 in Geneva the International Standards for drinking water were published in 1958. In this instance, the term "standards" was used to be applied to the suggested criteria of water quality (WHO 1958). The 1958 International Standards became to be widely used as a reference in the development of local national standards and as a basis for improved water treatment practices.

Some countries adopted the International standards as the official and legal standards of water quality while other countries developed national standards based in part or in whole on the International Standards Increasing knowledge of the nature and effect of various contaminants and improved techniques for identifying and determining their concentrations have led to a demand for further revision of the recommendations. Accordingly, the International Standards for drinking water were revised in 1963 and 1971 (WHO 1958, 1963, 1971). The International Standards had been in existence for over a decade until they were superseded by the WHO Guidelines for Drinking Water Quality (GDWQ) in 1987. While it was recognized that it might not be possible by a number of member states to attain all the recommended guideline levels, it was anticipated that the member states would develop water quality standards as close as possible to these guidelines in the endeavour to protect public health.

The philosophy and content of the WHO Guidelines constituted a drastic departure from the previous International Standards. The revised guidelines were published in 3 Volumes including criteria monographs prepared for each substance or contaminant listed in the guidelines (WHO 1984,1985). The second edition of the GDWQ Volume 1 was published in 1993 followed by Volume 2 in 1996 and Volume 3 in 1997. The International Programme on Chemical Safety(IPCS) provided major input to the health risk assessments of chemicals in drinking water. In case of compounds considered to be genotoxic and carcinogenic, the International Agency for Research on Cancer (IARC) classification of Carcinogenic compound was taken into consideration and guideline values were established using a mathematical model, usually the linearized multistage extrapolation model.

The guideline values are presented as the concentration in drinking water associated with an estimated excess lifetime cancer risk of 10^{-5} (one additional cancer case per 100000 of the population ingesting drinking water containing the substance at the guideline value for 70 years). In cases in which the concentration in drinking water associated with a 10^{-5} excess lifetime cancel risk was not practical, because of inadequate analytical methodology, a provisional guideline value was set at a practicable level and the estimated cancer risk was presented (WHO 1993). A continuing process of updating guideline values was established with a number of chemical substances and microbiological agents subject to periodic evaluation . Addenda containing these evaluations were issued in 1998 for volumes 1 & 2 (WHO 1998).

Purpose of GDWQ

In GDWQ, it is often emphasized that the guideline values recommended are not mandatory limits. In order to define such limits, it is necessary to consider the guideline values in the context of local or national environmental, social, economic and cultural adoption of international standards for drinking water quality is the advantage provided by the use of a risk benefit approach (gualitative & quantitative) to the establishment of national standards and regulations. The final judgement as to whether the benefit resulting from the adoption of any guideline value as standard justifies the cost is for each country to decide (WHO 1993)

Risk assessment by Multistage Model

Multistage model is one of the mathematical models, which is most frequently used in regulatory process. It was also applied in the 1988 risk assessment for arsenic in drinking water done by USEPA using the data of an epidemiological study by Tseng et al in 1968. This model is based on the concept that a tumour develops from a single cell in an organ as a result of a number of biological events or stages (e.g. mutation)that occur in a prescribed order. According to this model, the probability of developing tumours, P(d), is

$$P(d) = 1-\exp[-(a+q_1d+q_2d^2+q_3d^3+\ldots+q_md^m)]$$

Where the parameter m is the n umber of stages, a is the background tumour rate and the q's are the values that maximize the likelihood of observing the experimental results. In practice, the a, the q and the m are estimated from the data. Some of the q's may be zero but none can be negative. When the unknown values of the multistage model parameters are replaced by their MLE's, the resulting model estimates what the risk is most likely to be in the experimental situation. At low doses, the dose-response relationship is thus approximately linear. This model will fit almost any observed data set as long as the dose-response curve is not marked by concave downward at low responses. It is important to note that quantitative risk estimates may give an impression of accuracy which in fact they do not have. In general, the risk assessment values for carcinogens are at best, "order of magnitude" estimates.

It should be emphasized that the guideline values for carcinogenic substances have been computed from hypothetical mathematical models that cannot be verified experimentally and that the values should be interpreted differently than TDI based values because of the lack of precision of the models. At best, these values must be regarded as rough estimates of cancer risk. However, the models used are conservative and probably err on the side of caution. Modernate short term exposure to levels exceeding the guideline value for carcinogens does not significantly affect the risk.

6. **Statistical Accounting Of Drinking Water Quality**.

Water quality parameters are measured at selected sites.These are compared with BIS standard limits at Annexure-2 in India.For the chemicals exceeding the limits,control measures and prevention are followed.However the basket of chemicals on which the observations are taken must extend to include all the chemicals in USEPA standards of USA listed at Annexure-1.It has been noticed that in some of the common chemicals,the USEPA limits are even higher as in Flouride,Mercury,Chromium,and Cyanide etc.

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SAFE WATER OPTIONS AGAINST ARSENIC PROBLEMS IN WEST BEBGAL: AN AWARENESS AND SOCIO-ECONOMIC STUDY

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Abstract

In India, around 90 percent of drinking water supplied in rural areas comes from ground water. Almost 52 percent of the total irrigation potential has been created from development of groundwater. The total number of wells in the country has gone up from about four million in 1951 to more than 15 million and the number of energized pump sets in the same period has grown from an initially negligible number to about 12 million. This massive expansion in exploitation in groundwater resources has high stress in the ground water system and as a result ground water levels have declined by 2 to 4 meters. Decline in levels of more than 4 meters have been observed in certain parts of the country. In 249 blocks all over the country, the level of groundwater development has exceeded its replenishable limit and in another179 blocks the development is more than 85 percent of the annual replenishable resources.

Thus what started as a well-meaning policy of the Government to provide safe drinking water to its citizens in West Bengal has turned into a disaster with the drilling of deep tube wells that contain geological deposits of arsenic. Consequently, about 34,000 km^2 (38.4% of the area of West Bengal) in eight districts of West Bengal with a population of 30 million (44.4% 0f total population of West Bengal) are exposed to arsenic poisoning.

To combat the situation it is important to reduce the load on Ground water and to find alternative sources of drinking water and irrigation. Surface water is abundant in the wet season in West Bengal. The alternative water supply options on surface water are:

** Dug Well* ** River Sand Filter*
** Pond Sand Filter* ** Rain Water Harvesting*

The problems of these water options are contamination with high level of bacteria along with few other contaminants (i.e. iron, phosphate etc.). If the surface water can be treated and maintained properly then it is possible to make it contamination free from bacteria and make it potable for domestic use. Slow sand filters like Pond Sand Filter (PSF) to make water potable can successfully treat low contaminated surface water.

This paper attempts to find the awareness and the perception of Pond Sand Filter (PSF) method and the use of surface water in the villages of North 24 Pagans District of West Bengal. To study the impact of Arsenic Pollution a survey was carried out in some rural areas of West Bengal –like Chatra, Kamdevkati and Shimulpur in North 24 Pargana District which are arsenic affected areas. A study was also carried out in Fooltala village in North 24 Pargana District where an attempt was made to conserve rainwater during monsoon and use the same by the Pond Sand Filter (PSF) method. The socio-economic conditions of the respondents were also studied. The study reveals that most of the people *in the studied area are aware of the water pollution and the hazards of drinking contaminated water. The Binary Logistic Regression Analysis reveals that with the increase in education level the awareness level increases but the level of income has nothing to do with the level of awareness. Besides, people are found not so much eager of accepting the water for drinking purposes from rain water harvested surface water.*

INTRODUCTION

Water is the most common resource on earth. It covers more than 70% of the earth's surface. Throughout the history, water has been people's slave and their master also. Great civilizations have risen where water supplies were plentiful. They have fallen when these supplies failed

Thus water is a prime natural resource, a basic human need and a precious national asset. Planning, development and management of water resources need to be governed by national perspectives.

In India, around 90 percent of drinking water supplied in rural areas comes from ground water. Almost 52 percent of the total irrigation potential has been created from development of groundwater. The total number of wells in the country has gone up from about four million in 1951 to more than 15 million and the number of energized pump sets in the same period has grown from an initially negligible number to about 12 million. This massive expansion in exploitation in groundwater resources has high stress in the ground water system and as a result ground water levels have declined by 2 to 4 meters. Decline in levels of more than 4 meters have been observed in certain parts of the country. In 249 blocks all over the country, the level of groundwater development has exceeded its replenishable limit and in another179 blocks the development is more than 85 percent of the annual replenishable resources.

Thus what started as a well-meaning policy of the Government to provide safe drinking water to its citizens in West Bengal has turned into a disaster with the drilling of deep tube wells that contain geological deposits of arsenic. Consequently, about 34,000 km^2 (38.4% of the area of West Bengal) in eight districts of West Bengal with a population of 30 million (44.4% 0f total population of West Bengal) are exposed to arsenic poisoning

Water Management & Groundwater Resources in West Bengal:

Main source of water in West Bengal is rainfall. A part of it returns back to the atmosphere. Another part runs as surface run off. The remaining part percolates to form the groundwater aquifers. West Bengal is well endowed with groundwater resources.

Status of Groundwater Exploration

Out of 341 Development Blocks in the State, 58 Blocks in 24-Parganas, Medinipur and Haora fall in confined aquifer areas and 8 are in hilly terrain in Darjiling district. Out of the remaining 275 blocks, resource-evaluation has been completed by 1990-91 in respect of 261 blocks, leaving 9 coal belt blocks of Bardhaman and 5 of Haora where groundwater exploitation has been negligible.

Groundwater Quality

Ground water in the northern district of Darjiling, Jalpaiguri and Koch Behar in the Brahmaputra basin is less mineralized with the specific conductance values ranging from 100 to 600 micromhos/cm at 25o C and Cl values less than 200 g/l in majority of water samples. In hard rock terrain of Bankura, Birbhum and Puruliya districts, it is similarly less mineralized and specific conductance values range between 150 and 1000 micromhos/cm at 25o C and Cl values vary from 20-150 mg/l. In South 24-Parganas, Medinipur and Haora district specific conductance of ground water from deeper aquifers ranges between 1000-2000 micromhos/cm at 25o C and Cl values varies from 50 to 300 mg/l. In the rest of the state, mineralisation of ground water lies in between the two extreme limits of Northern and Southern districts. Thus the important chemical types of water in the state are Ca-Mg-HCO3 type for low mineralized water, Na-HCO3 type in South 24 Paraganas district and Ca-Mg-Cl type in Calcutta and some isolated pockets.

In the coastal tracts of Medinipur, South 24 Parganas and Haora districts lying in the active delta of the Ganga-Bhagirathi river system ground water is, in general, high in chloride content in upper aquifers (in Subarnarekha basin 8-100 m, in Haldia area, Kasai Basin 40-115 m, in South 24 Parganas and Haora districts 20-150 m depth range), and specific conductance also records a higher value (above 1500 micromhos/cm at 25o C. However, aquifers occurring in the depth span of 115-350 m in South 24-Parganas district are relatively fresher and chloride content of ground water is within permissible limit. A high concentration of chloride in ground water in these upper aquifers is probably related to the sub-marine and estuarine environment in which the sediments were deposited as also owing to seawater intrusion owing to proximity to the sea and tidal influence.

In the northern part of the state, ground water is very fresh being generally below 500 micromhos/cm at 25o C. Likewise in the western part of the state comprising Bankura, Puruliya, Birbhum and parts of the Bardhaman and Medinipur districts ground water is fresh with conductance being below 1000 micromhos/cm being essentially a recharge area. Specific conductance values the fresh water group of aquifers is higher in the southern part of the state lying in the coastal tract and its adjoining areas. Broadly speaking in the entire state of West Bengal except the coastal and deltaic part quality of water is in general suitable for drinking, irrigation and industrial purposes as specific conductance values are well within permissible limits.

Arsenic Contamination of Groundwater

The arsenic contamination problem in ground water in West Bengal has been reported from time to time since 1978. A systematic study undertaken by the School of Environmental Studies and School of Water Resources Engineering, Jadavpur University has shown the presence of arsenic above maximum permissible limit of 0.05 mg / l in ground water and clinical manifestations of arsenic contamination in six districts of West Bengal viz 24 Parganas (North & South), Murshidabad, Nadia, Bardhaman and Malda. The total affected area in these districts is about 34000 sq km (38.4 % of the area of West Bengal) having a total population of 30 million (44.4% of the total population of West Bengal). The study also reveals that at least 125000 people are showing clinical manifestation of arsenic poisoning in 242 wards / villages and at least 600000 people are prone to drinking arsenic contaminated water out of compulsion. The Rural Water Supply scheme in Malda and Murshidabad district is supplying about 1 million gallons of water daily to the villages which is reported to be arsenic contaminated (Chakraborty et al 1993).

The source of arsenic in ground water is primarily the clayey sediments immediately above and intercalated within the intermediate aquifer. These sediments were transported from the Deccan shield and deposited in sluggish meandering streams. Under such conditions, traces of arsenic got deposited partly as arsenious matter and were partly absorbed on surfaces of mineral of clay size and partly formed of organic complexes. Heavy ground water withdrawal specially during the dry season may have triggered off geochemical changes resulting in decomposition Whole blood samples were collected from adult individuals who were working as compositors in presses of different areas of middle and north Calcutta metropolis. The blood samples were taken on same individuals on three occasions. on of iron pyrites in the surrounding rocks and subsequent release of arsenic (Saha 1991).

Arsenic contamination has become a serious problem in the state with 75 blocks in different districts showing presence of arsenic in ground water. In these blocks, the state government has taken up a number of projects to supply safe drinking water. Consequently at the end of 2003 it has been made possible to provide arsenic free water to a population of 83.21 lakh i.e. 51.69% of the population of arsenic affected blocks were provided safe drinking water sources.

Utilization of Ground Water

Groundwater is tapped by means of heavy and medium duty deep tubewells. Shallow tubewells also cater to water requirement for small-scale irrigation and domestic uses. The status of groundwater utilization in West Bengal is assessed on the basis of a census of groundwater structures conducted during March 1981. While the number of individual type of structures is available, the unit draft (annual) has been computed on the basis of results of sample survey for each type of structures.

Table-1: Groundwater Structures in West Bengal (March 1981)

District	Tubewells				Dugwells	
	Heavy Duty	Shallow		Filter Point	Mechanical	Manual
		Electric	Diesel			
Bankura	82	362	3252	671	857	6188
Birbhum	49	813	3667	385	108	538
Bardhaman	362	2298	13510	762	16	168
Cooch Behar	49	630	3206	3128	240	7918
Darjeeling	1	6	151	7	32	12
Hugli	350	1296	16275	72	3	75
Haora	122	145	1008	37	-	-
Jalpaiguri	37	270	735	181	245	359
Malda	178	1225	8902	1179	-	5
Medinipur	302	1359	8963	499	1369	20260
Murshidabad	434	2464	20509	7070	-	-
Nadia	605	6236	22258	6750	-	1
Puruliya	-	1	-	-	103	25403
24-Parganas (N)	353	2330	22469	4051	134	30
24-Parganas (S)	-	38	2456	1922	-	-
West Dinajpur	142	908	7908	4123	10	2738
Total	2,964	20,322	1,35,299	31,066	3,686	63,623

Source: State Water Investigation Directorate, West Bengal

It should be mentioned that during the last 15 years or so there has not been any sizable increase in the utilization of surface water, except for construction of additional water intake points to meet the demands for urban centres and for river-lift schemes to meet the needs of irrigation in the rural areas. Thus the pressure of increasing demand is being put on the groundwater stock. This has led to drying up of many shallow tubewells. In the tidal zones, penetration of saline prism into the aquifers has also been reported.

Utilization of Surface Water

Surface water is widely utilized by directly pumping water from rivers at suitable locations to meet urban, industrial and irrigation water demands. Surface water is also tapped by way of construction of dams or barrages on rivers at favorable geological locations for generation of power, irrigation; industrial and municipal water supply.
In West Bengal, several reservoirs have been constructed by constructing dams across rivers. Amongst these the major reservoirs are the Panchet Dam on the Damodar, the Maithon Dam on the Barakar, the Canada Dam on the Mayurakshi and the Mukutmanipur Dam on the Kangsabati. Apart from these, there are several smaller reservoirs constructed through damming of smaller rivers mostly in Puruliya district. These are designed for flood protection as well as for consumptive use of water. The Panchet, Maithon and Canada dams also produce small quantities of hydroelectric power. To satisfy the multiple purposes for water utilization, the operations of the schedules of water release lead inevitably to sub-optimal realization of one or the other objectives. From all these reservoirs, water is primarily used for irrigation during the Kharif season. Gravity flow irrigation from rivers unsupported by reservoirs is also practiced in parts of the state. The major one of this kind is using the resources of the Mahananda river. The eastern part of the southern West Bengal has no command area under gravity flow system. However, there are many river-lift irrigation structures where by pumping out water from the surface flow minor irrigation command areas have been developed. Most urban centres are also using the system of pumping water to meet their needs.

Variation of Rainfall

A more sensitive element of climate is the variation in rainfall. It varies not only from place to place or from year to year, but also between seasons. Annual rainfall is higher in the proximity of the mountain in the north. The order of departure of any year's rainfall from the normal for a district also varies between regions. While the northern districts of Darjeeling and Jalpaiguri record a rainfall of 400-532cms, or more, on the south facing slopes of Himalayas and have 130 or more rainy days in a year, the drier region of western districts of Puruliya, Bankura, Birbhum record a rainfall of 130cms within 70 days or less per year.

Table - 2: Actual Annual Rainfall (in mm)

District	Normal	1990	1991	1992	1993	1994	1995	1996
Sub-Himalayan Tract								
Darjeeling	3212	3810	3843	2729	3045	2448	3288	2633
Koch Behar	3193	3157	3064	2345	3254	1972	3159	2860
Jalpaiguri	4136	3434	3903	2820	4085	2521	4173	3722
Uttar Dinajpur	1802	2377	2186	1523	1844	1521	2416	1688
Dakshin Dinajpur	1802	2377	2186	1523	1977	1081	2402	1638
Malda	1498	1526	1940	1294	1419	1325	2159	1391
Gangetic Tract (West)								
Birbhum	1234	1542	1348	1069	1554	1338	1453	1293
Bardhaman	1271	1557	1443	1019	1539	1192	1470	1386
Bankura	1271	1640	1587	1149	1569	1459	1616	1323
Puruliya								
Medinipur	1428	2152	1584	1466	2219	1639	1672	1389
Haora	1676	1953	1651	1210	1662	1317	1563	1322
Hughly	1516	1571	1854	1057	1580	1176	1621	1393
Gangetic Tract (East)								
Murshidabad	1338	1538	1429	1030	1584	1208	1623	
Nadia	1401	1685	1386	1071	1501	1501	1514	
24 Parganas (North)	1579	2208	1718	1432	1836	1352	1670	
24 Parganas (South)	1579	2208	1718	1432	2216	1938	2655	

Most of the rain comes during the summer months, i.e., from June to September. In the parlance of agricultural economy, this period is generally referred to as the Kharif season. This is the major agricultural season of the whole State. The factors governing rainfall are the seasonal changes in the direction of wind and the presence of cool upper air current over the given parts of the State. During the kharif season, large depressions develop over one or the other parts of the State. When its intensity increases, cyclonic storms often cause cloudbursts. These storms generally come from the Bay of Bengal. During more stable atmospheric pressure conditions, conventional rainfall predominates.

Utilisation of Surface Water

In spite of abundant surface water due to poor management and improper investment, we are hardly to utilize this. Now time has come to protect our next generation from drinking arsenic poisoning water by proper management of surface water that is the most cheap safe water option for the people of our country and also is easy to maintain. There are different methods by which surface water can be used.

Dug Well:

Dug wells are the most cheap safe water option for the people of arsenic affected areas of our country and also are easy to maintain. The only problems of these water options are contaminated with high level of bacteria along with few other contaminants.

Percolation of contaminated surface water is the most common route of pollution of well water. However, all these hazards or contamination is possible to stop by following affordable steps during construction and maintaining some guideline for keeping the dug well safe.

Pond Sand Filter:

It is a package type slow sand filter unit developed to treat surface water, usually low saline pond filter for domestic water supply in the coastal areas. Slow sand filters are installed near or on the bank of a pond, which does not dry up during dry season. The water from the pond in pumped by a manually operated hand tube well to feed filter bed, which is raised from the ground, and the treated water is collected through tap(s). It has been tested and found that the treated water from a PSF is normally bacteriologically safe or within tolerable limits. On average the operating period of PSF before cleaning is usually two months, after which the sand in the bed needs to be cleaned and replaced.

The problems encountered are low discharge and difficulties in washing the filter beds. The PSF is a low cost technology with very high efficiency in turbidity and bacterial removal. For 100% removal of pathogen, the treated water may require chlorination to meet drinking water standards.

Rain Water harvesting:

The collection and storage of rainwater is an alternative option of water supply in the acute arsenic affected areas of Bangladesh. There are two main constrains in development of a completely rainwater based water supply system:

- Availability of suitable catchments area and
- The need for larger storage tank

The quality of rainwater is good, but it is not completely free from contamination. Wind blow dirt, bird dropping and other debris contribute some pollution. Water quality tastes have shown some bacteriological contamination of water from roofs. It is recommended that water running of the roof during first 10-20 minutes of rainfall should be discarded. Many devices have been suggested to store or divert the first foul flush away from the storage tank. In view of difficulties which may make the rejection of first flow impracticable, cleaning of the roof and gutter at the beginning of the rainy season and their regular maintenance are very important to ensure better quality rainwater. The storage tank requires cleaning whenever the tank is empty or at least once per year. If possible, the storage tank should be disinfected during cleaning.

The Problem Studied

To study the effect of arsenic contamination and to explore the possibility of using surface water, in particular the use of Pond Sand Filter Method, for mitigating this problem a study was carried out in North 24 Pargana District of West Bengal. The results are placed here.

North 24 Parganas of West Bengal

The district of North 24 Parganas of West Bengal is in the southern part of the Bengal Basin. The geographical extent of the district lies between 88d19m E, 23d20m N to 89d10m E,22d01m N . The basin is actually a peri-cratonic basin and comprises of Ganga-

Brahmaputra delta in the southern part. It had broken from the Gondowanaland along the margin of the Indian plate and then moved towards northerly in the early Cretaceous (125Myr ago).

The block wise population of the district is as follows:

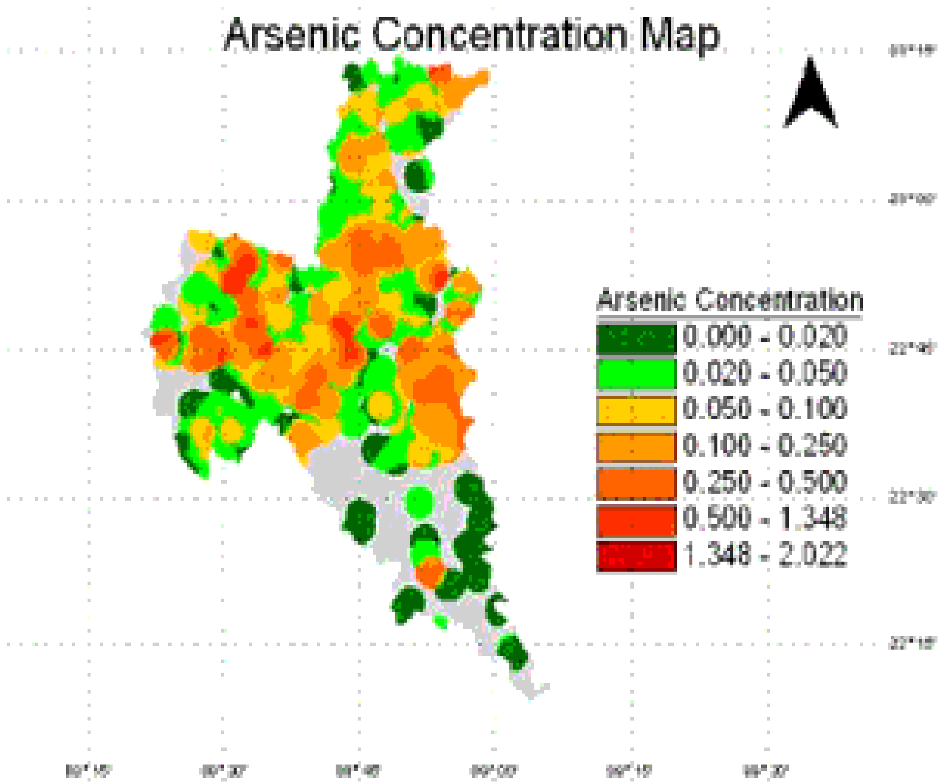
Table:3: Populations of North 24 Parganas

Town	Total Population 2001 in the Town		
	Person	**Male**	**Female**
Kachrapara (M)	**126118**	**65197**	**60921**
Halishar (M)	**124497**	**67124**	**57355**
Habra (M)	**127695**	**65263**	**62432**
Bangaon (M)	**102115**	**52489**	**49626**
Ashoknagar Kalyangarh (M)	**111475**	**56340**	**55135**
Garulia (M)	**76309**	**40600**	**35709**
Barasat (M)	**231515**	**118367**	**113148**
North Barakpur (M)	**123523**	**63827**	**59696**
Barakpur (M)	**144331**	**76268**	**68063**
Titagarh (M)	**124198**	**70608**	**53590**
Khardaha (M)	**116252**	**61254**	**54998**
Panihati (M)	**348379**	**180068**	**168311**
New Barackpur (M)	**83183**	**41790**	**41393**
Kamarhati (M)	**314334**	**168633**	**145701**
Baranagar (M)	**250615**	**132701**	**117914**
North DumDum (M)	**220032**	**112868**	**107164**
South DumDum (M)	**392150**	**200182**	**191968**
Bidhannagar (M)	**267848**	**85215**	**82633**
Rajarhat Gopalpur (M)	**271781**	**140179**	**131602**

Mr. Balen Basu and Mr Samik Sil of GISNET have studied the North 24 Pargana District from Satellite Images by remote sensing and other scientific methods for environmental mapping. They have reported as follows:

The NATMO District planning Map Series (1:2,50,000) of North 24 Parganas was scanned. The following images with Path/Row 108/55, 108/56 , 108/57 and 109 / 55 covers the whole district.

From the arsenic values as provided from the field data, contour was generated over the whole district using point-to-surface generation programs in SPANS as shown in figure 2. The thematic map indicates the area of high arsenic concentration and low arsenic concentration as observed from the water tested in the laboratory and plotted on the map as points corresponding to each block. The arsenic concentration map is shown below:



Arsenic Concentration map
Figure 1

Survey Results

In order to study the extent of damage caused by Arsenic contamination the authors had carried out survey in some villages of North 24 Pargana District of West Bengal which are in the red areas of the above maps.

PROFILE OF THE STUDIED SAMPLE: Table 4

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Table4 show the results of the test of the Arsenic affected people of the three villages those have been studied by us.

