STATUS OF WATER RESOURCES RESEARCH IN SRI LANKA AND THE POTENTIAL FOR FURTHER STUDY

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HYDRAULIC CIVILIZATION IN EARLY HISTORY

Sri Lanka has the unique distinction in the history of mankind of having developed a *hydraulic civilization* even before the beginning of the Christian era. As Brohier records in his monumental work, ancient Sri Lankan engineers were even called upon to help in the solution of hydraulic problems of neighboring countries. The hydraulic structures that have survived to this day, such as long canals with imperceptible gradients, *bisokotuwas, ralapanawas* and *cascades of village tank systems*, bear ample testimony to the high achievements in irrigation management and technology. The water-sealed toilet systems (Anuradhapura and Polonnaruwa), and ornamental fountains in landscape gardens (Sigiriya) indicate great skills in the management of urban water supply and waste disposal systems.

The reasons that led to the collapse of this ancient hydraulic civilization around the twelfth century, constitute an academic field where many imaginations have wandered. The climatic change, malaria, impoverishment of soil, foreign invasions and famine represent only some of the reasons attributed to this historical catastrophe. Paranavitana, the veteran archaeologist and historian of Sri Lanka, believed that the breakdown of the efficient management of the irrigation systems was a result of the debilitation or the annihilation of *kulinas*—the nobility who possessed water-resources expertise—by invading South Indian forces, and that this acted as the immediate cause of the collapse of the hydraulic systems on which the civilization depended heavily. These water experts had their own standard and insignia as reflected by the symbol of the multi-hooded cobra found at the sites of major ancient water works. Others attributed it to a *push and pull* process that attracted the people to wetter areas while there was a *push* from the dry zone.

Whatever the reasons attributed to the collapse of the *hydraulic civilization,* the experience of its development and decay brings out several important historical facts. The first is that the development of ancient hydraulic systems was rooted in some indigenous scientific wisdom, which grew over the centuries through experience, external input and sheer trial and error. Although it is likely that this knowledge would have passed down from generation to generation by word of mouth, at least some parts of it would have been recorded in inscription, copper plates or *ola* leaf. It appears that much of this ancient knowledge could have been destroyed or lost along with the collapse of the civilization. However, it is still possible that at least a small proportion of this documentation exists in unknown homes, temples and other places. Much of the knowledge carried by the water resources nobility and usually passed through word of mouth with, of course, a certain element of *guru musti* would have disappeared along with

their annihilation. On the other hand, those who were spared by the sword of the invader receded into oblivion and lived in the territory that was taken over by the jungle tide. It is perhaps possible that, *wannihuru or wanniars*[1] of the north central regions constituted this residual element of ancient water resources expertise. After the collapse of the major irrigation works, *wannihuru* continued to live in the *purana* villages fed by old village tanks, which were organized into *cascading* systems with sustainable land use that survived for centuries. It is obvious from this brief historical caricature that the management of water resources during ancient times remains an area of research, which is largely unchartered.[2]

Water Resources Management during the Kandyan Period and Colonial Times

The colonial period which began in the early sixteenth century with the occupation of the maritime provinces by the Portuguese, and subsequently by the Dutch created a fresh interest in the development of water resources in the coastal areas while traditional practices continued to remain in the interior. In the hill country where the rule of indigenous monarchy prevailed, the traditional irrigation systems that developed in the dry zone plains underwent certain interesting adjustments. At first, the march of capital cities and centers of population from the dry zone to the intermediate climatic zones led to the development of smaller tank systems that suited the conditions of shorter dry-period water shortages. Thus the highest densities of old *(purana)* village tanks are found in the interior of the northwest and in the south and southeast.

A different form of hydraulic civilization developed in the hill country where hills and their slopes were used as store houses of water in place of village tanks. The canal systems that were constructed around the hills collected both groundwater and surface water and conveyed the collected water to the rice fields located in the *deniyas* which provided names for not only places but also the people. The small tanks, however, did not disappear altogether, and remained even in places like Amabagamuwa (near Nawalapitiya), which is located in the highest rainfall belt in the country. Many canal systems fed by hill forests as well as by Kandyan Forest Gardens also protected the villages from land slides. The implications of changing land use on hydrology and slope stability in the hill country, particularly after the advent of plantation agriculture, remains an area with much potential for research.

