ASM Position Paper 2/2014

A Study on the Current Status and Needs Assessment of Water Resources Research in Malaysia

VOLUME 2

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Foreword

Congratulations to members of the ASM Task Force on Water R&D for producing this Advisory Report on 'Setting a National Agenda for Integrated Water Research'. This Advisory Report is the outcome of an ASM-commissioned Study on the Current Status and Needs Assessment for Water Resources Research in Malaysia. The Study was commissioned in June 2012 and was completed in May 2014. Subsequently, a set of summary conclusions and recommendations based on feedback received from stakeholders during Strategic Consultative Laboratories (SCL) on Water R&D was presented.

Malaysia zas embarked on a National Transformation Program, including the adoption of Green Technology on its road towards the achievement of Vision 2020. The Water Sector is an integral part of this mission and needs also to move in tandem. The Water Sector Transformation Road Map comprises of a wide array of strategic action plans anchored by a central Integrated Water Resources Management (IWRM) Implementation Road Map. The main goal of this Integrated Water Research Framework is to seek and provide ***sustainable solutions*** in support of Malaysia's water resources development and management plans pursued along essentially two discrete objectives, namely 'water as a resource and related wealth creation', and 'water for livelihood & wealth creation'. Therefore, a sustained **multi-disciplinary** water R&D program is a pivotal and essential prerequisite **to ensure that the best of science, engineering, technology and innovation** is harnessed for national good and advantage.

This Advisory Report is yet another important deliverable of the Academy of Sciences Malaysia as part of its mandate to provide strategic advice to Government. We are confident that the findings, recommendations and strategies contained therein would assist the Government in the implementation of a robust and continuing water R&D programme to ensure increased resilience and provide timely solutions to the many issues and challenges facing the country's water sector. It would also be in line for the achievement of the country's post-2015 Sustainable Development Goals (SDGs) for the water sector; an outcome from the recent Rio + 20 Earth Summit held in June 2012 that carried the theme 'The Future We Want'.

TAN SRI DATUK DR. AHMAD TAJUDDIN ALI
F.A.Sc.
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Preface

The Academy of Sciences Malaysia (ASM), an independent think-tank providing strategic advice to Government on Science, Technology and Innovation (STI) matters, has since 2008, been undertaking studies pertaining to the water sector, considered strategic for the country's economic development. The studies have been overseen by a dedicated ASM Water Committee. Adopting IWRM as the central thrust and noting that IWRM *per se* is a rather abstract concept, the Committee has for practical application in the Malaysian context, broken down IWRM into discrete subsets or subthemes. Each of these subsets or sub-themes is then subjected to in-depth studies culminating in the preparation of an advisory report, for consideration and adoption by the relevant authority or agency which is responsible for their implementation. The studies have also undergone a process of strategic consultations with relevant institutional, community and private sector stakeholders. One of the key studies undertaken by the Academy, overseen by the ASM Task Force on Water R&D, is this Advisory Report entitled 'Setting a National Agenda for Integrated Water Research'.

In leading up to this Advisory Report, ASM had earlier commissioned a position paper entitled '**A Study on the Current Status and Needs Assessment for Water Resources Research in Malaysia**'. This two-year Study that was completed in May 2014 found that past and current research on water in Malaysia had been largely ad-hoc, fragmented, and very often undertaken with a limited and narrow focus to meet academic interests. Furthermore, there was no clear direction in place to ensure the harnessing of STI to address the country's water management issues and challenges through an integrated and coordinated multi-disciplinary research that was underpinned by an overall R&D framework based on national needs and priorities.

ASM considers that a major revamp of the current institutional arrangements for managing integrated water research is urgently required. In moving forward, ASM has developed, and thus is recommending an appropriate integrated water research framework comprising strategic research themes and need-based research topics which are designed to support the IWRM implementation road map towards sustainable development and management of the country's water resources. ASM also recommends a major revamp to the current water research governance structure, the deployment and provision of adequate human and financial resources that includes a launching grant to kick-start the proposed integrated water research programme.

Indeed, the successful completion of the both the Advisory Report (Volume 1) and the Water R&D Status Report (Volume 2) by the Task Force would not have been possible without the guidance of Academician Tan Sri Shahrizaila Abdullah, the first Chair of the ASM Water Committee, as well as the members of the ASM

Water Committee itself. The completion of the work of the Task force would also not have been possible without the full cooperation, support and commitment of the Task Force members, the Water R&D Study Team and the ASM Secretariat. We commend them for their invaluable contribution. Above all, we would like to place on record our deep appreciation for the strong support and cooperation of the many water-related institutional and community stakeholders from the public, private and NGO sectors who had participated and provided feedback at the Strategic Consultative Laboratories (SCL) held on Water R&D.

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Chairman
ASM Task Force on Water R&D

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Chairman
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Acknowledgement

The Academy of Sciences Malaysia acknowledges with gratitude the Study on the Current Status and Needs Assessment of Water Resources Research in Malaysia Report's Consultancy Team made up of the following Lead Members:

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The other important contributors include Ms Nurfarhain binti Mohamed Rusli and Ms Nor Ai'han Mujar who had helped the consultancy team in organising workshops, internal meetings of the project team, including the documentations for project completion. Ms Zuriany Zaki helped the project team in holding strategic consultation workshops and communicating between the consultancy team, the technical committee of the Academy Sciences Malaysia and other stakeholders especially water experts for interviewing them.

The Academy of Sciences Malaysia would also like to thank Prof Dr Ahmed Fauzi Ismail FASc for providing technical inputs to the consultancy team in improving the final report. Inclusive comments from Tan Sri Ir Hj Shahrizaila Abdullah FASc on the draft of the final report have significantly improved the final project report.

Last but not least, the Academy of Sciences Malaysia would like to record its utmost thanks to the participants of both Consultancy Workshops (SC-1 & SC-2) for their inputs on Water R&D listings. The water experts who dedicated their precious time in face-to-face interviews conducted by the consultancy team for developing priority ranking of Water R&D fields are highly acknowledged by the Academy of Sciences Malaysia.

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%	-	percent
l/c/d	-	liter per capita per day
ACWUA	-	Arab Countries Water Utility Association
AnMBR	-	Anaerobic Membrane Bioreactor
ASM	-	Akademi Sains Malaysia
BOD	-	Biological Oxygen Demand
BOD5	-	Biological Oxygen Demand in 5 days
CAST	-	Controlled Atmosphere Separation Technology
CIF	-	Community InnoFund
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
DAF	-	Dissolved Air Floatation
DID	-	Department of Irrigation and Drainage
DOA	-	Department of Agriculture
DOE	-	Department of Environment
EA	-	Extended Aeration
EC	-	Emerging Competency
eg	-	example
EIA	-	Environmental Impact Assessment
EIF	-	Enterprise InnoFund
EPU	-	Unit Perancang Ekonomi
ERGS	-	Exploratory Research Grant Scheme
EU	-	European Union
FDPM	-	Forestry Department of Peninsular Malaysia
FFPRI	-	Forestry and Forest Product Research Institute
FO	-	Forward osmosis
FOR	-	Field Of Research
FRGS	-	Fundamental Research Grant Scheme
FRIM	-	Forest Research Institute
FTE	-	Full Time Equivalent
FTER	-	Full Time Equivalent Researchers
GAC	-	Granular Activated Carbon
GDP	-	Gross Domestic Product
GERD	-	Gross Expenditure On R&D
GIS	-	Geographic Information Systems
GNP	-	Gross National Product
GWP	-	Global Water Partnership
HRAP	-	High Rate Algal Ponds
HRD	-	Human Resource Development
ICT	-	Information and Communication Technology
ICZM	-	Integrated Coastal Zone Management
IF	-	Impact Factor

IFM	-	Integrated Flood Management
IHL	-	Institutes Of Higher Learning
IIUM	-	International Islamic University Malaysia
ILM	-	Integrated Lake Management
IPASA	-	Institut Pengurusan Alam Sekitar dan Sumber Air
IRBM	-	Integrated River Basin Management
ISI	-	Institute for Scientific Information,
ISM	-	Integrated Shoreline Management
IWK	-	Indah Water Konsortium
IWRM	-	Integrated Water Resource Management
JBA	-	Water Supply Department
JICA	-	Japan International Cooperation Agency
JPBD	-	Department of Town and Country Planning
KeTTHA	-	Ministry of Energy, Green Technology and Water
km	-	kilometre
KTAK	-	Ministry of Energy, Water and Communication
LRGS	-	Long Term Grants Scheme
LUAS	-	Selangor Water Management Authority
m3	-	cubic meter
m3/yr	-	cubic meter per year
Mm	-	milimeter
MARDI	-	Malaysian Agricultural Research and Development Institute
MASMA	-	New Drainage Manual
MASTIC	-	Malaysia Science and Technology Information Centre
MBR	-	Membrane bioreactor
MFC	-	Microbial Fuel Cells
MITI	-	Ministry of International Trade and Industry
MMS	-	Malaysian Meteorological Service
MMU	-	Multimedia University
MNA	-	Malaysian Nuclear Agency
MNRE	-	Ministry of New and Renewable Energy
MOE	-	Ministry of Education
MOF	-	Ministry of Finance
MOH	-	Ministry of Health
MOHE	-	Ministry of Higher Education
MOSTE	-	Ministry of Science, Technology and Environment
MOSTI	-	Ministry of Science, Technology and Innovation
MPKSN	-	Majlis Penyelidikan Kemajuan Sains Negara
MPOB	-	Malaysian Palm Oil Board
N	-	Nitrogen
NAHRIM	-	National Hydraulic Research Institute of Malaysia
NEM	-	New Economic Model
NEP	-	New Emerging Pollutant
NGO	-	Non-Governmental Organisation

NKEA	-	National Key Economic Areas
NKRA	-	National Key Result Areas
NRC	-	National Research Council
NRE	-	Ministry of Natural Resources and Environment
NRW	-	Non Revenue Water
NSRC	-	National Science and Research Council
NSTIP	-	National Science, Technology and Innovation Policy
NSTP1	-	National Science and Technology Policy First
NTSP2	-	National Science and Technology Policy Second
NUP	-	National Urbanization Policy
NWRC	-	National Water Resources Council
NWRP	-	National Water Resource Policy
NWRS	-	National Water Resource Study
O&G	-	Oil and Grease
P	-	Phosphorus
PAC	-	Powdered Activated Carbon
PBT	-	Local Authorities
PCC	-	Per Capita Consumption
PE	-	Population Equivalent
PHA	-	polyhydroxyalkonates
PRGS	-	Prototype Research Grant Scheme
PWD	-	Public Works Department
R&D	-	research and development
RAC	-	Research Advisory Committee
RAPID	-	Refinery and Petrochemical Integrated Development
RBC	-	Rotating Biological Contactor
REDAC	-	River Engineering and Urban Drainage Research Centre
RIS	-	Research Information Systems
RSE	-	researchers, scientists and engineers
RU	-	Research University
S&T	-	Science and Technology
SAJ	-	Syarikat Air Johor
SBR	-	Sequential Batch Reactor
SC-1	-	Strategic Consultation 1
Sg.	-	Sungai
SI	-	specific initiatives
SMEs	-	Small and Medium Enterprises (
SPAN	-	Suruhanjaya Perkhidmatan Air Negara
SPS	-	Sanitary & Phyto-sanitary
SS	-	Suspended Solid
STI	-	Science, Technology and Innovation
STP	-	Sewerage Treatment Plant
SYABAS	-	Syarikat Bekalan Air Selangor
TOR	-	Terms of Reference

UASB	-	Upflow Anaerobic Sludge Blanket
UITM	-	Universiti Teknologi MARA
UKM	-	Universiti Kebangsaan Malaysia
UM	-	Universiti Malaya
UMP	-	Universiti Malaysia Pahang
UMS	-	Universiti Malaysia Sabah
UMT	-	Universiti Malaysia Terengganu
UNDP	-	United Nations Development Programme
UNIK	-	National Innovation Unit
UniTEN	-	Universiti Tenaga Nasional
UPM	-	Universiti Putra Malaysia
USA	-	United States of America
USEPA	-	US Environmental Protection Agency
USM	-	Universiti Sains Malaysia
UTAR	-	Universiti Tunku Abdul Rahman
UTM	-	Universiti Teknologi Malaysia
UTP	-	Universiti Teknologi Petronas
UV	-	Ultraviolet
WOS	-	Web of Science
WRDC	-	Water Research and Development Centre

Executive Summary

1.0 Introduction

Water and water resource problems are becoming more critical every day. In the coming decades no natural resource may prove to be more critical to human well-being and health than water. Yet, a future water crisis is unlikely to materialise as a monolithic catastrophe that threatens the health and/ or economic welfare of large numbers of people. The emerging water crisis will be the sum of many water problems at regional and local scales. Problems include the need to preserve the quality of drinking water supplies, finding sufficient water to support economic growth and the environment, finding ways to make responsive and effective water policies with a modern context, to maintain and enhance water resources quality, and to create water management systems that can be adapted to climate change.

The National Water Resources Policy (NWRP) which was launched in March 2012, for the period of 2010 until 2050, is aimed at determining the future direction for the water resources sector based on a review of the national water resources. The formulation of the NWRP for Malaysia provides clear directions and strategies in water resources management to ensure water security and sustainability for both man and nature. Besides having a solid policy on water resources, the making of good decisions about water issues will also require scientific understanding. The growing complexity of water problems only reinforces the need for new scientific information upon which to base new and innovative solutions. Such scientific understanding can be gleaned only by continuing to invest in water-related research in ways that optimise the effectiveness and productivity of research money. Investment in scientific research needed to better understand water problems and to devise appropriate ways of managing these problems has stagnated over the last four decades. Much of the current Federal and State research agenda is focussed on short-term problems of an operational nature and too little research is focussed on the kind of fundamental, integrated, and longer term research that will be needed to successfully address current and emerging water problems. The sectoral approach of solving water problems is not only ineffective but tends to add more complications. Prominently, R&D activities play crucial roles to promote and support sustainable management of waters. However, diverse and complex water issues have led to a rather fragmented categorisation of water-related R&D activities.

In order to chart a more specific direction for Water R&D direction for Malaysia up to 2020, Akademi Sains Malaysia (ASM) has undertaken a Study on the Current Status and Needs Assessment of Water Resources Research in Malaysia. This task is aimed to support the previous initiative by ASM Water Committee on Sustainable Water Management Programme with the overall goal to manage water resources in a sustainable manner. This is in accordance with Integrated Water Resources Management (IWRM) principles and practices. This Programme has since been expanded to include the realisation of the longer-term twin STI opportunities identified under the Mega Science Framework Study for Sustained National Development for the Water Sector (2010–2050).

The objectives of this study were three-fold: (1) to compile a complete inventory of past and ongoing research on water and water-related topics, duly classified under distinct categories for ease of reference; (2) to assess Water R&D research needs until the year 2020 of different ministries, departments, agencies, companies and public and private NGO sectors; and (3) to review the overall governance of R&D on water for greater effectiveness and efficiency including the need for the creation of centres of excellence in existing institutions or forming new ones to undertake specialised and integrated research on specific thematic areas.

2.0 Situational Analysis

Prior to begin the task of prioritising research field in water and water resources, it is imperative to lay down the background information on R&D related issues that are useful as a basis. This situational analysis is initiated by highlighting the country's economic performance, followed by brief description on water resources availability and demand, water management issues and related policies toward sustainable water management. Additionally, the reviews also captures trend in water technology locally and globally.

The drivers for technology changes in the 21st century have now shifted from waterborne diseases and hazards of the chemicals found in water sources, to more globally challenging issues. These include the dire need of water due to substantial increase in population and hence, water demand, urbanisation, scarcity of resources, and global warming. Additionally, advancement in analytical techniques, increase in public awareness, change in lifestyle, the desire for treatment cost saving, and the installation of more stringent standards and regulations have added to the challenge. While environmental protection, cost, and wastewater reuse remain as the important criteria in treatment technology development; new important consideration factors include energy management, nutrient and material recovery, low footprint in terms of carbon and area requirement, and sustainability.

With global warming and climate change being the current threatening issues, 'sustainability' is an important issue that needs to be addressed. Sustainable practices should include improving access to safe water supplies, reducing costs, energy and chemical usage and without threatening the environment. As for wastewater management, sustainable practices are to provide collection, treatment, and reuse of water in a way that does not adversely impact the health of humans or other species, preserves environmental quality and the integrity of ecological systems, recovers energy and nutrients present in waste, and utilises resources efficiently.

3.0 Trend in Water R&D

Analysis of the publication and grants related to water research showed the dominance of Research Universities (RUs), suggesting a bias towards established universities with significant critical mass of researchers. However, the total grant value awarded was abysmal; for example, only 3% of the total of grants was awarded for the Eighth Malaysia Plan. A majority of the research grants is biased on Science and Engineering. The research level is mostly fundamental and the interest of universities is reflected in their repeated themes in grant applications. Research Universities (RUs), again, showed good intra-institution collaboration and within themselves when publishing their research. However, the result suggests weak inter-institutional collaborations among top authors in Malaysia. The research themes that garner a strong publication output are pollution and river related. In short, the result suggests an unhealthy trend of excessive 'networking' that publishes medium to low impact papers with too many authors within an institution sharing the same publications. The water research community in Malaysia seems to be fragmented along institutional lines and dominant personality as well as research themes that lack multidisciplinary collaborations. The extremely limited allocation of research funds for water themed research would intensify competition and exacerbate the situation in the existing research ecosystem.

The retrospective analysis of the publication and grants related to water research showed the dominance and bias towards Research Universities (RUs). The total grant value awarded for water research was abysmal; for example only 3% of the total grants awarded for the Eighth Malaysia Plan. The research grant award trend showed 83% are fundamental research and 66% in Science and Engineering. An analysis of 3,216 publications, spanning from 1963 to 2012, identified 5,277 unique authors from 814 institutions with publication themes that have focussed mainly on pollution and river-related research. Overall, there is an unhealthy trend of excessive 'networking' that publishes medium to low impact papers, with too many authors within an institution sharing the same publications. There is evidence of weak inter-institutional collaborations, with only strong intra-institution collaboration within established RUs. This suggests that there is a lack of multidisciplinary collaborations, and that there is fragmentation within the Malaysian research community along institutional lines and dominant personality. The extremely limited allocation of research funds for water themed research would intensify competition and exacerbate the situation in the existing research ecosystem.

4.0 R&D Needs from the Stakeholders' Perspective

One of the five project TORs was "to assess research needs in Water R&D until the year 2020". This may include all water resources research areas related to management, environment, policy, planning, supply, demand, storage, stakeholder engagement, hydrology, ecology, irrigation and drainage, and others. For this, stakeholders' consultation is important to see which Water R&D areas are more important than others so that the government may consider these in future Malaysian Plans on priority basis and may allocate more funds to boost research in high priority Water R&D areas.

The consultation of stakeholders was completed in two phases, namely: 1) holding a strategic consultation workshop; and 2) conducting interviews with water experts. In the strategic consultation workshop, a questionnaire designed by the project team was distributed and the stakeholders' priorities on selected 95 Water R&D areas falling in five major categories (i.e. water resources and watershed management; water supply and demand; irrigation and drainage; sanitation, wastewater treatment & environmental issues; as well as water and climate change) were elicited. A total of 22 filled questionnaires were received and data analysis was carried out. The findings of this stakeholder consultation suggested that the water resources and watershed management fields of research should be promoted on a priority basis as the stakeholders perceive that these Water R&D areas may have great influence on fairness allocation of water and these may also have higher role in enhancing water use efficiency.