Village	Shimulpur	Kamdevkati	Chatra
G.P	Machhalandapur - II	Kolsur	Chatra
Block	Habra - I	Deganga	Badurai
P.S.	Habra	Deganga	Badurai
District	24-Pgs.(N)	24-Pgs.(N)	24-Pgs.(N)
Population	5000 (as per survey)	3000 (as per survey)	3200 (as per survey)
No. of houses	450	431	450
No. of SC/S	85% & !%	90% & 8%	85% & 12%
Community Water Resources	12	17	11
Private Water Resources	250	251	73
Concentration of Arsenic in Community Water Resources	10	9	11
Concentration of Arsenic in Private Water Resources	241	230	73
No. of Individuals affected by Arsenic Contaminated as per Hospital Record	15	150	10
Death due to the diseases caused by the use of Arsenic Contaminated Water	4	5	Nil

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The Tube wells were the main source of water in these villages. So the water qualities of the tube wells were studied. The results are as follows:

Table: 5 Water Testing results of Shimulpur

Depth of the Tubewell	Frequency	Ar. Detected	Percentage	Ar. Not Detected	Percentage	BDL	Percentage	Doubtful	Percentage
< 40'	2	nil	nil	2	0.76	nil	nil	Nil	nil
40' - 75'	203	174	66.41	12	4.58	nil	nil	17	8.33
76' - 100'	31	29	11.06	2	0.76	nil	nil	Nil	nil
101' - 150'	16	15	5.72	nil	nil	nil	nil	1	0.38
151' - 200'	2	2	0.76	nil	nil	nil	nil	Nil	nil
> 200	8	1	0.38	1	0.38	nil	nil	6	2.29
Total	262	221	84.35	17	6.48	nil	nil	24	11.00

Table: 6 Water Testing of Kamdevkati

Depth of the Tubewell	Frequency	Arsenic detected	Percentage	Ar. Not Detected	Percentage	BDL	Percen Tage	Doubtful	Percentage
< 40'	nil	nil	nil	nil	nil	nil	Nil	nil	Nil
40'- 75'	160 (78.43 %)	123	60.29%	nil	nil	11	5.39%	26	12.74%
76' - 100'	23 (11.27 %)	17	8.3%	Nil	nil	5	2.45%	1	0.49%
101' - 150'	6 (2.94%)	5	2.45%	nil	nil	nil	Nil	1	0.49%
151' - 200'	1 (0.49%)	Nil	Nil	nil	Nil	nil	Nil	1	0.49%
> 200'	14 (6.86%)	4	1.96%	Nil	nil	5	2.45%	5	2.45%
Total	204	149	73.03%	nil	nil	21	10.29%	34	16.66%

Table: 7 Water Testing for Chatra

Depth of the Tubewell	Frequency	Ar. detected	Percentage	Ar. Not Detected	Percentage	BDL	Percentage	Doubtful	Percentage
< 40'	1(0.60 %)	nil	nil	1	0.60	nil	Nil	nil	nil
40'-75'	131 (79.39 %)	32	19.39	78	47.27	Nil	Nil	21	12.72
76' - 100'	20(12.12%)	6	3.63	10	6.06	Nil	Nil	4	2.42
101' - 150'	10 (6.06 %)	3	1.81	6	3.63	Nil	Nil	1	0.60
151' - 200'	1 (0.605 =%)	Nil	nil	Nil	nil	Nil	Nil	1	0.60
> 200'	2(1.21 %)	2	1.21	nil	nil	nil	Nil	nil	nil
Total	165	43	26.04	95	57.56	nil	Nil	27	16.34

Table: 8 Table Showing the People of the Village Shimulpur Tested for the Concentration of Arsenic in their Body along with the Diseases they are Suffering from

Individuals	Water Mg/l	Nail Mg/g	Hair Mg/g	Urine Mg/l	Blood Mg/l	Disease Suffering From
1	20.00	3.4872	O.9746	270	BDL	Gastroentritis
2	94.00	12.93	6.87	270	BDL	"
3	60.00	13.0369	9.333	136.8	BDL	"
4	21.27	10.41	8.42	640	BDL	"
5	270.6	1.8164	0.8527	190.0	BDL	"
6	270.6	6.46	2.55	44.5	BDL	"
7	10.00	4.007	1.08	ABSENT	BDL	"
8	50.00	3.44	1.31	150	BDL	"
9	10.0	1.5788	0.8401	92.1	BDL	"
10	WNS	7.23	5.98	80	BDL	"
11	50.00	6.896	5.017	16.7	BDL	"
12	WNS	5.14	3.49	ABSENT	BDL	"
13	WNS	11.12	3.9416	73.6	BDL	Neurological
14	100.00	3.36	1.65	130	BDL	"
15	WNS	ABSENT	1.42	114.1	BDL	"

16	137.1	6.53	1.4537	90	BDL	TB
17	132.1	3.2611	4.49	112.8	BDL	Skin
18	391.5	13.37	1.34	100	BDL	"
19	WNS	3.17	1.28	4.3	BDL	"
20	207.4	ABSENT	1.64	16.59	BDL	"
21	WNS	4.76	4.66	ABSENT	BDL	"
22	WNS	15.52	0.89	25	BDL	"
23	WNS	2.75	4.642	51.36	BDL	"
24	WNS	6.308	14,338	8.3	BDL	"
25	20	18.591	3.27	ABSENT	BDL	"
26	WNS	3.53	4.628	ABSENT	BDL	"
27	WNS	7.382	4.618	106.5	BDL	"
28	WNS	7.382	4.043	ABSENT	BDL	"
29	140	6.759	4.752	ABSENT	BDL	"
30	60	7.265	2.26	ABSENT	BDL	"
31	WNS	8.35	7.587	ABSENT	BDL	"
32	167.75	8.137	6.301	29.94	BDL	"
33	90.13	8.351	1.04	ABSENT	BDL	"
34	120.33	3.14	1.02	27	BDL	"
35	160	3.36		27.56	BDL	"

Table: 9 Table Showing the People of the Village Kamdevkati Tested for the Concentration of Arsenic in their Body Along with the Diseases they are suffering from

Individuals	Water Mg/l	Nail Mg/l	Hair Mg/l	Urine Mg/l	Blood Mg/l	Disease Suffering from
1	21.27	5.7068	4.17	22.77	7.96	Gastroentritis
2	39.47	4.5091	1.298	62.6	5.24	"
3	335.7	19.92	4.29	298.6	6.17	Arsenicosis
4	270.6	3.321	1.559	128.4	8.32	Gastroentritis
5	32.46	ABSENT	1.077	33.7	7.65	Neurological
6	102.1	0.674	0.694	13.5	6.27	Gastricites
7	67.7	4.13	1.59	64.3	5.55	TB
8	102.1	3.71	3.07	68.3	5.25	Gastroentritis
9	28.05	2.60	1.22	95.22	6.31	Skin
10	37.92	2.258	4.21	78.6	7.1	Gastroenteritis
11	39.5	1.071	2.02	4617	6.26	Neurological
12	26.8	2.497	1.02	67.7	5.74	Gastroenteritis
13	126.1	0.321	0.84	12.92	7.12	"
14	19.21	1.76	3.31	36.9	4.21	Gastroenteritis
15	9.6	2.53	1.52	111.8	8.87	Gastroenteritis
16	67.7	1.72	1.35	93.1	4.45	Gastroentrities
17	15.0	6.07	4.73	123.6	3.34	Neurological

From the above tables the devastating effect of arsenic contamination of water was seen. Now in order to find whether there is any way by which poor people can be saved, Pond Sand Filter
Method was tried in a small village and the experience is described below.
In West Bengal the concept of rain water harvesting and Pond Sand Filter method have not yet taken proper shape. The reason could be that the people of West Bengal are not suffering from water crisis but they are suffering from water pollution. In the urban areas water pollution is of much concerned than water crisis. Necessary steps are being taken to make water free from pollution. But in rural areas even if some people are aware of the water pollution they do not have any other alternative rather than consuming the polluted water.

In our study we have attempted to study the socio-economic condition of the village Fooltala and some of its adjacent areas of North 24-Parganeas of West Bengal by giving emphasis on the rainwater harvesting. Our total sample size is eighty-five. The methodology followed is quite simple; questionnaires were prepared to interview the inhabitants of the village.

Study Report of Village Fooltala in the North-24 Parganas of West Bengal:

Fooltala is small hamlet in the North-24 Parganas where water crisis is not due to the unavailability of water but due to the arsenic contamination of water. In that village an attempt has been made to conserve rainwater during the monsoon and to use the same water for the consumption. A pond has been used to conserve rainwater. A passage made of sand bags and gravel of different sizes has been connected with a covered well, so that the accumulated water get filtered and can be preserved in the well made nearby. Beside the well a tube well has been installed for the collection of water for usage.

It is generally assumed that rural people as against their counterparts in urban areas are more easily identifiable and easier to target and reach in terms of their socio-economic conditions and other characteristics. They are considered to be heterogeneous lot differing from each other on account of composition of family, their employment status, castes, migratory status etc. in the present section an attempt has been made to study the distinguishing characteristics of the semi urban poor households in some of the areas of North 24 parganas. We have combined the different sample of different areas into one for the final study as geographically and socially these areas are almost same. Total studied sample size is eighty-five and total studied areas are three. Out of total eighty-five total sample twenty-nine (34%) are males and fifty-six (66%) are females.

Drinking water is another most important factor of leading healthy life. In the urban areas the main sources of drinking water are tube-well/hand pipe, tap and well. The tap water is regarded safe for drinking as it is supplied after the suitable treatments, (which makes it fit for drinking) by corporation, municipality, or any other local authority or any private or public housing estate or water treatment agency. In our study, it has been found the sample uses Dugwell, Tube well, and Municipality tap, Private Tap, Pond, arsenic Removal Plant and Arsenic Removal Filter as different sources of drinking water. The following Table 8 reveals that more than fifty percent of the sample households are using water from tubewells for drinking purpose, of which 59 percent (34/58*100) belong to the group having income up to Rs.2000 and 52 Percent (14/27*100) belong to the income group of more than Rs.2000. Twelve percent use tap water supplied by municipality for drinking and fifteen percent uses water from private tap for drinking purpose. 9% are found using dugwell water for the same purpose and 5% were found using water from the ARP installed by Govt. & Non-Govt. organizations. Only one household is found using water from pond and again one household is found using water from ARF installed at their home having a monthly income more than Rs.10, 000.

Table 10: Sources of Drinking Water Used by the Sample Household along with their Monthly Income

Household Monthly Income	Drinking Water Sources							Total
	Dugwell	Tubewell	Municipality Tap	Private Tap	Pond	ARP	AR Filter	
<=1000	4	11	3	3		1		22
1001-2000	3	23	3	6		1		36
2001-400	1	9	3	2		1		16
4001-7500		4	1	2	1	1		9
7500-10,000		1						1
>10,000							1	1
Total	8	48	10	13	1	4	1	85

The following table shows the sources of drinking water of the studied areas and the distance of the sources from the households. The measurement of the distance is an approximate one. The table distinctly implies that 80% of the total studied households have to bring drinking water from outside and only 20% are having the sources of drinking water within the households. Among the 80% households that depend on the sources installed outside their premises, almost 50% have to go 1/2km to fetch drinking water. 38% households have the sources of drinking water less than 1/2km from their premises. Nine percent go more than 1/2km for collecting water for drinking purpose and rest 3% have to depend on the sources of drinking water installed almost 1km away from their premises. For cooking, bathing and washing the households use the sources nearer to their household premises.

Table 11: Sources of Drinking Water Used by the Sample Household & the Distance of the Sources from their Households

Drinking water sources	Distance of the Sources from the Households					Total
	<1/2km	1/2km	>1/2km	1km	Within the Premises	
Dugwell	2	5			1	8

Tubewell	17	23	2	1	5	48
Municipality Tap	2	4	2	1	1	10
Private Tap	3	1	1		8	13
Pond					1	1
ARP	2	1	1			4
AR Filter					1	1
Total	26	34	6	2	17	85

Among our study sample we have found that 48 tubewells are in use as a source of drinking water. Out of the total 48 tubewells in use, about 85% are installed by the govt. organization, the user himself installs 6% of the total studied tubewells and about 8% tubewells are installed by the NGOs. Out of 85% of the tubewells installed by the Govt. 18 tubewells were installed with proper guidelines from them and rest 23 tubewells were installed without any guidelines. The NGOs installed 3 tubewells with proper guidelines and one was installed by them without any guidelines.

Table: 12 Type of Tubewell use by the sample household & the tubewell installed by with guidelines

Type of Tubewell	**Tubewell Installed by**						**Total**
	Govt.		**private**		**NGO**		
	Any Guidelines from the Installed Organization						
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	
Shallow	1	1		3			5
Deep	17	21			3		41
Don't Know		1				1	2
Total	18	23		3	3	1	48

It is observed that the percentage of sample households depend on tube-well and the percentage of sample households using municipality water vary significantly and the reason of significant variation may be because of the fact that availability of water is based on location. So far as the quality of available water is concerned Table 11 reveals that about 66 percent of the interviewers feel that the water they are drinking is pure and safe, 24 percent have a view that they are drinking contaminated water and about 11 percent do not have any knowledge on the consumed water. About 78 percent responded positively when it was inquired that, do they know drinking water may be the source of health and other problems. On the other hand nearly 8 percent have negative respond on the question, 5 percent do not know about it and for about 7 percent of the sample households did not anything to answer. When we compare table 12 and table 13 we find that people of high-income category and people of Madhyamik and above category are concerned about the quality of water and water borne diseases.

Table 13 Sources of Drinking Water Used by the Sample Household and Their Feeling about Their Drinking Water.

Sources of drinking Water	Freq-uency	Feeling about						
		Quality of the available drinking water			Drinking water may be the source of Health or other problem			
		Pure and safe	Contaminated	Not known	Yes	no	DK	DA
Dugwell		5	3		7	1		
Tubewell	48	32	13	3	39	4	3	2
Municipality Tap	10	7		3	7		1	2
Private Tap	13	6	4	3	8	1	1	3
Pond	1	1			1			
ARP	4	4			3	1		
AR Filter	1	1			1			
Total	85	56	20	9	66	7	5	7

Table 14Household Monthly Income & Perception about the Quality of the Drinking Water

Household Monthly Income	Perception about the Quality of the Drinking Water			Total
	Pure & Safe	Contaminated	Don't Know	
<=1000	10	8	4	22
1001-2000	24	9	3	36
2001-400	12	3	1	16
4001-7500	9			9
7500-10,000			1	1
>10,000	1			1
Total	56	20	9	85

Table 15: Level of Education of the Informants & Knowledge about the Hazards of the Contaminated Water

Level of Education	Water may be the Source of Health Problems			Total
	Yes	No	Don't Know	
Illiterate	21	6	4	31
Primary	34	2	1	37
Madhyamik	4	1		5
HS	4			4
Graduate	6	1		7
Studying	1			1
Total	70	10	5	85

A person can lead a healthy life when he or she has general awareness about environmental pollution and prevention. The statistical table of the collected data's reveals that most of the people are aware of access to safe water, pure air and healthy environment. Seventeen informants (20 percent) out of 85 cases are not aware of safe water, pure air and healthy environment. 46% of the total informants are aware of water scarcity and about 53% do not have any knowledge of the water scarcity. Almost 90% were found aware of the fact that drinking contaminated water is hazardous to health.

TABLE 16: Distribution of Sample Households by Level of Education and their Awareness regarding several aspects of Environment Pollution

Level of education in the household	No. of house-hold	No. of household						
		Aware of		Aware of			Aware of	
		Pure air and healthy environment		Scarcity of Water			Drinking Arsenic Contaminated Water is Harmful to Health	
		yes	no	Yes	no	Vaguely	Yes	no
Illiterate	31	20	11	14	16	1	24	7
Primary	37	31	6	13	24		35	2
Madhyamik	5	5		2	3		5	
HS	4	4		4			4	
Graduate	7	7		5	1		7	
Studying	1	1		1			1	
TOTAL	85	68	17	39	45	1	76	9

The following table shows the awareness among the people of the studied areas about the rainwater harvesting. The study reports that out of the total 85 studied sample, 74% are aware of the Pond Sand Filter method from the different sources, 26% were found sill to be aware of the Pond Sand Filter method. Most the studied sample (84%) has no concept about the fact that rainwater can be recharged to ground water reservoir through different methods. 16% are aware of some methods like abandon dugwell, abandon or running handpump, recharge pit, gravity head recharge well etc. to recharge rainwater to groundwater reservoir. In our field as mentioned earlier that a pond has been utilized to harvest rainwater, but the study reports the project has a futile impact on the studied sample as only 8% informants were found using water from the project area rest are least interested on the project. The basic reason found was that the informants were not much eager to accept water from pond for drinking & cooking purpose as the pond is not hygienically maintained and also because of the availability of the other sources of drinking water.

TABLE 17: Distribution of Sample Households by Level of Education and their Awareness regarding several aspects of Pond Sand Filter Method

Level of education in the household	No. of house-hold	No. of household					
		Aware of		Aware of		Aware of	
		Pond Sand Filter Method		Recharging Groundwater		Water from Pond Sand Filter Method	
		yes	no	Yes	no	Yes	no
Illiterate	31	24	7	7	24	3	28
Primary	37	25	12	4	33	3	34
Madhyamik	5	4	1	1	4		5
HS	4	3	1		4		4
Graduate	7	6	1	1	6	1	6
Studying	1	1		1			1
TOTAL	85	63	22	14	71	7	78

Observations:

We have studied some of the villages of the north 24-Pargansa and have found that the problem of water in those areas is mainly due to the accumulation of arsenic. For further verification we have studied some other villages to find the awareness among the people regarding the safe drinking water. In our study we have found that most of the people are aware of safe drinking water and also the long-term affect of the consumption of arsenic contaminated water. The people were found conscious of collecting water from the sources free from arsenic. But the studied samples are not so much eager to draw water from the pond, where Pond Sand Filter method was used, as the pond was not hygienically maintained.

Awareness of the Problem:

Predicting whether an event will or will not occur, as well as identifying the variables useful in the prediction, is important in most academic disciplines and in the 'real' world. So wheather some people are aware of the existing pollution or not is important to know.

To know the extent of general awareness about water pollution and its prevention we have given emphasis on the following six questions based on the environmental and Pond Sand Filter awareness that were put to them.
Regarding the pollution awareness we have put first four following questions to the respondents. If he could answer all the four questions positively we treated the person to be 'aware' of the environmental pollution problem. We attempted to estimate whether the

awareness depends on (i) the level of education and (ii) level of education and income level.

Similarly we tried to estimate whether the respondents are aware of Pond Sand Filter Method and whether the awareness is dependent on the level of education.

1. Are you aware of the fact that access to safe water, pure air and healthy environment is constitutionally protected?
2. Are you aware of scarcity of water?
3. Are you aware of the term arsenic?
4. Are you aware of the fact that drinking arsenic contaminated water is harmful to health?
5. Are you aware of Pond Sand Filter method?
6. Are you aware of the fact rainwater can be recharged to ground reservoir through
   a. Abandon dugwell b. abandon/running handpump c. recharge pit d. recharge shaft gravity head recharge well e. defunct borewell f. trench pit with injection well

Logistic Regression

A variety of multivariate statistical techniques can be used to predict a binary dependent variable from a set of independent variables. Here we shall consider the binary logistic regression model. This model requires less assumption than other methods. Logistic Regression is used for situations in which we want to be able to predict the presence or absence of a characteristic or outcome based on values of a set of predictor variables.

In logistic regression, one directly estimates the probabilities of an event occurring. For the case of a single independent variable, the logistic regression model can be written as

$$\text{Prob (event)} = \frac{e^{B_0 + B_1 X}}{1 + e^{B_0 + B_1 X}} \cong \frac{1}{1 + e^{-(B_0 + B_1 X)}} = \frac{1}{1 + e^{-Z}}$$

Where B_0 and B_1 are the coefficients estimated from the data, X is the independent variable 'e' is the base of the natural logarithm, which is approximately 2.718.

Awareness about pollution:

On the basis of the four environmental awareness questions we have graded the respondents into two categories. In the first category the indicator variable is 'aware 0'. If the respondent is found not aware of any of the four questions the respondent is considered to be 'aware 0' and the person aware of all the four questions based on environment is considered to be 'aware 1'. A person found to be aware under the strong condition 'aware 1' is a most desirable person in a study on environmental awareness that has been the part of the questionnaire.

Same is applied for the awareness of Pond Sand Filter

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Tools of logistic regression can be applied to the data set with which we are working to discuss about the factors that might cause a variation in the level of awareness among the respondents. However the degree of awareness cannot be expressed in quantitative terms. The expected information in the fieldwork can be in two terms of 'Being aware' and 'Not being aware'.

With respect to the data set that is being analyzed in this paper, we have considered a binary logistic regression model for predicting whether the event of 'Being aware' will or will not occur, as well as identifying the variables that would be useful in making the prediction.

We have tried to find out whether the level of awareness increases with the increase of education and income. For that we first calculate the LR on Aware 1 (i.e. answered all the questions positively that are given above) and the level of education. We also calculated the LR on Aware 1 and the level of income.

Education vs Environment Awareness

The following figure shows the estimated coefficients (under column heading B) and related statistics from the logistic regression model. Value 1 for education level indicates the level of education.

Table 18

Variables in Equation

Level	Step 1	B	SE	Wald	df	Sig.	Exp(B)	Probability
1	Educat 1	-.236	.459	.265	1	.607	.789	
	Constant	-.223	.274	.664	1	.415	.800	.387223078
2	Educat 2	-.734	.455	2.606	1	.106	480	
	Constant	.000	.289	.000	1	1.000	1.000	.324317569
3	Educat 3	-.103	.940	.012	1	.913	.902	
	Constant	-.302	.226	1.786	1	.181	.739	.400111631
4	Educat 4	7.628	18.330	.173	1	.677	2054.526	
	Constant	-.426	.227	3.514	1	.061	.653	.99925546
5	Educat 5	1.077	.896	1.447	1	.229	2.937	
	Constant	-.384	.229	2.813	1	.093	.681	.666633959
6	Educat 6	6.536	22.241	.086	1	.769	689.632	
	Constant	-.336	.221	2.311	1	.128	.714	.997974679

Given these values the logistic regression coefficients can be written as

Z_1 = -.223-.236 =-0.459 Z_2 = .00 - .734 = -.734
Z_3 = -.302-.103 = -.405 Z_4 = -.426 + 7.628 = 7.202
Z_5 = -.3841.077 = 0.693 Z_6 = -.336+6.536 = 6.2

Given these coefficients the logistic regression equation for the probability of awareness can be calculated as

$$P = \frac{1}{1+e^{-z}}$$

$$P_1 = \frac{1}{1+e^{-Z_1}} = \frac{1}{1+e^{+.459}} = .387223078 \qquad P_2 = \frac{1}{1+e^{-Z_2}} = \frac{1}{1+e^{+.734}} = .324317569$$

$$P_3 = \frac{1}{1+e^{-Z_3}} = \frac{1}{1+e^{+.405}} = .400111631 \qquad P_4 = \frac{1}{1+e^{-Z_4}} = \frac{1}{1+e^{-7.202}} = .99925546$$

$$P_5 = \frac{1}{1+e^{-Z_5}} = \frac{1}{1+e^{-.693}} = .666633959 \qquad P_6 = \frac{1}{1+e^{-Z_6}} = \frac{1}{1+e^{-6.2}} = .997974679$$

Based on these estimates, we would predict that the awareness about the environment pollution increases as the level of education increases. In general, if the estimated probability of the event is less than 0.5, we predict that the event will not occur. If the probability is greater than 0.5, we predict that the event will occur. From the above table it can be seen that as the level of education increases the probability of awareness increases and for education level above 4 or more it can be predicted that the people are aware about environmental pollution.

Testing hypothesis about the coefficients

For the large sample sizes the test the coefficient is 0 can be based on the Wald Statistics, which has a chi-square distribution. When a variable has a single degree of prediction the Wald statistics is just the square of the ratio of the coefficient to its standard error.

The coefficient of education level 1 is -.236 and its standard error is .459. the Wald Ststistics is $(-0.236/0.459^2)$ or about .265. The significant level for the Wald Statistics is shown in the column labeled Sig. In this case all the coefficients appear to be **significantly different from 0,** using a significance level of 0.05.

Interpreting the regression coefficient

To understand the interpretation of the logistic coefficients, consider a rearrangement of the equation for the logistic model. The logistic model can be rewritten in term of the odds of an event occurring (the odds of an event occurring are defined as the ratio of the probability that it will occur to the probability that it will not occur). The odds ratio for the variables tell the change in odds for a case when the value of that variable increases by 1. The odd ratio are shown in the column Exp(B) in Table 1.

Classification Table

One way to access how well the model fits is to compare our predictions to the observed outcomes. Following table 2 compares the observed and predicted group memberships. Where cases with a predicted probability of 0.5 or greater are classified as having positive nodes.

From the table we can see that for education level 1, 49 respondents within education level 1 were correctly predicted by the model not to be aware of pollution. Similarly 0 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tell how many men were incorrectly classified. A total of 36 men were misclassified in the example. Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% were correctly classified. Overall 57.6 percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of education. The overall percentage increases with the increase in level of education.

Table 19: Classification Table

Level	Observed	Predicted Environment Awareness		Percentage
		0	1	
Edu 1	Step 1 EA 0	49	0	100.0
	Overall Percentage	36	0	.0
				57.6
Edu 2	Step 1 EA 0	25	24	51.0
	Overall Percentage	12	24	66.7
				57.6
Edu 3	Step 1 EA 0	49	0	100.0
	Overall Percentage	36	0	.0
				57.6
Edu 4	Step 1 EA 0	49	0	100.0
	Overall Percentage	32	4	11.1
				62.4
Edu 5	Step 1 EA 0	47	2	95.9
	Overall Percentage	32	4	11.1
				60.0
Edu 6	Step 1 EA 0	49	0	100.0
	Overall Percentage	35	1	2.8
				58.8

From the table we can see that for education level 1, 49 respondents within education level 1 were correctly predicted by the model not to be aware of pollution. Similarly 0 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tells how many men were incorrectly classified. A total of 36 men were misclassified in the example._Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% were correctly classified. Overall 57.6 percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of education. The overall percentage increases with the increase in level of education.

Table 20 Changes in 2-log likelihood

Level		Chi Square	df	Sig.
Edu 1	Step 1 Step	.266	1	.606
	Block	.266	1	.606
	Model	.266	1	.606
Edu 2	Step	2.670	1	.101
	Block	2.670	1	.101
	Model	2.670	1	.101
Edu 3	Step	.012	1	.912
	Block	.012	1	.912
	Model	.012	1	.912
Edu 4	Step	7.138	1	.008
	Block	7.138	1	.008
	Model	7.138	1	.008
Edu 5	Step	1.549	1	.213
	Block	1.549	1	.213
	Model	1.549	1	.213
Edu 6	Step	1.730	1	.188
	Block	1.730	1	.188
	Model	1.730	1	.188

Education VS. Pond Sand Filter Awareness

Next we examine whether there is relationship between education and knowledge of rain water harvesting. We apply the same method of binary logistic regression method.

Table 21: Variables in Equation

Level	Step 1	B	SE	Wald	df	Sig.	Exp(B)	Probability
1	Educat 1	.672	.590	1.296	1	.255	1.958	0.22583157
	Constant	-1.904	.405	22.092	1	.000	.149	
2	Educat 2	-.775	.638	1.478	1	.224	.461	0.10812866
	Constant	-1.335	.355	14.109	1	.000	.263	
3	Educat 3	.253	1.158	.048	1	.827	1.288	0.199887121
	Constant	-1.640	.303	29.271	1	.000	.194	
4	Educat 4	-6.637	30.217	.048	1	.826	.001	0.000273755
	Constant	-1.566	.294	28.386	1	.000	.209	
5	Educat 5	.015	1.137	.000	1	.989	1.015	.166588613
	Constant	-1.625	.303	28.666	1	.000	.197	
6	Educat 6	7.897	22.242	.126	1	.723	2690.323	.994508242
	Constant	-1.698	0.302	31.671	1	.000	.183	

Given these values the logistic regression coefficients can be written as

Z_1 = -1.904+. 672= -1.232 Z_2 = -1.335-. 775= -2.110

Z_3 = -1.640+. 253= -1.387 Z_4 = -1.566-6.637= -8.203

Z_5 = -1.625+. 015= -1.610 Z_6 = -1.698+7.897= 5.199

Given these coefficients the logistic regression equation for the probability of awareness can be calculated as :P = $\frac{1}{1+e^{-z}}$. Then

$P_1 = \frac{1}{1+e^{-Z_1}} = \frac{1}{1+e^{+1.232}}$ = .22583157 $P_2 = \frac{1}{1+e^{-Z_2}} = \frac{1}{1+e^{+2.11}}$ = .108128666

$P_3 = \frac{1}{1+e^{-Z_3}} = \frac{1}{1+e^{+1.387}}$ = .199887121 $P_4 = \frac{1}{1+e^{-Z_4}} = \frac{1}{1+e^{8.203}}$ = .000273755

$P_5 = \frac{1}{1+e^{-Z_5}} = \frac{1}{1+e^{1.610}}$ = .166588613 $P_6 = \frac{1}{1+e^{-Z_6}} = \frac{1}{1+e^{-5.199}}$ = .994508242 Based on these estimates, we would predict that the awareness about the Pond Sand Filter does not increase as the level of education increases. In general, if the estimated probability of the event is less than 0.5, we predict that the event will not occur. If the probability is greater than 0.5, we predict that the event will occur. From the above table it can be seen that as the level of education increases the probability of awareness does not increase and only for education level above 6 or more it can be predicted that the people are aware about Pond Sand Filter.

Fitness of the Model

From the following table we can see that for education level 1, 71 respondents were correctly predicted by the model not to be aware of Pond Sand Filter. Similarly 0 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tell how many men were incorrectly classified. A total of 14 men were misclassified in the table. Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% was correctly classified. Overall 83.5percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of education. The overall percentage increases with the increase in level of education

Table 22: Classification Table

Level	Observed	Predicted Pond Sand Filter Awareness		Percentage
		0	1	
Edu 1	Step 1PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
Edu 2	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
Edu 3	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5

Edu 4	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
Edu 5	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
Edu 6	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5

Table 23:Model Summary

Level	Step	-2 Log Likelihood	Cox & Shell r Square	Nagelkerke R Square
Edu 1	1	74.772	.015	.025
Edu 2	1	74.475	.018	.031
Edu 3	1	76.011	.001	.001
Edu 4	1	74.581	.017	.029
Edu 5	1	76.056	.000	.000
Edu 6	1	72.392	.042	.071

Table 24: Changes in 2-log likelihood

Level			Chi Square	df	Sig.
Edu 1	Step 1	Step	1.285	1	.257
		Block	1.285	1	.257
		Model	1.285	1	.257
Edu 2		Step	1.581	1	.209
		Block	1.581	1	.209
		Model	1.581	1	.209
Edu 3		Step	.046	1	.831
		Block	.046	1	.831
		Model	.046	1	.831
Edu 4		Step	1.476	1	.224
		Block	1.476	1	.224
		Model	1.476	1	.224
Edu 5		Step	.000	1	.989
		Block	.000	1	.989
		Model	.000	1	.989
Edu 6		Step	3.665	1	.056
		Block	3.665	1	.056
		Model	3.665	1	.056

Income VS. Environment Awareness

Next we studied the relationship between Income of the respondent and his awareness about environment pollution by the same binary logistic regression method.