During the Portuguese and Dutch periods, the focus of water resources development activity was on the coastal belt, which these invaders occupied in turn for approximately 150 years each. Here the flood protection works and canal systems for navigation would have required feasibility studies of a scientific nature. At the same time, some of their ecological implications were gradually becoming evident as in the case of the possible transformations at Muthurajawela. However, the studies during the Portuguese and Dutch periods are important as they represented the first attempts at bringing the western scientific knowledge for water-related development activities in Sri Lanka.

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[1]The word "vanni" is usually taken to denote, a forest or a forested area; It can also be taken as ""vahni" or flowing substance as in the case of the origin of the term "ana" or the spill-way.

[2]Most of the writings on the collapse of the hydraulic civilization are in the form of descriptive writings by the historians and archaeologists. However, ancient irrigation works have attracted the attention of surveyors (such as R.L. Brohier) and more recently of engineers (such as D.L.O. Mendis).

During the British period, particularly after the fall of the kingdom of Kandy, attention was shifted to the interior where they promoted plantation agriculture. In the latter stages of the British rule, interest in renovating ancient irrigation works, particularly in the dry zone, was initiated. The more benevolent Governors such as Henry Ward and Gregory took the initiative in this regard. Thus Le Mesieur in his Manual of the Nuwara Eliya Distrct stressed the need for protection and maintenance of the intricate canal systems in the drier areas of the hill country. This marked the beginning of interest in water resources development during the period culminating in the establishment of the Irrigation Department at the turn of the century. The Irrigation Department has remained in the forefront of water resources development since its inception and has contributed much to the development of expertise in the field. The Department of Agriculture, begun again during the British period, contributed to this effort in a different way. To date these two departments represent the main repositories of knowledge on water resources of Sri Lanka.

At the same time, the emerging adverse impacts of indiscriminate clearing of montane forests for plantation agriculture were gradually recognized. The need for protection of land above 5,000 feet for stream reservations, and for soil conservation led to several studies, primarily through the committees and commissions appointed by the colonial government from time to time as reflected by the Committee on Soil Conservation appointed in 1931. This process was facilitated during the path to National Independence through the executive committee system of the State Council. The appointment of the Land Commission of 1927 and the introduction of the Land Development Ordinance of 1935 under the able guidance of Hon. D.S. Senanayake, the then Minister of Agriculture and Lands, gave the much-needed fillip to irrigation and water resources development. Food shortages during the period of war provided some impetus to promote irrigation schemes even in the hill country.

Water Resources Development and Research since National Independence

With National Independence in 1948, a concerted effort was made to develop water resources through irrigation projects such as Gal Oya, followed by Uda Walawe and subsequently Mahaweli, which even attracted some criticism. However, the renovation of ancient irrigation works and rehabilitation of minor irrigation systems continued along with the construction of a few new ones. In the meantime, hydropower development, flood control, water supply and sanitation and land reclamation programs gained new vigor and dynamism under a new political leadership. Thus the Laxapana hydropower station, though proposed in 1918, was commissioned only in 1950. On the other hand, the mini-hydropower plants in the plantations, which were operational during the colonial period, were gradually neglected. Similarly, the preoccupation with large-scale irrigation projects led to a relative neglect of small irrigation systems and groundwater development until recently.

The research output in the field of water resources is also directly or indirectly related to the development efforts in the field. The international involvement in the development of water resources in Sri Lanka had been a major factor in encouraging research and publications. The development of aerial photography covering the entire island in the mid-fifties, among other things, opened many vistas for water resources research. Thus the Hunting Survey Corporation that conducted the air surveys was responsible for an array of reports on the resources of major river basins. This also led to the compilation and systematization of data on the hydrometeorology of Ceylon.[3] This was followed by studies that led to the formulation of the Mahaweli Master Plan. It resulted in several studies on Climate and Hydrology and the modernization of data collection under the Hydrological Crash Programme.

Considerable interest in water resources research was generated during the International Hydrological Decade and its successor—International Hydrological Programme. A National Committee based at the Irrigation Department was established and several seminars and conferences were held under its impetus. However, some writings that arose from such activity did not find an outlet for publication for many years. Many research studies resulting from internationally funded water-related projects too remain unpublished. With the opening of the economy in the late 1970s, consultancy reports became a more common medium of conveying research findings. Thus the environmental assessment report for the accelerated Mahaweli Developemnt Programme and the Master Plans for Forestry, Coast Conservation, etc., were based on investigations that generated valuable information.