The other Water R&D that has been identified as second most important was 'water and climate change'. However, we emphasised that the difference between the most important and the second most important Water R&D areas was very small and a definite conclusion could not be made without validating these findings in a larger sample of stakeholders.

The second phase of stakeholder consultation was conducted by interviewing selected water experts whom are attached with different ministries, departments, and NGOs. For this purpose, a separate questionnaire was designed and administered in a face-to-face survey with 12 water experts. The analysis of expert opinion survey data suggested that water resources and watershed management should be placed on top priority in funds allocations. The second most priority should be given to water supply and water demand fields of water research. We believed that expert opinion findings could be trusted more than the consultation workshop as these findings are based on some stable sets of relative importance emphasis.

In order to have more understanding on the findings of the both surveys, the results of the survey were aggregated and a generic list of Water R&D areas was developed. For that purpose, the results of strategic consultation and expert opinion survey were merged and aggregate relative importance weights were generated for all sub-topics in five different categories of Water R&D areas. This report presents details on how these weights were generated and how these could be interpreted in terms of prioritising Water R&D areas. The report also shows three priority listings (strategic consultation, water expert interviews, and aggregate of strategic consultation and water expert interview findings) separately for all 95 sub-topics of Water R&D.

Based on the results of the surveys and interviews, the top fifty per cent (50%) of the subtopics from each topic that were listed in the questionnaire where chosen in which more specific research topics were developed. The research topics were made by carefully examining the current needs and situations of the country. These topics are proposed to help the government to more focus towards allocating funds as well as identifying niche and relevant areas in water research that will benefit the country.

5.0 Setting a National Agenda for Water Research

Currently, there is no formal or informal framework/ mechanism in the country for identifying the nation's water research and development priorities or even for prioritising the nation's water problems on a unified basis. Despite the number of Federal programmes for water research, there is no single catalogue of Federal funds directed to these purposes. A more viable mechanism is needed for setting and overseeing the water resources research agenda in the country and this research agenda should be based on the following main principles:

- The R&D activities must aim at supporting the recently launched NWRP. The policy statement spell out the need for the security and sustainability of water resources to be made a national priority to ensure adequate and safe water for all, through sustainable use, conservation and effective management of water resources enabled by a mechanism of shared partnership involving all stakeholders;
- The water research effort should be aligned towards sustaining the existing resources and towards creating new wealth as discussed in ASM Mega Science Framework;
- A specific policy designed for Water R&D is needed to guarantee that the nation is benefited from the State-of-arts available techniques and tools;
- The concept of Integrated Water Resources Management (IWRM) should be promoted and applied in the country for managing water resources in most holistic and efficient way;
- The core research agenda should develop: (1) greater understanding of the basic processes — the physical, biological, and social which underlie environmental systems at different scales; (2) appropriate environmental monitoring programmes; and (3) research tools to identify and measure structural and functional attributes of aquatic and related ecosystems;
- The national water resources research effort should be coordinated to reduce duplication and to ensure that gaps in water research do not occur; and
- The research effort should be multidisciplinary and interdisciplinary.

6.0 Water Research Fund

The administration of R&D funds is largely related to the Ministry of Science, Technology and Innovation (MOSTI) and Ministry of Higher Education (MOHE). The R&D funds related to MOSTI cluster focuses on research areas namely Biotechnology, ICT, Industry, Sea to Space and S&T Core under 4 types of funds: (i) ScienceFund; (ii) TechnoFund; (iii) InnoFund; and (iv) Flagship Programme. However, the research priority areas under these funds do not indicate Water R&D as an important research area. MOHE also provides R&D funds including (i) Fundamental Research Grant Scheme (FRGS); (ii) Long Term Grants Scheme (LRGS); (iii) Prototype Research Grant Scheme (PRGS). Similarly, Water R&D is not highlighted as significantly important by MOHE as the research project areas in MOHE grant schemes hence limiting the positive outcomes of water research areas. As these funds were offered by the government to academic institutions and various industrial players, it is suggested that Water R&D should be included as one of the research priority areas.

7.0 Water Research Governance

Science, technology and innovation are central to success in today's modern economy. Malaysia first introduced the Science and Technology (S&T) Policy in 1986, followed by the Industrial Technology Development Action Plan in 1990. Within a span of 20 years, among other things, Malaysia has successfully integrated S&T in the national development plan, strengthening out S&T infrastructure, built up human resources for S&T and establishing funding mechanism for R&D. The Government has undertaken a review of the S&T Policy and has launched the Second National Science and Technology Policy and Plan of Action in June 2003. It was formulated to create a conducive environment to further spur the development of science and technology and hence Malaysia's competitiveness. The Second S&T Policy focussed on strengthening research and technological capacity and capability in Malaysia with emphasis on commercialisation of research outputs, strengthening of institutional framework and management of S&T.

However, despite being comprehensive, Water R&D is not highlighted as one of the specific focus area under this policy. Although other initiatives in S&T Policy are also indirectly covering Water R&D, they are not specifically targeting the Water R&D field. Since the third S&T Policy is currently under preparation, it is highly recommended that Water R&D should be specifically given priority in the forthcoming S&T Policy. Availability of water resources equivalent to the minimum demand is government responsibility and guarantees the continuous development activities. Nonetheless, this may not be easily possible if water resource is not placed as the top agenda in the government S&T Policy. Consequently, the absence of Water R&D in the country's S&T Policy may cause some hindrance in the country's development targets and ultimately may slow down the pace to be a developed nation in 2020. Therefore, to remain competitive in the future, the Malaysian Government must support the development of critical bases for future specialisation and competence in carefully selected areas including Water research.

Furthermore, the findings of this study indicate that the present and future needs of the water sector requires the continuous development of a workforce which is both adequate in size, capable in skills and strong in leadership. Thus, the establishment of a Water Research Consortium is proposed as the way forward to facilitate the centralisation of various organisations representing the water sector in Malaysia. Formation of the water consortium will serve as a collaborative platform for water research and its nexus in which NAHRIM becomes the nuclei of this consortium. In this regard, NAHRIM has the main responsibility to ensure the coordination between various academic institutions and research organisations in the management of water research.

8.0 Conclusion

The findings of this study indicate that stakeholder engagement used in devising water-related policies in Malaysia is not encouraging except in the limited involvement of farmers of certain irrigation schemes in the country. However, their engagement in decision-making process is still required to build confidence between the water operators and users. This type of cooperation will ultimately improve efficiency of water application and reduce non-revenue water (NRW) in the country.

Over the past ten years, Malaysia has spent between 0.5 and 1.07% of its GDP for Research and development (R&D). This is still relatively low compared to the developed nations. Water R&D share in total annual GDP investment is very small compared to energy and other sectors. Water R&D field is diverse and precise estimation of total investment in this field is difficult. However, this can be generally ascertained that the government spending on Water R&D may be much less than 0.5% of the country's annual GDP. It is proposed that the government increase the investment in Water R&D to explore new techniques and tools in capturing surface runoff, transporting and managing fresh water resources, and disposing off wastewater to safe locations without adversely affecting the country's population and environment. The regional effects of climate change still need to be assessed to estimate precise amount of fresh water available in the country. This can also be projected by using different climatic models for the next few decades. The accurate amount of available water is necessary for long-term planning in the country as most development activities directly or indirectly depend on the reliable supply of fresh water.

The funding information for this study was provided by the Malaysian Science and Technology Information Centre (MASTIC) and Ministry of Education (MOE). The awarded grants were categorised according to research theme categories (biodiversity, climate change, drainage, energy, pollution, water management and others), geological classification of the water (coast, island, lake, rain, river, waste and undefined) and the type of research (science, technology and social). Analysis of the MOSTI grants data revealed that Research Universities (RUs) received 56% of the research projects awarded in last decade (from 2001 to 2011) with a total of 139 research projects. We also found that the highest number of research grants related to water research was awarded in the 9th Malaysia Plan (2006-2010) by MOHE (159 projects) and MOSTI (88 projects).

The strength of any higher education institute could possibly be judged from the number of publications, which are being published by its researchers. In this study, a bibliometric analysis on past water research in Malaysia was conducted using the data mined from Web of Science (WOS) and SCOPUS. The bibliometric analysis was performed via basic statistical approach such as citations distribution; publications growth, authors' and institutions' networks were carried out. The results are summarised in graphical visualisations to portray the complex bibliographic relationships, trends and patterns. A total of 2,516 publications were identified, with 489 from WOS, and 2,027 from SCOPUS. The period for the publications ranges from the year 1964 to 2012. The report also presents number of publications per institution and analysis of popular authors in different specific Water R&D fields.

It should be highlighted that the study findings have some limitations, which are highlighted in details in the final chapter. These constraints should be taken into account while interpreting and employing the study findings in solving any real world water-related problems.

Chapter1

Introduction

1.1 Introduction

Clean and adequate water supply is crucial for any country to develop and achieve prosperity. Water resources utilisation must go hand in hand with sustainable management of other resources to ensure a clean, safe, healthy, conducive and productive environment for the present and future generations. Water issues are diverse and complex. Unfortunately, they are not always addressed in a holistic manner. More often than not, water and land are seen as separate entities with lack of integration and coordination amongst the parties and professionals involved due to their different interests and backgrounds. The situation becomes even more complicated when land and water matters are assigned to different agencies, sometimes with conflicting management objectives. Water managers have now realised that the sector-oriented approach in natural resource management will only create more problems rather than solving them.

Research and development activities play crucial roles to promote and support sustainable management of waters. Water management problems and their related issues are getting increasingly more complicated and the solutions demand integration of various water-related knowledge. The sectoral approach of solving water problems is not only ineffective but tends to add more complications. Water issues are so diverse; ranging from demand and supply, water pollution, catchment management, policy and institutional, human behaviour to climate change impact. These have led to a rather fragmented categorisation of water-related R&D activities. Presently, there are about 500 FORs entries related to water under the Malaysian Science and Technology Information Centre (MASTIC) data base. A more specific data base pertaining to water is necessary to facilitate assessment of R&D achievement and charting future strategy.

1.2 Role of Academy of Sciences Malaysia

The ASM WEHABE Committee on Water (preceded earlier by the ASM Water Committee since 2008) had initiated the Sustainable Water Management Programme during the 9th Malaysia Plan with the overall goal “to manage water resources (both surface and ground water) in a sustainable manner and in accordance with IWRM principles and practices”. This Programme has since been expanded to include the realisation of the longer termed, twin STI opportunities identified under the Mega Science Framework Study for Sustained National Development for the Water Sector (2010–2050), emphasising on wealth creation and for sustaining the resources. The Programme is also consistent with and complements work done by others towards achieving the goals and objectives of the National Water Resources Policy (2012).

Consistent with the Terms of Reference mandated to the Committee, the main objectives of the programme are four-fold:

a) Provide advice to Government on strategic water and water-related policies, issues and programmes;

b) Setting and facilitating R&D agenda based on S&T needs for the water sector;

c) Raising S&T Awareness, Advocacy and Capacity Building; and

d) Promoting International Networking and Collaboration.

1.3 Study Objectives, Scope and Deliverables

The essential first step prior to the development of the envisaged strategic plan/advisory report on the Water R&D Agenda is the compilation of R&D database from various government agencies and private sectors that have undertaken water-related research. A comprehensive database is essential for assessing the R&D achievement and charting appropriate strategy to move forward. The Study reviews references to previous study reports, conference/workshop proceedings and the like, summary transcripts of interviews with relevant institutional and community stakeholders, from which the main findings and recommendations would be extracted and compiled, leading to a synthesised set of summary conclusions and recommendations presented in a consolidated report to the ASM. The Study also takes into consideration the potential research programmes and initiatives required to support the various thrust areas identified under the National Water Resources Policy's (2012) Key Core Area 1 (Water Resources Security), Key Core Area 2 (Water Resources Sustainability) and Key Core Area 3 (Partnership – Governance Aspects). Of particular importance is the ASM Mega Science Framework Study for Sustained National Development for the Water Sector (2010 – 2050), and the similar studies for agriculture and energy sectors.

1.4 Study Approach

Over the past ten years, Malaysia has spent between 0.5 and 1.07% of her annual GDP for R&D (MIDA, 2013). This is still relatively low as compared to Israel (4.38%), Finland (3.79%), Korea (3.74%), Japan (3.02%), Singapore (2.23%) and Mainland China (1.84%). In view of limited resources for R&D, it is necessary to balance the R&D desires and the reality or constraints faced by the country as shown in Figure 1.1. Being a small country with small GDP, Malaysia has to be very focussed by setting R&D priorities so that the resources are not spread too thin; and being ineffective.

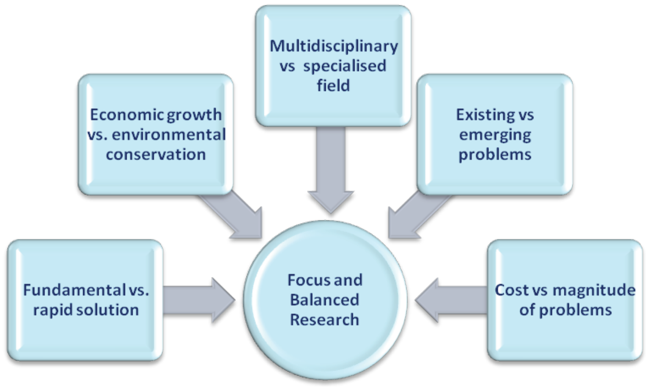


Figure 1.1. Balancing the R&D desires and constraints.

The Study also takes into consideration the increasingly complex water management issues which have evolved from relatively simple and straightforward to complex and diverse. The solutions to the various issues required a holistic and multi-disciplinary approach. An example of the level of complexity involved is illustrated in Figure 1.2, in the case of dam planning and practices. It evolves from merely engineering consideration to economic, environment, socio-economic, indigenous people and now the full understanding of the upstream and downstream interaction, processes and impact. This means that more resources and professionals are required to meet the people expectation and sustainably managed water resources and its ecosystem.

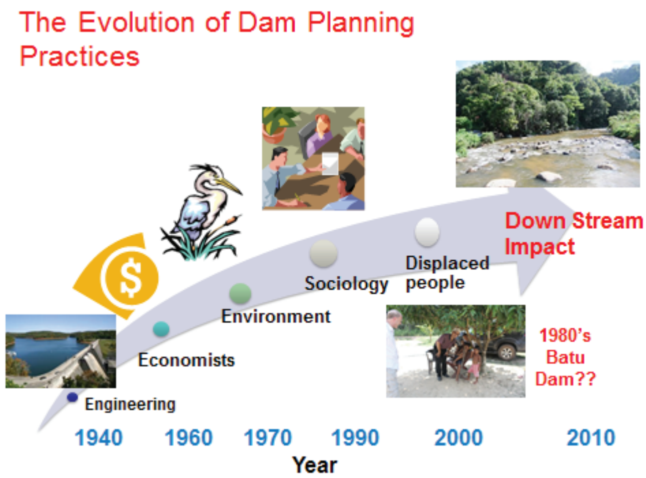


Figure 1.2. Increasingly complex dam planning and practices over time.

1.5 Terms of Reference for the Study Consultant

The Terms of Reference and Scope of the Study are as follows:

i. To undertake the compilation of a complete inventory of past and ongoing research on water resources and water-related topics, duly classified under distinct categories for ease of reference;

ii. To undertake a research needs assessment until the year 2020 of the many ministries, departments, agencies, companies and organisations in the public, private and NGO sectors that are involved in water resources management in some form or other;

iii. To collate information pertaining to current funding mechanisms for water resources R&D, their current levels and distribution according to their funding sources;

iv. To ensure comprehensiveness, all data and information compiled under items (i), (ii) and (iii) above shall be obtained through desk studies, from responses to suitably framed questionnaires, and through interviews with responsible personnel of relevant public and private stakeholder agencies and organisations. Prior to their adoption, all information shall be duly validated with their respective sources;

v. To review the overall governance of R&D on water resources for greater effectiveness and efficiency including the need for the creation of centres of excellence in existing institutions or forming new ones to undertake specialized and integrated research on specific thematic areas;

vi. To extract, compile, synthesise and summarise the findings complete with conclusions and recommendations for submission to ASM; and

vii. To submit a report to ASM addressing items (i) – (vi) above.

1.6 Deliverables

Based on the TOR above, the following outputs will be provided:

a) Actual investment in Water Resources and Hydrology R&D

b) List of R&D related institutes (public private & NGOs) and their respective task or focus

c) Categorisation of R&D areas in Water Resources and Hydrology

d) It will also help in identifying needed knowledge and corresponding water resources research areas that should be emphasised immediately, over the midterm and long term

e) Position paper on national Water R&D agenda

This Final Report presents the complete findings of the study which consists of eight chapters that include situational analysis, review on past and current Water R&D, survey on R&D prioritisation and lists of R&D topics, and proposed new agenda of water research.

Chapter 2

Situational Analysis

2.1 Introduction

This chapter attempts at providing background information on R&D related issues that are useful as the basis for prioritising research field. It starts by highlighting the country's economic performance, followed by brief description on water resources availability and demand, water management issues and related policies toward sustainable water management. The chapter also reviews trend in water technology locally and globally.

2.2 Malaysia Economy and GDP Growth

Malaysia has progressed from being a supplier of raw materials such as tin and rubber in the 1970s, to being a diversified economic nation with economic growth of 7.3 per cent (on average) between 1985 and 1995. After the Asian financial crisis of 1997-1998, Malaysia has continued to post solid growth rates, averaging 5.5 per cent per year from 2000–2008. Malaysia is an upper-middle income economic nation with a gross national income of USD 8,770 per capita (2011). It is a highly open economic country and a leading exporter of electrical appliances, electronic parts and components, palm oil, and natural gas. Malaysia is also externally competitive, ranking 12th (out of 135 economies) in the World Bank 2013 (MOF, 2013).

In 2010, Malaysia launched the New Economic Model (NEM), which aims for the country to reach high income status by 2020 while ensuring that growth is also sustainable and inclusive. The NEM envisions economic growth that is primarily driven by the private sector and moves Malaysian economy into higher value-added activities in both industry and services (New Economic Model for Malaysia - Part 1). To achieve these goals, Malaysia will need better skills worker, more competition, a leaner public sector, a better knowledge-based society, smarter cities, and greater efforts to ensure environmental sustainability.

In 2012, the economy of Malaysia was the third largest economy in South East Asia behind the more populous Indonesia and Thailand, as well as the 29th largest economy in the world by purchasing power parity with gross domestic product stands at US$492.4 billion and US$16,922 per capita. Malaysia's GDP growth was 5.1 per cent in 2012, and projected at 5.0 per cent in 2013 (Figure 2.1).