Table 25: Variables in Equation

Level	Step 1	B	SE	Wald	df	Sig.	Exp(B)	Probability

1	Income1	-.511	.443	1.332	1	.248	.600	.268744
	Constant	-.049	.312	.024	1	.876	.952	
2	Income2	.341	.744	.210	1	.647	1.406	.5
	Constant	-.341	.231	2.174	1	.140	.711	
3	Income3	-.428	.744	.331	1	.565	.652	.33336604
	Constant	-.265	.231	1.308	1	.253	.767	
4	Income4	.341	.744	.210	1	.647	1.406	.5
	Constant	-.341	.231	2.174	1	.140	.711	
5	Income5	1.038	1.245	.695	1	.405	2.823	.666633959
	Constant	-.345	.224	2.367	1	.124	.708	
6	Income6	-.823	1.176	.490	1	.484	.439	.250490123
	Constant	-.273	.224	1.485	1	.223	.761	
7	Income7	6.536	22.241	.086	1	.769	689.632	.997974679
	Constant	-.336	.221	2.311	1	.128	.741	
8	Income8	1.038	1.245	.695	1	.405	2.823	.6666339
	Constant	-.345	.224	2.367	1	.124	.708	
9	Income9	6.536	22.241	.086	1	.769	689.632	.99797
	Constant	-.336	.221	2.311	1	.128	.714	
10	Income10	6.536	22.241	.086	1	.769	689.632	.99797
	Constant	-.336	.221	2.311	1	.128	.714	
12	Income12	6.536	22.241	.086	1	.769	689.632	.997974679
	Constant	-.336	.221	2.311	1	.128	.714	

Given these values the logistic regression coefficients can be written as

$EI_1 = -.49 - .511 = -1.001$ $EI_2 = -.341+.341 = 0$
$EI_3 = -.265 - .428 = -.693$ $EI_4 = -.341 + .341 = 0$
$EI_5 = -.341+1.038 = .693$ $EI_6 = -.273 - .823 =-1.096$
$EI_7 = -.336 +6.536 = 6.2$ $EI_8 = -.345+1.08 = .693$
$EI_9 = -.336 + 6.536 = 6.2$ $EI_{10} = -.336 + 6.536 = 6.2$
$EI_{12} = -.336 + 6.536 = 6.2$

Given these coefficients the logistic regression equation for the probability of awareness can be calculated as:

$P = \frac{1}{1+e^{-z}}$. Then-

$P_1 = \frac{1}{1+e^{-Z_1}} = \frac{1}{1+e^{+-1.001}} = .268744$ $P_2 = \frac{1}{1+e^{-Z_2}} = \frac{1}{1+e^{+0}} = .5$

$P_3 = \frac{1}{1+e^{-Z_3}} = \frac{1}{1+e^{.693}} = .33336604$ $P_4 = \frac{1}{1+e^{-Z_4}} = \frac{1}{1+e^{0}} = .5$

$P_5 = \frac{1}{1+e^{-Z_5}} = \frac{1}{1+e^{.693}} = .666633959$ $P_6 = \frac{1}{1+e^{-Z_6}} = \frac{1}{1+e^{-1.096}} = .250490123$

$P_7 = \frac{1}{1+e^{-Z_1}} = \frac{1}{1+e^{6.2}} = .997974679$ $P_8 = \frac{1}{1+e^{-Z_2}} = \frac{1}{1+e^{.693}} = .6666339$

$$P_9 = \frac{1}{1+e^{-Z_3}} = \frac{1}{1+e^{6.2}} = .99797 \qquad P_{10} = \frac{1}{1+e^{-Z_4}} = \frac{1}{1+e^{6.2}} = .99797$$

$$P_{12} = \frac{1}{1+e^{-Z_5}} = \frac{1}{1+e^{6.2}} = .997974679$$

Based on these estimates, we would predict that the awareness about the environment pollution increases as the level of income increases. In general, if the estimated probability of the event is less than 0.5, we predict that the event will not occur. If the probability is greater than 0.5, we predict that the event will occur. From the above table it can be seen that as the level of education increases the probability of awareness increases and for education level above 4 or more it can be predicted that the people are aware about environmental pollution.

Fitness of the Model

From the table we can see that for education level 1, 49 respondents within education level 1 were correctly predicted by the model not to be aware of pollution. Similarly 0 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tell how many men were incorrectly classified. A total of 36 men were misclassified in the example._Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% were correctly classified. Overall 57.6 percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of education. The overall percentage increases with the increase in level of education.

Table 26

Classification Table

Level	Observed	Predicted Environment Awareness		Percentage
IN1	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN2	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN3	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN4	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN5	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 6	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6

IN 7	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 8	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 9	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 10	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 12	Step 1 EA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6

From the table given below we can see that for income level 1, 45 respondents were correctly predicted by the model not to be aware of pollution. Similarly 4 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tell how many men were incorrectly classified. A total of 32 men were misclassified. Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% was correctly classified. Overall 57.6 percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of income. The overall percentage increases with the increase with the increase of the level of income

Table 2 7: Classification Table Constant Predicted

Level	Observed	Environment Awareness		Percentage Correct
		0	1	
IN1	0	45	4	100.0
	1	32		.0 57.6
IN2	0	71	0	91.8
	1	14	0	11.1 57.6
IN3	0	49	0	100.0
	1	36	0	.0 57.6
IN4	0	45	4	91.8
	1	32	4	11.1 57.6
IN5	0	48	1	98.0
	1	34	2	5.6 58.8
IN6	0	49	0	100.0
	1	36	0	.0 57.6
IN7	0	49	0	100.0

	1	35	1	2.8 58.8
IN8	0	48	1	98.0
	1	34	2	5.6 58.8
IN9	0	49	0	100.0
	1	35	1	2.8 58.8
IN10	0	49	0	100.0
	1	35	1	2.8 58.8
IN12	0	49	0	100.0
	1	35	1	2.8 58.8

Table 28: Model Summary

Level	Step	-2 Log Likelihood	Cox & Shell r Square	Nagelkerke R Square
IN1	1	114.496	.016	.021
IN2	1	115.630	.002	.003
IN3	1	115.496	.004	.005
IN4	1	115.630	.002	.003
IN5	1	115.093	.009	.012
IN6	1	115.290	.006	.009
IN7	1	114.109	.020	.027
IN8	1	115.093	.009	.012
IN9	1	114.109	.020	.027
IN10	1	114.109	.020	.027
IN12	1	114.109	.020	.027

Table 29 Changes in 2-log likelihood

Level		Chi Square	df	Sig.
IN1	Step 1 Step	1.343	1	.247
	Block	1.343	1	.247
	Model	1.343	1	.247
IN2	Step	.209	1	.647
	Block	.209	1	.647
	Model	.209	1	.647
IN3	Step	.343	1	.558
	Block	.343	1	.558
	Model	.343	1	.558
IN4	Step	.209	1	.647
	Block	.209	1	.647
	Model	.209	1	.647
IN5	Step	.746	1	.388
	Block	.746	1	.388
	Model	.746	1	.388
IN6	Step	.549	1	.459
	Block	.549	1	.459

	Model	.549	1	.459
IN7	Step	1.730	1	.188
	Block	1.730	1	.188
	Model	1.730	1	.188
IN8	Step	.746	1	.388
	Block	.746	1	.388
	Model	.746	1	.388
IN9	Step	1.730	1	.188
	Block	1.730	1	.188
	Model	1.730	1	.188

<u>Income VS. Pond Sand Filter Awareness</u>

Next the relationship between Income & Pond Sand Filter Awareness have been studied-

Table 30 Variables in Equation

Level	Step 1	B	SE	Wald	df	Sig.	Exp(B)	Z	Probability
1	Income1	-.084	.585	.021	1	.885	.919	-1.664	.15922
	Constant	-1.580	.415	14.498	1	.000	.206		
2	Income2	1.281	.800	2.566	1	3.600	.109	-0.511	.374959
	Constant	-1.792	.326	30.270	1	.167	.000		
3	Income3	.421	.861	.239	1	1.524	1.524	-1.253	.2221812
	Constant	-1.674	.315	28.317	1	.188	.188		
4	Income4	-.352	1.111	.100	1	.751	.703	-1946	.124990
	Constant	-1.594	.304	27.452	1	.000	.203		
5	Income5	.976	1.262	.599	1	.439	2.654	-.693	.33336604
	Constant	-1.669	.302	30.477	1	.000	.188		
6	Income6	-6.637	30.217	.048	1	.286	.001	-7.933	.00035858
	Constant	-1.566	.294	28.386	1	.000	.209		
7	Income7	-4.590	22.241	.043	1	.836	.010	-6.199	.002027342
	Constant	-1.609	.293	30.220	1	.000	.200		
8	Income8	-6.622	34.891	.036	1	.849	.001	-8.202	.000274029
	Constant	-1.580	.293	28.999	1	.000	.206		
9	Income9	-4.590	22.241	.043	1	.836	.010	-6.199	.002027342
	Constant	-1.609	.293	30.220	1	.000	.200		
10	Income1 0	-4.590	22.241	.043	1	.836	.010	-6.199	.002027342
	Constant	-1.609	.293	30.220	1	.000	.200		
12	Income1 2	-4.590	22.241	.043	1	.836	.010		.002027342
	Constant	-1.609	.293	30.220	1	.000	.200	-6.199	

Based on these estimates, we would predict that the awareness about the Pond Sand Filter method does not increase as the level of income increases. In general, if the estimated probability of the event is less than 0.5, we predict that the event will not occur. If the probability is greater than 0.5, we predict that the event will occur. From the above table it can be seen that as the level of education increases the probability of awareness does not increase.

Table 31:Classification Table

Level	Observed	Predicted Environment Awareness		Percentage
IN1	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN2	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN3	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN4	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN5	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN 6	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN 7	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN 8	Step 1 PSFA 0 1 Overall Percentage	71 14	0 0	100.0 .0 83.5
IN 9	Step 1 PSFA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 10	Step 1 PSFA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6
IN 12	Step 1 PSFA 0 1 Overall Percentage	49 36	0 0	100.0 .0 57.6

From the table we can see that for income level 1, 71 respondents were correctly predicted by the model not to be aware of Pond Sand Filter method. Similarly 0 men with awareness were correctly predicted to have awareness. The off-diagonal entries of the table tells how many men were incorrectly classified. A total of 14 men were misclassified in the table. Of the men without the awareness, 100% were correctly classified. Of the men with awareness, 0% were correctly classified. Overall 83.5 percent of the eighty-five respondents were correctly classified. This is more or less true for other levels of income. The overall percentage increases with the increase in level of income.

Table 32:Classification Table Constant Predicted

Level	Observed	Pond Sand Filter Awareness		Percentage Correct
		0	1	
IN1	0	71	0	100.0
	1	14	0	.0 83.5
IN2	0	71	0	100.0
	1	14	0	.0 83.5
IN3	0	71	0	100.0
	1	14	0	.0 83.5
IN4	0	71	0	100.0
	1	14	0	.0 83.5
IN5	0	71	0	100.0
	1	14	0	.0 83.5
IN6	0	71	0	100.0
	1	14	0	.0 83.5
IN7	0	71	0	100.0
	1	14	0	.0 83.5
IN8	0	71	0	100.0
	1	14	0	.0 83.5
IN9	0	71	0	100.0
	1	14	0	.0 83.5
IN10	0	71	0	100.0
	1	14	0	.0 83.5
IN12	0	71	0	100.0
	1	14	0	.0 83.5

Table 33: Model Summary

Level	Step	-2 Log Likelihood	Cox & Shell r Square	Nagelkerke R Square
IN1	1	76.036	.000	.000
IN2	1	73.743	.27	.045
IN3	1	75.831	.003	.004
IN4	1	75.949	.001	.002
IN5	1	75.526	.006	.011
IN6	1	74.581	.017	.029
IN7	1	75.698	.004	.007
IN8	1	74.957	.013	.022
IN9	1	75.698	.004	.007
IN10	1	75.698	.004	.007
IN12	1	75.698	.004	.007

Table 34: Changes in 2-log likelihood

Level		Chi Square	df	Sig.
IN1	Step 1 Step	.021	1	.885
	Block	.021	1	.885
	Model	.021	1	.885
IN2	Step	2.314	1	.128
	Block	2.314	1	.128
	Model	2.314	1	.128
IN3	Step	.225	1	.635
	Block	.225	1	.635
	Model	.225	1	.635
IN4	Step	.108	1	.743
	Block	.108	1	.743
	Model	.108	1	.743
IN5	Step	.531	1	.466
	Block	.531	1	.466
	Model	.531	1	.466
IN6	Step	1.476	1	.224
	Block	1.476	1	.224
	Model	1.476	1	.224
IN7	Step	.358	1	.549
	Block	.358	1	.549
	Model	.358	1	.549
IN8	Step	1.100	1	.294
	Block	1.100	1	.294
	Model	1.100	1	.294
IN9	Step	.358	1	.549

	Block	.358	1	.549
	Model	.358	1	.549
IN10	Step	.358	1	.549
	Block	.358	1	.549
	Model	.358	1	.549
IN12	Step	.358	1	.549
	Block	.358	1	.549
	Model	.358	1	.549

CONCLUSION

Thus we can access from the observation of field and also from the logistic regression estimation that the awareness about pollution among the studied sample increases with the increase of education level as well as with the increase of income level. But regarding awareness about the Pond Sand Filter Method it is seen that increase in income or education do not increases the level of awareness about awareness. Thus it can be seen that this method is not at all known to the people. For a better tomorrow we should always attempt to aware the unaware people about the affects of polluted water and to conserve water.

Physical Accounting of Water Quality Parameters – Understanding Water Quality Accounting Through Case Study of Bhoj Wetland of Bhopal

[Technical Paper for the seminar on Environment statistics – A Statistical Accounting of Water Resources to be held at ISEC, Bangalore during 24th-25th June, 2005 organised by CSO, MoSPI]

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Abstract

A freshwater lacustarine lake Bhoj wetland (BWL), 1000 years urban wetland located in the heart of Bhopal city of India has been subjected to immense pressure by multiple stakeholders and hence is facing considerable degradation. The goal of the authorities managing BWL is essentially to balance the use of lake with conservation measures to sustain various wetland ecosystem services overtime. Lake degradation which mainly comprises of water pollution, is due to multiple causes hence lake's restoration requires multiple interventions. To address the issue, the paper first gives the concept of physical accounts of water quality, compares various studies done in India in this regard covering various aspects of water resource valuation and accounting presents water register of the lake as per use by various users and the does water budgeting in the form of water resource accounts in relation to water quality. The change in quality is then valued in monetary terms, which will form the environmental accounts of water.

Further for policy implication, it suggest interventions and it develops an ecosystem model for the lake following the system's dynamics approach based on water quality parameters which represents the base scenario. The base model is then subject to various scenario runs to show future status of lake based on interventions or their absence. Then based on these runs various interventions and their prioritization has been suggested for judicious decision making for sustainable management of this wetland.

Note: The case study of the paper is extracted from the World Bank assisted project titled "Economic Valuation of Bhoj Wetland for Sustainable Use" accomplished by the author in 2001)

Key words: Water Quality Parameters, Physical accounts of water quality, Ecosystem's Modeling, management strategies

Introduction

1. Ecological and Economic Importance of Wetlands - Hence Need for Water Resource Accounting of Wetland Stocks of Water Quantity and Quality

Urban wetlands are places within the city limits where water and soil mingles. They range from 'remnants' of ponds or creeks that once existed on sites where buildings now stand, to drainage ditches resulting from inadequately planned or engineered development. The wetlands extend numerous economic, environmental and social benefits in terms of recharging ground water table, maintenance of soil moisture, microclimatic effects like temperature and moisture control, control of floods, maintenance of flora- fauna relationship and maintenance of biodiversity, provide recreation to local people and the visitors and offer educational aspect. Further they are the direct source of livelihood of various communities like fishermen, washermen, boatmen, trapa cultivators and indirectly provide earnings to various road side petty traders. Urban wetlands have been utilized as natural cleansing agents to mitigate the additional pollutant levels introduced within the urban landscape. They absorb large amounts of point source pollutants like sewage, solid waste, industrial waste and from washing of vehicles and also those which 'runaway' from their source like agricultural fields, hospitals, open garbage dumps in rainwater.

These multilateral ecosystems through their numerous functions provide substantial benefits to society. However despite their important role in maintaining the ecology and economy of the regions, almost all wetlands in India are endangered by lack of appreciation of their role. A few of the country's wetlands, which have a great deal of biological wealth are protected under the wildlife protection Act, whereas others which may not be as biologically rich do not share the same protection, and are easy target of developers. Considered wastelands, wetlands are the obvious choice when land is needed for development. However more often than not these benefits are recognized and undervalued, as they fall outside the ambit the market economy (Sustainable Wetlands, Cap 21). People have well understood the uses of wetlands but not their use values. Though water registers in terms of stock of water and its usage have been maintained but there has not been much effort in the past to attempt water quality accounting due to anthropogenic socio economic pressures and to further assign the use value or a price tag to various extractives and non-extractive uses of the wetland such that it can be sustainably managed.

2. Case Area Details

2.1 Description of the site

The Bhoj Wetland comprises two lakes the Upper and Lower Lakes. The

Ministry of Environment & Forests (MoEF) of the Government of India has declared the Upper and the Lower Lake to be a Wetland of National Importance in the year 1988. Bhoj Wetland is one of the sixteen wetlands in the country that have been so far identified for under National Lake conservation Plan (NCLP).The Upper Lake is the highly diminished remains of the large lake constructed by Raja Bhoj, in the 11^{th} century. The seasonal river Kolans, originating from Sehore, some forty eight kilometres from Bhopal, and several small feeder streams at the western side of the lake, form the source. It has catchment area of 361 km^2 and water spread area of 31 km^2. The Lower Lake also known as the Chotta Talab or Small Lake, is situated towards the east end of the Upper Lake and is almost fully surrounded by built-up areas. It has a small catchment area of 9.60 km^2 and a water spread area of 1.29 km^2. Lower Lake receives its inflow in the form of seepage from the Upper Lake in addition to the drainage coming from 8 nallahs or drains. Water level is maintained constant by regular outflow through a waste weir at Pul-Pukhta into Patra Nallah.

2.2. Multiple Uses of the Bhoj Wetland

The Bhoj Wetland provides: Drinking Water – to nearly half of the city's drinking water supply comes from the Upper Lake and this is the most important use of the wetland as far as the welfare of the citizens is concerned; Employment - to various communities like the fishermen, washermen, boatmen, vendors and so on. Approximately, 300 families are engaged in fishing and *trapa* cultivation while some 100 washermen also make their living from the Wetland. There are some 50 boatmen whose livelihood is dependent upon the Bhoj Wetland; Microclimate stability - the microclimate of Bhopal is quite moderate as compared to the surrounding areas. The city according to its geographical location should actually have an extreme type of climate, but owing to the proximity of the Wetland, moderating effects on temperature and again cool land breeze during the evenings can be experienced which makes the evenings even during the peak of summer very enjoyable. Off course the moderating effects are also influenced by other factors such as the vegetative cover and all but the effect can be largely attributed to the Wetland; Recreation opportunities - like boating, scenic view, water sports to the people of Bhopal.

2.3 Multiple Stakeholders of the Bhoj Wetland Benefits

This group comprises of : Entire population – for drinking water & recreation; Lake front property owners- for aesthetic beauty; Washermen- for washing clothes in the lake; Fishermen- for fishing activities; Trapa cultivators- for cultivating trapa; Water supply agencies -for water purification and distribution; Bhopal Municipal Corporation -for management of Lake; Department of Housing & Environment, Govt. of Madhya Pradesh - for decision making process; MPTDC- for tourism development in lake; Vendors - for secondary benefits, Funding and Research agencies

2.4 Threats to the Wetland

The Bhoj Wetland is faced by major threats like siltation ,solid waste pollutants, sewerage, washermen, trapa cultivators, encroachment, increasing population, weeds and eutrophication, boating, agricultural waste, idol and *tadjia* immersion, hospital waste, on account of excessive use by large number of stakeholders.

2.5 Problem statement

Bhoj wetland being located in the heart of the Bhopal city is one such example of degradation of wetlands ecosystem on account of excessive extraction of its multiple use values by the fast increasing urban population comprised of multiple stakeholders. In the second half of the 20th century, the hydrological regime of the Bhoj wetlands had been heavily modified, and the influence of direct flow of sewage from the adjoining 17 municipal wards, flow of medical waste into then lakes and agriculture runoff from its catchments without much environmental consideration--created a substantial decline in the water quality of the lakes.

Water quantity available for specific uses declines with the extent of pollution flowing into the water body. When quality deteriorates, the economic value of water also gets reduced. With increasing quality deterioration, water uses may successively shift from drinking water to bathing water, water for livestock, agriculture and industrial uses etc. Same has been the case of Upper and Lower Lakes where the water quality levels have reduced to Class 'C' and 'E' respectively. The ultimate goal of the ongoing restoration project of the government is to bring the water quality of Upper Lake to the designated Class 'A' and that of Lower Lake to designated Class 'D' as per the following primary water quality criteria.

Table 1 : Primary Water Quality Criteria as per WHO Standards

Primary Water Quality Criteria					
Criterion	Class A	Class B	Class C	Class D	Class E
Dissolved oxygen (mg/I) minimum	6	5	4	4	
BOD (mg/I) maximum	2	3	3		
Total Coliform count (MPN/100 ml.) maximum	50	500	5,000		
PH	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6.5-8.5
Free ammonia (mg/I) maximum				1.2	
Conductivity (micro mho/cm) maximum					2,250
Sodium absorption ratio maximum					26
Boron (mg/I) maximum					2

BOD : Biochemical oxygen demand; pH : measure of the acidity of alkalinity of water, MPN : Most probable number, Mho : unit of conductivity.

Class A : Drinking water source without conventional treatment. Class B : Water for outdoor bathing,
Class C : Drinking water with conventional treatment, Class D : Water for wildlife and fisheries,
Class E : Water for recreation and aesthetics, irrigation and industrial cooling

3. Water Resource Accounting as per SEEA framework

3.1 Water Resources

The SEEA framework defines water resources as the water found in fresh and brackish surface water and groundwater bodies found within the national territory. In the case of surface water, the volume in artificial reservoirs and watercourses are included in addition to that in natural water bodies. The water of the oceans and open seas is excluded on the grounds that the volume involved are so enormous as to make any stock measure meaning less and that the extraction for human use has no measurable impact on them.

The asset classification of water resources in the SEEA can be described as follows:

EA.13 Water Resources
EA.131 Surface Water
EA.1311 Artificial Reservoirs
EA.1312 Lakes
EA.1313 Rivers
EA.132 Groundwater

Very large quantities of water flow through an economy, some as natural resources, and some as ecosystem inputs, some as products and some as residuals. Water is the only environmental asset which can be classified into each of these four sorts of flows.

3.2 General Accounting principles

Water resource accounts comprise stock and flow accounts in physical terms as well as quality accounts. The accounts offer an integrated view of water supply and uses by industry and by purpose. They include measures of water pollution, protection and management and describe water quality in physical and monetary terms. The accounts help to understand the interaction between human activity and the environment. They help to identify water availability for various uses, stresses on water, and qualitative and quantitative water scarcity.

3.3 Physical flow

Physical water accounts describe the whole system of flows of water in physical terms between the environment and the economy and within the economy. It can be described in a supply and use table. Supply and use tables are constructed such that basic identity 'Supply equals use' is satisfied for flows from the environment, within the economy and return to the environment separately. The supply and use table can be combined in a single 'water use table'

Table 2 : Water Use Table

(In Million cubic meters)

		Agriculture	Fisheries	Energy	Mining	Manufacturing	Distribution/irrigation water	Distribution /mains water	Sewerage	Government	Households	Rest of the world & sea	Environment	Total
From the environment	U1.Total abstraction From surface water From ground water From other water *For own use* *For delivery*													
Within the economy economy	U2.Total use of distributed water Water received by Users *Of which recycled water* Waste water collected by sewerage													
To the Environment	U3. Total residuals To inland water Returns from irrigation Discharge waste water after treatment Discharge of untreated wastewater Cooling water Water used for hydroelectricity Water lost in transport Other returns of water To the sea													
Consumption														
Total use														

3.4 Asset accounts for water

Asset accounts for water describe how the stocks of water at the beginning of the accounting period are affected by flows of water between the environment and the economy and transfers of water internal to the hydrological system to reach the stocks of water at the end of the accounting period.

For groundwater, reservoirs and lakes it is conceptually simple to measure stocks. For rivers, the stock of water is not well defined due to the flowing nature of the resource. Here to maintain consistency with the other water resource, the stock of water in a river is measured as the volume of the riverbed. However the volume of the river is not always the good measure of water stocks, an alternative solution is to consider equal runoff into the main river or the mean annual runoff in a country subject to a very large annual variation.

Table 3 : An Asset accounts for inland water

(In Million cubic meters)

		EA.131 Surface water			EA.132 Groundwater	Total
		EA.1311 Reservoirs	EA.1312 Lakes	EA.1313 Rivers		
Opening stocks						
Abstraction (-)						
Residuals (-)	Returns from irrigation					
	Wastewater					
	Lost water in transport					
	Others					
Net precipitation (+)						
Inflows (+)						
Net natural transfers (+-)						
Evaporation from water bodies (-)						
Outflows (-)	To other country					
	To the sea					
Other volume changes	Due to natural disaster					
	Discovery(+)					
	Others					
Closing stocks						

Source: Constructed water example

3.5 Monetary accounts

The physical supply and use table have monetary counterparts. Water supply in monetary units records the major economic output of industries related to water and imports. The water use table in monetary units records the use of water by different economic agents.

Valuation:

Water valuation is crucial for water management decisions, in particular for those related to the allocation of water to different uses in the presence of increasing demands and limited supply. There are two main ways in which water can be valued. The first and uncontroversial measure is that of the direct market price. The second is the appropriation method.

4. Importance of Water Resources for the Wellbeing of the People

In the past century with respect to the provisioning service of freshwater by natural ecosystems two fundamental problems have emerged. Rising populations and human needs have led to a rapid rate of 'development' of freshwater services, where development refers to the replacement of naturally functioning systems with highly regulated and modified systems oriented towards the satisfaction of human uses, specifically water for irrigation, municipal and industrial needs, hydropower and navigation. Structural and capital intensive responses to augment the availability of freshwater services have greatly increased the ability of natural systems to meet human needs for food, water, energy and transport - where these developments have taken place. If we compare the water stress index of various countries we find that in most of the developing countries there is wide gap between the water demand and its supply. In India the problem is very apparent where we are capable of catching only 1% of water that falls in our country. The linking of river project is still a dream. Infact it has been rightly said that the next world war may be fought not on the issues of land like the previous world wars but o the issues of water as it is so essential but so short in supply that future well being depends only on its availability.

5. Water Resource Budgeting of Lakes

The hydrological budget of in terms of quantity and quality parameters lake's ecosystem can be expressed in many ways like hydrological budget, phosphate budget etc. and all the parameters can be combined and can be represented in the form of ecosystem model of the lake. Such budgets and models help in building environmental accounts of water pollution or improvement whichever is the case.

5.1 Hydrological Budget of the Lake

In order to prepare hydrological budget of the lake one needs to know how much inflow is there into the lake and how much flows out it. Inflows include direct precipitation in the lake area, drain water, subsurface flow. Outflows include water evaporation, water pumped out for drinking purposes, which includes lake water as well as ground water, subsurface outflow and water released through sluice during rainy season. A study on Lake Nainital by Singh and Gopal (2002) estimated the main inflows and outflows of water for Nainital lake for the year 1994-95. It finds that the amounts of total outflow (4636 million 1/yr) and inflow (4687 million 1/yr) suggesting that a balance is kept with respect to the quantity of lake's water. Of the total inflow the subsurface flow from the nearby Sukhatal valley-fill accounts for nearly 43%. Though the filtration of water passing through the valley-fill is not effective in brining about substantial removal of nutrients, its lead (Pb) concentration is quite low. Perhaps, by developing a mud layer over the valley-fill rich in bacterial population may contribute to the reduction of both nutrients and Pb. Maintaining a high water level in the lake Nainital particularly after the rainy seasons and dilution of pollutants are the major ecosystem services performed by Sukhatala valley-fill.

Surface runoff during the rainy season is the next largest water source. Direct precipitation makes only a small fraction of the lake budget, while water that finds its way through the watershed is more than six times as the direct precipitation. Precipitation in the watershed amounts to 6466.5 million 1/yr. Of this amount 3917.5 million 1 or 60.6% finds its way into the lake as runoff and subsurface flow and drain water. The remaining 1543.15 million 1 or 39.4% is estimated to be the sum of the water retained in soil, silt deposits and rocks and vegetation and the water lost as transpiration. Some of this water can be used for drinking purpose. Water stored within the bed of Sukhatal is already being used for drinking purpose.