A large proportion of the data as well as any research output of government agencies came through the administrative reports, and the reports of committees and commissions set up by the government from time to time. The report of the Director, Department of Meteorology, and the publications by the Departments of Irrigation, Surveyor General and Agriculture, as well as those by the Water Resources Board and the Mahaweli Authority provide some valuable sources of information. However, much of the hard and fundamental research had come from the universities and research institutes, both local and international. The outlets for publication of research in the form of journals and occasional publications also remained largely with such institutions. The learned professional societies such as the SLAAS and the Institution of Engineers have provided fora at which researchers could present and discuss their findings. A noticeable fact here is the relatively insignificant involvement of the local private sector in the water research field.

Publications on Water Resources

There is hardly any comprehensive bibliography on water resources covering their manifold aspects, except those maintained occasionally by the research institutes and the universities concerned. An attempt has been made to compile such a bibliography from the personal library of the writer. This is only a preliminary step. It is anticipated that a comprehensive bibliography on water resources of Sri Lanka will eventually be developed by pooling resources and through the National Water Conference.

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[3]In 1972, the name "Ceylon" was changed to "Sri Lanka" with the new constitution of the countrys' parliament.

It is noteworthy that there are hardly any journals particularly devoted to the publication of papers arising from water resources research. There are a few newsletters, and popular magazines published by some government agencies that contain papers of informative and educational value. The most common local outlets for research seem to be in the journals published by NARESA, Department of Agriculture and the Institution of Engineers, SLAAS and those in the universities. At the universities many post-graduate dissertations related to water research seem to remain unpublished although some papers arising from them are published elsewhere.

Since its inception, IIMI has contributed immensely to water research in the irrigation sector, both nationally and globally. A narrower definition of water management adopted during the early phase of the Institute confined its activities largely to major irrigation systems and their more socioeconomic and institutional aspects of management. The recent expansion of the scope of IIMI (altered to IWMI) activities to focus research on the 'analysis of water use at the water basin level, and the identification of the practices for managing irrigation supplies that will lead to real water savings, reduction in soil salinity, and higher water productivity,' is undoubtedly a step in the right direction through which water research could be organized more holistically. In terms of publications and dissemination of knowledge, IWMI is taking a leading role in the field of water resources. It may be somewhat premature to evaluate the actual impact of IWMI on agrarian societies and on food security in relation to the investments made. There is a belief that IWMI should engage more on research to develop technology than on the soft socioeconomic aspects of irrigation.

It is encouraging to note the increase in the volume of publications related to water resources of Sri Lanka since national independence (figure 1). Although no claim is made to the completeness of the bibliography presented here, it is assumed that the growth of publications since national independence has been steady and significant. The takeoff in the 1960s may be attributed to the impact of the activities of the Hunting Survey, Mahweli Project Planning and the International Hydrological Decade.

Survey on Water-Related Research in Sri Lanka

In order to get an understanding of the present status of water research in Sri Lanka, a questionnaire survey was conducted by the Conference Organization with the help of a sample of knowledgeable persons in Sri Lanka who could be easily accessed. The questionnaire was divided into three parts: (a) Contact Information and Institutional Affiliation, (b) Opinions on Strengthening Water Research in Sri Lanka, and (c) Information on Organizations Conducting Water Research in Sri Lanka. The questionnaire was brief and was not intended to be a comprehensive survey on the subject. In all, 62 questionnaires were returned by the persons from whom information had been requested. A breakdown of the sample of persons who responded is given in figure 2.

Figure 1. Publications on water resources of Sri Lanka.

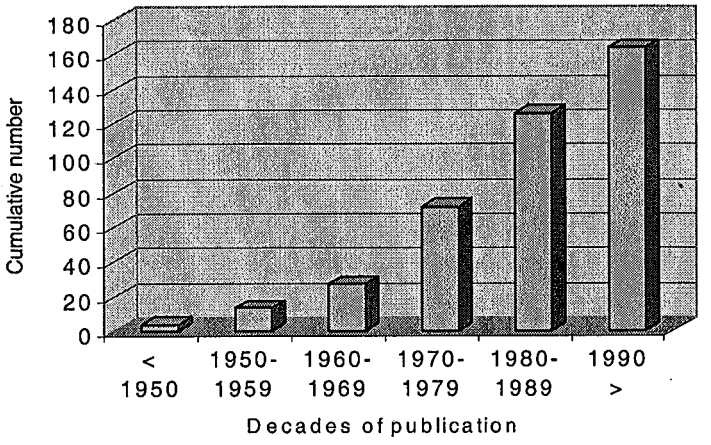
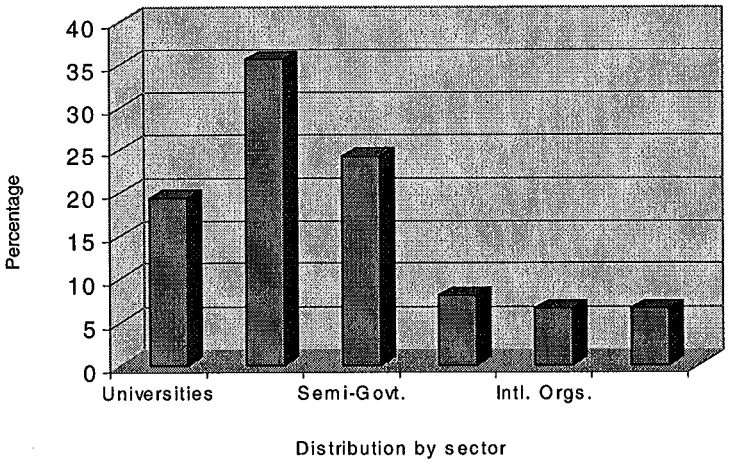