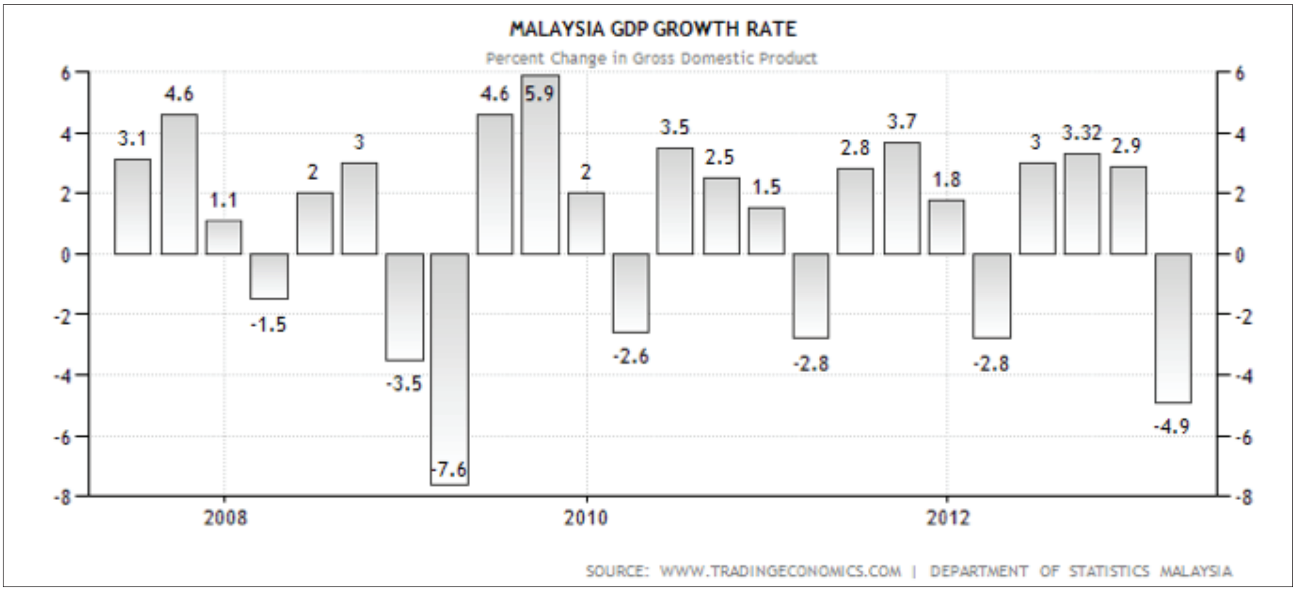


Figure 2.1. Malaysia GDP Growth Rate (Per cent change in GDP)

Source: http://www.tradingeconomics.com/malaysia/gdp-growth

The services sector is set to be the engine of growth for the Malaysian economy going forward, with a target contribution of 70% to the gross domestic product (GDP) by 2015, according to the Ministry of International Trade and Industry (MITI)(Star online, 19/2/2013).

2.3 Water Resources Management

2.3.1 Available Resources

Being located in the equatorial zone, Malaysia is blessed with abundant rainfall. The annual rainfall average of Peninsular Malaysia is 2496 mm whereas Sabah and Sarawak receive 2560 mm and 3640 mm, respectively. When expressed in terms of volume, the rainfall is equivalent to 972.8 billion m^3. Of the total, 495.71 billion m^3 is surface runoff, 64 billion m^3 goes to ground water and the remainder returns to the atmosphere through evapotranspiration (MNRE, 2011). The runoff potential varies between states, ranging from only 0.38 billon m^3/yr for small and relatively dry states like Perlis, to 267.6 billion m^3/yr for the largest State, Sarawak (Table 2.1). More than half of the runoff is available in Sabah and Sarawak, which have lower population density and relatively less water demand than many other states in the Peninsular.

Malaysia depends heavily on surface water, mainly rivers, lakes, wetlands and reservoirs for water supply, which presently constitute 98% of the total water consumption for irrigation, domestic and industry. The remaining 2% is from groundwater. The recently concluded water resources study by MNRE (2011) includes atmospheric water as potential source for future exploration in addition to coastal waters (up to three nautical miles of the Malaysian coastline).

The present water consumption is about 12.5 billion m^3/yr or less than 3% of the available runoff. The demand is expected to increase at about 5% per year due to rapid population increase and industrial growth. By the year 2020, the estimated total demand for the whole country would be 30.4 billion m^3/yr, with increases to 60.8 billion m^3/yr by the year 2040, and 121.6 billion m^3/yr in year 2060. Irrigation will continue to be the largest consumer but the share is expected to decline as demands for domestic and industrial consumption are growing at a higher rate. Provided there are no major changes in the national policy, the water demand for industrial and domestic uses is expected to exceed the agriculture requirement by about 15% in the year 2020.

TABLE 2.1 WATER RESOURCES BY STATE IN MALAYSIA

State	Rainfall	Actual Evaporation	Ground Water Recharge	Surface Runoff	Rainfall	Actual Evaporation	Ground Water Recharge	Surface Runoff
	mm/year				**BCM/year**			
Perlis	1,880	1,290	120	470	1.54	1.06	0.1	0.38
Kedah	2,310	1,430	130	750	21.95	13.59	1.24	7.12
Pulau Pinang	2,350	1,430	120	800	2.46	1.50	0.13	0.83
Perak	2,420	1,320	170	930	52.17	27.77	3.58	20.82
Selangor	2,190	1,280	150	760	18.39	10.44	1.26	6.38
Negeri Sembilan	1,830	1,210	130	490	12.24	8.09	0.87	3.28
Melaka	1,880	1,210	100	570	3.13	2.01	0.17	0.95
Johor	2,470	1,130	200	1,140	47.45	21.71	3.84	21.9
Pahang	2,470	1,250	120	1,100	89.26	45.17	4.34	39.75
Terengganu	3,310	1,470	150	1,690	43.15	19.16	1.96	22.03
Kelantan	2,600	1,290	140	1,170	39.26	19.48	2.11	17.67
West Malaysia	**2,495.5**	**1,283.8**	**147.6**	**1,060.0**	**330.98**	**170.28**	**19.56**	**141.11**
Sabah	2,560	1,190	190	1,180	188.5	87.62	13.99	86.89
Sarawak	3,640	1,250	240	2,150	453	155.56	29.87	267.57
FT Labuan	3,100	1,480	150	1,470	0.28	0.13	0.01	0.14
East Malaysia	**3,238.5**	**1,227.8**	**221.4**	**1,789.3**	**641.78**	**243.31**	**43.87**	**354.60**
Malaysia	**2,940.6**	**1,250.3**	**191.8**	**1,498.5**	**972.78**	**413.60**	**63.45**	**495.71**

Source: MNRE, 2011

At present, groundwater resource is still underused because it is relatively more expensive to explore. The use of groundwater is concentrated in the State of Kelantan. In Sarawak, a number of villages, especially along the coast obtain their water supply mainly from groundwater as the investment for laying pipes from central facilities to these isolated areas is not cost effective. Groundwater is also an important source of water supply in many small islands and is used in conjunction with surface runoff and rainwater.

The first comprehensive water resource study in Malaysia was carried out by JICA (1982) which outlines recommendations for the development of a national water policy and water administration and for staged investment in water resources infrastructure to meet water demand up to year 2000. The report also addresses issues of sewerage management, hydro-power development, flood mitigation, water quality and in-stream water requirements. However, the report provides less emphasis on the aspects of legislation, policy and administration.

The Economic Planning Unit had carried out the second National Water Resource Study in 1998, which addresses key issues to be considered in planning the development of the water resources sector in Peninsular Malaysia, up to the year 2050. This report also formulates recommendations for new initiatives in the policy and management areas of water resources at the Federal and State levels and recommends a staged programme of investments for meeting future demands. Two approaches are adopted in identifying physical source works development. The first is to deliberately exploit intra-State opportunities to the limit before looking for complementary inter-State development options. The second is to identify the most cost-effective solution to solve the problem of future shortages by selecting source works investments regardless of whether the developments are intra or inter-State in nature.

The recently concluded National Water Resources Study (MNRE, 2011), which was conducted by a consortium of consultants (EPU, 2000), provided a comprehensive review on water resources and demand for all States in Malaysia. Interestingly, the study provides lower projections of future water demand by almost half of the earlier national water resources study completed in year 2000 as can be seen from Figure 2.2. The lower projections were obtained based on the following scenarios and assumptions:

a) Lower projected future population, especially due to government policy to cap foreign workers at 1.5 million;

b) Greater demand management which is expected to reduce the Per Capita Consumption (PCC) from 230 l/c/d (litre per capita per day) in 2010 to 150 l/c/d by year 2020 for urban areas and from 160 to 80 l/c/d for rural areas; and

c) Lower non-revenue water (NRW).

The assessment also takes into consideration the possible impact of climate change on water resources.

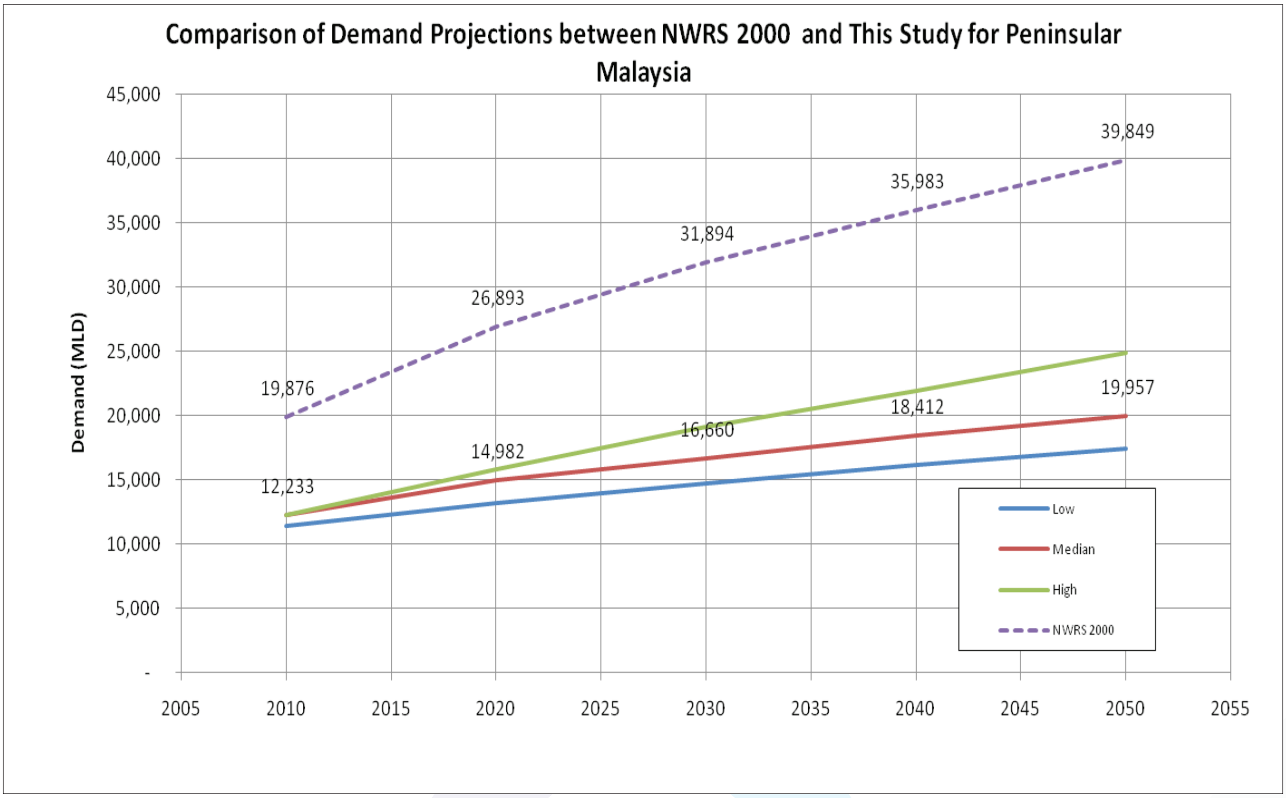


Figure 2.2 Projected water demand for Peninsular Malaysia from the recent study and the earlier study in year 2000.

Source: MNRE, 2011

2.3.2 Management Issues

Although the overall water balance seems to suggest that Malaysia has a luxury of water resources, there are already a number of water-related problems that could affect the well-being of the public and socio-economic development. The major water management problems are associated with either excess of water (floods) or water shortages (droughts), and water pollution. Specifically, the major issues in water resources management are as follows:

- Rapid increase in urban water demand. The urban population in Malaysia has exceeded 60% of the total population and one third of them reside in the Klang Valley. At present, all potential water resources in this region have been explored. Additional sources of surface water have to come from neighbouring states through inter-State and inter-basin water transfer projects. Similarly, the major economic zones, especially in southern Johor, which involved rapid development of Iskandar Malaysia and the newly started Refinery and Petrochemical Integrated Development (RAPID), need to be supported by major water resources development projects.

- Weather variability. Water shortages in Malaysia have been associated with prolonged droughts which occurred mostly during El Nino years (Lim and Ooi, 1999). The most notable one was in 1997 and 1998. It has caused extensive impacts to the environment and disrupted the socio-economic activities throughout the nation (Kheizrul, 2006). During the 1997-98 drought episode, Klang Valley experienced six months of water supply shortages. Other major cities were also affected by water shortages. In 2005, Malaysia experienced another major drought which also coincided with El Nino year.

- Large flood prone area. About 9% of Malaysia's land areas are flood prone, affecting about 21% of the country's population (Kheizrul, 2006). In the future, the hydrological impacts of climate change could be far more reaching in view of the predicted increases in the frequency and intensity of extreme hydrological events, particularly drought and flood (Kavvas et al., 2006).

- High Non-Revenue Water (NRW). Despite the government initiatives in implementing several remedial measures, there is no sign of significant reduction in NRW, ranging from 18% for Penang to as high as 59% for Perlis, with a national average of 37% (SPAN, 2009). The main reason for high NRW is leakages of old asbestos cement pipes. NRW has been identified as one of the priority issues to increase water supply efficiency.

- Water pollution. River pollution is still a major issue in Malaysia despite substantial investment and effort to improve and conserve the river quality. More than half of the rivers are either polluted or slightly polluted (DOE, 2012). Both point and non-point pollution sources are significant contributors to water pollution. Among the major sources of point pollution are effluent from oil palm, rubber and food processing industries which contribute to high concentrations of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The major sources of non-point pollution are from land use activities especially land clearing for agricultural areas, forestry activities and construction which contribute to high concentration of suspended solids. The future scenario is even more challenging in managing water pollution with the present of micro-pollutants and new emerging pollutants (NEPs) due to excessive use of pharmaceutical and personal care products. Some of these NEPs are endocrine disrupting chemicals which are carcinogenic even at low concentration.

- Weak demand management strategy. Despite shortage of resources as compared to the demand in certain areas, the water management strategy is slow to move from supply enhancement to demand management (ASM, 2010). Demand management has been proven effective in many water scarce countries. This would require for the implementation of the right policy, incentive as well as the enforcement of penalty. It is also important to have organised and continuous awareness programmes to ensure acceptance by the public and industry. Preliminary study in the State of Selangor suggests that with simple demand management such as by installing water saving devices at home could reduce demand up to 20% (Cherian, 2009).

- Sectoral and fragmented management. Effective water resource management requires strong coordination and implementation strategy. Over the past two decades, the importance of river basin as a logical platform for managing water, land and other resources has been frequently discussed and debated among policy makers, scientists and water managers. However, the progress so far has been slow (CheNgah and Othman, 2010). The recently launched National Water Resources Policy (MNRE, 2012) again reemphasises the need to strengthen integrated approach in managing water resources through Integrated Water Resources Management (IWRM), Integrated River Basin Management (IRBM), Integrated Lake Management (ILM), Integrated Coastal Zone Management (ICZM), Integrated Shoreline Management (ISM) and Integrated Flood Management (IFM).

- Climate Change Impact: Specific studies on the impact of future stream flow were presented by Saaban (2008). Increases in maximum monthly flow from 11% to 47% were predicted over most rivers in Peninsular Malaysia. However, minimum monthly flow would decrease between 31% and 93% for rivers in Johor and Selangor. This is due to expected decreases in minimum monthly precipitation from 32% to 61% over most parts of Peninsular Malaysia. On the other hand, maximum monthly precipitations are predicted to increase up to 51% in states like Pahang, Kelantan and Terengganu. The implications of these changes are that more severe floods and droughts could be expected in the future.

2.3.3 Efficiency and Sustainability

Sustainable water management incorporates two important concepts in relation to water. Firstly, 'sustainable' refers to activities that fulfil the needs of the present generation without compromising the ability of the future generation to meet their own needs. This definition implies an equitable distribution of the resources between users over time, including water. On the other hand, 'management' of water refers to the process of planning, developing, distributing and managing water resources. The combined effect of these two words will mean managing water resources while taking into account the need of present and future users.

Sustainable water management can be achieved with a good design of neighbourhood and site master plan. They will integrate water-sensitive design principles and concept plan for soft landscaping and permeable paving to support drainage and water retention, designing public place with planting that take into account surface water and natural irrigation, as well as identifying, conserving, restoring and enhancing natural features of water courses. It also concentrates on alternative or non-conventional water supply such as rainwater or grey water. There are many benefits of sustainable water management. It will generally reduce the climate change effect by creating cooler microclimate through evaporative cooling, reducing vulnerability to flooding and reducing the urban heat island effect as the greens are properly irrigated. It also improves the quality of life of residents by giving access to natural features and water recreation as well as reducing the risk of flooding, water shortage or pollution. From the economic standpoint, sustainable water management helps to strengthen local economy by reducing the running costs for business and household on water consumption and reducing clean-up costs from pollution and flood. It will also reduce the need for water transfer between states and reducing the need for high energy water treatment processes (Rahman et al., 2010).

2.4 Water Resources Infrastructure Development

The large and reasonably well-developed water utilities, wastewater treatment infrastructures and waste management systems in Malaysia have emerged from a cycle of privatisation and nationalisation of competitive leading companies. Certain water and wastewater treatment systems were privatised to foreign firms in the late 1980s and 1990s. In water utilities, eight regional private companies manage water utility operations and generate an estimated RM2.5 billion in annual revenues (Asia-Pacific Economic Cooperation Secretariat, 2010).

As Malaysia grows, the problem of providing sufficient clean water to the population has also increased. Malaysia's 29 million populations generate about six tons of sewage every year, most of which is treated prior to discharge into receiving water bodies, mainly rivers. Hence, proper treatment is paramount considering 98 per cent of Malaysia's fresh water supply originates from the surface water.

Great emphasis has been placed on the conservation and preservation of water. The enactment and enforcement of the Suruhanjaya Perkhidmatan Air Negara (SPAN) Act in 2007 aim to address all previous deficiencies and to promote a holistic approach for efficient water services, via two main objectives:

a) To support and provide an operating climates that are viable for operators to provide effective management of water and sewerage services; and

b) To protect the interest of consumers of water and sewerage services in the country

More serious efforts to restructure the water services industry covering water supply and sewerage services began during the Eighth Malaysia Plan period with the objective of creating an efficient and sustainable water services industry. The Ninth Malaysia Plan (2006-2010) took effect in March 2006 and continued until 2010. Under the plan, a total of RM12 billion had been allocated to the water-related sector, representing a 39 per cent increase over the RM8 billion allocated under the Eight Malaysia Plan. During both of the Malaysia Plan's period, restructuring efforts will enter into its final phase as outlined in the Tenth Malaysia Plan.