5.2 Phosphate Budget

The excessive input of Phosphorus is the primary cause of eutrophication of lakes (Schindler 1977). The essential dynamics of phosphate (P) input from watershed, and P loss per unit time, include several processes: sedimentation, surface and subsurface outflow, and sequestration in biomass of consumers or benthic plants, rate of P recycling. Several factors can affect the rates of P losses; all of them are proportional to the mass of material in the water column.

Phosphate budgeting of the lake Nainital is also done by Singh and Gopal (2002) by using the hydrological data of NIH, Roorkee (1999) and concentration of PO_4 input. However, our estimates are gross approximations, and to achieve precise values more frequent samplings of various inflow and outflow waters are required.Among the inflows, drains had the highest concentration of PO_4 accounting for 33.4% of total PO_4 inflows, vis-à-vis their total water inflow of only 16.7%. This implies drains are the net contributor of the PO_4, this is largely because the drain water consists of bathrooms wastewater of clothes washed in detergents, which are rich in PO_4.[13] One of the extreme steps to reduce the input of PO_4 is by clamping a ban on the use of PO_4 containing detergents.

Because of the large volume, however, the subsurface water inflow is the largest source of PO_4 input (34%). The outflow load of PO_4 can be reduced by collecting subsurface inflows before it gets polluted. Detailed investigations are required to duct such points and collect water.Much of the PO_4 leaves the lake through the sluice during the monsoon months when the lake receives massive water input from the watershed. At this time of the year the lake is still thermally stratified therefore accumulating the PO_4.

5.3 Eutrophication Accounts

The resultant of increase in phosphate content of a lake due to increased sewage flow, medical waste and agricultural runoff leads to excessive eutrophication which in turn promotes weed growth and reduction in the quantity of water. Lakes can be divisided into three types with respect to reversibility of eutrophication (Carpenter et al. 1999):

(i) Reversible lakes – generally deep and cold lakes, rapid flushing, eutrophied for a short period. Eutrophication of these lakes could be restored by P input control alone.

(ii) Hysteretic lakes – often small or shallow lakes, with rapid P recycling, therefore, eutrophication cannot be reversed by P input controls alone. Temporary intervention such as aluminium sulphate treatment and biomanipulations are required to bring about shift from a high-P steady state to low-P steady state.

(iii) Irreversible lakes – includes lakes of P-rich regions, or lakes that have received extreme P-inputs for an extended period of time. Their eutrophication is so high that even severe reduction in P input and temporary manipulations may not shift the lake out of the eutrophic state. The lake of Nainital with a large anoxic hypolimnion and the associated rapid P-cycling and extended time period of eutrophication has almost reached the irreversible eutrophication state.

6. Hydrological Budget of Bhoj Wetland and Uses by Various Agencies

The following Table depicts the current status of water supply from the Bhoj Wetland and the adjoining sources of the Bhopal city. The Bhoj Wetland is currently able to supply only to the 40% population of the city hence the remaining requirements have to be met from other sources.

Table 4. STATUS OF WATER SOURCES IN BHOPAL

Source of water supply	Capacity	Current Extraction
(A) Pumping from the Upper lake (Bhoj wetland)	One mgd	One mgd
❑ Bairagarh Pump House	½ mgd	½ mgd
❑ MES Pump House	3 mgd	3 mgd
❑ Karbala Pump House	One mgd	One mgd
❑ Badal Mahal Pump House	½ mgd	½ mgd

❑ Railway Pump House ❑ Kamla Park Pump House ❑ BHEL Pump House ❑ Boat Club Pump House (1) ❑ Boat Club Pump House (2) ❑ Pul Pukhta Pump House	5 mgd 12 mgd 4.5 mgd 2 mgd 3 mgd	5 mgd 6 mgd 4.5 mgd 2 mgd 2 mgd
(B) Pumping from Kolar Dam ❑ Kolar Pump House	34 mgd	30 mgd
(C) Ground Water Supply ❑ Through BMCs tube well	5 mgd	2 mgd
(D) Total installation capacity	70 mgd	70 mgd
(E) Total supply by the BMC	62 mgd during normal days	
(F) Private Tube-wells.	Not estimated (about 2.5 lakh residents using ground water through private tubewells.	

Source: Bhopal Municipal Corporation, 2005

7. Ecosystem Modelling of Bhoj Wetland

7.1 Ecology and Ecosystems

Ecology literally means “the study of homes”. The term was coined by Haeckel in 1869 to mean the study of organisms in their organic and inorganic environment. More recently, Krebs (Krebs, 1978) has defined ecology as “the scientific study of the interactions that determine the distribution and abundance of organisms”. Ecological systems are definitely not ‘stand alone’ systems. Each component in these systems cannot be treated as an individual component because of the many interlinkages present. None of the components can in fact be dealt with in isolation since the entire network of linkages has to be taken into account whenever the system is being considered. For example, if one has to study the population dynamics of a particular species, then an understanding of how this system interacts with other species, the dynamics of all these species and so on are required.

Physical systems are definitely easier to model since initial conditions can be specified and external influences largely eliminated here. But with ecological systems this is a drawback since these may be influenced greatly by external factors such as climate which may introduce large variations in the system. Thus replicated designs may be impossible to study in ecological systems (Robertson et al.1991).

7.2 Ecosystem Modelling

Ecosystem modeling involves the depiction of ecosystem functions by changes over time or space (or both) in measurable quantities, thereby allowing some test of the set of process hypotheses at the ecosystem level. Modelling becomes important because it can construct a symbolic representation of the functioning of ecosystems. It can also predict and simulate conditions that might be existent if present trends to continue or new factors introduced into the system. It helps to identify the stress areas in a system and help to develop management strategies to help deal with them. Generally, modelling is used to make predictions about the responses of ecosystems, or components of ecosystems to specify stresses or disturbances.The first simulation models for ecosystems were developed in the mid-1940s by Gordon Riley, for marine ecosystem primary and secondary production. These models were developed before the advent of the digital computer and required laborious calculations. Present day ecosystem simulation requires use of a digital computer and simulation is now inseparable from the digital computer. (Gordon &Stephen 87).

7.3 Major Model Types

Models can be classified in many different ways, and it is frequently true that the classification applies more appropriately to parts of models rather than to the model itself and that some models can be put into more than one class.

7.3.1 Statistical Models:

These models are simply used to summarise large amounts of data in a mathematical form. The choice of the mathematical form itself has little or no theoretical justification, and the resulting parameter values, obtained by the statistical procedure, have little biological meaning. A common example is the fitting of polynomial equations to growth data, as in agricultural crops or forest stands.

7.3.3 Theoretical / Analytical Models:

These are developed from simple theoretical considerations, frequently with little or no basis in observed sets of data. These models are used to explore abstract ecological concepts, such as the coexistence of two competing species, or the relation between complexity and stability in ecological systems. The models are frequently handled analytically, and mathematical tractability is more important than ecological sense. Such models therefore tend to make highly simplistic ecological assumptions (for example, that there is a linear relationship between the amount of food eaten by a predator and the amount of food available), and this makes many of the conclusions of very doubtful value.

7.3.4 Numerical Simulation Models

Numerical simulation models involve the literative solution of a mathematically - specified model. In a relatively few cases, such as the statistical simulation of sampling problems, the iteration is over the set of individuals in a population. In the vast majority of cases, the primary iterative loop is forward through a set of points in time. In these cases, the model specifies the changes that take place over one time step, and the model is solved by repeatedly working out changes in the system, then updating the state of the system. (Robertson et al.1991).

In more simple terms, models are likely to be either conceptual or numerical. Stochastic models use mathematical representations of ecosystems, which take account of probability, so that a given input may yield a number of possible results. Deterministic models, on the other hand, rest on mathematical descriptions of ecosystems in which relationships are fixed, so that any given input invariably yields the same result (Allaby 1994).

Simulation models consist of a collection of hypotheses, in equation form, for how the major elements of the model (state variables) change over time. These hypotheses are usually categorised into several processes controlling the rates of change of the state variables. The choice of processes to consider depends on the major variables in the model and on the degree of detail desired to represent the changes in these variables. These depend in turn on model objectives and on the ecosystem under study. The process rates are combined into a system of *different equations*. These equations give the rate of change of the state variables as a function of their own condition and of other state variables and environmental conditions. (Gordon &Stephen 87).

Thus conceptual models assist in the understanding of complex, multivariable problems. Management models should offer reliable predictions of the outcome of alternative approaches to problems that assist the manager to decide the optimal course of action. It is rare for one model to fulfil both purposes. The ability to make a mathematical model which simulates a natural system or process is a measure of the modeller's understanding of that system.

7.4 Ecosystem Modelling of Bhoj Wetland Using Water Quality Parameters

7.4.1 Model Justification

The main objective of the Ecosystem Modelling of Bhoj Wetland was to understand the quality of resource such that various interventions can be suggested accordingly. The modelling exercise used water quality parameters to study the current status of the lake, followed by changes in the water quality parameters over the last few years and to project the status of the Upper and Lower Lakes in the future, based on past data and information from the restoration activities being carried out. It was expected that this exercise shall provide to the planner an insight for sustainable management techniques through prioritisation of various interventions and such that restoration activities shall be undertaken wherever required.

Wetland models have been very much in focus during the last five to eight years due to an increasing interest for these ecosystems as habitats for birds and amphibians. Restoration of previous wetlands or erections of new wetlands seem furthermore to be the most effective method of abatement of nutrient pollution from non-point sources (agricultural pollution). This has obviously increased the demand for good management models in the area. Bhoj Wetland, the lifeline of Bhopal, being a man made reservoir within the city is facing threats due to various anthropogenic activities inside and outside the lake area. The primary use of the lake, as mentioned, is providing drinking water to nearly half the city's population. The drinking water quality has been deteriorating steadily over the years owing to increased human activities in the region.

A detailed conceptual model with causes, impact and feed back control strategy (restoration and pollution prevention activities) has been developed . It attempts to assess the impact of economic, ecological, social and technological factors on the lake' ecosystem and suggests the control strategies through the feedback mechanism and thus follows a holistic approach for the sustainable management of Bhoj Wetland. But due to lack of availability of data the model presented here has considers only the basic water quality parameters. Though indirectly the pressure of economic, social and technological factors does gets expressed in terms of changing values of these parameters but not so explicitly.

Thus a detailed ecological model linking basic parameters and their impact on water quality has been developed. Though it is clear that the linkages are very complex, to the extent data and information are available, and to the extent the parametric specifications stand the test of stable relationships, the model is put to explain the eco-system dynamics. Therefore, one may not take this model to be a complete description of the ecology of Bhoj Wetland. Here the modelling factors are its drinking water quality parameters .

7.4.2 Model variables

The goal of management is to balance the uses of lake with conservation measures to sustain ecosystem services over time. Lake degradation is a syndrome with multiple causes. Because lake degradation has multiple causes, lake restoration usually requires multiple interventions. The basic ecological parameters brought under the purview of the conceptual model for Bhoj Wetland are weeds and sewage. All are linked with each other in one way or another. The water quality parameters like Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), pH, Total Hardness, Total Alkalinity, phosphate, Turbidity, Total Dissolved Solids (TDS) and Bacterial Count are linked with these variables and with each other.

a. Bio Chemical Oxygen Demand (BOD*)*

BOD, an important water quality parameter, shows the level of biodegradable waste pollution. The BOD value of the system is affected by sewage which releases nutrients and biodegradable domestic waste (food wastes) in the lake waters. BOD is also affected by total solids which itself is dependent upon household wastes coming through the sewage. BOD shows a positive link with bacterial count and total dissolved solids. Dissolved Oxygen (DO) content of the water body affects the BOD greatly. A high DO value indicates good primary production and life supporting potential of the system.

b. *Bacterial Count*

Bacterial Count can provide a better picture of drinking water quality. Total bacterial count through Maximum Probable Number (MPN) technique shows the number of bacterial pathogen(*E.Coli*) present in the sample of water. They are the causative agents of many water borne human diseases. The bacterial count has increased in an alarming way in the Bhoj Wetland over the last few years. In this model the bacterial count is connected to sewage, pH, turbidity and BOD. The change in pH value affects bacteria the most. Similarly, high BOD means more biodegradable material in water which also provide nutrients to bacteria. Total solids are also linked with the increase of bacterial count. But the main source of the bacteria is the waste (solid and sewage) from the hospitals and houses.

c. Total Hardness

Total Hardness is the sum of hardness due to calcium and magnesium ions present in the water. This is linked with the geological conditions of the catchment area. Soil structure and land use practices of catchment area affects its value. In this system it is linked with sewage and total dissolved solids. The high value of hardness makes white precipitates in the boilers and consume more soaps and detergents while washing in such waters.

d. Dissolved Oxygen

Dissolved Oxygen is an important parameter of all ecosystems because it controls life inside the water. Very low oxygen indicates high polluting levels of oxygen demanding wastes and lack of primary production. Temperature, turbidity, phytoplankton count and high BOD are the controlling factors of Dissolved Oxygen.

e. Total Phosphate

Total Phosphate content in the lake water indicates the pollution from sewage and agricultural run off. This is the limiting nutrients for primary production and helps excessive growth of weeds and lower aquatic plants. Fertilisers and detergents are the main sources of inorganic phosphate which plants can absorb directly. Organic phosphates of living cells and dead cells also contribute phosphate to the system. High value of phosphate is considered nutrient rich condition of the water body.

f. Turbidity

Turbidity of the lake is related the suspended and colloidal particles of the water. It reflects or hinder the light penetration, thus impact on primary production and dissolved oxygen value of water body. Turbidity can measured in Naphthalene Turbidity Units (NTU) and here mentioned Formazin Attenuation Unit (FAU) which is equal to NTU.

7.4.3 Inter-linkages of Model variables

The inter linkages in the model may be illustrated by one parameter, say sewage coming to the lake. Sewage from the city household waste contains mainly water food wastes and detergents with silt. It increases)of the lake water and silt content which reduce lake area. It leads to eutrophication by bringing more nutrients that cause excess weed growth. This causes lake area reduction and affects the BOD of the ambient water of the lake.

Weed growth has its ecological benefits and is a cause of problems to the system too. It helps in biodiversity conservation by providing a nesting and breeding ground to fish and provides food for a number aquatic and avian fauna. It is also responsible for the bio treatment of sewage, i.e., nutrient retention, as filter to the silt and as primary producer giving dissolved oxygen to the water. But excessive growth of weeds reduces the water spread area, increases evapotranspiration (increases water loss), creates problems in fishing and navigation. The decayed parts of the weeds add more nutrients to the sediments and increase BOD in the lake waters. It also produces bad odour and breeding grounds for mosquitoes and other vectors. The drinking water quality gets affected by this, and a high cost for treatment of such water has to be incurred. Weed growth is affected mainly by sewage because it provides more nutrients which encourages such growth. It itself then affects bacteria, BOD and Turbidity. Thus weeds can adversely affect lake area and BOD but has positive link with dissolved oxygen of the lake.

7.4.5 Linkages of Model Variables with Population

All these parameters are directly linked with the population change. Increase in the population over the years has obviously led to an increase in the amount of sewage inflow into the water body. Population increase has also led to increase in development activities and encroachment in the catchment area resulting in more siltation and solid waste entry into the lake.Population growth in the adjacent areas of the lake is the most important factor of pollution. Encroachment in this area is considered in the restoration activities and useful measures like physical barriers (Link road) have been taken to check further encroachment. Increase in population increases water consumption and generate more waste water. Increase in sewage quantity affects the system adversely. In this model population of the wards nearing the fringe area of lake are taken for each lakes separately.

7.4.6 Wetland restoration

Wetland restoration approaches are numerous and include engineering solutions such as backfilling canals and the removal of contaminated groundwater, biological interventions including controlling the impact of feral fish and re-establishing wetland plants, through to hydrological management to increase the effective inundation across floodplains and reintroduction of drying cycles (www.ramsar.org). The decision to restore wetlands is often tied to governance. Thus the purpose of ecosystem modeling is to assess the response of wetland restoration, rather than the policy process that leads to its initiation.

7.4.7 Assessment of Impact of Ongoing Restoration Activities with Water Quality Parameters

The present scenario of the lake, undergoing restoration activities, is quite different from the situation of a few years back. The major changes have been in the quantity and quality of the sewage and weed infested area of the lake. After desiltation and dredging the lake area and volume will also change. The total impact of the restoration activities are yet to be quantified. The restoration of Bhoj Wetland which include Upper Lake and Lower Lake gives priority to its drinking water use in Upper Lake. The water quality in the Lower Lake is not in this criteria so can be used for other purposes like fresh water aquaculture and tourism activities.

To find out the impact of ongoing restoration activities, the basic model has been simulated in two ways and the data of pre restoration stage and ongoing project activities is used separately. The two models show the variance in their stimulation out puts. Using the available data first model has been developed for the pre restoration state for Upper Lake. In this model base year data of year1985 is compared with the water quality data of year 1992.The post project implementation model has been made separately for each lake. The basic structure of the model for both the lakes is same with some variation in the variables. The 1993 base year value of water quality data has taken here in the case of Upper Lake and data of year 1991 is used for Lower Lake and both are compared with 1999 data population data of the wards adjacent to each lake is used taking 1991 census data and compared to the estimated population of year 2001. The ecology of lake may change after the completion of restoration projects which are targeted to be completed by the year 2001.

The year 1999 data of ambient water for both lakes is calculated from the station wise data collected from the monitoring sub project of Bhoj Wetland project. The seasonal surface samples data of five sampling stations of Upper Lake and two sampling stations of Lower Lake for four seasons is considered for calculating the average value of water quality of year1999. As the Upper Lake is a large water body having different catchment area land use shows variation in the water quality in various stations. So it is necessary to take the maximum diversified and distant stations to cover the total area of the lake. The stations selected can give maximum variation of the water quality.

Lower Lake is small water body compared to the Upper Lake. Even though the limnological conditions in the sampling stations selected are different. Two sampling stations of distant locality and where maximum management activities have been done is selected to calculate the average value for 1999.

7.4.8 Determination of Compound Growth Rates and Elasticity Effects of Limnological Parameters

As mentioned above that to develop the ecological model for various parameters it is essential to first work out their compound rates of growth so as to see the changing trend of a particular parameter overtime and then to see the extent by which change in the value of one parameter effects the value of the other parameter. The compound growth rates so calculated for the Upper and Lower Lakes are shown in the following Tables .

Table 5: Compound Growth Rates of Selected Parameters in 1992 using1985 as base year (for the Upper Lake)

Sl.No.	Variable	Units	CGR	Base Year (1985)	Final year 1991
1	Population		0.0338	109187	133287
2	Sewage	Million Litre /Day	0.0101	31.3927	33.344
3	Weeds	Km2	0.3046	0.7	5.875 (1993)
4	BOD	Mg/l	0.0417	2.5545	3.28
5	Bacteria	Counts/100 ml	0.1098	358	670
6	PH		0.0051	8.7	9.0
7	Total Dissolved solids	Mg/l	0.0608	86	122.55
8	Total Hardness	Mg/l	0.0351	88	108.24
9	D.O	Mg/l	0.0324	4.0	4.84

10	Phosphate	Mg/l	0.5838	0.01	0.1578
11	Turbidity	NTU	-0.0188	4.0	3.57

Formula used for CGR, r = (P/I) **1**/t

Where, **P= Final year (Latest)**

I = Initial year

t= No. of years between P and I

Table 6: Compound Growth Rates of Selected Parameters in 1999 using1993 as base year (for the Upper Lake)

	Variables	**Units**	CGR	**1993**	**1999 (Average)**
1.	Turbidity	NTU	0. 2704	9.5	39.93
2.	p H		-0.0109	9.0	8.426
3.	TDS	mg/l	-0.0009	128	127.302
4.	Phosphate	mg/l	-0.0053	0.4	0.3874
5.	Hardness	mg/l	0.0075	86	89.968
6.	D.O	mg/l	0.0280	7.6	8.968
7.	BOD	mg/l	0.1933	2.1	6.066
8.	Bacteria	counts/100ml	0.1604	2400	5858
9.	Weed area	Km2	0.3046	5.875	0.7 (1985)#
10.	Population		0.0338	142471	185931*
11.	Sewage	Million Litres Day	0.0458	44.92	58.77

* Projected for 2001 (From Detailed project report of Solid Waste Management subproject, BMC)

No Data for 1999

Table 7: Compound Growth Rates of Selected Parameters in 1999 using1993 as base year (for the Lower Lake)

	Variables	Units	CGR	1993	1999 (Average)
1.	Turbidity	NTU	-0.0160	42	36.915
2.	P H		-0.0131	9.36	8.42
3.	TDS	mg/l	0.0056	170	177.75
4.	Phosphate	mg/l	-0.2180	4.4	0.6155
5.	Hardness	mg/	-0.0221	156 l	130.5
6.	D.O	mg/l	-0.0934	16.5	7.53
7.	BOD	mg/l	0.1209	4.6	11.465
8.	Bacteria	counts/100ml	0.0837	6000	11415
9.	Population		0.0339	143895	200889*
10.	Sewage	Million Litre per Day	0.0248	33.142	38.39

* Projected for 2001 (From Detailed project report of Solid Waste Management subproject, BMC)

Table 8: Elasticity Matrices of Ecological Parameters of Pre-Restoration stage (Upper Lake)

Sl.No.	**Population**	Sewage	**Weed area**	B .O. D	Bacterial Count	pH	Dissolved Solids	Hardness	D. O	Phosphate	Turbidity
CGR	**0.0603**	**0.0101**	**0.3046**	**0.0417**	**0.1098**	**0.0051**	**0.0608**	**0.0351**	**0.0324**	**0.5838**	**-0.0188**
Population	1.000	0.1675	5.0514	0.6915	1.8209	0.0846	0.3051	0.5821	0.5373	9.6816	-0.3118
Sewage	5.9703	1.000	30.1584	4.1287	10.8713	0.5049	1.8218	3.4752	3.2079	57.8019	-1.8614
Weed area	0.1979	0.0322	1.000	0.1369	0.3605	0.0167	0.0604	0.1152	0.1064	1.9166	-0.0617
B .O. D	1.4460	0.2422	7.3046	1.000	2.6331	0.1223	0.4412	0.8417	0.7770	14.000	-0.4508
Bacterial Count	0.5492	0.0919	2.7741	0.3798	1.000	0.0464	0.1676	0.3197	0.2591	5.3169	-0.1712
PH	11.8235	1.9803	59.7255	8.1765	21,5294	1.000	3.6078	6.8824	6.3529	114.4706	-3.6863
Dissolved Solids	3.2772	0.5489	16.5543	2.2663	5.9674	0.2772	1.000	1.9076	0.5329	9.6020	-0.3092
Hardness	1.7179	0.2877	8.6781	1.1880	3.1282	0.1453	0.5242	1.000	0.9231	16.6325	-0.5356
D. O	1.8611	0.3117	9.4012	1.2870	3.3889	0.1574	1.8765	1.0833	1.000	18.0185	-0.5802
Phosphate	0.1033	0.0173	0.5218	0.0714	0.1881	0.0087	0.1041	0.0601	0.0555	1.000	-0.0322
Turbidity	-3.2074	-0.5372	-16.2021	-2.2181	-5.8404	-0.2713	-3.2340	-1.8670	-1.7234	-31.0532	1.000

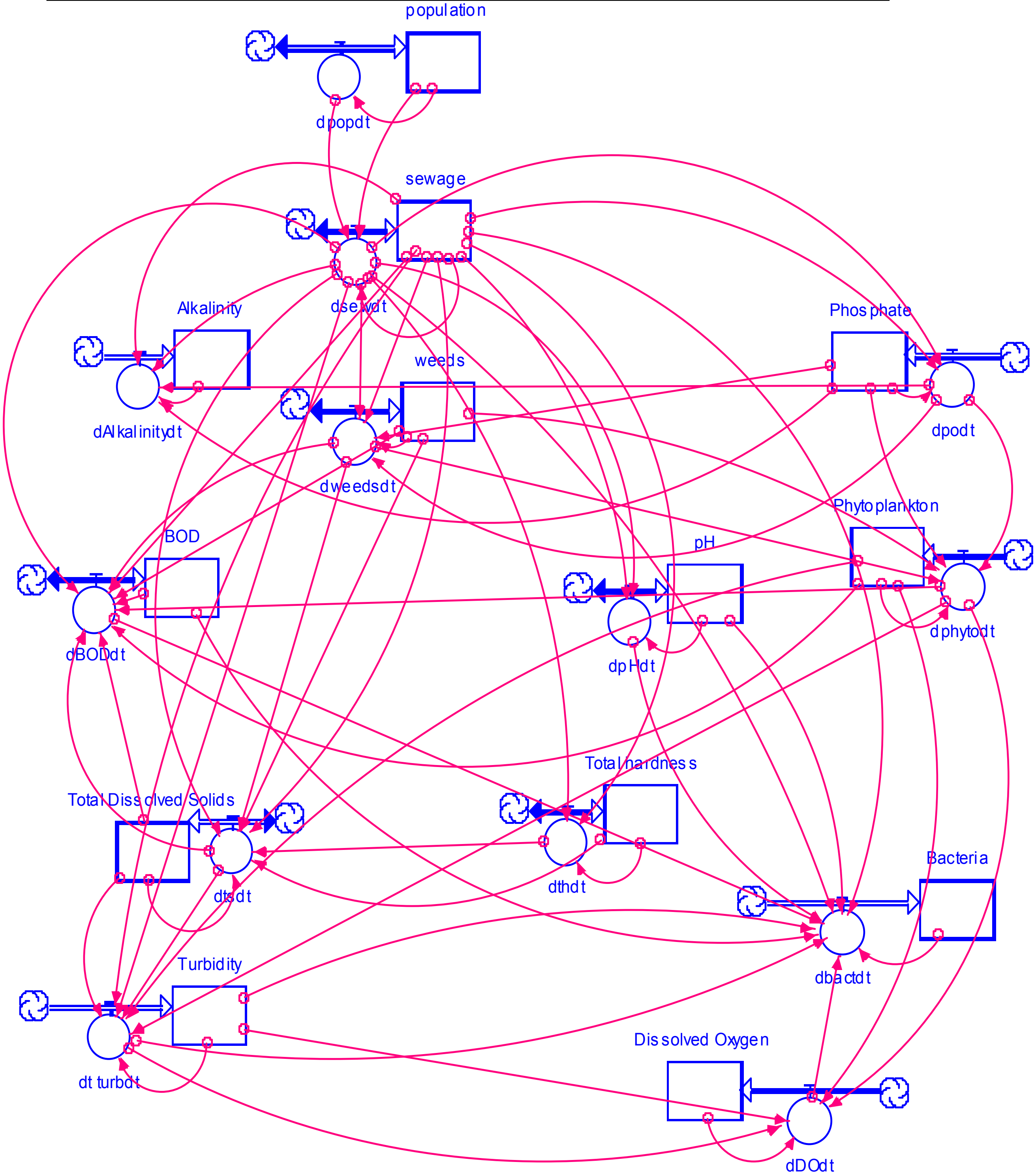
Table 9: Elasticity Matrix of Limnological Parameters of Ongoing Restoration Stage (Upper Lake)

	Turbidity	pH	Dissolved Solids	Phosphate	Alkalinity	Hardness	D. O	B .O. D	Bacterial Count	**Weed area**	Population	Sewage
CGR	**0.2704**	**-0.0109**	**-0.0009**	**-0.0053**	**0.0545**	**0.0075**	**0.0280**	**0.1933**	**0.1604**	**0.3046**	**0.0338**	**0.0458**
Turbidity	**1.000**	**-0.0403**	**-0.0033**	**-0.0196**	**0.2016**	**0.0277**	**0.1036**	**0.7149**	**0.5932**	**1.1265**	**0.1734**	**0.1694**
PH	**-24.8073**	**1.000**	**0.0826**	**0.4862**	**-5.000**	**-0.6881**	**-2.5688**	**-17.734**	**-14.716**	**-27.945**	**-4.3027**	**-4.2018**
Dissolved Solids	**-300.444**	**12.1111**	**1.000**	**5.8889**	**-60.5556**	**-8.8333**	**-31.111**	**-214.78**	**-178.222**	**-338.444**	**-52.1111**	**-50.8889**
Phosphate	**-51.0189**	**2.0566**	**-0.1698**	**1.000**	**-10.2830**	**-1.4151**	**-5.2830**	**-36.4716**	**-30.2642**	**-57.4717**	**-8.8491**	**-8.6415**
Alkalinity	**4.9614**	**-.2.000**	**-0.0165**	**-0.0972**	**1.000**	**0.1376**	**0.5138**	**3.5468**	**2.9431**	**5.5890**	**0.8606**	**18.3486**
Hardness	**36.0533**	**-1.4533**	**-0.1200**	**-0.7067**	**7.2667**	**1.000**	**3.7333**	**25.7733**	**21.3867**	**40.6133**	**6.2533**	**6.1067**
Dissolved Oxygen	**9.6571**	**-0.3893**	**0.0321**	**-0.1893**	**1.9464**	**0.2679**	**1.000**	**6.9036**	**5.7286**	**10.8786**	**1.675**	**1.6357**
B.O.D	**1.3389**	**-0.0564**	**-0.0047**	**-0.0274**	**0.2819**	**0.0388**	**0.1449**	**1.000**	**0.8298**	**1.5758**	**0.2426**	**0.2369**
Bacterial Count	**1.6858**	**-0.0680**	**-0.0056**	**-0.0330**	**0.3398**	**0.0468**	**0.1746**	**1.2051**	**1.000**	**1.8990**	**0.2924**	**0.2855**
Weed area	**0.8877**	**-0.0358**	**-0.0030**	**-0.0174**	**0.1789**	**0.0246**	**0.0919**	**0.6346**	**0.5266**	**1.000**	**0.1540**	**0.1504**
Population	**5.7655**	**-0.2324**	**-0.0192**	**-0.1130**	**1.1620**	**0.1599**	**0.5970**	**4.1215**	**3.4200**	**6.4947**	**1.000**	**1.3550**
Sewage	**5.9039**	**-0.2380**	**-0.0197**	**-0.1157**	**1.1899**	**0.1638**	**0.6114**	**4.2205**	**3.5022**	**6.6507**	**1.0240**	**1.000**

Table 10: Elasticity Matrix of Limnological Parameters of Ongoing Restoration Stage (Lower Lake)

	Turbidity	pH	Dissolved Solids	Phosphate	Alkalinity	Hardness	D. O	B .O. D	Bacterial Count	Sewage	Population
CGR	-0.0160	-0.0131	0.0056	-0.2180	-0.0242	-0.0221	-0.0934	0.1209	0.0837	0.0248	0.0339
Turbidity	**1.000**	**0.8188**	**-0.35 00**	**13.625**	**1.5125**	**1.3813**	**5.8375**	**-7.5563**	**-5.2313**	**-1.5500**	**-2.1188**
pH	**1.2214**	**1.000**	**-0.4275**	**16.6412**	**1.8473**	**1.6870**	**7.1298**	**-9.2290**	**-6.3893**	**-1.8931**	**-2.5878**
Dissolved Solids	**-2.8571**	**-2.3392**	**1.000**	**-38.9286**	**-4.3214**	**-3.9464**	**-16.6786**	**21.5893**	**14.9464**	**4.4286**	**6.0536**
Phosphate	**0.0734**	**0.0601**	**-0.0257**	**1.000**	**0.1110**	**0.1014**	**0.4284**	**-0.5546**	**-0.3839**	**-0.1138**	**-0.1555**
Hardness	**0.7240**	**0.5928**	**-0.2534**	**9.8643**	**1.0950**	**1.000**	**4.2262**	**-5.4706**	**-3.7873**	**-1.1222**	**-1.5339**
Dissolved Oxygen	**0.1713**	**0.1403**	**-0.0600**	**2.3340**	**0.2591**	**0.2366**	**1.000**	**-1.2944**	**-0.8961**	**-0.2655**	**-0.3630**
B O D	**-0.1323**	**-0.1084**	**0.0463**	**-1.8031**	**-0.2002**	**-0.1828**	**-0.7725**	**1.000**	**0.6923**	**0.2051**	**0.2804**
Bacterial Count	**-0.1912**	**-0.1565**	**0.0669**	**-2.6045**	**-0.2891**	**-0.2640**	**-1.1159**	**1.4444**	**1.000**	**0.2963**	**0.4050**
Sewage	**-0.6452**	**-0.5282**	**0.2258**	**-8.7903**	**-0.9758**	**-0.8911**	**-3.7661**	**4.8750**	**3.3750**	**1.000**	**1.3669**
Population	**-0.2804**	**-0.3864**	**0.1652**	**-6.4307**	**-0.7139**	**-0.6519**	**-2.7551**	**3.5664**	**2.4690**	**0.7316**	**1.000**

Figure 1: Ecosystem Model for Bhoj Wetland Using Water Quality Parameters



7.4.9 Results of Simulation Runs

Simulation run results of STELLA model for pre and post restoration project of Bhoj Wetland find out the changes of lake watrer quality conditions for next 25 years. The main changes is depend upon sewage coming into the lake. A small changes in the sewage can make a remarkable difference in in all parameters. But the post restoration data have little difference with the quantity of pre-restoration data due to the incompletance of the subproject. Still the other parameters, interlinked each other shows the variation.