Figure 2. Distribution of sample.



As could be seen in figure 2, the largest proportion of responses were from governmental organizations such as Ministries and Departments. The semi-governmental sector including Boards and Corporations came next and accounted for nearly 25 percent of the sample. The universities, which comprised the next category represented nearly 20 percent of the sample. While the private sector accounted for 8 percent, the balance was from international organizations like IWMI and the World Bank (4%) and individuals (4%). In view of the heavy responsibility cast on governmental agencies and corporations in water resources management, it is presumed that the sample is broadly representative.

The answers received for questions 1,2, and 3 are listed in tables 1, 2, and 3. With regard to important topics for water-related research in Sri Lanka, there was a wide variety of opinion. What is listed in table 1 (as well as in 2 and 3) is only a summary and a short list with key words where most duplicating answers were avoided. An attempt to classify the suggested topics tend to fall into the following categories in terms of frequency and ranking:

- Policy, planning and institutional
- Irrigation and agriculture
- Water quality and treatment
- Environmental and coastal
- Economics of water use
- Watershed management
- Groundwater
- Water resources information and education
- Rainfall and rainwater harvesting
- Other topics

The first three broad areas of topics accounted for nearly half the total responses. It appears that policy, planning and institutional issues provide the most important topics for water research in Sri Lanka. This may partly be due to the preponderance of government agencies in the sample.

The responses to the question on the consequences of inadequate water-related research were more specific than the topics for research. Here, in terms of ranking, the most important categories were: poor coordination in policy and planning; environmental problems; lack of public sensitivity and underinvestment; and improper use of water in irrigation and agriculture. All others including health, hydropower, social welfare, etc., accounted for the balance.

The response to questions 2–6 in general reflected the recommendations suggested by the respondents. The list of recommendations as appearing in table 3 is much longer and proved difficult to classify compared with responses to the questions on topics and consequences. However, the most significant feature here is the overwhelming agreement that there should be a centralized agency to manage water resources and related research activities. This was expressed through the use of a variety of terms such as, authority, institute, council, commission, interagency committee, etc. It appeared to be based on the premise that there is a lack of coordination resulting in duplication of effort and wastage of resources. With regard to funding, nearly two-thirds of the respondents felt that water resources research is only partially funded or not funded at all, and that this fact is a serious limitation for research.

Only a limited number of responses were received for the long list of questions under the category on Organizations Conducting Water Research and Investigations. It appears however that, a large majority of organizations are involved with applied research rather than with basic or fundamental studies. Even the universities seem to prefer applied research in view of better prospects for locating funds. Most organizations that undertake water research seem to

address a wide variety of issues but with greater concern on environmental and watershed-related aspects. The most common disciplines represented in the organizations include hydrology, agronomy, engineering, sociology, economics and chemistry, while occasional mention was made to geology, biology and geomorphology. This may be taken as a reflection that, at present, water research is primarily a task of civil engineers and agricultural scientists.

The survey also reveals that most organizations keep in touch with current research in their fields, through conferences, personal contacts and professional journals. The majority of them also have mentioned that they collaborate with others. Most of the organizations decide on their research priorities through ongoing programs and consultation with clients.

Conclusions

It appears that, despite serious limitations of funding and coordination, a substantial amount of research on water resources is undertaken in Sri Lanka. The growing number of publications on water-related themes during the last few decades indicates the increasing interest and output in research. However, in order to meet the challenges posed by threatening water scarcity, deterioration of water quality, wastage of resources, and increasing competition and conflict in sharing the available resources, Sri Lanka has a long way to go in developing a better research culture. To achieve this end, the need to establish a centralized agency with constitutional authority is now felt more than ever before.