2.4.1 Sectoral Allocation

A long term strategy for water resource management underlined by the National Water Resources Policy (NWRP) will ensure efficient and effective management of the resource to cater for growing demands. Efficient management of water resources provides important benefits to mankind, both commodity benefits and environmental values. Table 2.2 tabulates key findings on sectoral allocations for water and wastewater infrastructure resources development according to Malaysia Plans. The sectors include agricultural drainage and irrigation, urban drainage and flood mitigation, sewerage, urban and rural water supplies, hydro-electric projects, dam projects and water treatment initiatives. Due to crucial factors contributing to scarcity of water resources, economic consideration plays an increasingly important role to determine allocation by government to distinguish water from other scarce resources. For example, in Table 2.2, the allocation for rural and urban water supplies shows an almost 100 per cent consistent increment from the First Malaysia Plan to the Tenth Malaysia Plan. This figure is indicative of water projects which are commonly associated with large investments over the necessary time period.

TABLE 2.2 SECTORAL ALLOCATION FOR THE MALAYSIA PLAN

	Allocation for Malaysia plan (RM millions)									
Sector	1st (1966-1970)	2nd (1971-1975)	3rd (1976-1980)	4th (1981-1985)	5th (1986-1990)	6th (1990-1995)	7th (1996-2000)	8th (2001-2005)	9th (2006-2010)	tenth (2011-2015)
Agricultural drainage and irrigation	332.70	256.49	621.03	1451.26	337.44	463.30			1458.1	
Urban drainage and flood mitigation				15.75	159.27	715.2	1500.00	2170.20	3997.6	
Sewerage	40.90	23.97	138.50	217.41	178.77	550.9	112.00	1583.60	3132.80	228.40
Water supplies and water treatment plant						2845.5	3575.3	3966.30		754.00
-Urban	147.70	183.75	302.7	1791.71	1,695.77				8203.60	
-Rural	54.30	10.00	289.4	346.20	1,430.00				1206.50	
Hydro-electric and dam projects	211.00	72.80	385.92	994.00	1531.50	1820.5	87.00	7930.20		

Source: From Economic Planning Unit (www.epu.gov.my)

Presently, as for the Tenth Malaysia Plan, some of key focus areas highlighted are as follows:

a) Full migration of State water operators to the new licensing system will be completed;

b) The phasing in of a tariff setting mechanism to allow full recovery of costs to encourage sustained investments in upgrading and rehabilitating water treatment plants and distribution systems. The tariff increase will be segregated in bands based on consumption levels;

c) National water supply coverage will increase from 93 per cent of population last year to 97 per cent in 2015;

d) Sewerage services for households served by the grid and septic tanks will be extended from 28.8 million to 37.7 million. Some RM1.1 billion will be allocated to replace pipes and old meters to improve water quality and reduce losses in water supply;

e) Parcelling the operations of centralised sewerage services to State water operating companies; and

f) RM5 billion will be allocated for flood mitigation programmes.

2.4.2 Allocation Trend

The major trends of water pollution and control measures in developed countries as summarised in Table 2.3 have been adapted for the development of water resources for Malaysia.

The major trends of water pollution control have significantly contributed to the development of a conventional sanitation approach in terms of legal and financial frameworks, as well as water and wastewater technological advancements. With increasing knowledge of health effects of trace pollutants, sewerage services to maintain healthy sanitation in Malaysia had been provided for by local councils in the past and the cost was borne by the rates charged by the local council and municipalities to the property owners. Sewerage services have to be integrated as part of water services as wastewater must be treated prior to discharge into receiving water bodies. Back in the 1930s, flush toilets and septic tanks were introduced by British, while the urban areas had bucket latrines until the 1960s. It is worth to note that 79.4% of the population in 1970 were using unsanitary facilities, i.e., bucket latrines, pit latrines, direct discharge to the rivers or sea or without proper sanitation facility. Different types of sanitation facilities available in Malaysia are shown in Table 2.4.

TABLE 2.3 TRENDS IN WATER POLLUTION AND THE CONTROL MEASURES

Era	Issues/Environmental impacts	Control measures
Pre-1900s	Pathogenic organisms	Sewer network
1910s	Organic pollutants from sewerage	Biological sewage treatment plant
1950s	Industrial waste, inorganic	Wastewater treatment on site before discharge to sewer
1960s	Other organics, pesticides, fat and grease, colour, solvents	Advanced biological and chemical treatments
1970s	Eutrophication	Nitrogen and phosphorus removal in sewage plant
1980s	Odour, taste, colour	Membrane technology, activated carbon
1990s	Greenhouse gases	Biotechnology
2000s	Micro-pollutants, eco-hazards	Membrane technology
2010s	Nutrient and energy recovery	New separation technology

Source: Ujang and Henze, 2006

During the Seventh Malaysia Plan, various water projects had been implemented to meet domestic and industrial demand as well as to meet irrigation requirement. In addition, several actions were undertaken to improve water supply management and to ensure better distribution of water resources among river basins to match supply and demand. Table 2.5 outlines the water infrastructure spending under Malaysia Plans.

Based on Table 2.5, in the Eighth Malaysia Plan, the Government focussed on the need to efficiently manage water resources to ensure adequate supply of safe water for the nation. Water treatment technologies capable of coping with deteriorating river water quality and remove micro-pollutants, especially recalcitrant organics such as phenolics, will emerge as rivers become more contaminated with manmade chemicals. For example, biofilm water treatment processes have been employed in Europe to remove micropollutants so as to meet the stricter new EU drinking water limits. Studies using biofilm processes have also shown them being capable of removing not only nutrients but also chloroorganics. There are present technologies that help cope with water resources which include aquifer recharge and water reuse removal by adsorption-biodegradation in packed bed and expanded bed operating conditions.

TABLE 2.4 PERCENTAGE OF VARIOUS SEWERAGE FACILITIES IN MALAYSIA

Type of Facility	Percentage of Population Served		
	1970 (%)	1980 (%)	1990 (estimate %)
Central sewerage system	3.4	4.0	5.0
Septic tank/communal sewerage system	17.2	21.8	37.3
Pour flush system	2.6	30.3	45.0
Bucket latrine	19.8	7.7	0.0
Pit latrine	29.9	15.3	4.3
Hanging latrine	9.4	4.5	2.1
Indiscriminate/no facility	17.7	16.4	6.3

Source: Water Tablet Malaysian Water Reforms, Ministry of Energy, Water and Communications Malaysia

TABLE 2.5 WATER INFRASTRUCTURE EXPENDITURE UNDER THE MALAYSIA PLANS*

Malaysia Plan	Period	Allocation for Water Infrastructure (RM Million)
Third Malaysia Plan	1976-1980	538.0
Fourth Malaysia Plan	1981-1980	2085
Fifth Malaysia Plan	1986-1990	2348
Sixth Malaysia Plan	1991-1995	2089
Seventh Malaysia Plan	1996-2000	2385
Eighth Malaysia Plan	2001-2005	4000
Ninth Malaysia Plan	2006-2010	4690
Tenth Malaysia Plan	2011-2015	1720*

*Until December 2012

Source: Taken from Malaysia Plans and Official Website of Ministry of Energy, Green Technology and Water

In 2006, RM1, 678 million was allocated for water supply projects to implement water supply infrastructure projects under the Ninth Malaysia Plan. A total of RM1, 358 million was spent during that period for various water projects throughout the nation. This amount included continuation projects from the Eighth Malaysia Plan.

For Sewerage Projects under the Ninth Malaysia Plan, there were 11 new projects and 47 continuation projects, with an overall total cost of RM3, 012 million. In 2006, about RM755 million was spent out of the budget of about RM760 million allocated for National Sewerage Projects for the year, which was 99 per cent of the budget. In addition, a total of RM1.64 million was spent on repossessing land for sewerage projects in Peninsular Malaysia from an allocated budget of RM1.65 million in 2006. According to the Ministry of Energy, Green Technology and Water, RM1, 720 million was allocated for water supply and sewerage infrastructures in the Tenth Malaysia Plan.

2.5 Water and Wastewater Technology

2.5.1 Overview

Waterborne diseases mainly cholera, typhoid, and dysentery was the driving force on the development of water supply and sewerage system in early modern history. The initial water filters were developed for individual domestic application back in 1700s, made of wool, sponge and charcoal (http://www.lenntech.com/history-water-treatment.htm). About 100 years later, the first actual municipal water treatment plant became in place. It was built in Scotland, and consisted of slow sand filtration. This was followed by chlorination in 1850s and rapid sand filtration in 1890s.

The initial septic tank was first invented in 1860, but only named in late 19th century. The initial function of the tank was mainly to remove gross solids before the wastewater was discharged into the nearest water body. Trickling sand filter technology was also developed at this time and later on used to filter the effluent from septic tank. During the same period, sewer systems were developed in big cities such as London and New York. At the same time, the understanding on the role of aerobic and anaerobic bacteria in treating sewage starts to emerge.

The first formal arrangement for water supply system in Malaysia can be traced back to Pulau Pinang in early 19th century while effort on treating sewage started about 50 years later (http://www.jba.gov.my/index.php/en/semenanjung-malaysia). Since then, many improvements have been developed within water and wastewater management systems. The main purpose was mainly for public health and environmental protection, in which water-borne diseases have been the major focus during the so-called 'conventional sanitation' era. A similar situation was observed ever since the Industrial Revolution in Europe, and the occurrence of rapid industrialisation in the United States and Japan; in which water-borne diseases were also the major focus for the development of water treatment systems.

2.5.2 Water Supply

The British laid down the foundation for piped water supply in Malaysia, shortly after they had set themselves up in Penang; their first base in Malaysia. The first formal arrangement for a water supply system was drawn up in 1804. An aqueduct of brick was initially constructed to transport clear stream water from the hills to town. Earthen pipes were laid under the streets and water was taken from them through tin pipes to homes.

However, as the bricks in the aqueduct were often dislodged, the aqueduct was eventually replaced with a cast iron main in 1877. This cast iron main is recorded as the first water main in Malaysia, and traces of it can still be found in the Penang water supply network. Sarawak was the next British colony to have water mains in Kuching in 1887 to provide water to 8,000 households. This was followed by Kuala Lumpur, Melaka and the rest of the Federated Malay States as they came under British colonial administration. Piped water was soon available to urban households and from standpipes throughout the country.

By the early 1900s, water was no longer delivered untreated directly from the source to homes. As a result of an international movement in developed nations, treatment of drinking water is required to prevent the outbreak of water-borne diseases such as cholera, typhoid, and dysentery. As a British colony, Malaya and the Borneo territories, Malaysia now, benefited from this development in water supply. Initially, slow sand filters, which were inexpensive and easy to build, were adopted. They were later replaced with modern rapid gravity filtration plants. Disinfection technology using hypochlorite and later, gaseous chlorine made its appearance by 1915.

By 1939, households in the major towns of Malaya were well served with piped water. Many water installations, however, deteriorated from neglect during the war years of the Japanese Occupation (1941-45). Post-war rehabilitation was slow and painful, with a shortage of treatment chemicals and demand overtaking supply. One of the most difficult supplies to operate then was the Kuala Lumpur supply which had reached the limit of its capacity before the war and was now required to provide water to a swollen civilian population and heavy troop concentration. A number of small schemes were hastily implemented around Kuala Lumpur to meet the demand of the increasing population.

By 1950, Malaya had 100 treatment plants producing 195 million litres of water per day to supply a population of 1.15 million. Then, as now, water shortages were not uncommon, caused in part by drought but mainly by rapid population growth. Demand for water increased sharply in the years after Independence in 1957, especially in the capital city in the Kuala Lumpur, which was the focal point of the rural-urban drift that occurred in the newly independent nation. To cope with the rising demand, the Klang Gates Dam and the Bukit Nanas Treatment Plant was constructed and commissioned in 1959; ending a long period of water shortage and water rationing.

Water development has since figured prominently in Malaysia Plans. During the colonial period, the focus was mainly on urban and suburban supplies. It was under the 3rd Malaysia Plan (1976-1980), which attempted to redress the inequalities of earlier policies, that rural water supply received a much needed boost. The investment in rural water supply before 1975 was insignificant, but under the 3rd Malaysia Plan the State of Sarawak alone received an allocation of RM4,139,876 to convey piped water to remote areas. The success for this and subsequent five year plans was reflected in the number of households in Peninsular Malaysia receiving treated water in both urban and rural areas –the figure rose sharply from

23% of all household in 1950 to 85% in 1990. Table 2.5 outlines the water infrastructure spending under Malaysia Plans.

To date, despite the characteristics of the water sources, conventional treatment processes (Figure 2.3) are commonly employed in the treatment plants for public water supply. However, variation exists in terms of chemicals (e.g. coagulants, flocculants, disinfectants) and technology (e.g. pulse clarifier, plate settling for settling) used in the system. Ozone treatment and carbon adsorption were once used in Sg. Linggi water treatment plant but was discontinued due to technical and financial constraints. Advanced treatment processes such as ozone and UV disinfection, membrane filtration, and ion exchange are currently being employed for further purification of treated water for industrial use and home filtration system.

2.5.3 Wastewater

Malaysia has seen the evolution of its sewerage industry over the last half a century (IWK, 2007). Before its independence in 1957, there were few proper sewerage systems in Malaya due to the low population densities and very limited urbanised developments. Sewage treatment was mainly by way of primitive methods, such as pit and bucket latrines, over-hanging latrines and direct discharge to rivers and beaches. When Malaya began to develop and move from an agricultural based to an industrial based country, the need for proper sanitation gained importance. In the 1950's, sewage treatment systems in the form of individual septic tanks and pour flush systems were introduced while small communal systems involving mainly primary treatment, such as the Communal Septic Tanks and ImhoffTanks were used in the 1960's. In the 1970's, the technology expanded to biological treatment processes in the form of oxidation pond systems utilising natural means of treatment.

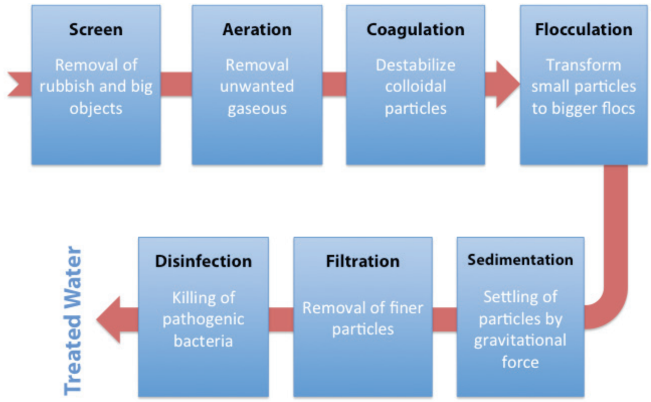


Figure 2.3 Typical conventional water treatment flow diagram used in Malaysia.

Later in the 1980's, mechanised systems started to be introduced and oxidation ponds were converted to aerated lagoon systems. In the late 1980's and early 1990s, the development of fully mechanised sewage treatment systems started to accelerate. These systems include activated sludge process, bio-tower, and rotating biological contactor (RBC). The schematic diagram of the conventional treatment terrain is shown in Figure 2.4. For the mechanised system, different biological processes as mentioned earlier have been adopted.

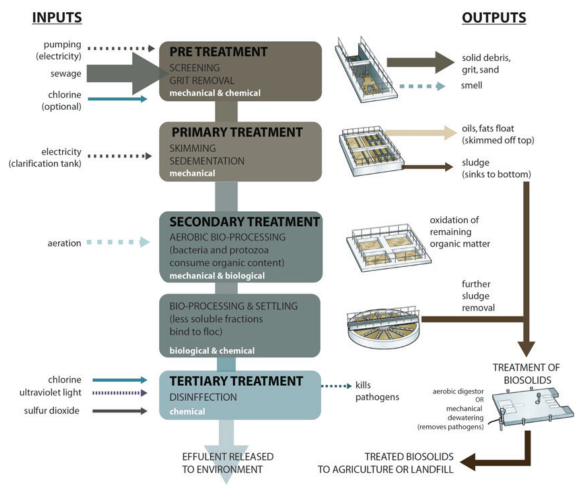


Figure 2.4 Conventional mechanised sewage treatment plant.

Source: Carliesle and Pevzner, 2013

Activated sludge process is the most commonly mechanised system used with Extended Aeration, representing more than half of the treatment plant in operation (IWK, 2011). More recently, a Sequential Batch Reactor (SBR), a modification of an activated sludge system, has been installed to treat sewage from 1 million PE in Jelutong, Penang. Presently, Indah Water Konsortium (IWK), a company owned by the Minister of Finance Incorporated, has been entrusted with the task of developing and maintaining a modern and efficient sewerage system for all Malaysians. Indah Water currently operates and maintains 5,749 STPs, 14,991 km underground sewer pipelines, with 829 pumping stations and 58 sludge treatment facilities; serving a nationwide population of approximately 19 million. Additionally, there are other treatment systems and facilities that are operated and maintained by local authorities and private companies.

Most of the existing sewage treatment plants are mainly focusing on the removal of organic contaminants (in terms of BOD5 and COD), suspended solids, oil and grease and ammonia. New treatment plants are expected to have better removal of oil and grease and ammonia and are also expected to remove nitrate and phosphate.

While the biological process is the main process used in treating sewage, different type of processes have been employed to treat industrial wastewaters depending on the characteristics of the effluent. Ponding systems are commonly used to treat high-strength biodegradable wastewater such as those generated by agro-industries (e.g. palm oil, rubber, and pineapple). The system typically comprised of anaerobic pond, followed by facultative and aerobic. In certain system, the methane gas generated in the anaerobic pond is captured; some utilised as fuel while some is flared producing CO_2 into the atmosphere. Alternatively, mechanised anaerobic systems such as Upflow Anaerobic Sludge Blanket (UASB) has also been used.

Due to their relatively lower cost, aerobic biological processes are normally employed to treat biodegradable wastewaters. Activated sludge system in its original configuration or modified forms such as Extended Aeration (EA) or SBR is commonly employed when space is limited. The addition of powdered activated carbon (PAC) into the aeration tank has also been reportedly used to enhance the performance of the system.

For non-biodegradable wastewaters, the use of physico-chemical processes such as coagulation and chemical oxidation are quite common. These processes are either used as primary treatment prior to biological processes or employed as secondary treatment. Chemical precipitation in combination with coagulation and ion exchange process are used to remove heavy metals from electronic and metal-related industries. The use of granular activated carbon (GAC) as tertiary treatment and dissolved air floatation (DAF) for the removal of oil and grease (O&G) and low-density suspended solids have also been reported.

2.5.4 Future Trends

In the 20th century, waterborne diseases and hazards from the chemicals found in water sources have become the main driving forces to the development of water and wastewater treatment technology. While these still remain as issues that require attentions, the drivers for technology changes in the 21st century have now shifted to more globally challenging issues. These include the dire need of water due to substantial increase in population and hence, water demand, urbanisation, scarcity of resources, and global warming (Reardon et al, 2013; Tchobanoglous, 2012). Additionally, advancement in analytical techniques, increase in public awareness, change in lifestyle, the desire for treatment cost saving, and the installation of more stringent standards and regulations have added to the challenge.

While environmental protection, cost, and wastewater reuse remain as the important criteria in treatment technology development, new important consideration factors include energy management, nutrient and material recovery, low footprint in terms of carbon and area requirement, and sustainability (Reardon et al, 2013; Tchobanoglous, 2012) (Figure 2.5).