According to the model input data population of the lake fringe wards has compound growth rate of 0.0603 and no other variables are in the model are affecting its growth. So it shows a steady growth for next 25 years.

Sewage in the model shows the same graph like the population. It also increases along with population. But the inflow of sewage can be syopped with proper drainage system, which is one of the important subprojects in restoration of Bhoj Wetland. The subproject is yet to complete so the post project results of this important variable can not be accessed. But the growth rate in pre-restoration model (Model no.1) and post restoration model (Model no.2)is different and model no 2&3 touching the maximum range given here as 75 MLD with in 10 years of time. In the Model no. 3 (post restoration data based for Lower Lake) sewage shows a steady growth.

PH in model no.1 is increasing slowly and reaches near 10 units in 25 years. But in post restoration model pH value for both lakes (Upper Lake-model no.2) is coming down to neutral conditions the present slightly alkaline conditions of both lake is going to normal range in the future years. Restoration activities gives best results in pH values.

The main source of dissolved solids mentioned in the model is sewage. As the value of sewage is increasing continuous and the TDS value also shows the same graph. TDS graph of model no.1 shows sudden increase and reaches the range of 1500 mg/l given in the model, with in 12 to 13 years. But its growth rate is very less in post restoration model results. TDS never reaches its maximum range in this 25 years time in these models(No.1 &2)

Turbidity of model no. 1 has slow growth rate. This variable in post restoration modelno.2 has high growth rate and increase fast touching the range given in the model as 100 NTU with in 9-10 years. But in Lower Lake the growth rate is negligible.

Chemical parameters in model no.1 was in sudden increase of growth rate but in post restoration models the growth rate is under control. Except dissolved oxygen BOD and phosphate values reached the maximum range given in the model 1000mg/l and 5mg/l respectively, with in 12-13 years. The same parameters in post restoration model run showed improvement and phosphate got a condition of little growth rate in the graph. BOD attained its maximum range in the graph after 18to 19 years. Dissolved oxygen got remarkable improvement and is increasing its value gradually in course of time. The same parameter in Lower Lake showed an unchanged straight-line graph with out any growth. Here the weed is not taken as the parameter. BOD value increases slowly and reaches the value of 1000mg/l with in 15 years in Lower Lake. Total hardness increases slowly in model no. 1 but in model no 2 the value observed was same. The simulation run results shows good results in the case of total hardness in Lower Lake. The current value of 156 mg/l is going down to a value of 50.38 mg/l in 25 years.

Biological parameters like bacterial count touches its model maximum range of 16000 counts/ 100ml with in 10 years in the pre restoration model the same was shown a sudden growth and touches this upper limit with in 5 years of time in the Upper Lake post restoration model simulation results. This result is alarming to the usage of this lake as potable water . Lower Lake also shows the same graph. This establishes that not enough has been done and that too in sequential manner to restore tha water quality of the lakes..

Weed area increases faster in the pre restoration model and reaches maximum of 32 km2 area with in 13-14 years. With the same inflow and sewage the weed area variable get a sudden increase in its value in post restoration model in Upper Lake. This parameter reaches maximum range given as 32 km2 in a period of 10 years even after project.

7.2.10 Conclusion

The simulation run results of pre and ongoing restoration activities disclose the impacts of the ongoing restoration projects on the water quality parameters of Bhoj Wetland. The restoration activities in the Bhoj Wetland show changes in all the parameters selected in this model. This way most of the parameters growth rate can be negligible for the coming 10 years. Parameters like pH and dissolved oxygen shall improve in the future years. Only bacterial count showed difference in this output with a sudden growth graph touching the maximum with in 4-5 years. The diversion of sewage after completion of sewerage sub project can bring better conditions for all the water quality parameters.

Based on the modeling exercise, The following set of Technical and Policy recommendations are proposed:

I. Technical Recommendations

As the restoration activities are going on & shall take another year or so to complete and their impacts could be rightly assessed only after their complete execution. At the same time has been observed that the restoration and prevention activities have not been taken up in sequential manner. It becomes necessary to first bring the preventive measures into working order before implementing what are known as the corrective measures. If the former are not implemented at the right time, the effect of the latter cannot be of any consequence. For example, floating fountains have been put up in the Lower Lake at huge costs without first of all completing the garland drain project which would stop the sewage from entering the Lower Lake. As a result sewage continues to flow unabated into the Lower Lake and at the same time, the floating fountains are supposed to aerate the Lakes. Naturally, the effect of the latter cannot be observed unless the flow of sewage is stopped.

II. Policy Related recommendations:

The critical need today is to recognize the inter-linkages and benefits that could be obtained if the wetland is managed in 'integrated manner' and is 'sustainably used'. It is a very challenging task and requires actions at many levels and delicate integrity of diversity of issues and management institutions. Such an approach must begin with involving all stakeholders in the wetland in the form of a local area institution, which shall be helpful in eliciting their views for use and future management of the Bhoj Wetland. The Institution so formed could frame the action plan to cover all ecological, economic, social and institutional issues. To cover the above issues the following set of policy recommendation is proposed :

a. It is imperative to take into account the perceptions of the people before carrying out any management exercise and especially one of this scale and to also involve the people at every stage of the planning process.

b. The management of the Lakes looks at the restoration and maintenance from each and every side. For this effective co-ordination between all the line departments that are connected with the use or maintenance of the lakes becomes necessary.

c. There needs to be more transparency in the system. When huge amounts of public money/funds are used for development activities, it becomes the responsibility of the concerned authorities to reveal to the people how the funds have been used.

d. There is need of setting up of a Bhoj Wetland Management Agency which should comprise of all the concerned stakeholders.

e. A cost benefit exercise needs to be carried out once all the values have been calculated. This exercise taking all social costs and benefits into account would provide a picture of how effective the restoration programmes have actually been.

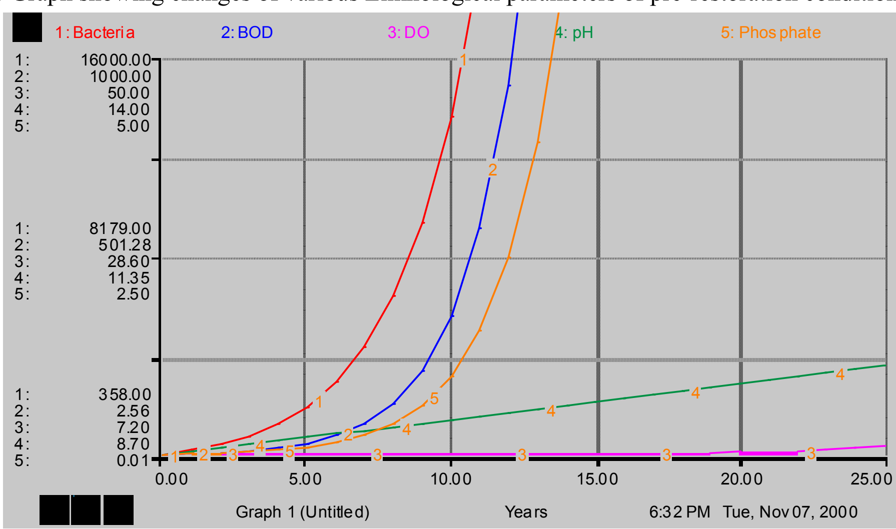
f. It is necessary to promote eco-tourism in the city. The city has two picturesque lakes which can provide an excellent site for adventure tourism as well. This would provide employment to a large number of people and would also bring the much required revenue into the coffers of the government. For this purpose, the Lower Lake and the Spill channel of the Upper Lake are wonderful sites. Sports like sport fishing, para sailing and para gliding, water scooters, yatching and many more can be introduced at these sites. Bhopal could soon figure on the international map for water sports provided the sports and the tourism ministry take up this challenge seriously.

g. It is also important for all the concerned departments to prioritise their activities according to the simulation runs of the model for both the lakes. These models depict the scenario as in the past, present and as expected in the future at the following trends. Thus the effect of any management decision can be studied by using this model and this becomes extremely necessary for the effective implementation of the project.

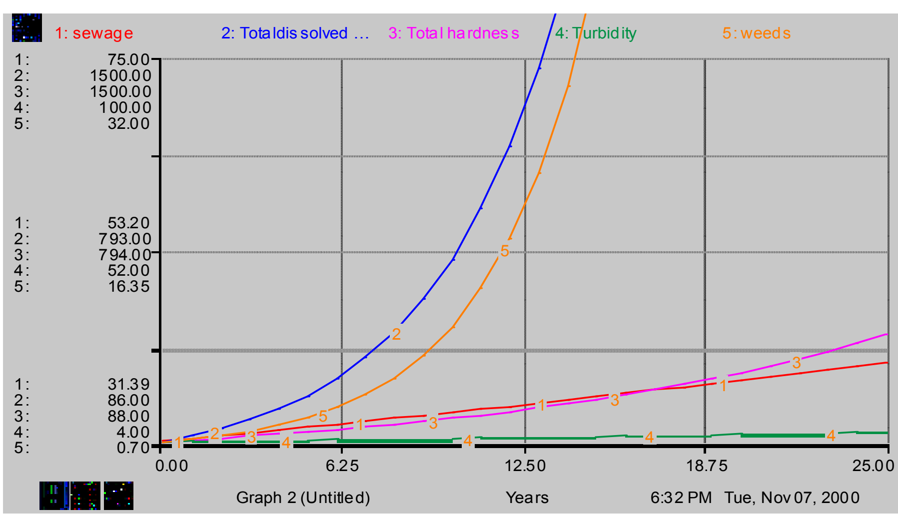
It is believed that the recommendations listed above based on the ecosystem modeling simulation runs and seeking perceptions of the stakeholders, if taken care off by management authorities shall help in economically wise, environmentally sound and socially acceptable process for sustainable management of such an important 'Urban Wetland'.

Annexes

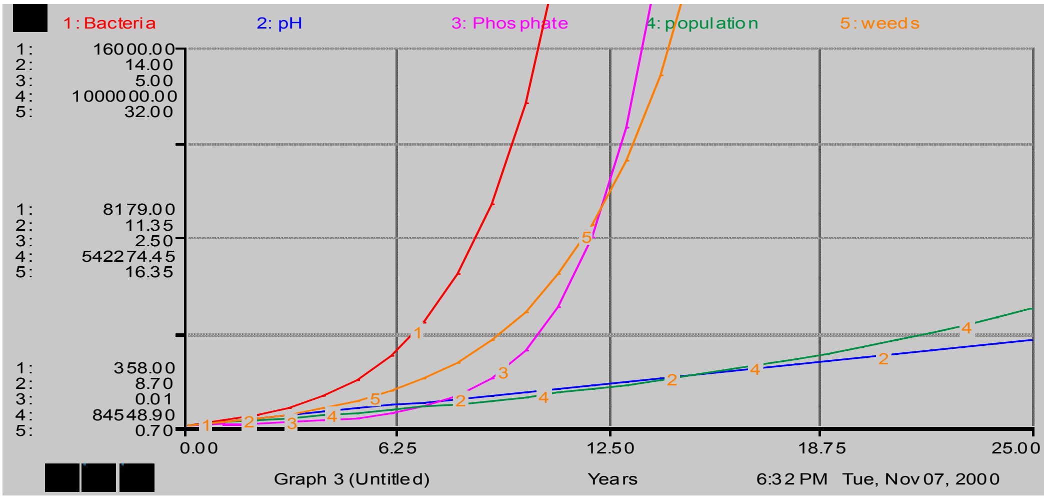
Graph.1 Graph showing changes of various Limnological parameters of pre-restoration condition of Bhoj Wetland



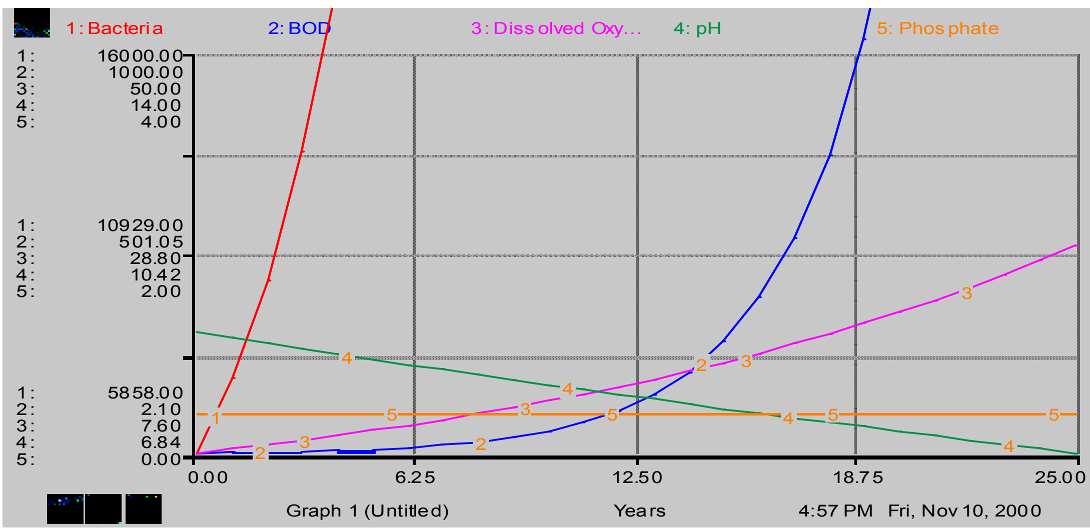
Graph 2 Graph showing changes of various Limnological parameters of pre-restoration condition of Bhoj Wetland.



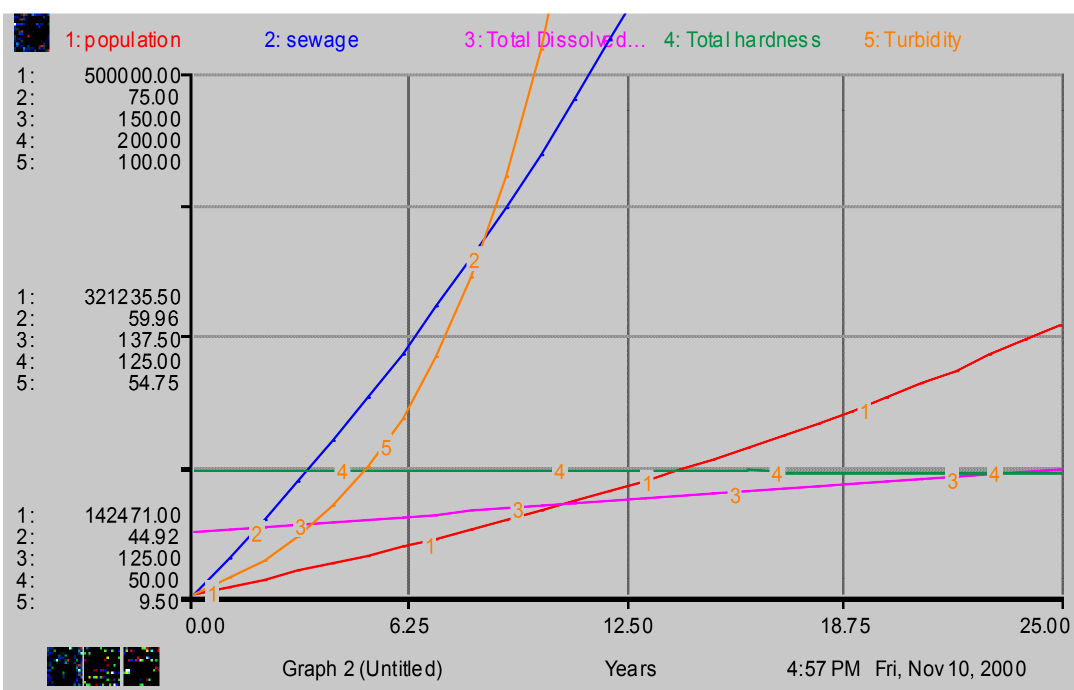
Graph 3 Graph showing changes of various Limnological parameters of pre-restoration condition of Upper Lake.



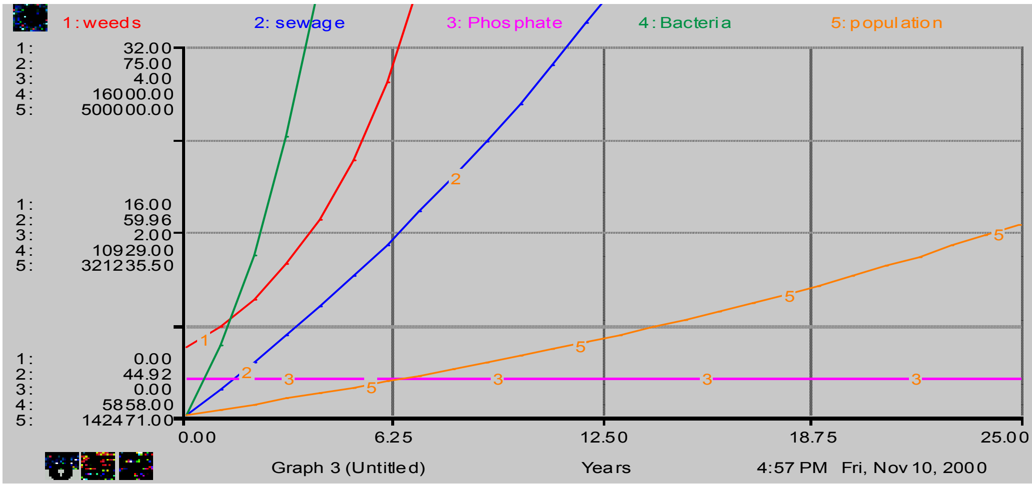
<u>Graph .4 Graph showing changes of various Limnological parameters of ongoing restoration condition of Upper Lake.</u>



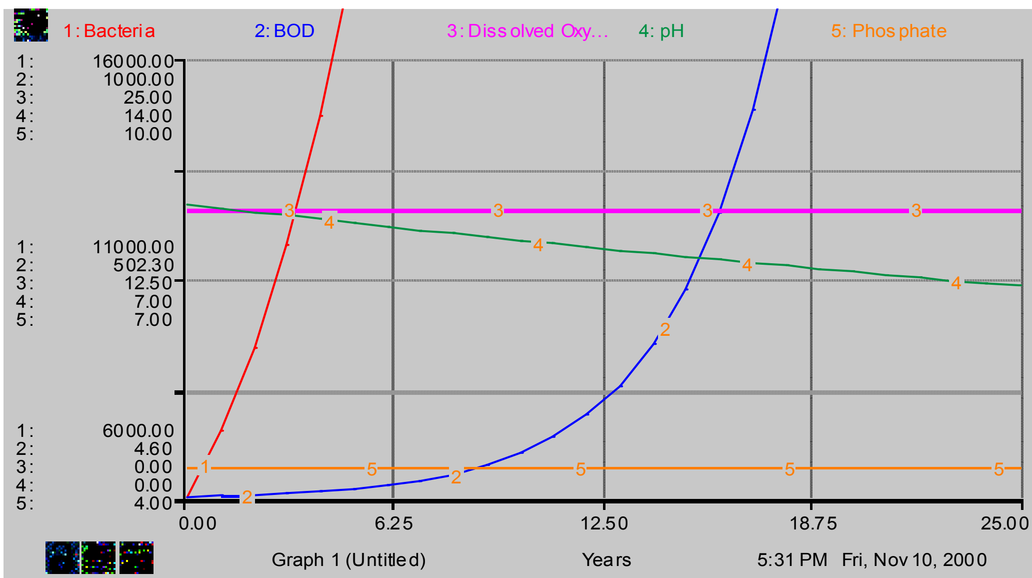
Graph 5 Graph showing changes of various Limnological parameters of ongoing restoration condition of Upper Lake



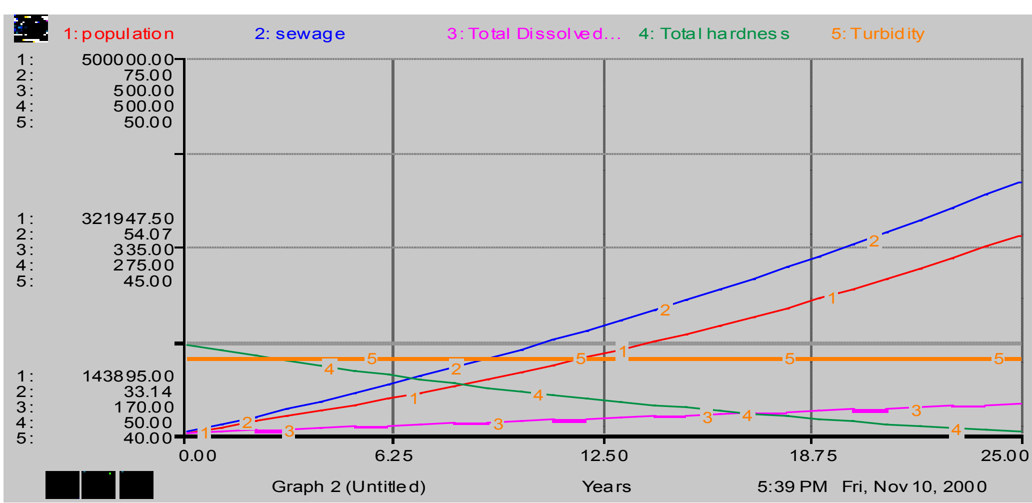
Graph.6 Graph showing changes of various Limnological parameters of ongoing restoration condition of Upper Lake



Graph 7 Graph showing changes of various Limnological parameters of ongoing restoration condition of Lower Lake



Graph 8 Graph showing changes of various Limnological parameters of ongoing restoration condition of Lower Lake



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Lake Characterization and Classification

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Abstract

An effective management of lakes requires their description and classification as per the accepted scientific norms. Lakes may be characterized and classified on the basis of depth, surface area, shoreline, littoral area, shape, trophic status, chlorophyll content, Secchi disc transparency, phosphorus content, mixis, water hardness, salinity and many other such characteristics. Osgood Index, Shoreline Development Factor and Trophic State Indices are the important indices for lake characterization and classification. In the present paper we propose Lake Interface Factors at air-water and soil-water interfaces, which would take into account area characteristics of the lake water at the interface of air and soil in relation to lake volume.

Introduction

India has a rich diversity of lakes, which if managed properly may help in conservation of surface and ground water resources. Nineteen of the wetlands in India have been declared as Ramsar sites, accounting for a total area of 648507 hectares (Table 1).

Several accounts are available on lake morphometry and other lake characteristics (Carlson and Simpson, 1996; Kalff, 2002; Aggarwal, 1999; Osgood, 2000; Kavern et. al., 2004 a,b; Fuller et. al., 2004 and WAL, 2001; Newton and Jarrell, 1999). Most of these reports deal with temperate regions. Though substantial data is available with respect to the Indian lakes, the data is largely incoherent and needs compilation for a relative assessment. In this paper we give parameters of study of lakes with a view to their classification.

Lake characteristics and classification

Lake length and lake breadth: Maximum length of the lake is the distance between two most distant points on the lake surface. Maximum breadth is the maximum distance between the shores of the lake at right angles to line of maximum length. Average breadth is the lake area divided by lake maximum length. Lake length and breadth may be given in units of meters or kilometers.

Table 1. Ramsar sites in India (http://www.wetlands.org/reports/index.cfm)

Ramsar site #	Name	State	Coordinates	Area (ha)
2IN019	Vembanad-Kol Wetland	Kerala	09°50',76°45'	151250
2IN001	Chilika Lake	Orissa	19°42',85°21'	116500
2IN014	Kolleru Lake	Andhra Pradesh	16°37',81°12'	90100
2IN010	Bhitarkanika Mangroves	Orissa	20°39',86°54'	65000
2IN009	Ashtamudi Wetland	Kerala	08°57',76°36'	61400
2IN015	Point Calimere Wildlife and Bird Sanctuary	Tamilnadu	10°19',79°38'	38500
2IN005	Loktak Lake	Manipur	24°26',93°49'	26600
2IN006	Sambhar Lake	Rajasthan	27°00,75°00'	24000
2IN003	Wular Lake	Jammu & Kashmir	43°16',74°33'	18900
2IN016	Pong Dam Lake	Himachal Pradesh	32°01',76°05'	15662
2IN013	East Calcutta Wetlands	West Bengal	22°27',88°27'	12500
2IN018	Tsomoriri	Jammu & Kashmir	32°54',78°18'	12000
2IN004	Harike Lake	Panjab	31°13'75°12'	4100
2IN012	Deepor Beel	Assam	26°08',91°39'	4000
2IN011	Bhoj Wetland	Madhya Pradesh	23°14',77°20'	3201
2IN002	Keoladeo National Park	Rajasthan	27°13',77°32'	2873
2IN008	Ropar Lake	Panjab	31°01',76°30'	1365
2IN017	Sasthamkotta Lake	Kerala	09°02',76°37'	373
2IN007	Kanjli Lake	Panjab	31°25',75°22'	183

Lake depth: One of the most important characteristics of the lake is the lake depth. The deepest lake of the world is Lake Baikal in Russia (ILEC, 2005), both in terms of maximum lake depth (Z_{max} = 1741 m), and average lake depth (Z_{mean} = 730 m). Average lake depth is inversely related to lake productivity. Maximum lake depth is measured by sonar. Average lake depth is given as,

$$Z_{mean} = \text{Lake volume} / \text{Lake surface area}$$

Lakes may be classified in to shallow or deep in relative terms. In the shallow lakes most volume of water is located in the euphotic zone. Shallow lakes are more susceptible to environmental degradation as compared to deep lakes. Lakes may also be classified in to shallow, intermediate or deep on the basis of percentile score of maximum depth (Table 2):

Table 2. Lake classification on the basis of percentile score of maximum lake depth.