Table 1. Most important topics for water-related research.

- Water quality deterioration and monitoring
- Water conservation and optimal utilization
- Water yields of catchments
- Irrigation performance
- Domestic water use
- Quantitative and qualitative assessment of surface water and groundwater
- Collecting, recording and updating water-related data
- Groundwater-related research
- Economic value of alternative uses
- Pricing mechanism for water use
- Conjunctive use of surface water and groundwater
- On-farm water management issues
- Regional water balance studies
- Water-use-related education
- Drainage and its effects on salinity
- Rainwater harvesting
- Planning of water resources

- Political commitment for water source protection
- Implications of devolution of power
- Catchment management and hydrological impacts
- Low cost water treatment option for rural areas
- Water resources information systems
- Planning for reduction of water use for agriculture
- Strengthening water user institutions
- Low-cost, appropriate technology
- Algal toxins
- Dynamic roughness filters
- Sectoral demand for water at present and in the future
- Rational and equitable allocation of water
- Urban and industrial water supply
- Gender and water
- Wastewater treatment and disposal
- Supply of potable water in areas of tourist interest
- Studies on deep groundwater
- Salinity intrusion of surface water and groundwater
- Crop water requirements
- Impacts of forest crops on groundwater
- Effect of water use on the environment
- Small catchment hydrological research
- Socioeconomic problems related to watershed management
- Improved characterization of rainfall probabilities
- Relationship between water rights and property rights
- Irrigation and land tenure
- Water problems related to sea-level rise
- Irrigation management and reservoir sedimentation
- Coastal zone management
- Treatment of industrial effluents
- Monitoring of surface water and groundwater quality
- Mitigation of drought impacts
- Impacts of global climatic changes
- Hydro-politics
- Policy research, cost-effective policy formulation
- Longshore currents and sediment transport
- Low water use efficiency
- Environmental pollution of inland freshwater
- Drainage problems in agriculture
- Irrigation and weed control

- Small tank irrigation research
- Beneficiary participation in decision making for water use
- Ability of farmers to pay for irrigation water
- Reuse of irrigation water
- Abstraction limits on groundwater and surface water
- Industrial end of pipe water quality
- Coordination of water policies with other national policies
- Tradable water rights
- Evaluation of polluted waters for their potential use
- Risk assessment of land areas for their suitability to various uses
- Water as an economic good in Sri Lanka
- Waterborne diseases
- Bureaucracy, water and farmers
- Analysis of agro-chemicals in water
- Industrial pollutants, metals and organic compounds in water
- Institutional strengthening of water sector organizations
- Private sector participation in the water sector
- Regulatory bodies/tariffs for extraction of surface water and groundwater

Table 2. Consequences of inadequate water-related research.

- Health problems (spread of waterborne diseases)
- Improper use of water in agriculture
- Landslides
- Poor coordination of research (in agriculture)
- Lack of sensitivity to critical needs
- Overexploitation of resources (groundwater)
- Underinvestment in the water sector
- Loss of potential social welfare
- Planning without due consideration to the availability of water resources
- Inability to meet water demands
- Inability to fulfill project objectives
- Inadequate planning (bi-water Hatton/Dick Oya, gam udawa)
- Unsustainable use of surface water and groundwater resources
- Misallocation of resources (public expenditure)
- Adverse impacts on the environment
- Wastage of irrigation water
- Consumption of poor quality water
- Inefficient allocation of water in irrigation projects
- Underutilization of water resources (rainwater, river water below Randenigala)

- Nonoptimal hydropower generation
- Increase in capital and operational costs
- Consumer sufferings
- Sedimentation problems
- Uneconomical use of water
- Productivity losses
- Conflicts over water resources
- Lack of equity
- Poor policy framework
- Irreversible ecosystem deterioration
- Scarcity of quality water
- Pollution of drinking water
- Interruptions in pumping due to discharge of effluents (Colombo)
- Adverse effects on proper planning of major irrigation systems
- Overlooking of small tank cascades in planning
- Lack of appropriate catchment parameters for planning
- Emerging water quality and salinity problems (Mahaweli)
- Siltation of dams (Polgolla)
- Pollution of metropolitan waterways
- Insufficient recharge capacity in agro-wells
- Multiplicity of water-related institutions
- Erroneous decision making related to irrigation and agriculture
- Adverse impacts of sea-level rise on water supply schemes
- Coastal erosion
- Unexpected threats to aquatic life (prawn farming)
- Slow economic growth
- Limited number of trained scientists
- Poor yields — poor income — poor people
- Delayed policy corrections
- Expensive, misguided irrigation projects
- Failure of water resources projects (Nilwala, coastal drainage)
- Scarce resources dissipated on unimportant areas while problems of farmers remain unresolved
- Increase in rehabilitation costs
- Increase in the cost of provision for health care
- Failure of ADA's dug-well program in Galgamuwa AGA division
- Lack of data for pollution control
- Increase in the possibilities of water poisoning
- Water shortages during severe droughts
- Waste of water during rainy seasons
- Increase in freak flooding