2.5.4.1 Environmental Protection

The protection of the environment through standards and regulations has been an important criteria and drivers for the development and innovation of treatment technology. With the advancement of analytical techniques and the increase in public awareness, new and stringent standards have been introduced by the authorities. In developed countries, the traditional and basic water quality parameters such as BOD, COD, SS, N and P are no longer sufficient as indicators of good quality water. The public is more concerned on the safety of the water, with regards to existence of micro-pollutants such as pesticides, pharmaceutical, surfactants, and various industrial additives as they have been found to be persistent in the environment.

As the removal of these emerging pollutants in the conventional water and wastewater treatment is not satisfactory, new technologies at a reasonable cost will therefore be needed.

2.5.4.2 Wastewater Reuse

The reuse of wastewater has been around for more than 100 years (http://www.athirstyplanet.com/). In the early days, wastewater mainly from sewage was reused for irrigation purposes. This remains the case until today, particularly in regions where water is limited but in great demand such as Middle East and North Africa countries, United States, and Israel (http://www.athirstyplanet.com/; ACWUA, 2010).

Figure 2.5 The criteria for future water and wastewater treatment technology.

With the constant increase in water demand as populations grew and water supplies became limited, purposeful reuse of high-quality reclaimed water has increased greatly in the last 30 years. Reclaimed water is now considered to be a valued resource in many parts of the world, and the trend has shifted toward higher-level uses, such as urban landscape irrigation, toilet flushing, industrial uses, and drinking water augmentation. Table 2.6 (Advanced Wastewater Management Centre, 2007) lists some of the few examples of planned reclaimed water schemes around the world.

TABLE 2.6 EXAMPLES OF PLANNED RECLAIMED WATER SCHEMES
(ADVANCED WASTEWATER MANAGEMENT CENTRE, 2007)

Location	Description
Los Angeles County, California, USA	Surface spreading of secondary effluent (dual media filtration + chlorination) into the Whittier Narrows Groundwater basin since 1962. Potable water is subsequently withdrawn. Estimated that 23% of potable water is indirectly recycled water.
St Petersburg, Florida, USA	Dual distribution system uses highly treated recycled water for irrigating 8000 homes, 46 schools, 66 parks and 6 golf courses. It has been operating since 1977.
Orlando, Florida, USA	Walt Disney World Resort Complex uses recycled water for irrigating 5 golf courses, highway medians, a water park and tree farm.
Windhoek, Namibia	Windhoek has low rainfall, high evaporation and a limited catchment. It has exploited all surface water resources within 500km, has maximum groundwater utilisation, demand management in place and now depends on direct recycled potable water supply. Treatment consists of secondary treatment, pre-ozonation, DAF, sand filtration, ozonation, GAC, UF and chlorination.
Singapore	The NEWater plant produces recycled water from secondary effluent. Treatment is by micro-screening, MF/RO, plus UV irradiation. Most recycled water is supplied to high technology industries. Small portion returned to water supply reservoir.
Yokohama, Japan	Yokohama International Stadium uses recycled water as a heat source for heat pumps, toilet flushing, sprinklers and artificial streams in surrounding landscaped parks.
Osaka, Japan	Osaka has a target of 100% water recycling by 2030. The Nagisa Plant already produces recycled water for landscape irrigation and as a heat exchange source for district air conditioning, for fire mains and toilet flushing.
Woollen, Belgium	The Woollen STP in Belgium recycles 2.5 GL of domestic wastewater. It is treated by MF/RO, stored in an aquifer for 1-2 months, and then used for water supply augmentation.
Israel	In 1994 20% of Israel's water supply came from recycled water, with the aim of 100% recycling by 2010. The Dan Region project provides 95 GL/annum of secondary effluent from Tel Aviv to recharge a coastal aquifer for further treatment and storage. Water is then pumped from aquifer to irrigation areas.

However, despite the long practice of wastewater reuse planned or unplanned and albeit its potential as main alternative water resources, many issues and challenges need to be addressed, particularly in developing countries. These include the high cost of advanced treatment for high-quality reclaimed water; high pollutants load of sewage due to legal and illegal mixing with industrial wastewater; and governance issues in terms of lack of policy, regulations, fundings and infrastructures.

2.5.4.3 Energy Management

Rising energy costs paired with restrictions on greenhouse gases provides the impetus to institute more effective energy management and alternative energy strategies in water and wastewater treatment plants. These trends are raising the bar for these facilities, in the move towards becoming energy neutral or energy positive, whereby energy is not just managed, but instead recovered and reused. It is estimated that the energy available in the wastewater is between two to four times the amounts required for the treatment (Tchobanoglous, 2012). Hence, initiatives to increase biogas production, manage oxygen demand, or control equipment for efficient power use will move the industry in the right direction.

The most common energy recovery technology in wastewater facilities is the anaerobic digestion of liquids and solids, which produce methane as biofuel. However, the applications of anaerobic digestion for low organic wastewater such as those of sewage have previously been regarded as not feasible. With the advancement in membrane technology, anaerobic membrane bioreactor (AnMBR) has been seen as a viable option due to several advantages (Smith et al., 2012; Lin et al., 2013). Additionally, other new technologies are currently being explored for energy recovery, which include microbial fuel cells and biofuel from microalgae.

2.5.4.4 Nutrient and Material Recovery

Nutrients such as nitrogen and phosphorus are found in municipal, industrial and agricultural wastewater. While these nutrients are beneficial in promoting healthy plant growth in a controlled environment when uncontrolled these same nutrients can cause significant environmental damage through eutrophication to streams, rivers, lakes and estuaries.

Although biological nutrient removal processes, which utilise integration of anaerobic, anoxic and aerobic phases has been well documented, nutrient removal is still a growing challenge for operators due to its high cost. The USEPA has identified nutrient reduction as a major environmental problem requiring wastewater plants to spend thousands and millions of dollars to upgrade their facilities. Wastewater treatment for agricultural anaerobic digesters for example, is 50% of the capital costs of the project making many projects uneconomic (http://www.thermoenergy.com/). While the challenges are to lower the treatment cost and to meet the lower effluent limits, the opportunity is to recover this nutrients as fertilizers or transforming them into biofuel.

As for industrial wastewaters, recovery of precious metals and other resource materials are the way forward. Through this approach, the discharge limit can be met, savings can be made through water reclamation and recovered materials and maximum sustainability can be attained.

2.5.4.5 Sustainability

With global warming and climate change being the current threatening issues, 'sustainability' has been the word of mouth and important agenda for industry, communities, and regulators. When addressing the issue of water supply and treatment, sustainable practices should include improving access to safe water supplies, reducing costs, energy and chemical usage and without threatening the environment. As for wastewater management, sustainable practices are to provide collection, treatment, and reuse of water in a way that does not adversely impact the health of humans or other species, preserves environmental quality and the integrity of ecological systems, recovers energy and nutrients present in waste, and utilises resources efficiently (Reardon, 2013). In other words, sustainability encompasses the criteria that have been discussed earlier.

2.5.5 Examples of Emerging Technologies

A conventional water and wastewater treatment that system comprises of a series of processes, with each having its unique function, has resulted in the removal of certain types of pollutants. In addition to these processes, advanced treatments are sometimes employed to further enhance the quality of the treated water. These processes involve the removal of dissolved solids or constituents that cannot be removed by the conventional process. The technologies that are currently used at this stage include membrane technologies, adsorption, ion exchange and advanced oxidation processes.

In addition to the existing advanced technologies, emerging technologies have been and are currently being developed; responding to the driving factors as mentioned earlier. A comprehensive study was conducted on emerging technologies in water and wastewater treatment by Frost and Sullivan (2010). As it is impossible to provide the whole array of the emerging technologies, the following sections provide some examples of those reported by Frost and Sullivan (2010) and also from other sources.

2.5.5.1 Membrane Technology

Advances in filtration membrane technologies have been displacing chemical treatment system. The membrane water treatment market is expected to grow from US$1.5 billion in 2009 to US$12.07 billion in 2020 (Badkar, 2011). The commonly used membrane technology includes microfiltration, ultrafiltration, nanofiltration and reverse osmosis. These membranes are mainly classified by their pore size, which affects the size of pollutants that they can remove and eventually the pressure that is required in the process (Interdonato and McCarthy, 2001). Membrane bioreactor (MBR) is a type of activated sludge system, which utilises membrane as solid separation facility replacing secondary clarifier.

Forward Osmosis (FO) is a new type of membrane process based on direct osmosis across a reverse osmosis membrane. It is currently developed for desalination purposes. In FO, water transfers from saline side to the draw solute side due to osmotic pressure (Figure 2.6). At present, the technology has been patented by several inventors, which include Oasys (http://oasyswater.com) and Hydration Technology Innovations (http://www.htiwater.com). The technology utilises membrane and low-grade heat, instead of electricity, to drive the desalination process. The technology is reported to produce the same standard of potable quality at much lower cost.

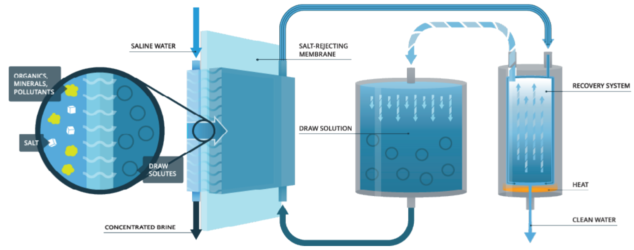


Figure 2.6 The flow diagram of the Forward Osmosis process.

Source: http://oasyswater.com

In addition to the development of FO, membranes are currently being developed using new materials such as zeolites, carbon nanotubes, and Aquaporines, a class of proteins. The successful development of these new membranes will result in low energy requirement, less biofouling and higher rate of water transfer (Frost and Sullivan, 2010).

2.5.5.2 Nutrient and Materials Recovery Technology

Technologies have been developed to recover nutrients and materials from sewage treatment plant. The recovery technologies help in generating a revenue stream for wastewater utilities. Examples of these technologies are Ostara's Pearl® Process, CAST® Wastewater Technology, urine separation unit and bio-polymer production from wastewater (Frost and Sullivan, 2010).

Ostara's Pearl® Process provides a comprehensive approach to nutrient management (http://www.ostara.com). The technology is based on controlled chemical precipitation in a fluidised bed reactor that recovers struvite in the form of highly pure crystalline pellets or 'prills.' Nutrient-rich feed streams are mixed with magnesium chloride, and if necessary, sodium hydroxide and are then fed into the Pearl reactor forming pellets with sizes ranging from 1.0 mm to 3.5 mm. In a sewage treatment plant, up to 90% of the phosphorus and 40% of the ammonia load is removed from sludge dewatering liquid using this process and the resulting product is marketed as a commercial fertilizer called Crystal Green®.

Thermo Energy's CAST® wastewater treatment and recovery systems offers a low-cost, sustainable solution that is capable of recovering up to 99% of the process chemistry and metals in process wastewater such as glycol, BODs, acids/bases, ammonia, chromium, copper, zinc, nickel or other transition metals (http://www.thermoenergy.com). It also offers a Zero Liquid Discharge System that can separate process chemicals and impurities in wastewater streams to recover 100% of the wastewater. The Thermo Energy CAST® system is based on a low-energy, high-efficiency flash vacuum distillation system called Controlled Atmosphere Separation Technology (CAST). The CAST® systems are energy efficient, easy to operate and maintain, and have a small footprint.

Nutrient recovery from urine is one of the simple but significant steps in nutrient recovery from sewage. Urine only represents just less than 1% by volume of the wastewater but most of the nutrients in sewage are present in the urine (about 80% of the nitrogen and at least 50% of the phosphorus) (Ganrot, 2005). The nutrients in urine are, therefore, quite concentrated and are readily available to plants. Compared with other 'alternative' systems, the urine separation technology is comparatively simple and has been adequately tested. The challenge now is to build large-scale systems with a sustainable organisation and economic incentives for recirculating human urine to farmland.

Technology is also currently being developed to produce biodegradable polymers as a by-product of biological wastewater treatment (Madkour et al. 2013; Akaraonye et al., 2010). The process involves a specific class of bacteria that feeds on pollutants, and in turn, generate residues with high contents of polyhydroxyalkonates (PHAs). The PHAs provide an alternative to the polymers produced from fossil fuels.

2.5.5.3 Energy Recovery

Recovery of energy from high strength biodegradable wastewater through anaerobic digestion is an established technology. As for domestic wastewater, recovery of energy through sludge anaerobic digestion is also common (Kalogo and Monteith, 2008). Emerging technologies include microbial fuel cells (MFCs), algal biofuel, gasification, pyrolysis, and anaerobic membrane bioreactor (AnMBR) for low strength wastewater (WEF, 2011; Smith et al., 2012; Lin et al., 2013).

Out of these options, MFCs is the new technology of generating electrical power directly from wastewater. The MFCs feed on the organic matter in the wastewater by disintegrating it and in the process produce electrical current. Equipped with an anode and a cathode chamber, MFCs can also be used to generate hydrogen gas from wastewater using electrical power as an input. The successful scale-up and commercialisation of this technology can potentially change the energy intensity and the economics of wastewater treatment.

Algae biofuel production in conjunction with wastewater treatment is a relatively new technology. While current technology for algal wastewater treatment uses facultative ponds, this approach has several drawbacks, which include low productivity, are not amenable to cultivating single algal species, require chemical flocculation or other expensive processes for algal harvest, and do not provide consistent nutrient removal. Studies have been carried out to develop high rate algal ponds (HRAPs) with much higher productivities and promote bioflocculation settling which may provide low-cost algal harvest (Craggs et al., 2011). The daytime addition of CO_2 doubles the production hectares to □60 tonnes/ per year (ha/yr); improves bioflocculation algal harvest; and enhances wastewater nutrient removal. However, further research is required, particularly on the large-scale demonstration of wastewater treatment HRAP algal production and harvest.

2.5.6 Conclusion

The drivers for the development of water and wastewater treatment technology have changed with time from waterborne diseases to the more globally threatening issues. Evolution of the treatment technologies takes place along with these changes from simple filtration for removal of suspended solids to highly low carbon sophisticated technology for recovery of energy and materials, as shown in Figure 2.7. The technology development is led by the developed countries such as Europe, USA and Japan and trailed by the developing countries including Malaysia.

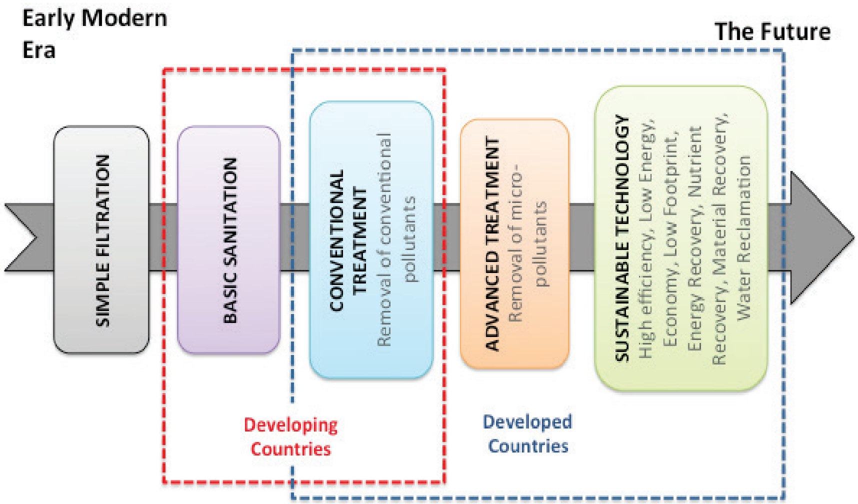


Figure 2.7 Evolution of water and wastewater technologies in modern era.

2.6 Water Policies and Regulations

2.6.1 National Water Resources Policy

The formulation of the NWRP for Malaysia provides clear directions and strategies in water resources management to ensure water security and sustainability for both man and nature. According to the Tenth Malaysia Plan, this Policy will set out the means and measures to ensure uniformity of existing legal provisions, institutional mandates and policy directions and consolidate the same through effective and efficient measures and mechanisms.

Bearing in mind that water resources are seen as a continuous process from their transformation from a gaseous, liquid or solid form, right up to the effluent, the NWRP was not in isolation of existing policy directions. This component of study takes great care to ensure that the assessment of water resources research in Malaysia is drafted in accordance to formulation of the Policy's Core Areas, Thrusts, Targets, Strategies and Strategic Action Plans to be adopted by many stakeholders.

2.6.1.1 Policy Rationale

The Policy Rationale was tabled at various consultative platforms and this study will adopt similar rationale to ensure the establishment of a system that will gear water resources towards sustainable use as the following:

"The NWRP shall set the strategic direction and framework for strategic action to ensure that water resources are used and developed in a sustainable manner to benefit the nation, both people and environment as a whole. It sets out strategies that will help guide water resources stakeholders to structure actions for effective conservation and management of water resources. The approach that will be taken will be based on existing integrated approaches that have been adopted so as to continue and further inculcate actions that are concerted and consolidated."

The rationale above seeks to address the following:

a) The NWRP will set the framework for water resources governance – introduce sustainability and uniformity.

b) The NWRP will benefit the nation.

c) Policy 'limitations' (note: protect State rights and protect from rights and tjurisdictional conflicts; protect States in the event of crisis and disaster; facilitating assistance overriding State privileges).

2.6.1.2 Policy Objectives

The proposed draft NWRP is hinged on three key objectives:

a) To set direction to facilitate uniformed actions towards ensuring water resources security and sustainability;

b) To set out mechanisms and identify processes to facilitate concerted actions for water resources security and sustainability; and

c) To establish mechanisms for partnership between multiple stakeholders and means for stakeholder engagement.

The objectives are self-explanatory, the first looks at consolidating the 'what and how'; the second sets out to structure uniformed approaches and means; and the third provides means for partnership establishment.

2.6.1.3 Policy Principles

The discussions have also led to identifying key values that will serve as the grounding principles that will guide the implementation, such as follows:

Water Resources Security

Water resources must be secured to ensure that their availability could cater the demand for both human and environment.

Water Resources Sustainability

Water resources is the catalyst for environment and development, and therefore, it should be sustained for present and future uses and Federal and State Governments will look at optimising and minimising wastage of water resources. It also opens up the opportunity to bolster self-dependency of states, to not just rely on transfers but to shift towards exploring alternative sources, and address aspects related to demand management.

Partnership

Stakeholder inclusiveness and collaboration are essential towards ensuring the security and sustainability of water resources as well as the achievement of common goals towards addressing multiple water resources governance concerns and priorities.

2.6.1.4 Policy Cores Areas, Thrusts, Strategies and Action Plans

Grounding the policy are four core key areas that will help cluster all actions; i.e.:

a) Policy Key Core Area 1: Water Resources Security

b) Policy Key Core Area 2: Water Resources Sustainability

c) Policy Key Core Area 3: Partnerships

d) Policy Key Core Area 4: Capacity Building

2.6.1.5 Implementation Plan

It is intention here that the policy be implemented through a stakeholder partnership arrangement; namely, helmed by the Ministry of Natural Resources and Environment (NRE) Malaysia that serves as a secretariat to the NWRC, and with the principle function under its Ministerial mandate, water resources management and conservation. It is also important to note that water resources makes up a component in natural resources and serves as the catalyst for environmental integrity, both which are areas within the NRE purview. As stated earlier, the NWRP is a time bound policy matched to the Malaysia Development Plans time line, and revisions can be instituted focusing on any aspect be it core area, thrusts, targets, strategies or action plans.