Lake type	Percentile of Z_{max}
Shallow	< 25 percentile
Intermediate	25 to 75 percentile
Deep	> 75 percentile

Shallow lakes are more productive as compared to deep lakes of the same volume. Most of the lakes of the world are small and shallow and are < 20 m in depth (Wetzel, 2001). The WRC

Technical Report-144 (2002) on North Central Hardwood Forest Ecoregion (NCHF) of Minnesota (2002) concluded that deep lakes have better water quality as compared to shallow lakes. The maximum depths for the three categories of NCHF region were given as <6m, 6-15 m and >15 m. The average depths for these categories were <2 m, 2-4 m and >4 m respectively. Heiskary (1997) used maximum depth for type of mixis in the lakes (Table 3).

Table 3. Lake classification on the basis of mixis using lake depth.

Maximum depth	**Lake type**
> 30 - 35 ft	Dimictic
20 to 30-35 ft	Intermediate
< 20 ft	Polymictic

Lake surface area: Lake surface area is an important parameter in lake classification. Lakes may be classified into small, intermediate and large lakes on the basis of percentile score (Table 4).

Table 4. Lake classification on the basis of percentile score of lake surface area.

Lake type	**Percentile of lake area**
Small	< 25 percentile
Intermediate	25 to 75 percentile
Large	> 75 percentile

For NCHF lakes, the three categories were assigned the values, < 40 ha, 40 to 200 ha and >200 ha respectively.

Osgood index: Osgood index (Osgood, 1988) is defined as the ratio of mean depth of the lake in meters to square root of the lake surface area in km^2.

$$\text{Osgood index} = Z_{mean}\,(m) / A\ \ (km^2)$$

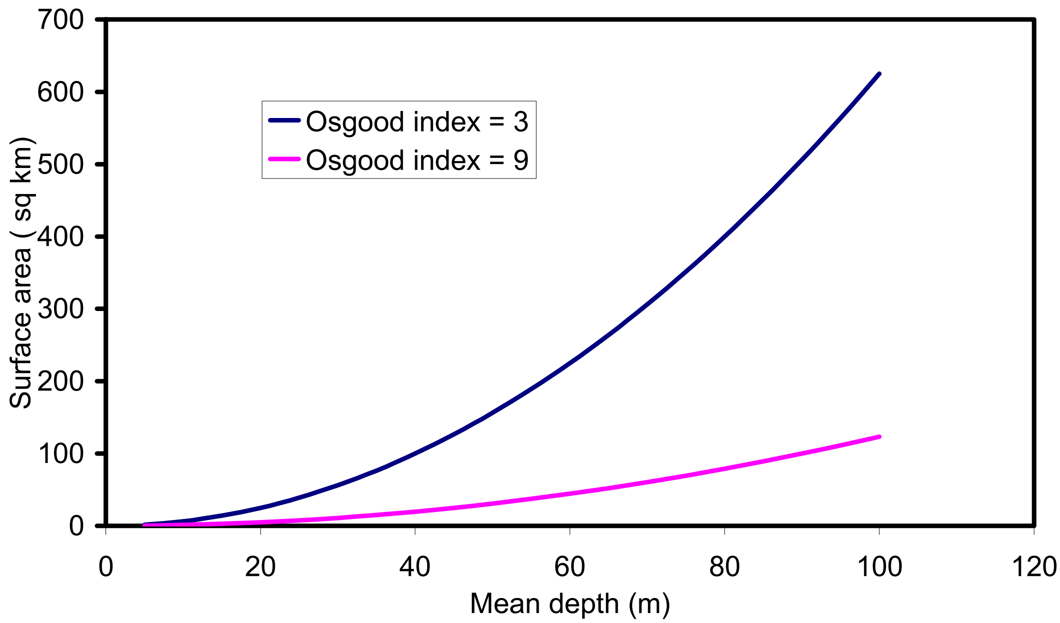
Osgood index is used to classify lakes on the basis of mixis into three categories (Table 5):

Table 5. Osgood index and mixis.

Osgood index	**Lake type**
> 9	Dimictic
4 to 9	Intermediate
< 4	Polymictic

A graph between surface area as a function of mean lake depth is given in Fig. 1.

Fig. 1. Osgood index



Littoral area: The littoral region is an interface between the land of drainage basin and the open water of lakes. Littoral zone comprises of eulittoral zone between the highest and lowest seasonal water levels and the infralittoral zone, between zone of submersed rooted macrophytes and lower level of eulittoral zone. Macrophytes predominate in shallow lakes with large littoral areas, whereas, plankton predominate in deep lakes with small littoral areas (Table 6).

Table 6. Lake classification on the basis of littoral area.

Percent littoral area	**Lake type**
> 67% of lake area	Macrophyte dominated
33 to 67% of lake area	Intermediate
< 33% of lake area	Plankton dominated

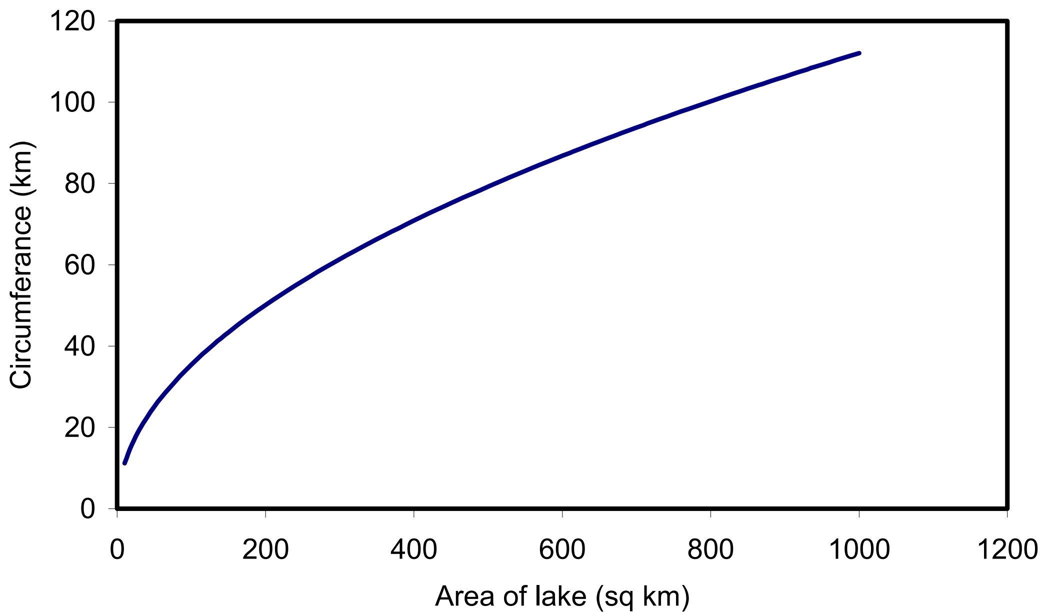
Shoreline: Shoreline is an interface between the water of the lake and the exposed soil surrounding the lake. Shoreline Development Factor (SDF), which compares the length of the lake's shoreline to that of the circle of the same area. SDF is defined the ratio of the length of the lakes shoreline (S) to the circumference (C) of the circle of area equal to lake area (A_o).

$$SDF = S / C$$

Since, $C = 2\ \pi r$, and $A_o = 2\ \pi r^2$, $C = (4\pi\ A_o)^{1/2}$.

SDF is a measure of the deviation of lake from circularity. A circular lake will have SDF equal to 1. The value of SDF can not be less than 1. A graph between circumference of the circle and area of the lake is given in Fig. 2.

Fig. 2. Circumferance of a circle for given lake area



The ratio of shoreline length to surface area is called the density of the shoreline, and it decreases as the lakes surface area increases.

Hydraulic residence time: The time required to fill the empty lake is known as hydraulic residence time (T_r).

$$T_r = V/ Q$$

Where, V is the volume (m^3) of the lake and Q is the rate of flow of water through the lake (m^3 /day). Lake classification on the basis of T_r is given in Table 7.

Table 7. Lake classification on the basis of T_r

Type of lake	**Volume**	**Q**	$\mathbf{T_r}$	**Production status**
Lacustrine	Large	Small	More	High
Riverine	Small	Large	Less	Low

Trophic state indices: Trophic state is defined as the total amount of biomass/ nutrients in a lake. Carlson (1977) introduced lake classification on the basis of total phosphorus (µg L^{-1}), chlorophyll a (µg L^{-1}) and Secchi disc transparency (m), into oligotrophic, mesotrophic and eutrophic lakes. The three Carlson trophic state indices (TSI) are given by equations:

$TSI\ (TP) = 14.4\ Ln\ (TP) + 4.14$

$TSI\ (Chl\ a) = 9.81\ Ln\ (chl\ a) + 30.6$

$TSI\ (SD) = -14.4\ Ln\ (SD) + 60$

The indices generally lie within the range of 0 to 100. The three indices are correlated to each other. Sometimes the three indices are averaged, although the validity of such an averaging of logarithmic functions is questionable. The characteristics of lakes on the basis of trophic states as given by (Wetzel, 1983) are given in Table 8.

Table 8. Trophic status and lake classification.

Class	**TP (μg L^{-1})**	**Chl a (μg L^{-1})**	**SD (m)**
Oligotrophic	8.0	1.7	9.9
Mesotrophic	26.7	4.7	4.2
Eutrophic	84.4	14.3	2.45

In case lake consists of aquatic macrophytes, Canfield et. al. (1983) proposed that total phosphorus content should be calculated from algal biomass in the water column and total submerged macrophytic biomass (TSMB):

$TSMB = SA \times C \times B$

where, SA is the surface area of the lake, C is the % cover of submerged aquatic macrophytes and B is the average biomass.

Kratzer and Brezonik (1981) defined TSI based upon total nitrogen (mg/L) in the lake.

$TSI\ (TN) = 14.43\ Ln\ (TP) + 54.45$

Graphs for TSI’s are given in Figs. 3-6.

Fig. 3. Trophic state index (TP)

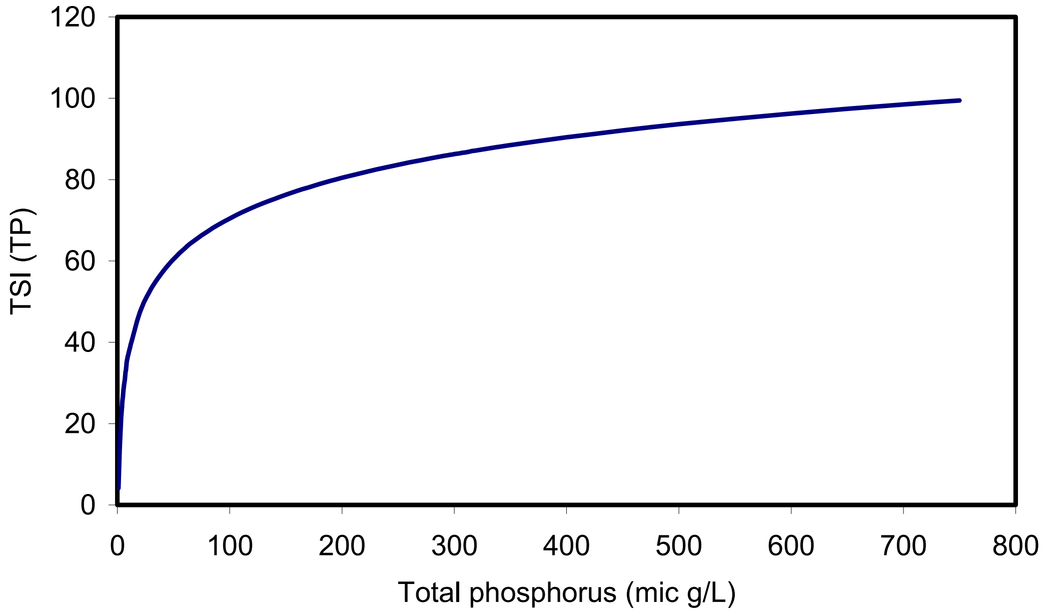


Fig. 4. Trophic state index (Chl. a)

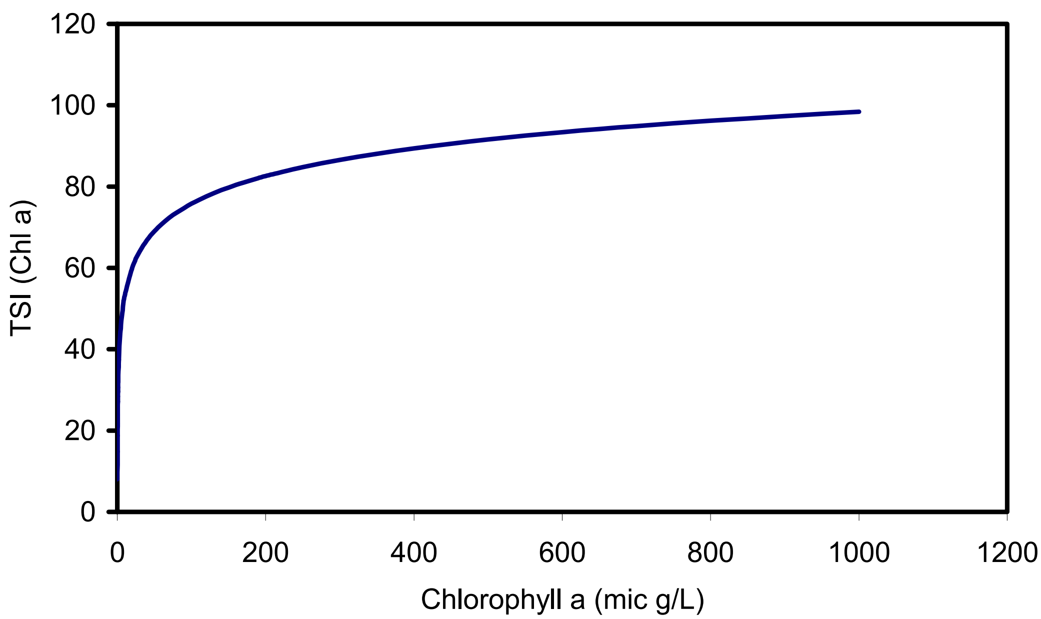


Fig. 5. Trophic state index (SD)

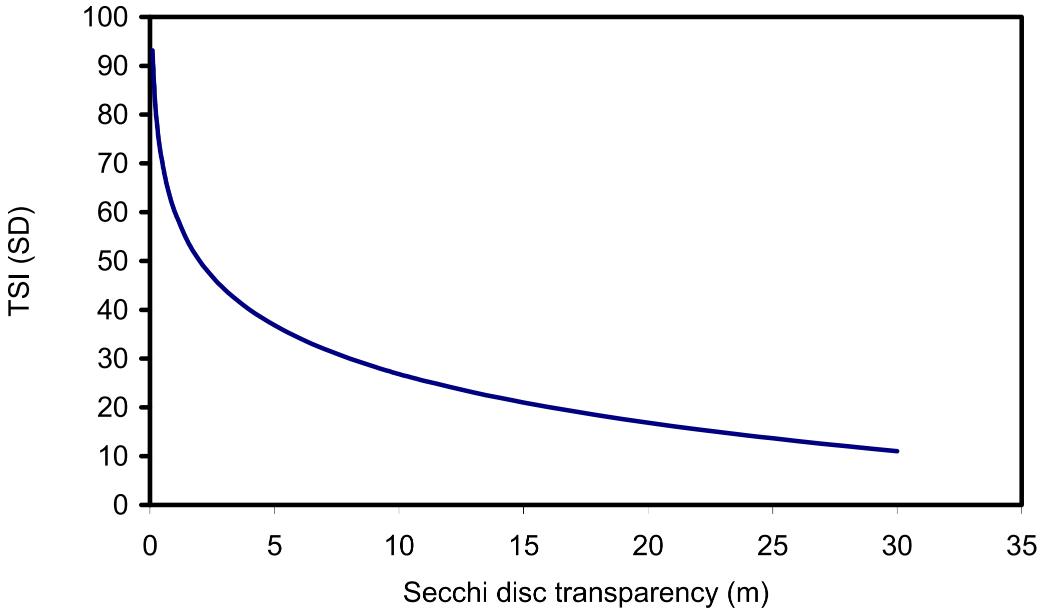
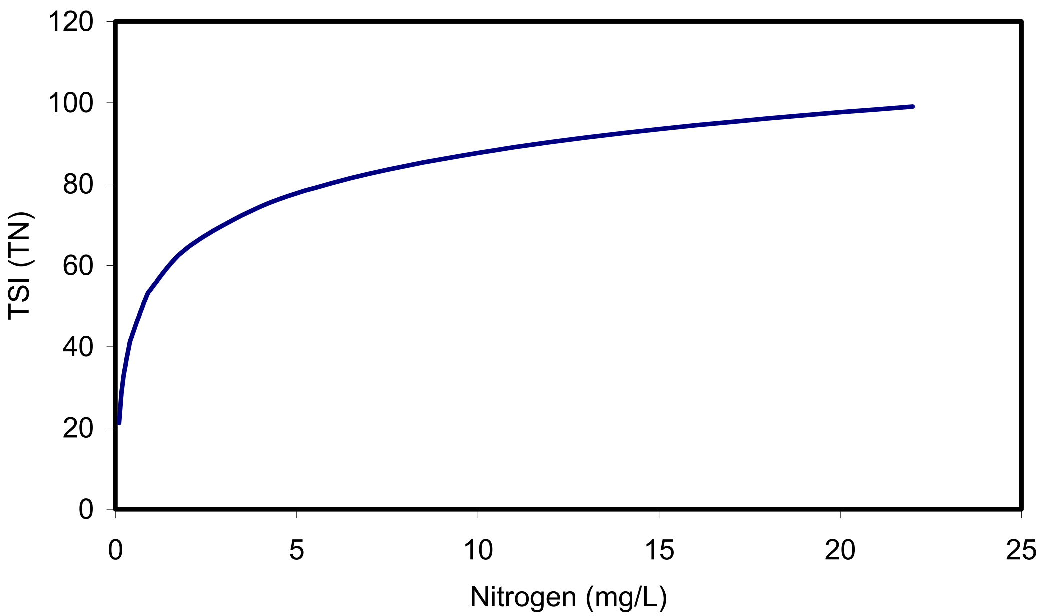


Fig. 6. Trophic state index (TN)



Lake water interface indices

Though SDF is an important index, a need arises for the characterization and classification of lakes on the basis of interaction of lake water with air and soil. Lake water has interfaces between water and air, and water and soil. The water-air-soil edge is the shoreline of the lake. We propose three indices in this regard.

Air – water interface factor (AWIF): AWIF is defined as the ratio of the surface area of the lake at air-water interface (A_{aw}) to the open surface area of hemisphere of equal volume (A_o). Since volume of the hemisphere (V) =
(2/3) πr^3, and surface area of the hemisphere (A_o) = πr^2

$$AWIF = A_{aw} / A_o = A_{aw} / (1.919\ V^{2/3})$$

A shallow lake will have a higher value of AWIF and will be more vulnerable.

Soil - water interface factor (SWIF): SWIF is defined as the ratio of the surface area of the lake at soil-water interface (A_{sw}) to the curved surface area of hemisphere of equal volume (A_c). Since curved surface area of the hemisphere (A_c) = $2\pi r^2$

$$SWIF = A_{sw} / A_c = A_{sw} / (3.838\ V^{2/3})$$

Larger the value of the SWIF, more vulnerable the lake will be.

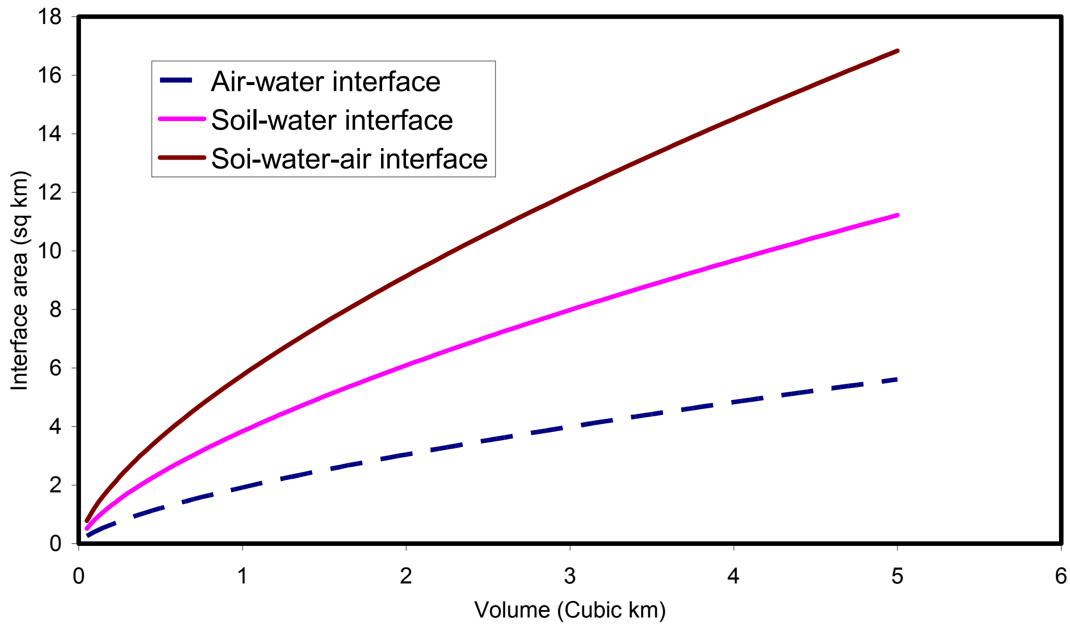
Total water interface factor (TWIF):

TWIF is defined as the ratio of the total surface area of the lake (A_{swa}) at air-water interface (A_{aw}) and soil-water interface (A_{sw}) to the total surface area of hemisphere of equal volume (A_h). Since total surface area of the hemisphere (A_t) = $3\pi r^2$

$$TWIF = A_{swa} / A_t = A_{sw} / (5.757\ V^{2/3})$$

Larger the value of the TWIF, more vulnerable the lake will be. A graph between volume and lake surface area is given in Fig. 7.

Fig. 7. Lake water interface area



Though sufficient work has been done on lakes of the world in terms of characterization and classification, there is a need to put in concerted efforts to compile data on Indian lakes on a comparative basis. Online data available on Indian lakes at the site http://www.worldlakes.org is incomplete and incomprehensive. Similarly another site maintained by the International Lake Environment Committee, http://ilec.or.jp/eg/index.html gives quite comprehensive account of only few lakes. Further, since most of the work on lake classification pertains to temperate climates, there is a need to compile data to characterize and classify Indian lakes for a relative assessment and conservation of resources, and protection of environment.

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Protecting Environment through Promotion of Water Resources: Challenges and Strategies

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ABSTRACT

In the recent time the mankind is entering into a new era with a threat of self-inflicted extinction, with more toxic waste and more damage to the biosphere. Environmentalists say that the problem of fresh water supplies is likely to be the most important issue in the 21st century. The precious water due to its growing demand ultimately is a scarce natural endowment. Indian economy is based on agriculture. A majority of rural people maintains their livelihood through the agricultural avocation. To sustain and increase the productivity of crops and to maintain the production potential of the country water plays a pivotal role. Without hampering the existing water resources it is very difficult to nurture the growing demand of water to the increased population in India. In such a research climate this paper has envisaged some strategies for promoting the water resources in different purposes to protect our environment for the future generation. The National Water Supply Policy has also indicated the water allocation for supplies to meet the irrigation needs to the crops, drinking water, hydropower, ecology, agro and non agro industries, navigation and various other uses. The study had explored the strategies like educating the farmers about judicious and prudent use of irrigation water, recycling of water, controlled irrigation water supply, application of information technology to control water problem, water audit, careful crop planning, bio-drainage, reviving the traditional water recharging structures, prevention of sedimentation in reservoirs, watershed management etc. The water resources endowment requires a careful management of biotic and abiotic factors in a holistic manner. The proper utilization of eco-friendly, social, environmental and economic attributes related to the water resources will help to usher a new era of water resource conservation wherein the scientists in the field of water management, extension specialists will work together to create awareness regarding water utilization and to mobilize the precious resources of our need and destiny. As a result we can protect our environment with a view to get the optimum utilization of water by promoting the water resources.

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INTRODUCTION

For the first time in the history of mankind, people entered into a new century faced by the threat of self inflicted extinction, with explosive population growth bringing not just the more people but also more pollution, more toxic waste and more damage to the biosphere. The environmental issues have moved from a peripheral to central concern of the global agenda. Environmentalists opined that the problem of fresh water supplies is likely to be the most important issue in the 21st century. Water being precious, finite and in view of growing demand, Ultimately is a scarce natural endowment. Water the most common liquid on this planet, is known for its unique properties among them, its universal solvent action. Water is susceptible to contamination and its quality remains vulnerable. Many of us don't realize that water is the scarcest resource in the World. Of the total water available on the earth only 0.07% is available for human consumption. More over the situation in a Country like India is acute considering the population. The per capita availability of water in Asian Countries is lowest. There is need for over all policy and mission approach aimed to implement various technology options to conserve this precious resource. Since per capita availability of water has been steadily declining while net sown area has remained around 140 to 142 million ha, the alternative left is to increase the productivity of land and water resources through improved irrigation efficiency. The important and best-rendered technology for the preparation and management of action plan regarding the protection of the environment *vis a vis* the best useful resource of the world, water should be properly implemented with the help of the local peoples knowledge. So, the present paper envisages the approach of water resource management through people's participation and improvement in water use efficiency.

CONTENT

Critical Issues/Challenges

With the existing water resources of the Country, per capita availability of water varies in the range of 300 to 13,754 cu.m. per year with the natural annual average of per capita availability about 1829 cu.m. in 2001. By 2015 AD the country will be faced water stress conditions with annual per capita availability of water at about 1557 cu.m. The conditions will be further worsening due to continued population growth. It is estimated that by 2050 AD, 22% of the geographical area and 17 % of the population of the country will be under absolute scarcity condition having access to water availability of less than 500 cu.m per year and 70% of the area and 76% of population will be on the verge of the affected health and economic activities with access to water availability of less than 1000 cu.m per year, which is identified as stress or scarcity level.

Irrigation has a major role in enhancing agricultural production. Sustainability of irrigated agriculture and maximization benefits from this sector through environment friendly irrigation management now assumes much more significance. In our Indian context farming is the back bone of our rural livelihood security system, all out efforts needs to be made to provide new impetuous to agricultural intensification, diversification and value addition and to create new jobs and sustainable livelihood.

India, which has 2.45% of the World's land resources, has roughly 4% of the World's fresh water resources, where as the Countries population is 16% of the World's population. The Ganga- Bramhaputra-Meghna System is a major contributor to India's water resources, representing about 60% of the total. The topographical variations caused the wide gap between total surface water and utilizable water out of it. The overall utilizable surface water is about 37% of the total resources, with more of the water resources being harnessed, with increasing efficiency in water used for water from other users proportion of water resources available to irrigation is expected register a decrease in due course.

Water requirement for different uses

Quantity in BCM

Sl. No	Uses	Year 1997-98	Year 2010			Year 2050		
			Low	High	%	Low	High	%
1	Irrigation	**524**	**543**	**557**	**78**	**628**	**807**	**68**
2	Domestic	**30**	**42**	**43**	**6**	**90**	**111**	**9**
3	Industries	**30**	**37**	**37**	**5**	**81**	**81**	**7**
4	Power	**9**	**18**	**19**	**3**	**63**	**70**	**6**
5	Inland navigation	**0**	**7**	**7**	**1**	**15**	**15**	**1**
6	Flood Control	**0**	**0**	**0**	**0**	**0**	**0**	**0**
7	Afforestation	**0**	**0**	**0**	**0**	**0**	**0**	**0**
8	Ecology	**0**	**5**	**5**	**1**	**20**	**20**	**2**
9	Evaporation loss	**36**	**42**	**42**	**6**	**76**	**76**	**7**
	Total	**629**	**694**	**710**	**100**	**973**	**1180**	**100**

The anthropogenic activities covering minning, smelting, agriculture as well as industrial establishment constitute important contributory factors to influence the quality of water. Added to such avenues are the geogenic sources of contaminations of ground and surface water. Arsenic contamination of water in Bengal delta basin, selenium toxicity in Punjab and Fluoride contamination in Rajasthan, Andhra Pradesh and West Bengal are among those of more serious concern. Contaminated surface and groundwater often carries the toxins and deposits them on soil causing its pollution : The two issues are often unseparable:

- ❖ Soil acts as a sink of the toxins – May also act as a source when its **carrying capacity** is exceeded.
- ❖ Soil acting as a **Source** may also lead to the entry of the toxins in the human **food-web** accompanied with possible biomagnification up in the food-chain.