Table 3. List of recommendations.

1. Provide funds for university students for research
2. Set up an irrigation agronomy research institute
3. IWMI should engage in research to develop technology rather than focus on socioeconomic aspects
4. Local water institutions should be integrated into a common agency
5. Irrigation Department to have a Division of Irrigation Agronomy
6. Involve and obtain participation of beneficiaries
7. Integrating water studies into school and university teaching
8. Research should address real issues
9. Create more public awareness
10. Interagency coordination to be enhanced through a Water Resources Council
11. Encourage regular publications through electronic networks
12. Create a central agency like the Water Resources Secretariat
13. Establish one or more water resources research centers preferably attached to universities
14. Publish a biannual journal
15. Develop a central database
16. A systematic identification of priority areas for research
17. Identify critical areas of research based on an assessment of needs
18. Identify the capacities of each institution currently involved in water-related research
19. Establish a National Committee on water-related research
20. Eliminate superfluous research conducted by different institutions
21. Encourage collaborative research with international agencies
22. Relate water resources research to national development needs
23. Improve trained manpower in the water sector
24. Test the research findings with the beneficiaries
25. Establish a National Coordinating Committee for water research
26. Government agencies should have a separate research vote
27. Introduce a more efficient extension service
28. Make funding available to universities on a priority basis for water research
29. Introduce more courses related to water at the university
30. Recognition by way of reward should be made to outstanding researchers
31. Establish an independent central agency
32. Publicity of problems faced by the managers will help in orienting research
33. Establish a coordinator position in each major institution
34. The Water Resources Secretariat must act as the coordinator for all water agencies
35. Provide basic research facilities such as equipment
36. Establish a research and development fund
37. Involve the private sector in the management of water resources
38. Incorporate research findings to national and regional planning

39. Improve interagency interaction including politicians
40. Create a think tank (brainstorming group) linked to WRS
41. Agree on a standard format for information on water research
42. Draw up a research master plan for all major agencies
43. Centralize in one organization
44. All revenue earning agencies to contribute to a research fund
45. Set up and promote an interagency standing committee
46. Set up a National Specialist Group drawn from all relevant agencies under the coordination of WRS to draw up a broad agenda
47. Research funding should be at least 0.1% of the value of water used in the country
48. Research budget should be at least 5-10% the overall budgets of implementing agencies
49. Research should be demand-driven and based on the needs of user groups
50. Set up an apex body for inter-institutional collaborative research
51. Introduce hydrological boundaries for regional administration
52. Introduce one responsible agency as a directorate for all water-related activities
53. NARESA should maintain a data bank on available research findings
54. Increase links between research organizations
55. Develop a network of parties involved
56. Implement Land Commission recommendations to establish a Watershed Management Authority or a Central Body
57. Establish a well-endowed national water prize for research
58. Offer doctoral fellowships to train young scientists
59. Devote at least 1% of the budget for externally funded projects
60. Harness more modern electronic technology for water research
61. Establish a permanent commission on water resources management
62. Promote proper coordination among the research organizations and regulatory authorities
63. Set up technical working groups
64. Encourage effective use of electronic media
65. Establish a water resources coordinating institute
66. Publish seminar and conference proceedings
67. Translate research findings to swabhasha
68. Establish a Water Management Research and Training Institute at national level
69. Scientist and technologist should replace ignoramuses in framing policy and management
70. Raise funding level to 1% of GDP
71. Formulate a regulatory and legislative framework
72. Establish a Central Water Resources Authority with statutory provisions
73. Create awareness programs at school and university levels
74. A wealth of practical knowledge is available among practicing engineers and there should be some means of harnessing this knowledge
75. Let juniors be engaged in basic/fundamental research while seniors involve in applied research