2.6.1.6 The National Water Resource Policy Targets

The NWRP is designed to achieve the following targets:

a) To develop a comprehensive information system on, about and for water resources;

b) To strengthen database framework, software support, roster of trained experts;

c) To improve and shift towards standardisation of multiple scientific processes and methods related to evaluation and analysis of State, status and condition of water resources;

d) To set national standards to determine thresholds for water resources to protect resources, its availability and integrity of water bodies;

e) To reduce vulnerability of water resources to impacts and threats as well as strengthen adaptability to ecosystems and physical changes;

f) To develop water resources conservation plans for strategic, sensitive and critical water resources areas and bodies;

g) To explore options for alternative, conjunctive or contiguous of water resources.

h) To strengthen measures for preparedness and response as well as reduction of risks and threats from disasters;

i) To establish uniformed measure and guidelines;

j) To determine priority of water resources use;

k) To protect and maintain condition and State of water bodies;

l) To develop and establish economic instruments and measures to value water resources;

m) To ensure optimum water quality and yield;

n) To provide mechanisms for formal and informal consultation on matters related to water resources;

o) To enhance stakeholder collaboration in water resources governance;

p) To build capacity of key water resources stakeholders; and

q) To improve understanding and awareness on the importance of water resources security and sustainability.

2.6.2 Relationship Between the National Water Resource Policy and Existing Water Resources Related Policies

The formulation of the Core Areas, Thrusts, Targets, Strategies and Strategic Action Plans of the NWRP to be adopted by the many stakeholders took into consideration existing policies. More than 50 national policies were reviewed, and of those 17 were identified as having close links with the various aspects of water resources. As the focus and emphasis of the NWRP, it is on providing directions for means and measures. Whereas, the strategic action plans proposed are also geared towards complementing the goals of the existing policies. Table 2.7 indicates the core areas and their links with the 17 identified policies.

TABLE 2.7 EXAMPLES OF NWRP COMPLEMENTING EXISTING NATIONAL POLICIES

CORE AREA	THRUST	RELATED POLICY
Water Resources Security	Thrust 1: Water Intelligence	National Green Technology Policy National Policy on Environment National Physical Plan National Policy on Climate Change National Policy on Biological Diversity Third National Agricultural Policy
	Thrust 2: Water Resources Integrity	National Physical Plan National Green Technology National Policy on Environment National Food Security Policy National Timber Industry Policy National Land Policy
	Thrust 3: Alternative Options for Water Resources Use	National Policy on Environment National Policy on Climate Change National Green Technology Policy National Minerals Policy 2 National Energy Policy National Biofuel Policy
	Thrust 4: Disaster Risk Preparedness and Response	National Policy on Biological Diversity National Policy on Environment National Physical Plan National Policy on Climate Change National Food Safety Policy
Water Resources Sustainability	Thrust 5: Promote Consistent Application of Criteria & Characterisation of Water Resources	National Green Technology Policy National Policy on Biological Diversity Third National Agricultural Policy
	Thrust 6: Conserve and Protect Water Resources and Bodies, both Natural and Artificial	National Green Technology Policy National Policy on Environment National Policy on Biological Diversity National Policy on Climate Change National Physical Plan National Urbanisation Policy National Consumer Policy National Forestry Policy National Solid Waste Management Policy National Tourism Policy National Timber Industry Policy National Food Security Policy National Land Policy

<table>
<tr><td rowspan="2">Partnership</td><td>Thrust 7:
Stakeholder Inclusiveness and Engagement</td><td rowspan="2">National Policy on Environment
National Policy on Biological Diversify
National Green Technology Policy
National Solid Waste Management Policy</td></tr>
<tr><td>Thrust 8:
Shared Water Resources Governance</td></tr>
<tr><td>Capacity Building and Awareness</td><td>Thrust 9:
Capacity Building and Awareness</td><td>National Forestry Policy
National Environment Policy
National Policy on Biological Diversity
National Urbanisation Policy
National Physical Plan
Third National Agricultural Policy
National Minerals Policy 2
National Green Technology Policy
National Solid Waste Management Policy
National Education Policy
National Biotechnology Policy</td></tr>
</table>

2.6.3 Other Laws and Regulations related to Water Resources Management in Malaysia

The project team also works on regulations laws existing in Malaysia for surface and groundwater management. Malaysia's Water Services Industry Act 2006 provides law for regulating water supply services and sewerage services and for related matters in the country. The review on this law is not completed yet. However, the project team has summarised the literary definitions of these terms (see Table 2.8).

TABLE 2.8 SUMMARY OF BASIC LEGAL CONCEPTS AND SCOPE OF WATER LEGISLATION

Customary (Unwritten) Law	Custom is considered to be established by: • Consistent repetition of a given conduct by many members of the community • Conviction of the community that such conduct corresponds to a 'legal rule'
Legislation (Written Law)	Legislation, taking account of custom as accepted social behaviour, encompasses: • The fundamental law or constitution of a country • Laws enacted by the legislation body (parliament, national assembly) • Subsidiary legislation (decree or instruments adopted by the government executive) laws enacted by the legislative body may not repeal constitutional provisions, and in turn may not be repealed or contradicted by subsidiary legislation
Water Legislation	Aims to regulate the relationship between persons (physical and legal) and between the people and the State administration on water resources; it includes all legal provisions on development, use, protection and management of groundwater resources, which may be either scattered in various enactments or integrated into a comprehensive water law

The project team is also critically evaluating the existing water-related policies on these questions:

a) What are the impacts of alternative water policies on income generation and resource security?

b) What are the impacts of alternative water policies on supply and demand for water in agriculture, household and industrial uses?

c) What are the impacts of alternative water policies on food production and security?

What are the impact of alternative water policies on water-dependent ecosystems, including forest-water interactions and wetlands; and on water quality, including agricultural effluents such as fertilizer and pesticides, and household and industrial water pollution?

Elfithri (2012) summarised some of the main water-related laws and regulations introduced by the Federal and State Governments of Malaysia, as shown in Figure 2.8.:

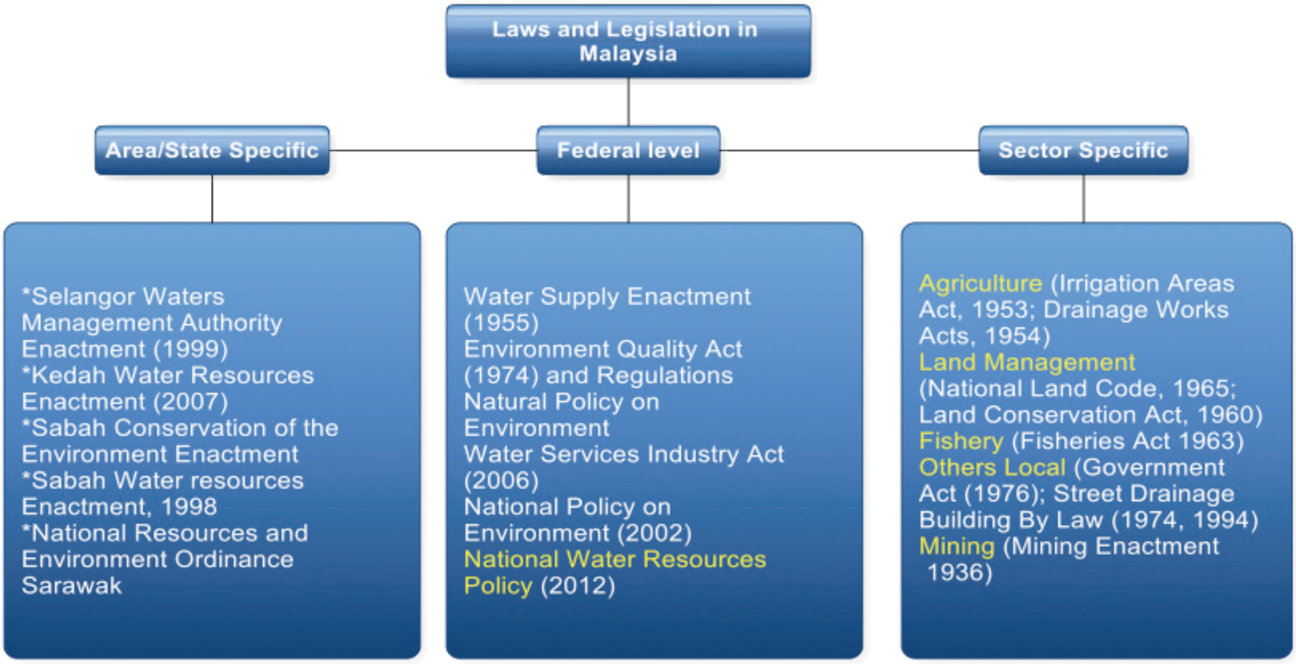


Figure 2.8 Water-related laws and regulations in Malaysia.
Source: Elfithri, 2012

Mokhtar et al. (2013) listed important water resources related laws and regulations stipulated by the Federal and State Governments, which are:

- Environmental Quality Act, 1974
- Land Conservation Act, 1960
- Irrigation Areas Act, 1953
- Fisheries Act, 1985
- Town and Country Planning Act, 1976
- National Forestry Act, 1984
- Mineral Development Act, 1994
- Water Services Industry Act, 2006
- National Park Act, 1980

The laws and regulations related to water resources as introduced by the State Governments are as follows:

- The Drainage Works Act, 1954
- Irrigation Areas Act, 1953 (Revised in 1989)
- The National Land Code, 1965
- Land Conservation Act, 1960
- Waters Act 1920 (Revised in 1989)
- The Forest Act, 1984
- Water Supply Enactments, 1955
- Selangor Waters Management Authority Enactment 1999
- Protection of Wildlife Act, 1972

- National Parks Act, 1980
- Town and Country Planning Act, 1976
- The Fisheries Act, 1985
- Fisheries Maritime Regulations, 1967 (Amended in1987)
- Merchant Shipping (Exemption) Order, 1961
- Poisons Act 1952
- Prevention and Control of Infectious Diseases Act, 1988
- Environmental Quality Act, 1974
- Local Government Act, 1976
- Street, Drainage and Building Act, 1974
- Mining Enactment, 1929
- Geological Survey Act 1974
- Pesticides Act, 1974
- Pesticides (Registration) Rules, 2005
- Pesticides (Exemption) Order, 2004
- Pig Framing Enactment
- Sewerage Services Act, 1993

2.6.4 Relevant Regulations and Guidelines

Several Acts were enacted to protect water resources in the country. Table 2.9 listed some of the available Acts for water management in Malaysia. Notably some states have more laws than the others. The list shows that these Acts are enacted on a case-by-case basis. Hence, now and then, in several occasions they overlap with each other.

TABLE 2.9 RELEVANT WATER ACTS AND GUIDELINES

Acts and Guidelines	Responsibilities
Water Act 1920	Only applies to the States of Negeri Sembilan, Pahang, Perak, Selangor, Melaka, Penang and Federal Territory - The provisions cover property of rivers, restoration, prohibition of diversions and pollution, licensing, penalties and compensation. An Act to provide the control of rivers and streams.
Water Supply Enactment (1955)	Empower State water authorities in supplying water to domestic and commercial users. Only serves as a regulatory body to oversee operations of supply company and ensure compliance with drinking water standards. No legal power to enforce compliance from the companies or for them to initiate corrective actions.
Environmental Quality Act (1974)	Prevent, abate, control of pollution and enhancement of the environment.
Water Supply (Territory of Kuala Lumpur), (Act 581)	The water supply and distribution of water in Selangor is applied to the Federal of Kuala Lumpur with modifications.
National Water Services Commission (SPAN), Act 2006	To transfer water supply services from the State List to the Concurrent List. Its vision is towards sustainable, reliable and affordable water services for all. To regulate and supervise water supply and sewerage services, enforce water supply and sewerage services laws and related matters.
Water Services Industry Act (Act 655)	To provide and regulate water supply services and sewerage services and incidental matters thereto.

The legislative approach in water quality management using the Environmental Quality Act 1974 has been successful in reducing pollution to a certain extent. It has involved pollution control, prevention and continuous assessment (monitoring) of the river environment. There are still many challenges that need to be addressed to achieve a holistic water quality management.

Under the tenth Malaysia Plan (2011-2015) improvements and enhancement to the quality of service and coverage to ensure sustainability from both an operational as well as environment perspective are planned:

Developing a long-term strategy for water resource management to achieve water security

a) The National Water Resources Policy (NWRP), currently being formulated by the Ministry of Natural Resources and Environment Ministry, will chart the future course for the water sector.

Improving pollution control targeting main sources of pollution

a) More than 90% of Malaysia's water supply comes from rivers and streams - efforts to tackle river pollution given due emphasis.
b) River pollution is due largely to an increase in the number of sources of pollution and a decrease in the amount of rainfall — improper discharge from sewerage treatment plants, agro-based factories, livestock farming, land clearing activities and domestic sewage.

The National Green Technology policy which was launched on 24th of July 2009 under the Ministry of Energy, Green Technology and Water (KeTTHA) incorporated Water and Waste Management under one of its four sectors. Under this policy, the Adoption of Green Technology in the management and utilisation of water resources, wastewater treatment, solid waste and sanitary landfill is promoted however, there is no direct elaboration and emphasise in terms of the type of technologies for water or wastewater treatment to be preferred towards achieving the aim of this policy, which is to reduce the emission of greenhouse gases.

2.6.5 Policy Gap

In Malaysia, environmental policy still lags behind other pressing issue such as the industrial development (Pierce, 2006). The public lack awareness on environmental issues and tend to leave all the responsibilities to the government. Since Malaysia achieved its independence, water policies were made by individual states on ad-hoc basis. There is no centralised or standardised water policy or guideline for States to adopt. As a result, there are numerous Acts and guidelines on water managed by multiple agencies. In 2002, the National Policy on the Environment was established. It intends to enhance societal quality of life through sustainable economy, which runs parallel with social and cultural progress (Shah et al., 2009). However, the policy is too general without any specific details in each of its section. It is not clear and thus could not be implemented by relevant departments.

Good water governance is therefore needed in Malaysia to handle water problems complexity, for a better or efficient water use and management. It is also to ensure economic, social and environmental sustainability (Sampford, 2007; Shah et al., 2009). However, in implementing good water governance, legislation becomes the central mechanisms (MOSTE, 2002; Ahmad Fariz et al., 2009). The legal instrument would then support the water policies, programmes or projects. It also allows the development of water resources management and water services sustainably. Ethical frameworks are also necessary to address water issues such as allocation of water resource, efficiency, productivity and valuation. Government agencies and State authorities should collaborate more and draw up State and national regulations to ensure proper and sustainable utilisation.

Wolf and Stanley (2011) added that law performed on behalf of the environment and local authorities should have preventive, remedial and compensatory functions. The water management needs to be under a single entity, with improved planning and continued attention. Unifying water-related activities under one ministry or agency are also a good alternative for good water governance (Melati, 2010). Ahmad Fariz et al. (2009) pointed that the communities, industries and stakeholders should be made aware of the importance of water and take part to protect the natural resource.

According to MOSTE (2002), well trained monitoring and enforcement officers are also required to effectively manage and enforce water issues.

2.6.6 Other Policies and Initiatives

2.6.6.1 National Science and Technology Policy

The policies on science and technology (S&T) in Malaysia were established to promote the utilisation of science and technology as a tool for economic development and the improvement of people and physical well-being. The development of these policies is led by the Ministry of Science, Technology and Innovation (MOSTI) (http://nitc.mosti.gov.my/nitc_beta/index.php/national-ict-policies/science-a-technology-sat-policy). As of now, three policies have been established spanning from 1986 to 2012. The vision, policy statement, goal and objectives of these policies are as follows:

Vision:	To establish Malaysia as a nation that is competent, confident and innovative in harnessing, utilising and advancing S&T towards achieving the goals of vision 2020.
Statement:	Maximise the utilisation and advancement of S&T as a tool for sustaining economic development, the improvement of quality of life and national security.
Goal:	Accelerate the development of S&T capability and capacity for national competitiveness.

Objectives:

a) To increase R&D spending to at least 1.5 per cent of Gross Domestic Product (GDP) by year 2010 in an effort to enhance national capacity in R&D; and

b) To achieve a competent work force of at least 60 RSEs (researchers, scientists and engineers) per 10,000 labour force by the year 2010 in order to enhance national capability in S&T

The first National Science and Technology Policy (NTSP1) was established in 1986 and spanned up to 1989. The policy was installed to promote scientific and technological self-reliance in support of economic activates through the enhancement of research and development capabilities. Under this policy, a conducive environment and infrastructure was created to nurture scientific creativity and education.

The NTSP1 was followed by the Industrial Technology Development: A National Action Plan, which ran from 1990 to 2001. The Plan was formulated focusing on three thrusts — strengthening institutions and support infrastructure for technological development, ensuring diffusion and application of technology, and elevating science and technology public awareness.

The Second National Science and Technology Policy (NSTP2) was formulated in 2002 and ran until 2012. The NSTP2 provides a framework for improved performance and long-term growth of the Malaysian economy with the following aims:

a) To enhance national capability and capacity for R&D, technology development and acquisition;

b) To promote partnerships betweenpublic funded organisations andindustries;

c) To accelerate the transformationof knowledge into value added products, processes, services or solutions;

d) To position Malaysia as atechnology provider in keystrategic knowledge industries;

e) To foster societal values andattitudes that recognise science and technology as critical to futureprosperity;

f) To utilise science and technology that are in conformity withsustainable development; and

g) To develop new knowledge-based industries.

h)

Due to limited resources, the allocation of the resources is closely aligned to national priorities for the country's transformation into a knowledge-driven economy so as to maximise economic and social returns. Therefore, the NTSP2 addresses seven key priorities areas, each with its own specific initiatives (SI), as follows:

a) Strengthening research and technological capacity and capability (7 SI);

b) Promoting commercialisation of research outputs (4 SI);

c) Developing human resource capacity and capability (13 SI);

d) Promoting a culture of science, innovation and techno-entrepreneurship (10 SI);

e) Strengthening institutional framework and management for S&T and monitoring of S&T policy implementation (10 SI);

f) Ensure widespread diffusion and application of technology, leading to enhanced market-driven R&D to adapt and improve technologies (6 SI); and

g) Build competence for specialization in key emerging technologies (5 SI).

The NSTP2 shows that there has been a steady increase in the gross expenditure on R&D (GERD), leading to a substantial increase in Malaysia's GERD/GDP from 0.22 per cent in 1996 to 0.82 per cent in 2008. GERD increased substantially from RM0.55 billion in 1996 to RM6.07 billion in 2008 (http://www.nst.com.my/nation/extras/r-d-accelerating-development-of-science-technology-and-innovation-1.98008).

In terms of human resource in R&D in Malaysia, in 2008, there was a total of 40,840 research personnel which comprised of researchers, technicians, and support staff; the highest recorded so far. Of this total, 77 per cent were researchers, followed by technicians (6.6 per cent) and support staff (16.4 per cent).The researcher headcount was estimated at 31,442 with a ratio of 28.5 researchers per 10,000 workers, showing a significant increase (76.7 per cent) over a period of seven years — 2002 to 2008.

MOSTI has been reported to be working on the third National Science, Technology and Innovation Policy (NSTIP), which was supposed to come into effect in 2013 (http://www.nst.com.my/nation/extras/r-d-accelerating-development-of-science-technology-and-innovation-1.98008). The new NSTIP is expected to cater to the current dynamic global science, technology and innovation scenario.