Pollution in water- soil-crop-animal continuum due to anthropogenic activities reported from Peri-Urban, Urban, Semi-rural and Rural areas.

Sources include

- ❖ **Rapid industrialisation** coupled with urbanization
- ❖ Indiscriminately sprouting small/cottage-scale industries in densely populated urban areas : Untreated industrial effluents discharged into sewer system of cities.
  - ✓ **Sewage/Sludge** farming, especially in the Peri-urban areas
  - ✓ **Use of fertilizers** (especially excess Nitrogen) and their management in soil-crop systems leads to **nitrate pollution** of groundwater, besides causing entrophication of surface water bodies. **Eutrophication** increases the COD and BOD loads of surface water bodies causing pollution : Threat to aquatic forms of life.

The causes of nitrate pollution are:

- ➢ Leaching of soluble nitrate to groundwater,
- ➢ Crop uptake
- ➢ Denitrification
- ➢ Excess NO3 causes ***methemoglobinemia*** (blue baby syndrome) in infants (<6 months old)
- ➢ Excessive nitrate consumption by humans increases the risk of cancer through *in vitro* formation of carcinogenic **nitrosamines**

Drinking water quality is adversely affected by faecal contamination and infectious agents causing water-borne diseases by pathogens (e.g., bacteria, virus, etc.), or those caused by toxic chemicals.

Total and Olsen Extractable Arsenic Content (mg/kg) of Some Affected Soils of West Bengal

Location	Total Arsenic (mg/kg)	Olsen Extractable Arsenic (mg/kg)
Gotera, Nadia	**20.1**	**9.8**
Ghentugachhi, Nadia	**23.0**	**15.8**
Nonaghata Dakshinpara, Nadia	**11.3**	**3.84**
Nonaghata Uttarpara, Nadia	**14.7**	**3.79**
Iajpur, North- 24- Parganas	**16.5**	**6.4**
Chakla, North - 24- Parganas	**8.4**	**4.50**
Barachampa-Ambikanagar, North - 24- Parganas	**15.1**	**2.90**
Baruipur, South - 24- Parganas	**24.3**	**4.2**

Strategies

So in this backdrop the water resources in India are to be planned for its effective and beneficial use. The need of the hour would be to work out the ways and means of judicious water use for industrial purposes too. The recycling of water within the industrial complex for which a treatment plant would require.

There is also a need to sort out ways and means of reducing evapo-transpiration losses. The evaporation from field could be reduced by changing the planting dates to match with the period when the evaporation rate is least.

The sedimentation of reservoirs is very much crucial in terms of water available for utilization from its storage reservoir. Removal of silt from the reservoir has been engaging attention since long. A cost effective method of removal of silt has yet to be devised. However, research efforts are required for developmental of economic technologies for the purpose.

Development of minor irrigation, tank system is another strategy to cope the challenges. It has multiple uses apart from irrigation, including pisciculture, water for cattle and recharging of ground water. There is also a need for renovation and modernization of tanks and other water resources in locality on priority. The renovation of old tank would lead to some extent restoration of lost potential.

Approximately two fifth of Indian's agricultural out put comes from areas irrigated with ground water. In rural areas, rainwater harvesting through check dams not only recharges ground water but also meets the local irrigation and drinking water needs of the people.

Farmers are the ideal persons to manage the system at farm level through formation of Water User's Association. When the adequate knowledge and skill are disseminated to the farmers for managing and running the system and ownership sense is develop in the beneficiaries, formation of the association will be easy for the purpose. It is a very clear indication that Government should withdraw itself from water distribution and maintenance of canal system in a phased manner and set target dates.

External agencies have facilitated for ushering in a number of reforms, both financial and institutional in the water sector like National Water Management Project, increasing water rates and farmers turn over of irrigation system.

In deed a comprehensive approach is necessary to combat the present crises relating to the quality of the drinking water as well as that of irrigation water supplies. The remedial alternatives may include optimum conjunctive use of ground water and surface water, irrigation with pond or reservoir – stored excess rain water and ground water, recharge of the ground water resources with rain water, enhancing water use efficiency for the agricultural irrigation and mass campaign for building awareness.

For drinking water, information technology based systems may be used in Water Treatment Plants to ensure the consistent quality of water as the alum is mixed based on the quality of raw water. Moreover it is possible to save water, chemicals as well as energy by using IT based systems and techniques. The environment protection and its sustainability depend on the endowment of knowledge in the mind of local people. In this direction the information technology can play a pivotal role to build awareness regarding the recent curse of water pollution and to keep abreast the local people with the technique for proper implementation of management strategy to cope the challenges. The participatory approach of water management technique can be handled with a proper manner to create influence on the strategic planners for protecting water in a sequential manner.

CONCLUSION

To conclude, most of the initiatives have already been undertaken since long and are being implemented with enthusiasm, the fact remains that there is no massive enhancement in crop productivity, however, some improvement have been noticed. The inequality in water distribution on one hand fails to irrigate part of the land, gives insufficient supply to some part of the land and at times causes damage to lands due to over irrigation and consequent problems of water logging and salinity. Accordingly, the particular problem, which needs to be addressed, is the improvement in water use efficiency. Not only that but also the primary duty is to educate and reeducate irrigated farmers about judicious and prudent use of irrigation water. Careful crop planning, less water consuming and short duration crops are to be introduced in water stress regions. However, the thrust areas in this context are:

- Management of water;
- Removing water logging;
- Introducing appropriate technique of irrigation;
- Reviving the concept of traditional water recharging;
- Development of traditional community tank;
- Water management through active participation of the farmers;
- Application of local peoples knowledge in water management strategy;
- Utilization of participatory technique for the preparation and implementation of action plan.

Environmental Accounting for Pollution Damages: The Monetary Approach by L. Venkatachalam, ISEC,

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I. Introduction:

At present, the water sector in India experiences two major problems namely, the depletion and degradation. While the depletion refers to reduction in the quantity which in turn reduces the availability of water to various sectors such as agriculture, industry, etc, the degradation reduces the quality of water making it unfit for specific activities. The depletion is caused both by supply and demand side factors. Reduction in the level of rainfall, evapotranspiration due to existence of invasive species, run-off in the catchment area that causes wastage, etc are some of the factors that cause depletion of water resources. In the case of degradation, water pollution becomes a major source causing deterioration in the quality of water.

The water pollution originates from two major sources namely, (i) non-point sources; and (ii) point sources. According to a definition by United Nation's Food and Agricultural Organisation (FAO), 'non-point source water pollution arises from a broad group of human activities for which the pollutants have no obvious point of entry into receiving watercourses. In contrast, point source pollution represents those activities where wastewater is routed directly into receiving water bodies by, for example, discharge pipes, where they can be easily measured and controlled'. Obviously, non-point source pollution is much more difficult to identify, measure and control than point sources. These two forms of pollution cause damages to the watercourse, which in turn affects both economic (agricultural, industrial, commercial, household, etc) and non-economic (bio-diversity, eco-system maintenance, etc) activities.

It should be noted that the pollution causes reduction in the environmental benefits enjoyed by various users and therefore, the pollution needs to be controlled. It should, however, be remembered that pollution cannot and should not be reduced to zero level because of two different reasons:

i) the "assimilative capacity" of the water itself is capable of absorbing certain amount of pollution and therefore, in principle the pollution load in a particular locality and pollution standards there of are set on the basis of the assimilative capacity of the water or land;

ii) the zero level of pollution control is not economically feasible because of the fact that cost of achieving zero level of pollution is much greater than the benefits restored due to pollution control. The simple reason is that zero pollution leads to zero production which in turn would bring the growth of the economy into standstill position. Moreover, if pollution control measures are undertaken then the polluting firm will have to transfer of scarce financial resources from producing goods to controlling pollution. For a owner of a polluting unit, producing more goods would fetch him more of profit but undertaking pollution control measures would actually reduce the profit. Since the producer is always interested in maximizing the profit, she would prefer to produce more goods with the available financial resources than using the financial resource for pollution control measures. But the crux of the problem is that if the pollution is not controlled, then it affects the quality of water which results in reducing the benefits enjoyed by various users. The amount of benefit reduced to the water users is called "social cost", because this cost is not borne by the polluter but by different kinds of individuals using the benefits generated by water resources.

For these two reasons, achieving zero level of pollution is not economically feasible. However, the next question that immediately arises is: If not zero level, at what level the pollution should be controlled? Alternatively, the question may be posed as follows: What is the maximum quantity of raw effluent that could be let into a particular watercourse used for specified purposes? An economist's answer is that the pollution should be controlled upto that point where the cost of controlling pollution does not exceed benefits restored due to pollution control. More precisely, an economically efficient level of pollution control would require that the marginal cost of controlling pollution (i.e. the cost of controlling a specified level of additional amount of pollution) is equal to the marginal benefit restored (i.e. the amount of benefit derived due to controlling a specified level of pollution).

The issues discussed above are pertaining to the issues at the micro-level. It should be noted that environmental damage at the micro level has repercussions on the macro level 'sustainable development' of an economy. This is attributed to the fact that the micro-level environment issues and the associated damages feed into the macro system, making the sustainable development more vulnerable. This warrants for estimating the reduction in the benefits caused by pollution in *money terms* and the resulting monetary value should be 'accounted' for in the income accounting system, so that environmental policy for macro sustainable development could be made effective. The first step towards formulating sustainable development polices depends on the measurement of environmental benefits and costs using macroeconomic framework. One such framework that is already used in many of the countries is called 'environmental accounting'.

Two Basic NRA Approaches:

The environmental economics provides two basic approaches to deal with the pollution and its impact – one is called "Natural Resource Accounting" (NRA) approach and the second is called 'Cost-Benefit Analysis" (CBA) approach. It should be noted that these methodologies, if properly adopted, would provide us the policy options to deal with various major environmental problems mentioned above. Both the NRA and the CBA should be adopted at the river basin level so that not only the micro level issues but also the macro issues could be dealt with adequately. Having suggested a river basin level approach, let us move on to discuss how the NRA could be used for water sector in Tamil Nadu.

There are two basic approaches to NRA namely, the physical accounting approach and the monetary approach. The physical accounting, which deals with documenting the benefits and costs of water resources in a systematic and scientific way, has three major components namely, (i) the stock account; (ii) the user account and (iii) the environment account. The stock account systematically deals with accounting for the information on stock and flow of the water resources (both ground and surface water sources separately) during a particular time period. The stock of the water at the beginning, the additions to the stock such as rainfall, water recharged, return flow, etc, the subtractions such as water withdrawn for various purposes, run-off, etc and the final stock after making adjustments for the additions and subtractions are arrived at systematically in the stock account. The stock account gives us a complete picture about what is going on in the water sector at the river basin level. However, the stock account is not comprehensive on the use side that includes how much water is being used in various sectors, how it is being used, etc. Hence, the user account deals specifically with documenting the information on water used in various economic activities in detail. For instance, the user account looks into identifying various sectors, not only within the basin but also from outside, that utilise water in the basin, how much water is being used in each sector, how efficiently the water is used within the sector, etc. In the case of industrial sector, the user account will document information on total amount of water used by the industrial sector in a particular time period, water used in each industrial category such as textiles, paper and pulp, chemicals, etc within the sector, how efficiently the water is used in each unit, etc. But the major lacuna with the stock and user accounts is that they document only those information related to the "quantity" of water. However, the "quality issue" is equally important in the sense that any deterioration in the water quality will make the entire quantity useless for various purposes. So, the "environment account" deals with the quality aspect in a more detailed way. The amount of pollution load let into the watercourse by various users such as industry, municipality, etc, the nature of pollutants, and other forms of natural pollutants such as weeds, etc are being accounted for in the environment account. Altogether, the physical accounts are essential part of the NRA, which would reflect the entire gamut of water sector in the state.

Despite the major advantage that proving baseline information about various aspects of water sector, the physical accounts are not that much efficient in guiding the decision makers on which sector needs to be given priority compared to the other sectors. For instance, the physical accounts will only show that the water used in the household sector is relatively much smaller than that of the agricultural sector. However, the economic value of the water used in the household sector may be much greater than that of the agricultural sector and therefore, the physical accounts may not help us to formulate efficient water policies on inter-sectoral water allocation. This being the case, there is a need for the monetary accounts. The monetary accounts try to place economic value on the water used in various sectors –or more precisely, the monetary accounts place economic value on the information provided by the user accounts and the environment accounts. Let us now see how economic valuation would be carried out to estimate the costs and benefits in the water sector.

The preparation of monetary accounts will be based on the user account and the environment account that identify the benefits enjoyed by various sector as well as costs imposed. In the case of user account, economic valuation exercise tires to place a value on the quantity of water used in the household sector, agricultural sector, industrial sector, etc using various "economic valuation techniques" available in the environmental economics literature.

In the case of monetary accounting, the major challenge is to convert the physical units available in the physical accounting into monetary values. Monetary valuation of physical information is important since cost-benefit analysis is the pre-requisite for almost all the environmental policies. Environmental economists have developed standard monetary valuation techniques to place values on the pollution damages that are in many cases 'non-marketed' in nature. In the following section, let us discuss in detail how these valuation techniques could be used for estimating the monetary values of pollution damages.

Estimating the Economic Value of Environmental Damages:

Suppose the water resource in a river basin is used for different purposes such as irrigation, drinking, industrial use, fishing, etc prior to pollution. As long as the water is of good quality, the quantity and the quality of the benefits derived would be unaltered. At the moment the pollution occurs, both the quality and the quantity would get altered. The crux of the problem, in many cases, is that the reduction in the economic value of the benefits is not reflected anywhere in the economic system, explicitly. This is because, many of the benefits generated by water resources are not sold in the conventional market (for example, the irrigation water supplied by the government sector to farmers is not sold through market) and therefore, the difference in the quality of benefits caused by pollution is also not reflected in the system. This being the case, estimating the economic value of the reduction in the quality of the benefits requires different types of direct and indirect approaches for each sector, which we will discuss in the following section.

A. AGRICULTURAL SECTOR:

The major benefit derived by the agriculture sector from the water sector is irrigation benefit. The environmental damage in the agricultural sector is reflected in terms of three major indicators: (a) change in the cropping pattern and reduction in the cropped area; (b) increase in the cost of production; and (c) reduction in the productivity. The economic valuation exercise looks at all these changes and estimate the monetary value so that the economic value of the damage could be compared with the cost of controlling pollution, at a later stage. There are different economic valuation methods by which the damage to agricultural sector (due to reduction in the quality of irrigation water) could be estimated. In the following section, we would discuss the steps involved in various economic valuation methods in assessing the economic damage to *agricultural sector* though similar approaches could be adopted in other sectors such as household sector, industry sector, etc.

(a) Hedonic Pricing Method:

This is an indirect market approach that looks at price of related goods/factors to derive information about the water pollution damage. As a form of surrogate market method the hedonic pricing method utilises the net difference in the market prices of lands and attributes it to the level of damage. The market price of land, other things remaining same, is assumed to differ between two different areas - one that experiences pollution and the other, without such a problem. More precisely the price of land in the unpolluted area will be higher than that of the polluted area. Hedonic method identifies this difference (especially -the reduction is the land price) and treats it as the economic value of damage. However, it may not always necessarily be valid to state that the price of land in the polluted area will be lesser than that of the non-polluted area. In some cases the price of land in the polluted area may be greater, because of various other factors such as proximity to the city, potential commercial value of the land etc. This being the case, one needs to find out the influence of other factors on the land price, including water quality. The estimation of economic value of agriculture damage involves the following steps:

(i) Select two different areas in the same river basin- one with pollution and another area without pollution. To determine whether an area is polluted or not we need not have to depend on exhaustive scientific data on pollution. On the basis of available amount of secondary data on pollution from various sources such as PCBs, soil science department, research and academic institutes, regional environmental cells of PWD, etc, one could select the polluted and non-polluted areas in a particular river basin;

(ii) Obtain information, especially from the secondary sources, on land transaction taken place in the respective areas over a period of time, the change in the price of land, cropping pattern, land use pattern, soil quality level of rainfall, general productivity, proximity to city form the land area, access to other facilities such as roads, etc, potential commercial value (whether the area would become an industrial estate, real estate, etc) and other kinds of variation in the region that may influence the land prices;

(iii) Using appropriate statistical techniques (especially, the regression analysis), the land prices can be regressed against the factors influencing the price. The statistical analysis facilities us to understand the extent of the impact of water quality on the land price. The net value (the difference in the average prices for hectare of land between the two areas) is estimated to be equivalent to the 'damage' caused by pollution;.

(iv) The data for the study may be collected from the secondary sources such as registrar of land records, department of agriculture, department of Agricultural Engineering, department of soil sciences, research reports, etc. In case of non-availability of data through secondary sources, a primary survey may be undertaken to collect specific data. The statistical treatment of the data could be carried out with the help of computer packages such as SPSS, EXCELL etc.

(b) Production Function Approach:

The production function approach looks at the changes in the level of production/agricultural output due to change in water quality. The production function approach takes two forms namely (i) the time series analysis (or dose-response method) (ii) the cross section analysis:

i) Time series analysis:

In the case of time series analysis, the data relating to productivity and the water quality for various years are collected and the trend between these two parameters are studied for a particular area affected by pollution. If they have direct positive correlation (i.e. deterioration in the water quality leading to reduction in the productivity, other things remaining the same) then it is easier to calculate the reduction in the level of productivity for a specified level of water quality deterioration. However, as we have already seen, the productivity is not only influenced by water quality but also by various other factors such as rainfall, climatic conditions, soil quality, amount of various inputs used, nature of farm management, etc. Obtaining time series data on productivity and other variables is a difficult task because (i) data may not be available on many variables; and (ii) even the available data may not be reliable for making better assessment of the impact. Moreover, the `dose' and response (or the water quality and the productivity) do not take place simultaneously. In other words, the pollution at a particular point in time has its impact on the productivity after at a very later stage and this make the dose – response analysis less meaningful. These issues lead to alternative method, namely "controlled experiment".

(ii) Controlled Experiment or Cross Section Analysis:

The alternative way of using the production function approach is it look at the impact of the water quality, for a particular time, rather than using time series data. The cross section analysis involves the following steps.

i) Selection of two different areas – with and without pollution in the same basis, based on the available information on the level of pollution.
ii) Collection of data relating to production, productivity, amount of various inputs and cost of production, climate, rainfall, soil quality etc.
iii) Use statistical techniques to understand the nature and extent of the influence of water quality on the productivity. The net productivity decline due to water pollution could be estimated and the market value of the difference in the output due to change in the productivity could be attributed to the damage.

This method has some disadvantages. First, the data on various aspects are not reality available from the secondary sources. This will lead to put the depending on the primary survey. Another practical problem is that if the lands are not cultivable, then the productivity approach may not be suitable.

(c) Replacement or Restoration Cost Approach:

The replacement cost approach looks at the cost of restoring the damage through some cost-effective mitigating measures and treats this cost as damage cost. The quality of water does not directly affect the productivity of the crops but it affects the productivity through adversely affecting the quality of the soil. The replacement cost approach is based on the notion that once the quality of the soil is restored to the previous unpolluted level, the productivity will also be restored. However, restoration of the soil quality involves cost. The restoration cost method estimates the cost of restoration and treats it as the damage cost. The restoration cost method has the following steps:

i) Select the area affected by pollution;

ii) Collect soil quality data for the affected area and estimate the average area affected by pollution. For example, number of hectares of land for different levels of soil quality parameters (pH level may be below 6 in 700 hectares; 5.5 in 800 hectares; 5 in 600 hectares and 800 and so on) can be estimated. Similarly, for other important pollution parameters also the average number of hectares could be estimated.

iii) Decide about the prescribed soil quality parameters to the level of which these parameters need to be restored. The prescribed parameters may be either the FAO Standard parameters or the level of parameters found in the non-polluted areas in the same basin.

iv) Decide about a method or a continuation of methods with which various levels of soil quality parameters could be restored to the prescribed level. The method may be to apply suitable chemical fertilizers in appropriate quantity in combination of both organic and in organic fertilizers.

v) Calculate the market price (that does not include the amount of subsidy) of the amount of fertilizers to be used for restoring the quality of the soil; for the total affected area, the total amount of fertilizers as well as the cost could be estimated. This cost is considered to be the damage cost.

(d) Contingent Valuation Method (CVM):

The CV method is a survey method by which the purchasers of the users of water are elicited. The contingent valuation method is extremely sensitive method and unless standard guidelines are not followed while conducting the survey the results obtained through CV method may not be useful for the purpose intended. Therefore, this method should be used very carefully. The empirical evidence shows that this method is capable of providing reliable and valid information if properly administered. The administration of EV method involves the following steps.

(i) Selecting the study area (may be a polluted area) where the pollution has become a major issues of irrigation;

(ii) Selecting the sample farmers from the study area using appropriate sampling techniques;

(iii) Administering a pre developed questionnaire to the sample farmers to obtain information related to the socio economic condition of the farmers, their households' demographic features, land holding pattern, cropping pattern, perception about the quality of irrigated water at prevent etc.;

(iv) Eliciting information on the farmers' WTP for improved, good quality irrigation water (by way of providing a realistic scenario to the respondents);

Estimate the average WTP value from the WTP value elicited from the sample farmers and extrapolate it to the to CV method, if properly used, would fetch useful information. How to conduct a good quality CV study is the major issue. However, lot of guidelines and texts an available on this subject, which may help us to conduct CU studies in the fields and elicit reliable and valid information.

Discussion:

In the above section, we have discussed about various techniques to economic valuation of environmental damages caused by water pollution. Though we have discussed only about how to value the damage in the agricultural sector, same approach can be used to value damage in other sectors such as household, industry and so on. Some of the valuation techniques discussed above (such as CV method) may not be useful to derive value at the aggregate level. However, CV values available from already conducted research studies may be used to arrive at a bench-mark value that could be used for deriving values in other policy sites. Moreover, for accounting purpose at the macro level certain 'feasible' macroeconomic valuation techniques such as production function approach and defensive expenditure approach could be used for valuation purpose. Even with the available information from various government departments and research institutions in India, the monetary accounting can be developed at a reasonable level.

The economic valuation helps us to build the monetary accounting that can be used to understand whether the development at the macro level moves on a sustainable path. When valuation is completed sector-wise, the aggregation of these values across sectors could be used for making adjustments in the national income (i.e. GDP) so as to understand whether the GDP is sustainable measure of national income. However, the issue here is that combining the actual market values used in SNA and 'imputed' values coming from the economic valuation exercise may not be clubbed together. This is because, the GDP and its variants are used for making various developmental policies and incorporating the imputed values will sometimes lead to misleading conclusions. Therefore, the suggestion is that the environmental accounting has to be done on a satellite basis, which can be used for comparative purposes.

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A **STATISTICAL ACCOUNTING OF WATER RESOURCES**

"A Technical Paper" By Mr. B. Purkayastha*, IAS

Abstract

Water Accounting is a water management tool, which provides to statistically account all the water resources within a defined area for its consumptive uses including scope of sharing it in the neighborhood areas. A relatively low on data base management system presently in place in many of the States including Meghalaya, it has become more so important to understand the water accounting and its purpose. This paper deals with water accounting and its use in policy, planning, and management of consumptive use of water resources at large.

Key Words: Environmental & Economic Water Accounting, Water Balance, Net inflow, Gross inflow, Committed water, Uncommitted outflow, Process depletion, Non- process depletion, Beneficial utilization, productivity of water, Consumptive use, and Depleted fraction of water.

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1. Introduction:

In the Constitution, water is a matter included in Entry 17 of List-II i.e. State List. So, it is the States' responsibility to manage water resources in best possible manner so that our children are not deprived of this precious resource.

Water is a rare, irreplaceable, vulnerable natural source that is the obvious basis for many ecosystems as well as the final destination of spill. It is essential to human activity and, whatever its situation or condition, it is subject to a permanent cycle where the aggressive economic development modifies its quantitative and qualitative characteristics.

Water is an indispensable natural resource for a country's economic development. The fact that India's economic and social structure is based on a strong agricultural sector with a growing irrigation farming and on a powerful tourism sector whose basic elements are the sun and water. The future development of these sectors is closely connected with the availability of water.

2. Environmental and Economic functions of water:

Water has several environmental economic functions, which may be summarized as follows:

a) It provides input to the economy. This input is fundamental for a great many economic activities, from the agricultural sector to the services sector.

b) It receives greatly varying residues and waste derived from society's productive and consuming activities.

c) It offers the possibility to mankind to directly receive comfort or aesthetic enjoyment.

However, water uses depend on the level of development of hydrographic infrastructures, which allow to adapt its irregular stock to the unceasing needs throughout time and space. This situation implies that it has become ever more necessary to study its availability and quality in order to increase the quantity of water, protect its quality and rationalize its use in accordance with the remaining natural resources.

The use of water may be analyzed from two angles, the economic and the environmental.

Economic viewpoint: Water is studied when it is directly or indirectly, actually or potentially, influenced by the development of human activities. Water provides inputs to the economy, is part of the production process of almost all economic activities and is the fundamental input for many of them.

Environmental viewpoint: Water resides in many ecosystems and contributes to the well being of human being. It receives waste that causes a loss of quality and important economic and environmental costs.

It is, therefore, necessary to set up a framework containing economic as well as environmental data on water as it will allow to work out policies in the field of hydrography. The model that solves most problems of users concemed with statistics on water is the water accounting.

3. Water Accounting for Integrated Water Management

Water Accounting system provides a clear view of water resources in a River basin such as - where water is going? How it's being used? and how much remains available for further use?

These information can be used by Policy makers, planners and resource managers to:

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- Develop effective strategies for allocating water among different users
- Conceptualize and test interventions in the context of multiple uses of water
- Identify opportunities for saving water and/or increasing water productivity
- Assess the scope for the development of additional water resources

4. **Water Accounting an important water management tool:**

The Water Accounting can be usefully utilized as a management tool for

a. Revealing the reality of availability and use

Water accounting clearly shows all users of water in a basin, including unplanned, and often unacknowledged users, such as trees. It has been found by the researchers and scientists world over that trees are the largest user of water -consuming a surprising 43 percent of the total water available. Although trees are an important natural resource - improving biodiversity within irrigated areas and providing people with food, medicine, fuel wood, a pleasant environment and raw materials for handicrafts - they are rarely considered in water resources planning. Water accounting helps water managers take a more integrated approach that more accurately reflects the reality of water use.

b. **Understanding the impacts of water management decisions on all users**

As more of the river basins become 'closed,' with all their available water used, it becomes increasingly important to plan water resources development, allocation, and management in the context of multiple uses of water. Policy makers and water resources planners can use Water Accounting to make decisions based on the actual amount of water available in a basin and with an understanding of the potential impacts on all users.

c. **Identifying opportunities for water savings**

Water planners have two basic options for increasing the amount of water available for beneficial use without building additional infrastructure.

- Reduce non-beneficial depletion.
- Produce more crops per unit of water beneficially depleted.

Improving the productivity of water and reducing waste are appealing options compared to developing new storage and diversion facilities, which often carry high financial, social and ecological costs. Water accounting gives planners and policy makers a clear view of their options and the scientific information necessary to effectively plan development and management efforts.

d. Providing a common language for water

Being able to clearly communicate how water is being used and the rationale for allocation can help avoid or minimize conflicts over water. This is especially important in cases where the competition for water is intense and giving more water to one user necessarily means taking it away from another. The Water Accounting System provides a common language to understand and describe the use and productivity of water.

5. **How to use Water Accounting?**

One of the most valuable applications for Water Accounting is in identifying opportunities for saving water and increasing its productive use. By showing where water is being used and providing a framework for assessing its productivity, Water Accounting helps:

- Pinpoint areas where water can be transferred from lower- to higher-value uses
- Evaluate the scope for improving productivity of water and target interventions
- Identify opportunities to reduce non-beneficial evaporation, pollution, or the flow of water into 'sinks' (deep aquifers or other areas where it can't be recovered)

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Once water is categorized, Water Accounting indicators refine the picture

Water accounting uses a 'water balance' approach to quantify the amount of water entering a system (through precipitation and river and groundwater flows) and the amount leaving a system (through evaporation, plant transpiration and river and groundwater flows). The amounts depleted within the basin are then classified according to use, whether or not the use is intended and whether or not it is beneficial. The amount of unused water flowing out of the system is classified according to whether or not it is committed for downstream use. Non-committed outflows are further subdivided into water that is currently utilizable and water that is not utilizable without additional infrastructure.

Depleted Fraction indicators reveal how much scope remains for water resources to be developed? How close they are to being fully committed? and how sustainable the system is? For example, the depleted fraction i.e. amount of water depleted divided by gross inflow into more than 1, it will mean more water is being depleted than is flowing into the system. This indicates groundwater overdraft and therefore unsustainable water use.

Beneficial Utilization relates the amount of water depleted by all beneficial processes to the amount of water available for use. This indicator offers a more accurate view of basin efficiency than traditional indicators, because it takes into consideration the water consumed by valuable natural ecosystems as well as the water consumed by human activities (such as agriculture).

Productivity of Water quantifies the value derived from the water used. In agriculture, it can be expressed as the yield (in kilograms) produced per cubic meter of water consumed by crops. More generally, it can be expressed as the economic value of production per unit of water consumed. These productivity values can also be related to the amount of water available, depleted or diverted.

6. **Ways of improving the productivity of water**:

The ways of improving the productivity of basin water resources are as follows:

a. Increasing the productivity per unit of water consumed by:

- Changing crop varieties
- Crop substitution
- Deficit, supplemental, or precision irrigation.

b. Tapping uncommitted outflows

- Improving the management of existing facilities to obtain more beneficial use from existing water supplies. A number of policy, design, management, and institutional interventions may allow for an expansion of irrigated area, increased cropping intensity, or increased yields within the service areas.
- Adding storage facilities and releasing water during drier periods. Storage takes many forms including impoundment in reservoirs, groundwater aquifers, and in small tanks and ponds on farmers' fields.

- Reuse of return flows through gravity and pump diversions to increase irrigated area.

c. Reducing non-beneficial depletion

Non-beneficial depletion can be reduced by decreasing,

- Evaporation from water applied to irrigated fields through specific irrigation technologies such as drip irrigation, or agronomic practices such as mulching, or changing crop planting dates to match periods of less-evaporative demand.
- Evaporation from fallow land, decreasing area of free water surfaces, decreasing less beneficial vegetation, and controlling weeds.
- Water flows to sinks (ocean or deep aquifers) and by reusing return flows, or by interventions that reduce deep percolation or surface runoff that flows to sinks.
- Flows through saline soils, or through saline groundwater to reduce pollution caused by the movement of salts into irrigation return flows.

  Preventing saline or otherwise polluted water from reentering the system by shunting it directly to sink

d. Reallocating water between uses: The reallocation of water can be,

- Between sectors-from lower- to higher-value uses.
- Between upstream and downstream uses

A note of caution: The water reallocation can have serious legal, equity, and other social considerations that must be addressed.

7. Water saving scope and strategy

Water saving strategies should focus on reducing the flow of irrigation drainage water to the sea. The downstream irrigation tanks (holding-ponds) are filled directly from the main reservoir-reducing their ability to catch rainwater and drainage flows from upstream. By changing this practice, so that upstream areas are irrigated first and downstream tanks are used to catch drainage, enough water could be saved in the reservoir for a second cropping season. Alternatively, drainage flows can be minimized by more closely matching the amount of irrigation water supplied to crops' actual needs. Finally, by reducing the evaporation from scrubland, fallow fields and surface water bodies potential savings can be achieved. However, more research is needed to accurately quantify environmental water needs in the river basins.

8. Physical Accounting of Water Quantity

1. Ground Water

National Water policy

The national water policy enunciates the following guidelines for ground water:

a. Periodic reassessment of ground water on scientific basis taking into consideration the quality of water available and its economic viability,
b. Regulated exploitation of ground water so as not to exceed the recharge possibility and to ensure social equity.
c. Integrated and coordinated development of ground and surface water and their conjunctive use, and
d. Avoid over-exploitation of ground water

GROUND WATER - HOW IT IS ASSESSED

Ground water is an important source of irrigation and caters to more than 45% of the total irrigation in the country. Although the ground water is annually replenish able resource, its availability is non-uniform in space and time. Hence, precise estimation of ground water resource and irrigation potential is a prerequisite for planning its development. A complexity of factors- hydrogeological, hydrological and climatological, control the ground water occurrence and movement. The precise assessment of recharge and discharge is rather difficult, as no techniques are currently available for their direct measurements. Hence, the methods employed for ground water resource estimation are all indirect. Ground water being a dynamic and replenish able resource is generally estimated based on the component of annual recharge, which could be subjected to development by means of suitable ground water structures. For quantification of ground water resources proper understanding of the behaviour and characteristics of the water bearing rock formation known as Aquifer is essential.

An aquifer has two main functions

a. to transit water (conduit function) and
b. to store it (storage function).

The varied modes of ground water occurrence may be broadly summarized as:

a) Porous formations comprising unconsolidated and semi consolidated sediments. Aquifers interconnected, often extensive, both continuous and discontinuous; moderate to very high yield potentials.
b) Consolidated and fissured formations. Aquifers discontinuous, Limited yield potentials.

The Ground water resources in unconfined aquifers can be classified as Static and Dynamic.

(i) The static resources can be defined as the amount of ground water available in the permeable portion of the aquifer below the zone of water level fluctuation.

(ii) The dynamic resources can be defined as the amount of ground water available in the zone of water level fluctuation.

The replenishable ground water resource is essentially a dynamic resource, which is replenished annually or periodically by precipitation, irrigation return flow, canal seepage, tank seepage, influent seepage, etc. These items are elaborated as below

I. Items of supply to ground water reservoir

1. Precipitation infiltration to the water table.
2. Natural recharge from stream, lakes and ponds.
3. Ground water inflow into the area under consideration.
4. Recharge from irrigation, reservoirs, and other schemes especially designed for artificial recharge.

II. Items of disposal from groundwater reservoir
1. Evaporation from capillary fringe in areas of shallow water table, and transpiration by phreatophytes and other plants / vegetation.
2. Natural discharge by seepage and spring flow to streams, lakes and ponds.
3. Ground water outflow.

4. **Artificial discharge by pumping or flowing wells or drains**.

A few of these are directly measurable, some may be determined by differences between measured volumes or rates of flow of surface water and some require indirect methods of estimation. The methodologies adopted for computing ground water resources, are generally based on the hydrological budget techniques. The hydrologic equation for ground water regime is a specialized form of water balance equation that requires quantification of the items of inflow to and outflow from a ground water reservoir, as well as of changes in storage there in.

The water balance equation is stated in general terms as follows for any specified period:

Input - Output = Storage increase

Over the years the ground water assessment techniques have evolved from progressive understanding of ground water occurrence and movement, recharge and discharge processes. The first attempt to estimate the ground water resources on a scientific basis was made in 1979. Subsequently, the Ground Water Estimation Committee (GEC) of Govt of India was constituted in 1982, which after reviewing the data collected by central and state agencies, research organizations, universities, etc., recommended during 1984, the following two approaches for ground water assessment,

a. Ground water fluctuation and specific yield method, and
b. Rainfall infiltration method

The total ground water resources for water table aquifers is taken as annual ground water recharge Plus potential recharge in shallow water table zone. The total ground water resources, thus computed would be available for utilization for irrigation, domestic, and industrial uses.

These norms of Ground Water Estimation Committee 1984 are currently utilized by the Central Ground Water Board and State Ground Water Departments to compute the ground water resources. However, there were some limitations in the above recommended methodologies. As such these got reviewed subsequently, which recommended modified methodologies in 1997. The State unit of the CGWB in consultation with State Govt. has already initiated ground water resources estimation based on the modified methodologies recommended by GEC 1997. The output is likely to be available sometimes in the year 2005.

II. Surface water

SYSTEMATIC COLLECTION OF HYDROLOGICAL DATA

Presently the Central Water Commission (CWC) operates a National Network of about 877 hydrological observation stations. The basic data observed at field units are processed at various levels and authenticated data is then transmitted to Central Water Commission for storage, retrieval and processing of the data request of various user agencies using available hardware and software facilities.

ESTIMATING CONSUMPTIVE USE BY VEGETATION

Consumptive use by vegetation is estimated as the residual in a water budget for the reach bounded by stream flow gauging stations. Components in the water budget include
(1) Inflow at the upstream boundary,
(2) Outflow at the downstream boundary,
(3) Change in storage in reservoirs along the budget reach,
(4) Quantity of water exported out of the area,
(5) Consumptive use by vegetation,

(6) Evaporation from open-water surfaces,
(7) Precipitation,
(8) Surface- and subsurface-tributary inflow,
(9) Domestic, municipal, and industrial consumptive use, (IO) Surface-water flow
(10) Change in storage in aquifers.

The first five components make up more than 90 percent of the water accounted for in the budget; only consumptive use by vegetation is not measured directly. The last six components are estimated and each is commonly less than I percent of the inflow at the upstream boundary.

9. Physical Accounting of Water Quality

The physical accounting of water quality is essential for assessment of total utilizable water available. In this context, we have to understand the water quality issues related to Surface & Ground water pollution sources, which are described here.

1. Surface Water

Contamination can enter the surface water bodies through one or more of the following ways:

a. Direct point sources
b. Diffuse agricultural sources
c. Diffuséd urban sources
d. Lakes and Reservoirs Pollution Pathways: The following pathways, in addition to the ones mentioned above, assume special significance in the case of lakes and reservoir pollution;

   i. Riverine sources
   ii. Atmospheric sources

e. Rivers & ground water draining watershed
f. Eutrophication
g. Lake Acidification
h. Bioaccumulation and Biomagnifications

The magnitude of damage caused to our water resources can be estimated from the fact that about 70% of rivers and streams in India contain polluted water.

II. GROUNDWATER

The ground water may get contaminated due to following.

- Unsewered Domestic Waste
- Disposal of Liquid Urban and Industrial Waste
- Disposal of Solid Domestic and Industrial Waste
- Cultivation with Agrochemicals
- Salinity from Irrigation
- Mining Activities
- Geological Formations
- Diffused sources

The incidence of ground water pollution is highest in urban where large volume of waste are concentrated and discharged into relatively small areas. The ground water contamination, however, is detected only some time after the subsurface contamination begins.

10. **WATER QUALITY MONITORING**

The Gazette notification on the constitution of WQAA inter-alia recognizes the need for constitution of State level "Water Quality Review Committees", and the importance of water quality monitoring through an extensive network at national and state levels. As per the notification, the Ministry of Water Resources (WM Wing) shall create a Cell to assist the Authority to carry out the following functions.

1. To coordinate the activities of the constituent agencies of the authority and preparation of action plan.
2. To set up State level Water Quality Review Committee and monitor their activities.
3. To provide necessary information to the authority for exercising powers under Section 5 and taking measures under sub-section 2 of Section 3 of the EP Act.
4. To organize public Awareness Programmes.
5. To prepare Agenda and organize the meetings of the Authority.
6. Preparation of Quarterly report for sub mission to Ministry of Environment..

A planned approach to set up stations on all major rivers of the State would be needed to generate data on water quality. Although, the Central Water Commission is also monitoring water quality, covering all the major river basins of India including northeast. But that is not adequate.

GROUND WATER MONITORING NETWORK

The Central Ground Water Board monitors the ground water levels from a network of about 25 stations in Meghalaya (mostly dug wells selected from existing dug wells evenly distributed throughout the State).

STATUS OF GROUND WATER HYDROGRAPH NETWORK STATIONS IN NORTH EAST STATES

Name of the States/Union Territories	As on 31-02-95
Manipur	25
Meghalaya	37
Mizoram	0
Nagaland	8
Sikkim	0
Tripura	37

Dug wells are being gradually replaced by piezometers for water level monitoring Measurement of water levels are taken at these stations four times in a year in the months of January, April/May, August and November. The ground water samples are also collected during April/ May measurements for chemical analyses every year. The data so generated are used to prepare maps of ground water level depths, water level contours and changes in water levels during different periods and years. The data is also used to prepare long term changes trends of rise and fall in water levels, which help to dewatered areas, prove to water logging and over exploitation.

11. **Water scenario in Meghalaya**

Megha]aya has a monsoon type of climate with wide variation depending upon altitude and physiographic difference of landmass. The Shillong plateau *(600-2000m)* has a bracing climate verging towards temperate type; the lower regions adjoining the Surma and Brahmaputra Valley (100-300*m)* have a tropical climate. Flood affected areas are mostly on the low altitude areas, bordering Assam and the IndiaBangladesh international boarder. The Agro-Climatic Zones and Sub-Zones in the State are as follows:

i Humid and warm with a average rainfall between 1279-2032 mm - Light to medium texture, depth varying between deep to very deep - Hills and rolling and undulating pediment.

ii Humid and hypothermic moderately cold in winter and warm in summer - rainfall varying between *2800-4000* mm - Light to medium texture, depth varying between deep to very deep - Upper and middle plateau.

iii Humid and moderately warm summer and severe winter - rainfall between *2800-6000* mm - Light to medium texture, depth varying between deep to very deep - Upper and middle plateau.

iv Humid and warm high rainfall ranging from *4000-10000* mm - Light to medium texture, depth varying between deep to very deep - severely dissected and undulating low hills gentle to steep slope and rolling pediment.

v Humid and hot, rainfall varying from *2800-4000* mm- Light to heavy texture, depth varying from moderately deep to very deep - rolling and undulating pediment and valley land having depression.

During]998 to2*001,* Meghalaya recorded average annual rainfall around *3800* mm, whereas during 1995-1997 and in *2003,* it has recorded reduced rainfall. However, during *2002,* it recorded a highest rainfall of *4100* mm. However, Cherrapunjee (now Mawsynram - approx. 12 kms away from Cherrapunjee), the worlds highest rainfall area receives an annual rainfall of approx 12000 mm.

The water used for potable drinking water supply is roughly estimated at around 3-5% of the total surface water sources. The remaining 97-95% is being used for irrigation & other allied sector. The total ground water resources in Meghalaya has been estimated at]229 Million Cubic Metres (1981- CGWB), of'which, the total utilizable resource for irrigation is estimated at approx 1046 Million Cubic Metres, whereas, only approx 190 million cubic metres is utilizable for drinking and other allied sectors. It shows that around only 15% of the total ground water reserve can be utilized for drinking water and other allied uses. These figures although speak of the extent of the availability of water and its potential uses, but it does *not* give the account of quantitative and qualitative account of total water resources of the State. A realistic database needs to be generated through application of the Water Account tool. The State would look forward to include the water accounting in its future agenda, which will enable the planners and policy makers to manage its water resources to its optimum capability. There are many rivers in the State having potential water quantity to be used. There are no natural lakes in the State. However, many man-made lakes are predominantly present in the State viz. Thadlaskein lake in Jaintia Hills, Barapani lake in East Khasi hills, etc.

But this alone is *not* adequate enough to account water resources. Each States shop]d develop a plan to systematically study and collect data on water resources both quantity and quality wise.

However, the efforts of the Local State Unit of CGWB, Megha]aya State Pollution Control Board, and Local Unit of Central Water Commission in monitoring the water sources with a very limited resources at their disposal. Is quite commendable. The Chemical Quality of ground water in Meghalaya collected by CGWB, Local State Unit during April 2004 is shown in table 1 on the *next* page.

Table 1: CHEMICAL QUALITY OF GROUND WATER COLLECTED DURING APRIL, 2004 (mg/I)

Sl.No.	Location	pH	EC	TH	Ca	Mg	Na	K	C03	HC03	CI	S04	N03	F	Fe
District: East Garo Hills															
1	Baiengdoba	7.0	80	30	6	3.6			0	24	11	2.4	Tr	0.25	
2	Mendipathar	7.0	54	15	4	12			0	31	7.1	3.8	3.1	Tr	
3	Depasarengma	6.9	104	35	6	4.9			0	37	7.1	10	Tr	0.09	
4	Darugiri	7.2	84	25	6	2.4			0	31	14	2.4	3.1	0.08	
5	Mendal	7.3	108	55	6	9.7			0	31	14	2.5	12	0.07	
6	Rongj eng	7.2	158	40	10	3.6			0	55	14	5	6.2	Tr	
7	. Williamnagar	7.1	204	60	18	3.6			0	55	21	10	19	Tr	
8	Rongmil	6.9	82	30	6	3.6			0	18	14	1.3	6.2	0.07	
District: West Garo HiIIs															
1	Barkona	7.1	64	25	6	2.4			0	31	7.1	1.4	Tr	0.06	
2	Ampati	6.8	562	95	18	12			0	183	39	35	3.7	0.17	
3	Mahendraganj	7.2	432	140	44	7.3			0	43	99	15	19	0.27	
4	Nidanpur	7.0	94	35	8	3.6			0	43	14	8.8	0.0	0.09	
5	Asanang	6.8	112	40	8	4.9			0	24	14	6.3	12	0.09	
6	Phulbari	6.9	266	80	22	6.1			0	85	25	10	19	0.19	
7	Purkhasia	6.9	118	25	6	2.4			0	18	14	2.5	22	0.05	
8	Zikzak	7.2	96	40	6	6.1			0	18	18	3.8	3.1	Tr	
9	Kherapara	6.7	92	20	6	1.2			0	18	14	10	Tr	0.05	
South Garo Hills															
1	Sibbari	7.0	194	50	10	6.1			0	49	21	5	25	0.17	
District: - East Khasi															
1	Shillong	7.8	361	125	24	16			0	159	28	5	6	0.66	
2	Pomlum														
3	Cherrapunji	7.9	121	55	16	3.6			0	31	11	9.6	12	0.39	
4	Mawngap	8.2	214	60	14	6			0	67	39	5	6	0.36	
5	Balat	8.1	275	115	32	8.5			0	92	18	10	37	0.49	
District: - West Khasi															
1	Mairang	8.1	257	75	22	4.9				31	31.9	9.6	56	0.38	
District: - Ri-bhoi															
1	Nongpoh	7.9	175	40	6	6.1 I			0	24	17.7	5	37	0.46	
2	Jorabat	7.6	296	135	44	6.1			0	85	53	5	6	1.01	
District: - Jaintia HiIIs.															
	Dauki	7.5	269	110	22	13.4			0	98	18	5	31	0.41	

Note: - 1. EC is micromhos/cm at 25° C

2. Tr - Trace.

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Appraisal of Water Resources of North Eastern Region of India

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Water resources occupy an important place among other natural resources as it is the basis of life of human beings and all other life forms on this planet. Freshwater resources which mainly comprise of rivers and ground water aquifers are fundamental for various human activities, socio-economic development and achieving and sustaining high quality of life. Inadequate supply of water and degradation of its quality adversely affect the human health and lead to spread of a number of water related diseases. It is also important for boosting food production to meet the future requirements of our growing population. Adequate supply of clean water for domestic, irrigation, industrial and other purposes is highly imperative for human wellbeing and maintaining healthy ecosystem and environment around us. The National Water Policy adopted in 1987 lays down the broad principles that govern the management of the nation's water resources. The policy recognizes that water is a scarce and precious national resource to be planned, developed and conserved as such and on an integrated and environmentally sound basis.

In prevailing situation of high population growth and ever increasing requirement of water for different purposes, it is a challenging task for planners and policy makers to provide optimum water supply for different sectors in the present and for the future. Lack of sufficient information on water resources make the task further difficult. Hence, assessment of water quantity and quality and its statistical analysis in relation to other factors are important for better utilization and sustainable management of available resources. The assessment of water resources of an area consist of inventory of spatial and temporal distribution of surface and ground water including precipitation, infiltration and runoff, its utilization potential, possible uses, assessment of water quality etc. Information on various anthropogenic activities that affect the quantity and quality of water resources can also become part of assessment as it is important for protection and sustainable management of available water resources. In this paper attempt has been made to appraise and discuss water resources of the northeastern region of India vis-à-vis that of India.

North Eastern Region of India

The North Eastern Region (NER) of India comprises of eight states namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and recently included state of Sikkim (Fig. 1). The region encompasses the eastern part of the great Himalayan Range and thus endowed with rich natural resources including water resources. About 54% of the total geographical area of the North Eastern Region is covered by forests. The topography of the area is mainly hilly excluding the flood plains of Brahmaputra valley in Assam and Manipur valley in Manipur. The region accounts for 7.9 percent (2.62 lakh Sq km) of the total land area of the country, of which over 70 percent is hilly. Hill ranges forming part of the Himalayas guard the northern side of the region. The area is made up of mountains above the snow line and plains a little higher than sea level. Mountains and hills cover most of Arunachal Pradesh, Mizoram, Nagaland, Meghalaya, Sikkim and about half of Tripura, one-fifth of Assam and nine-tenth of Manipur. The plains of the region are mainly made up of separate land masses - the Brahmaputra Valley and the Barak Valley in Assam and the Tripura plains in the South. In Manipur, the valley is small, comprising only about 10% of the total area of the state.

The region is predominantly inhabited by a large number of tribal ethnic groups. It is the home for about 4 percent population of the country. The region shares considerably large international border (about 98% of its total circumference) with China, Burma, Bangladesh and Bhutan. With the highest precipitation in the world, most of it falling between May and September, the area is lush and heavily wooded with a dense network of rivers and streams which drains the area into the Brahmhaputra, and Barak valley basin.

Figure 1. Map of North Eastern Region of India

River Basins of North Eastern Region

The North Eastern Region can be divided into three river basins namely Brahmaputra valley, Barak valley and Minor Rivers draining into Bangaladesh and Myanmar. However, Brahmaputra and Barak rivers flow from east to west in the north-eastern region and carry most of the water of the region. The distribution of the three basins in NER is indicated in Figure 2.

The Brahmaputra River basin: The Brahmaputra River has its origin on the northern slope of the Himalayas in China (Tibet), where it is called as Tsan-Po. It flows towards east for a length of about 1,130 km and then turns towards south and enters Arunachal Pradesh at its northern-most point and flows for about 480 Km. Then it turns towards West and flows through Arunachal Pradesh, Assam and Meghalaya states for another about 650 Km and then enters Bangladesh. Before entering Bangaladesh, the Brahmaputra Valley cuts across the Shillong plateau, by the Garo, the Khasi and the Jaintia Hills, through the Assam-Burma range. The Brahmaputra river basin stretches longitudinally for about 730 km, from North Lakhimpur to Dhubri district in Assam. The total length of the river from the source to the sea is about 2840 Km.

The discharge of the river Brahmaputra is mostly contributed by the snowmelt in its Chinese stretch. However, on entering India, it is mainly fed by heavy rainfall occurring in north eastern states of Arunachal Pradesh, Assam and Meghalaya of India. The rainfall in north eastern region is quite heavy and contributes substantial amount of flow in the river. The rainy season in this region generally commences from March and lasts till the middle of October. The total annual rainfall varies significantly in the region. In Khasi and Jaintia Hills, the annual intensity of rainfall reaches the maximum of about 1100-cm along Cherrapunjee - Mawsynram belt of Meghalaya. However, it is significantly low in the rain shadow area of Nagaon district in Assam. About two-thirds of the annual total rainfall occurs during the four monsoon months of June to September.

The Barak River Basin: The Barak Valley, formed by the river Barak and its tributaries covers the districts of Cachar, Karimganj and Hailakandi of South Assam. The Barak river originates on the Southern slopes of the Nagaland-Manipur watershed in the north eastern region of India. Later the river divides into two branches within the Cachar district of Assam. The northern branch is called Surma, which flows through eastern side of Bangladesh by the side of Sylhet town and drains southwards. The southern branch of the Barak is called the Kushiara, which also flows through Assam and then enters Bangladesh. Both the branches later join Meghna River.

Minor Rivers of Mizoram and Manipur: Some minor rivers of Mizoram and Manipur flow south eastwards and do not join the Brahmaputra and Barak River systems of NER. Rather, they drain directly into Bangladesh and Myanmar.

Figure 1. Map of River Basins of North Eastern Region of India

Water Resources of NER

Renewable water resources include the water yearly replenished in the process of water turnover in an area. The annually renewed volume is usually measured in Km3/year (volume per unit of time). It consists mainly of the regional runoff and the inflow of groundwater into the river network. Renewable resources also include the yearly renewable upper aquifer groundwater that is not drained by the river systems. The NER, comprising mainly of three river systems is richest in water resources in India. The per capita and per unit area availability of water in this region is the highest in the country. The per capita distribution of water resources in the Brahmaputra and Barak valley is as high as 16589 m^3 which is much higher than that of the national average of 2208 m^3.

The river Brahmaputra, Barak and their tributaries, form the largest perennial water system not only in NER but also in India. The average annual runoff of two major rivers in the region is 585 Km^3 which constitutes about 31% of total surface water potential of India. However, total surface water potential of the region has been estimated about 616 Km^3 which forms 32% of total surface water potential of India i.e. 1869 Km3. (Table 1). The region receives about 510 Km^3 of water annually as rainfall flowing through a riverine length of about 19 548 km. It has immense potential for energy, irrigation and also transportation.

In general, the mountainous and hilly regions do not allow adequate infiltration and as a consequence, groundwater is mostly limited to valleys and other low lying areas.

Groundwater is therefore scattered where fissures permit adequate storage or is found in shallow depressions near the surface. As a result, the overall yield potential in this region is low although some areas may see medium to high potential depending on the local geo-hydrogeology. Based on hydro-geological and related data generated by Central Ground Water Board regarding ground water availability, the total replenishable ground water in India is estimated to be about 432 Km^3. However, in the NER it is estimated to be about 54 Km^3 roughly 12.5 per cent of the total available ground water resources of India (Table 1). The ground water in NER has been found mainly distributed in Brahmaputra and Meghna-Barak basins and yet to be developed for proper use.

Table 1: Basin wise Replenishable Water Potential of North Eastern Region of India vis-à-vis Total of India

Sl. No.	Basin	Average Annual Water Potential in Km^3/year or BCM/year	Percentage of Total Water potential of India
1.	Surface Water		
a)	Total of India (20 basins)	1869.35	100.00
b)	Brahmaputra , Barak Valley & Others	585.60	31.33
c)	Minor River Basin Drainage into Bangaladesh and Myanmar	31.00	1.66
d)	Total Surface Water Resources of North East India	616.60	32.98
2.	Ground Water		
a)	Total of India (18 basins)	431.42	100.00
b)	Brahmaputra	26.55	6.15
c)	Meghna	8.52	1.97
d)	NE Composite	18.84	4.37
e)	Total Ground Water Resources of North East India	53.91	12.50
3.	Total Replenishable Water Resources of North East	670.51	29.14
4.	Total Replenishable Water Resources of India	2300.77	100.00

Table 2: Total Replenishable Water Resources and Geographical Area of North Eastern Region of India vis-à-vis Asia and World

Sl. No.	Geographical Unit	Replenishable Water Resources		Geographical Area	
		Average Annual Water Potential in Km^3 or BCM	Percentage of Total Water potential of the World	Geographical Area in Sq. Km	Percentage of Total Geographical Area of the World
1.	North East India	670	1.6	262,179	0.18
2.	India	2300	5.4	3,287,263	2.28
3.	Asia	13510	31.6	43,998,000	30.57
4.	World	42750	100	143,904,550	100.00

Table 3: Catchment Area of Major Basins in North Eastern Region vis-a-vis India

Sl. No.	**River Basin**	**Length (Km)**	**Catchment Area (Sq. Km)**	**Percentage of Total Catchment Area of Indian Rivers**
1.	Brahmaputra	916 +	194413+	7.69
2.	Barak Valley & Others		41723+	1.65
3.	Total of NER		236136+	9.30
4.	Total of all Major Basins of India		2528084	100.00

Hydroelectric Potential of the region

The hydroelectric power is a renewable and non-polluting source of energy. Hydroelectric generation provides a number of economic, operational and social advantages over other modes of energy. Storage-based hydropower schemes often form part of multipurpose river valley projects and render benefits such as flood control, irrigation, water supply, recreation etc. The hydroelectric power potential of the Brahmaputra basin alone has been estimated by the Central Electricity Authority, Government of India to be about 66000 MW, which is over 40% of the total hydroelectric power potential of India. It can be developed for improving the energy situation of the NER as well as .of the country. Multipurpose reservoirs can be used for development of aquatic resources, irrigation facilities and domestic water supply.

Status of Water Quality in NER

A number of chemical, physical, and microbial factors negatively affect water quality in the NER. This leads to severe water pollution in some areas and adversely effects the aquatic life. Contamination enters the water bodies through one or more of the following ways: (1) Direct point sources- Discharge of pollutants from municipal/industrial/domestic sites into nearby water bodies. (2) Diffuse sources- Runoff and soil erosion from agricultural lands carrying agrochemicals applied during agricultural use, mainly fertilizers, herbicides and pesticides; acidic discharge from mining areas etc. In NER both the above sources contribute towards pollution of water resources. However, water pollution is limited to certain localized areas near human settlements, agricultural farms using agrochemicals and mining areas.

The major point sources include transfer of sewage and untreated wastewater from urban agglomerations, towns and large settlements into nearby water bodies resulting contamination with organic matter, microorganisms, chloride ions, etc. Polluted water shows high BOD value and high coliform count. Lack of adequate wastewater treatment facilities in most towns of NER further aggravates the problem.

The notable diffuse sources in NER include runoff from tea gardens and agricultural fields which include various agrochemicals such as fertilizers, herbicides and pesticides. Soil erosion is a serious problem in the region that contributes suspended solids in water bodies and responsible for high level of total suspended solids (TSS) in water. In mining areas of the region (coal mining areas of Meghalaya and Assam) acidification, turbidity and high concentration of sulphate and heavy metals are common problems of local water bodies. The most common method of disposal of solid waste in many parts of the region is by throwing it into nearby rivers and streams. As result, most of the water bodies near urban areas are highly polluted with organic matter and infectious agents.

Conclusion

North Eastern Region of India is rich in water resources particularly surface water. However, most of it is lost in runoff. In order to ensure optimum use of the water resources, storage of the surplus monsoon runoff is necessary at suitable dams, reservoirs, embankments on the basis of regional understanding and co-operation for better utilization of the available water resources and socio-economic development of the region. Simultaneously, necessary steps are required for efficient use and conservation of water resources, their sources and local hydrology. Water quality issues also need to be addressed for abatement and control of water pollution in the region.

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