2.6.6.2 Rainwater Harvesting

The "Guidelines for Installing a Rainwater Collection and Utilisation System", 1999, can be seen as the initial phase of the rainwater harvesting policy in Malaysia. Introduced by the Ministry of Housing and Local Government after the 1998 drought, it aims at reducing the dependency on treated water and provides a convenient buffer in times of emergency or a shortage in water supply. The Guidelines also proposes the construction of 'mini dams' or rainwater tanks in urban areas instead of continuing to build giant dams upstream. This may not only conserve the treated water but can act as urban flood control. Nevertheless, the guidelines is only intended to be a reference for those who want to install the system.

Five years later, the same Ministry prepared another cabinet paper to the National Water Resources Council to encourage government buildings to install rainwater collection and utilisation system. The Council agreed that rainwater utilisation is to be encouraged, but not mandatory, in all Federal and State government buildings. In addition, the Council stated the need for rainwater utilisation campaign and to provide a solution to prevent mosquito breeding in the gutters or tanks. As rainwater harvesting was very alien to many Malaysians then, as well as the fact that most of the system was not available locally, the implementation of that new policy was not really successful (Rahman et al., 2010).

The most encouraging development for the success of rainwater harvesting in Malaysia came about after the announcement by the government to make it mandatory in March 27, 2007. Despite the fact that it will only apply to large buildings such as factories, schools or bungalows, it is certainly a right step towards having more sustainable building in Malaysia. The government has finally come to realise that although initial steps were taken since 1999, not much progress has been made in conserving treated water. It is hoped that by making rainwater harvesting mandatory, Malaysia building are more water efficient and will have less impact on the environment as a whole.

Be that as it may, compulsory rainwater harvesting has some implications on the existing legal provisions. Compulsory harvesting would involve amendment of certain laws since this attracts some planning, environmental and health issues. As design and requirement of a building are legislated under the Uniform Building By-laws 1984, it will be the most affected laws in this area (Rahman et al., 2010).

The proposed amended By-Laws shall require new buildings to include system installation in the layout plan. For a start, it should apply to the large buildings and it will be the responsibility of the Public Work Department to refuse applications that do not comply with the new requirements. Nevertheless, this could be easier said than done as the developers who will practically implement this new policy might have other concerns such as cost and technical issues.

2.6.6.2.1 Rainwater Harvesting as a Tool for Sustainable Water Management

Sustainable water management concentrates on efficient use of water and more sustainable water consumption behaviour. To this end, it is important to introduce water demand management, establish water use policy and design plan for sustainable water use. This can be done by integrating water management into individual site and building design through the concept of rainwater harvesting or greywater recycling. Rainwater harvesting implemented at a macro level helps to provide stormwater reduction that prevents flooding downstream and enhance surface water quality. The creation of large retention pond and sustainable drainage system incorporate rainwater harvesting concept and also provide landscape amenity for the community. It helps to secure water for irrigation to reduce the urban heat island, reduce the need for water transfer between regions and reducing clean-up costs from pollution incidents and flood.

Rainwater harvesting can improve the present unsustainable use of water. Almost a third of the treated water was used for flushing and less than ten per cent was used for cooking and drinking. The increasing numbers of new buildings, especially in cities, do put some pressure over the existing provision of water supply. Early this year alone, there have been calls for new dams as well as inter-State water supply to support the ever increasing water demand in Selangor, Kuala Lumpur and Putrajaya. Besides the high cost involves, these suggested projects will have a significant impact on the environment. If new or existing buildings are equipped with rainwater harvesting system, they will reduce the dependency over piped and treated water and protect the existing forest from turning into new reservoirs. Besides being the alternative source of water in cases of water shortage, general public can save money by utilising rainwater for their general washing, toilet flushing and gardening. The saving will be much more for large building such as school, factory and shopping complex.

2.6.6.2.2 Implementation of Rainwater Harvesting in Malaysia

Implementation of compulsory rainwater harvesting in Malaysia as announced by the Former Prime Minister, Tun Abdullah bin Haji Ahmad Badawi invites opinion from various stakeholders. As a matter of fact, several hundred households in Carey Island which has collected rainwater for more than 25 years would be the best group to comment on this. Their houses have been built with a gutter system that channels rainwater from the roof into large water tanks placed outside the houses. Water flows from the tanks from attaching the pipes just like treating pipe water. The houses are located in the oil palm estate belonging to Golden Hope Plantations Bhd that is occupied by estate workers and management staff on the estate. According to the President of Malaysian Water Association, Datuk Syed Muhammad Shahabudin (2007), the implementation of the rainwater harvesting system must be done selectively, as not all buildings could be fitted with the system, as it required a considerable roof size and also room for the storage tank (cited in Brenda and Rosmina, 2013). The Department of Irrigation and Drainage (DID) and The Ministry of Energy, Water and Communication (KTAK) are the two government agencies that have implemented the rainwater harvesting system in the early stages of implementation. The response of rainwater harvesting system in the beginning is far from encouraging (Shahwahid, 2007).

2.6.6.2.3 Challenges in Implementing Rainwater Harvesting System

Rahman et al. (2010) identified the following challenges in implementing rainwater harvesting system in Malaysia:

a) The high capital cost of installing the rainwater tanks by the developer that will have to be eventually borne by the house owners and this will further increase the price of the houses in Malaysia;

b) Maintenance problems in the long term period such as cleaning of the choked conveyance pipes, leaves in gutters and periodic pump maintenance; and

c) Water-related issues such as polluted rainwater from bird faeces, breeding of mosquitoes which might pose a danger of spreading of diseases to the public.

2.6.6.3 National Urbanisation Policy

The National Urbanisation Policy (NUP) developed by the Town of Country Planning and Development in August 2006, in particular stresses that cities need to improve water management efficiency which emphasise on the use of alternative sources and non-conventional of rainwater harvesting and water recycling. Under the policy, the relevant agencies for implementation are the Ministry of Technology, Water & Communication (KTAK) , the Water Supply Department as well as both State and Local Authorities.

2.6.6.4 Groundwater Policy and Regulation

In Malaysia only 2% of water demand is met by using groundwater. This figure is much lower than compared to Thailand (80%), China (78%), Austria (98%) and Denmark (100%). The use of groundwater can play a significant role in meeting Malaysia's water supply demand and can reduce the impact of drought.

Therefore, it is important to explore groundwater resources and exploit them for urban and rural water supplies. This can only be done with proper policies and strategies by practicing sustainable groundwater resource management. The groundwater policy, regulations and actions must cover the aspects groundwater data collection, setting water quality standards and regulation of groundwater abstraction. The groundwater policy and regulations should also cover areas like groundwater monitoring, identification of pollution sources, designating protection areas and enforcement of standards and regulations.

2.6.6.5 Mega Science Framework Study

The Mega Science Framework study for Sustained National Development (2011-2050) was carried out to identify future opportunities that Science, Technology and Innovation (STI) in water sector may provide to enhance Malaysia's economic development in domestic, regional and global markets in the foreseeable future. The study was conducted through several stages which include:

a) Assessing current situation;

b) Identifying future drivers of change;

c) Linking water STI to sustainable economic development;

d) Identifying opportunities in each relevant economic sector, including international and national case studies;

e) Prioritising STI investment opportunities in a Risk-Return framework;

f) Describing each recommended STI investment in detail;

g) Testing STI investments via a Stakeholder Workshop; and

h) Preparing STI investment roadmaps.

The sectors (besides water) that were included in the analyses are of crucial importance to national economy and well-being including energy, health, agriculture, forestry and fisheries, biodiversity including biosystems, climate change, STI education, infrastructure, environment, culture, housing, transportation, natural resources, human development, population, and materials.

During the initial stage of the study, 70 potential investment opportunities were identified. The list was also classified into two categories, namely 'creating new wealth' and 'sustaining the resource'. These were short-listed to 20 through prioritisation based on potential significance of the STI opportunity to Malaysia.

The 10 opportunities categorised under 'creating new wealth' are as follows:

a) Eco-tourism around high ecological value sites
b) Urban water-based tourism
c) Market and export high quality water
d) Clean water for aquaculture Industry
e) Malaysian brand for domestic water purification unit
f) World leading tropical aquatic research and education
g) Knowledge export
h) Tapping urban water
i) Rainwater harvesting
j) Zero pollutant discharge

The 10 opportunities categorised under 'sustaining the resource' are as follows:

a) Exploit groundwater further as a resource and drought protection
b) Improve flood forecasting and mitigation
c) Reform Water Education System in Primary, Secondary and Tertiary Sectors and Wider Public
d) Improve ecosystem protection from point and non-point pollution
e) Clean-up and rehabilitate waterways in highly visible locations to improve aesthetics and ecological functioning
f) Irrigation water use efficiency
g) Community (including decision-makers, planners, and politicians) values ecosystem services for Malaysia
h) Advanced water and wastewater treatment
i) Wetland ecosystem repair
j) Water management planning to improve resilience with uncertain climate future

The details of each list are provided in the study which includes its description, risk-return analysis, benchmarking against similar initiatives in Malaysia and abroad, specific potential projects and investment Roadmap. Each Roadmap consists of a timeline of proposed investments, enablers (e.g. visioning, policy, administration, governance) and outcomes that are anticipated within a specific period of time. The timeline segments are mostly the same for each STI opportunity (i.e. 2010-2015, 2015-2020, 2020-2030, 2030-2040, and 2040-2050).

2.6.7 The Role of Stakeholders in Water Policies

2.6.7.1 Definition, Goals and Levels of Stakeholders Engagement

Ertel (2007) defines 'stakeholder' as "any person, or group, who has an interest in the project or could be potentially affected by its delivery or outputs." Stakeholders should be engaged as early as possible, and this has been considered as essential for high quality and durable decisions (Chess and Purcell, 1999; and Reed et al., 2009). Many scholars categorise stakeholders into different groups, such as Blair and Whitehead's (1998) 'potential for collaboration' and 'potential for threatening', Goodpaster's (1991) 'fiduciary' and 'non-fiduciary', and Clarksons' (1995) 'primary' and 'secondary'. Having a clear definition of stakeholders and the different categories of stakeholders, it is important to have a good understanding on what level of stakeholder engagement is actually being sought. Stakeholder engagement can be broadly categorised into the following (Table 2.10).

TABLE 2.10 LEVELS OF STAKEHOLDER ENGAGEMENT AND GOALS

Inform	To provide the public with balanced and objective information to assist them in understanding the problem and opportunities.
Consult	To obtain public feedback for decision-makers to make decisions acceptable to all stakeholders.
Involve	To work directly with the public throughout the process to ensure that public concerns are taken into account in the decision making process.
Collaborate	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.
Empower	To place final decision-making in the hands of the public.

All these five different levels of stakeholder engagement need to be reviewed to see at which level the stakeholders should be involved in managing water resources in Malaysia. The project team intends to review all these levels of stakeholder engagement and propose the best one for the Malaysian conditions. Later, different types of methods for stakeholder engagement focusing on water resources management could be prioritised according to their suitability for managing water resources in Malaysia. We emphasise that the selection of stakeholder engagement methods requires knowledge about the methods that are available and which are best used for which purpose. The knowledge available is not yet comprehensive. Even in such countries where stakeholder engagement methods have a comparatively long history of practice (e.g. Australia), it is unclear to practitioners how to match 'what we want from stakeholders and the many ways in which people can participate' (Dovers, 2000). Yang et al. (2011) have developed a long list of methods applied in stakeholder engagement.

2.6.7.2 Types of Stakeholders

Partridge et al. (2005) had divided different types of stakeholders into two broad categories; namely, primary and secondary types of stakeholders (Figure 2.9). Figure 2.9 illustrates the relationship between research activities and the stakeholders.

Figure 2.9 Typical Primary and Secondary Stakeholders.
Source: Partridge et al., 2005

2.6.7.3 Types of Stakeholders in Water Resources

There are three major stakeholder groups in water resources. These groups comprise of scientists, policy-makers, and resource managers. Each of these groups have their own role in solving water resource problems but often the various approaches do not necessarily complement each other. Weaknesses of each stakeholder group of water resources are shown in Figure 2.10.

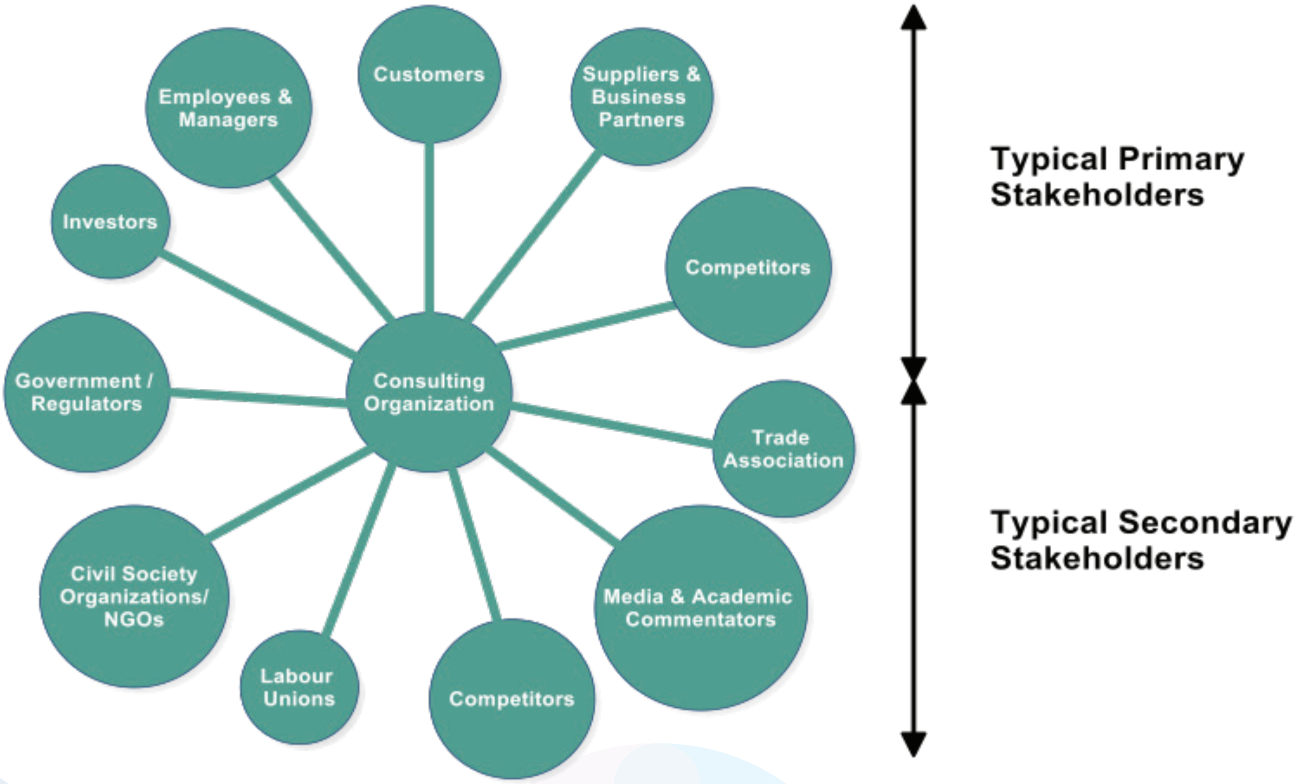
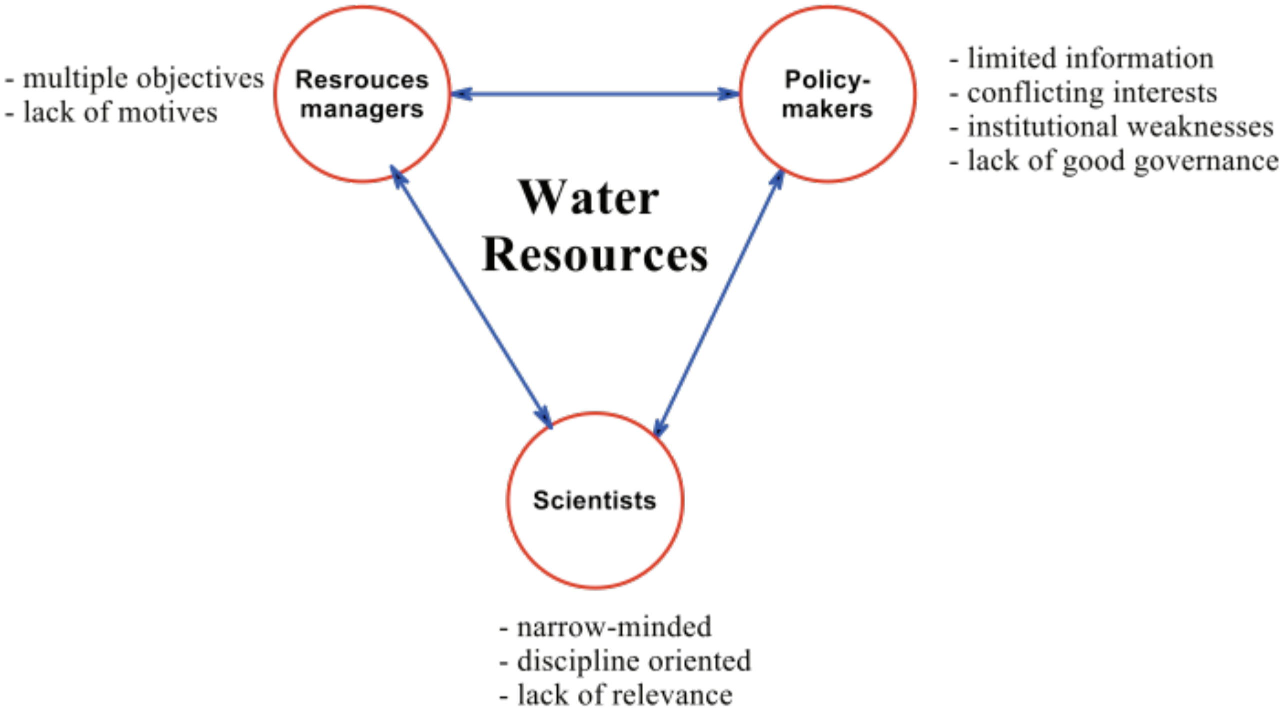


Figure 2.10 Weaknesses of major stakeholders in water resources.

Scientists are usually preoccupied with their disciplinary orientation, and as a result, are often insensitive to the scale and scope of the problems. In as much so that their efforts often lack relevance to public policy development. Most scientists are not aware of relevant policy questions. Consequently, their excellent and important research findings are often neglected in the public policy-making process. Likewise, the policy-makers often lose their credibility since the public policy they generate lacks the scientific background that has to be tapped from the scientific community. In addition, in the developing countries institutional weakness due to lack of capacity is very common and this contributes to the difficulty of implementing, monitoring and evaluating any policies. On the other hand, the resource managers often simply follow their own business-oriented agenda. Their motives are short-term benefits without consideration of the potential of long-term sustainable development objectives (Bonell and Bruijnzeel, 2005).

The role of stakeholders in water resources management can be unearthed by answering the questions such as: "How different stakeholders are affected by changes in environmental conditions and freshwater pollution?"; "How can stakeholders consensus be built around water resources management issues, including reducing non-revenue water (NRW)?" and "How to effectively engage different stakeholders in watershed management activities?"

In Malaysia, stakeholder engagement can rarely been seen except in minor scale in irrigation project where pilot testing usually include farmers to test the efficiency of the project given. However, in defining stakeholder engagement concept in those studies, the engagement defined as the engagement which required ideas and thought exchanges between various types of stakeholders and stakeholders with the decision makers and not their involvement in main process of the decision-making. This is an timeworn way of thinking: stakeholders are only notified of the decision; the traditional ways of posting survey forms without proper consultation and face-to-face contact are employed; and stakeholder engagement is not included in the definition of 'stakeholder engagement' in their studies. This is the main issue which breaks trust between stakeholders and the project managers and decision makers which likely may result in partial or complete failure of the projects. We are, thus, investigating this issue in detail in this study.



3.1 Introduction

In this section, the trends in water research are measured by examining the research input and output. The research inputs are determined by analysing the funding information acquired from the Ministry of Science, Technology and Innovation (MOSTI) and Ministry of Education (MOE). Acquiring the award date and the recipients enabled us to examine the historical research trends. The outputs are measured solely on publications as a quantitative measure of research. Academic literatures indexing services have been used to measure the productivity of scientific publications.

3.2 Funding Trends in Water Research

Institutions of higher learning in Malaysia generally rely on the local and Federal government for their research funding. In Malaysia, two of the biggest ministry providing funds are the Ministry of Education (MOE) and the Ministry of Science, Technology and Innovation (MOSTI). MOE's grants are opened only to institutions of higher learning, whereas government agencies, universities and private companies are eligible for MOSTI's. The funding information for this study has been provided by Malaysian Science and Technology Information Centre (MASTIC) and Ministry of Education (MOE). The raw data has been tabulated according to the awarded institution, award year and organised with reference to the 8th, 9th and tenth Malaysian Plans whenever available (Table 3.1 and Table 3.2).

The awarded grant are categorised according to research theme categories (i.e. biodiversity, climate change, drainage, energy, pollution, water management and others), geological and source classification of the water (i.e. coast, island, lake, rain, river, waste and undefined) and the type of research (i.e. science, technology and social) (Figure 3.1 and Figure 3.2).

TABLE 3.1 THE ANNUAL DISTRIBUTION OF RESEARCH GRANTS BY MOSTI ACCORDING TO RECEIVING INSTITUTIONS

No.	Name of Institutions	8th MP	9th MP	10th MP	Total
1	Universiti Teknologi Malaysia	13	11	1	25
2	Universiti Kebangsaan Malaysia	5	17	2	24
3	Universiti Putra Malaysia	5	12	4	21
4	Universiti Sains Malaysia	9	7	2	18
5	Universiti Malaysia Terengganu	2	7	1	10
6	Universiti Malaya	2	5	1	8
7	Universiti Teknologi MARA	2	4	0	6
8	Universiti Tenaga Nasional/Malaysia	2	3	0	5
9	Universiti Islam Antarabangsa	1	3	0	4
10	Universiti Malaysia Sabah	0	3	1	4
11	Agensi Nuklear Malaysia	1	2	0	3
12	SIRIM	2	1	0	3
13	Universiti Malaysia Sarawak	2	1	0	3
14	Forest Research Institute of Malaysia	0	2	0	2
15	MARDI	1	0	1	2
16	Universiti Tunku Abdul Rahman	0	1	1	2
17	CEMS Engineering Sdn Bhd	0	1	0	1
18	Logamahir (M) Sdn Bhd	0	1	0	1
19	Hydrogen Energen Technology Sdn. Bhd.	1	0	0	1
20	Omega Synergy Sdn Bhd	0	1	0	1
21	Pending Makmur Sdn Bhd	0	1	0	1
22	Jabatan Pengairan dan Saliran	1	0	0	1
23	Universiti Tun Hussein Malaysia	0	1	0	1
24	Universiti Malaysia Perlis	0	1	0	1
25	Universiti Malaysia Pahang	0	1	0	1
26	Universiti Teknologi Petronas	1	0	0	1
27	University of Nottingham Malaysia	0	1	0	1
28	International Medical University	0	1	0	1
	Total	**50**	**88**	**14**	**152**

Note: It is arranged from the highest to the lowest with the total number awarded per annum at the bottom and the total awarded per institution and its percentage at the far right. Each cell is highlights the number of project per institution per year as a progressive band to assist visualisation. The period within 8th Malaysian (2001-2005) are coloured blue, 9th Malaysian Plan (2006-2010) in orange and the Tenth Malaysian Plan (2011-15) in red.

Chapter 3

Review of Past & Current Water R&D

Analyses of the MOSTI grants data show that Research University (RU) received 63% of the research projects awarded from 2001 to 2011 (total of 96 research projects). Universiti Teknologi Malaysia (UTM) received the highest number of research projects, followed by Universiti Kebangsaan Malaysia (UKM), Universiti Putra Malaysia (UPM) and Universiti Sains Malaysia (USM). UTM and USM showed a consistent trend with at least one project awarded annually by MOSTI. In comparison, other RUs such as UKM and UPM showed only intermittent success in receiving research funding. However, since the detailed financial data is not available for each grant due to confidentiality concerns, these patterns will not reflect the financial quantum of these grants. Small recurring awards may imply small research projects while singular awards followed by absence of subsequent funding may suggest a large and significant research grant awards amounting to millions that are then disbursed via institutional mechanism to research peers in the same institutions. The distribution of research grants are also evidently biased towards established university with significant critical mass of researchers. Among the top 10 receiving institutions, nine are Institutes of higher learning (IHL) with only Agensi Nuklear Malaysia making the list at no 10 with three projects. The data also showed that the trend of awarding research grants is the highest during the early years upon the inception of each Malaysian Plan. This is a normal operational behaviour for funding bodies as the amount of funds available is the highest during the early phases and recedes in time as it is awarded.

Analyses of the MOE data revealed that from 7428 research grants awarded since the Eighth Malaysian Plan to the most recent in 2013, only 248 or 3% were related to water. UTM obtained the highest number of MOE grant in total (51), followed by UMT (41), UPM (29), USM (28), UITM (23) and UM (17). The dominance of RUs is broken with the inclusion of UMT and UITM in the top five grant receivers. UMT received 21 (50%) of their grants in 2007 and has continually received a relatively high number annually, mostly on research topics related to the coastline.

Overall, the highest number of research grants related to water research was awarded in the 9th

Malaysia Plan by MOHE (159 projects) and MOSTI (88 projects). The majority of the research grants from MOHE were awarded to topics in Science (166), Engineering (63) and followed by Social Sciences (21) (Table 3.3). The research level are mostly fundamental (207) with ERGS (24), LRGS (11) and PRGS (8). The geographical focus of the water source of the research projects are almost evenly distributed between Waste, Undefined, River and Coast with Island and Lake related research significantly under studied. Certain universities seems to focus on specific source; UMT on the coast and UTM on wastewater.

TABLE 3.2 THE ANNUAL DISTRIBUTION OF RESEARCH GRANTS BY MOHE ACCORDING TO RECEIVING INSTITUTIONS

No	University	8th Malaysia Plan				9th Malaysia Plan					10th Malaysia Plan			Total	%
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013		
1	Universiti Teknologi Malaysia						17	6	2	10	5	11		51	20.6
2	Universiti Malaysia Terengganu						21	2	1	6	5	6		41	16.5
3	Universiti Putra Malaysia					8	5		3	5	6	2		29	11.7
4	Universiti Sains Malaysia	1	1			1	8	1			12	4		28	11.3
5	Universiti Teknologi MARA						10		2	9	1	1		23	9.3
6	Universiti Malaya			3	2	1	2	2		2		4	1	17	6.9
7	Universiti Malaysia Sabah						6	2	1	2		1		12	4.8
8	Universiti Tun Hussein Onn Malaysia					1	6			1	1	2		11	4.4
9	Universiti Malaysia Perlis						3			2	2	2		9	3.6
10	Universiti Malaysia Pahang			1			1	1				3		6	2.4
11	Universiti Kebangsaan Malaysia										3	2		5	2.0
12	Universiti Malaysia Sarawak							1	1	1	1			4	1.6
13	Universiti Pendidikan Sultan Idris									2	2			4	1.6
14	Universiti Teknikal Malaysia Melaka						1					2		3	1.2
15	Universiti Pertahanan Nasional Malaysia									2				2	0.8
16	Universiti Sultan Zainal Abidin										1			1	0.4
17	Universiti Sains Islam Malaysia											1		1	0.4
18	Universiti Malaysia Kelantan						1							1	0.4
	Annual Total	1	1	4	2	11	81	15	10	42	39	41	1	248	

Note: It is arranged from the highest to the lowest with the total number awarded per annum at the bottom and the total awarded per institution and its percentage at the far right. Each cell is highlights the number of project per institution per year as a progressive band to assist visualisation. The years within 8th Malaysian (2001-2005) are coloured green, 9th Malaysian Plan (2006-2010) in blue, and the Tenth Malaysian Plan (2010-2013) in red.

TABLE 3.3 THE NUMBER OF GRANTS AWARDED ACCORDING TO THE TYPE OF RESEARCH AREA; ENGINEERING, SCIENCE AND SOCIAL SCIENCES

Rank	University	ENGINEERING	SCIENCE	SOCIAL
1	Universiti Teknologi Malaysia	15	36	0
2	Universiti Malaysia Terengganu	8	29	4
3	Universiti Putra Malaysia	7	19	3
4	Universiti Sains Malaysia	8	16	4
5	Universiti Teknologi MARA	3	16	5
6	Universiti Malaya	4	12	1
7	Universiti Malaysia Sabah	2	7	3
8	Universiti Tun Hussein Onn Malaysia	5	6	0
9	Universiti Malaysia Perlis	2	8	0
10	Universiti Malaysia Pahang	2	4	0
11	Universiti Kebangsaan Malaysia	2	2	1
12	Universiti Malaysia Sarawak	0	4	0
13	Universiti Pendidikan Sultan Idris	0	4	0
14	Universiti Teknikal Malaysia Melaka	3	0	0
15	Universiti Pertahanan Nasional Malaysia	1	1	0
16	Universiti Sultan Zainal Abidin	0	1	0
17	Universiti Sains Islam Malaysia	1	0	0
18	Universiti Malaysia Kelantan	0	1	0
TOTAL		**63**	**166**	**21**

TABLE 3.4 THE NUMBER OF GRANTS AWARDED ACCORDING TO THE TYPE OF RESEARCH FUNDING; ERGS, FRGS, LRGS AND PRGS

Rank	University	ERGS	FRGS	LRGS	PRGS
1	Universiti Teknologi Malaysia	4	42	3	2
2	Universiti Malaysia Terengganu	6	35	0	0
3	Universiti Putra Malaysia	4	24	1	0
4	Universiti Sains Malaysia	1	22	4	1
5	Universiti Teknologi MARA	1	23	0	0
6	Universiti Malaya	0	14	0	3
7	Universiti Malaysia Sabah	1	11	0	0
8	Universiti Tun Hussein Onn Malaysia	1	10	0	0
9	Universiti Malaysia Perlis	0	8	1	1
10	Universiti Malaysia Pahang	0	6	0	0
11	Universiti Kebangsaan Malaysia	3	0	1	1
12	Universiti Malaysia Sarawak	1	3	0	0
13	Universiti Pendidikan Sultan Idris	0	4	0	0
14	Universiti Teknikal Malaysia Melaka	1	2	0	0
15	Universiti Pertahanan Nasional Malaysia	0	2	0	0
16	Universiti Sultan Zainal Abidin	1	0	0	0
17	Universiti Sains Islam Malaysia	0	0	1	0
18	Universiti Malaysia Kelantan	0	1	0	0
TOTAL		**24**	**207**	**11**	**8**

TABLE 3.5 THE NUMBER OF GRANTS AWARDED ACCORDING TO THE TYPE OF GEOGRAPHICAL SOURCE OF WATER; COAST, ISLAND, LAKE, RIVER, UNDEFINED AND WASTE

Rank	University	COAST	ISLAND	LAKE	RAIN	RIVER	UNDEFINED	WASTE
1	Universiti Teknologi Malaysia	7	0	0	7	11	11	15
2	Universiti Malaysia Terengganu	17	3	0	3	10	5	3
3	Universiti Putra Malaysia	5	2	0	2	6	8	6
4	Universiti Sains Malaysia	4	0	0	5	7	3	9
5	Universiti Teknologi MARA	3	1	2	1	5	7	5
6	Universiti Malaya	6	0	0	0	2	6	3
7	Universiti Malaysia Sabah	3	2	0	0	2	4	1
8	Universiti Tun Hussein Onn Malaysia	1	0	0	0	2	3	5
9	Universiti Malaysia Perlis	1	0	0	2	0	2	5
10	Universiti Malaysia Pahang	1	0	0	1	0	0	4
11	Universiti Kebangsaan Malaysia	0	0	0	0	1	3	1
12	Universiti Malaysia Sarawak	4	0	0	0	0	0	0
13	Universiti Pendidikan Sultan Idris	0	0	1	1	1	1	0
14	Universiti Teknikal Malaysia Melaka	1	0	0	0	0	2	0
15	Universiti Pertahanan Nasional Malaysia	0	0	0	1	1	0	0
16	Universiti Sultan Zainal Abidin	0	0	0	0	0	1	0
17	Universiti Sains Islam Malaysia	0	0	0	1	0	0	0
18	Universiti Malaysia Kelantan	0	0	0	0	1	0	0
	TOTAL	**53**	**8**	**3**	**24**	**49**	**56**	**57**

Research institutions have been participating in water research in Malaysia. Institutions such as Forest Research Institute (FRIM) and The Malaysian Agricultural Research and Development Institute, (MARDI) have been awarded research grants by MOSTI. The National Hydraulic Research Institute of Malaysia (NAHRIM) for example has conducted 40 water-related research projects since 2001 using directly awarded research funds as well as various other joint inter-governmental research projects. One example of an inter-governmental research projects is the FRIM-Forestry Department of Peninsular Malaysia (FDPM) joint project on monitoring water quality and valuing hydrological function in forest reserves in 2012. Various agencies and research institutions do conduct collaborative research but information on these projects is kept internally and is only available later in annual reports or media releases. Such information on water research activities should be captured early on and managed by a lead agency that can them share the knowledge within the research ecosystem and potentially reduce redundancy in water research.

3.3 Publishing Trends in Water Research

The trend of water publications was determined using quantitative methods established in bibliographic analysis. The quantitative method used is a “neutral means of measure”, which is unlikely to be corrupted by human perceptions of reputation. Using a bibliometric analysis of research publications, we had removed personal bias and local perspective, hence generating a comprehensive and a ‘top-down’ review of the area of interest. Peer review, undoubtedly, has to remain the procedure of quality judgement but peer review and other related expert-based judgements have disadvantages. Opinions of peers may be influenced by subjectivity, narrow-mindedness and limited cognitive horizons. This dependence may result in conflicts of interests, quality unawareness, or a negative bias against newcomers to the research area. In addition to providing alternative perspective, in terms of research trend of a topic of interest, bibliometric analysis provides direct measurement to authors’ and institutions’ performance in scientific community (research outputs). Most importantly, such results from bibliometric analysis enable funding agencies to justify the research budget well spent.

Bibliometric analysis has been applied to various researches related to water. Hagendijk and Smeenk (1989) reported their case study on Dutch freshwater ecology back in 1989 and strongly suggested that bibliometric (among others) helps in understanding the intellectual continuity of researchers with relevance to science policy. Zhang et al. (2010) adopted a bibliometric study on global wetland researches with a detailed analysis on the keywords used; and hence, the temporal trends of the researches. Researches on drinking water were also mapped (Fu et al., 2013; Hu et al., 2010) using bibliometric approach in which regional contributions were presented and popular journals were identified. Bibliometric studies in water research are often topics specific (Hu et al., 2010; Fu et al., 2013; Hagendijk and Smeenk, 1989; Zhang et al., 2010) or journals specific (Wang et al., 2010, 2011) whereas water research is actually a wide research area covering basic sciences and applied sciences with major topics such as water resources management, alternative energy (hydroelectric), wastewater treatment and others.

A more general bibliometric study on water research could provide a broader perspective regarding research trends and focus. Unfortunately, bibliometric studies are very much data dependent; the bigger and the more accurate the dataset is, the better the results. Efforts have been done by various parties in order to index as many publications as possible. Although general search engines such as Google serves as a broad starting point for this task, they returns generic web results which may not be of particular interest to scientific communities, hence, the need for highly specialized indexing service. SCOPUS and Thomson Reuters's (formerly Institute for Scientific Information, ISI) collection of services (including the Journal Citation Reports, Web of Science, Web of Knowledge, etc. http://wokinfo.com, WOS) and Elsevier's SCOPUS (http://www.scopus.com), are known to be two of the most extensive academic publications indexing services. Datasets used for bibliometric analysis were mostly mined from ISI (Falagas et al., 2006; Nazim and Ahmad, 2008; Huet al., 2010; Rajendram et al., 2006; Francisco Mu~noz-Leiva et al., 2012; Zhang et al., 2010) while minority, were from SCOPUS (Bajwa and Yaldram, 2013; Kumari, 2009). There are some literatures which use datasets from other established alternative sources as well, such as PubMed (Falagas et al.,2006; Vergidis et al., 2005) and Google Scholar (Sanni and Zainab, 2010). In terms of preference, WOS is the more sought-after index as it is also the de-facto owner of the "performance index" known as the impact factor (IF). Impact factor is arguably one the most important criteria any author looks for; be it for citation purposes, reference purposes or publication purposes.

However, SCOPUS offered breadth as it has approximately 20% or more coverage than WOS. In addition, alternative indexing services are now available in Google Scholar. Specifically, the major difference between Google Scholar and WOS/ SCOPUS is that the index of most (if not all) of the known "scholarly" publications to date, including conference proceedings, technical reports, unpublished articles and legacy publication, even the hardcopies, are made available for free. Coverage of Google Scholar, in particular, is not known publicly although it is speculated that in theory, it covers all publications (as long as the publishers do not disallow it from indexing). Though started off with some limitations and lack of coverage, it is shown that Google Scholar is gaining ground, partly because of Google's (the search engine) popularity. More publishers have allowed Google Scholar to index their publications particularly those of conference proceedings to increase visibility since Google Scholar's service is free and easily accessible. In general, Google Scholar's dataset might not alter the ranking of top academicians and/or institutions, the relative ranking in the middle is affected (Meho and Yang, 2007). In our study, we highlighted this challenge by comparing data mined from Google Scholar with WOS and SCOPUS on specific water research theme in Malaysia.

a) SCOPUS as a benchmarking tool. The initial proposal proposed the use of the SCOPUS Scival Spotlight http://info.scival.com/spotlight as a benchmarking tool to compile all water-related publication in scientific journal publications and map the Water R&D publication at national level. The strength of various institutions in Water R&D can be evaluated based on publication based evidence. However, preliminary analysis showed that the use of Scival Spotlight is not suitable and may not reflect the actual publication landscape of Malaysia IHL and research ecosystem. These are due to several reasons.

b) SCOPUS as a recent phenomenon. Only until recently that SCOPUS has been given prominence by the research community in Malaysia; significantly after the creation of RU within Malaysia's IHL. Therefore, many research output are not available in SCOPUS because i) they are legacy and not indexed by SCOPUS ii) they are not published with international publishers.

c) Limited coverage of SCOPUS. Although SCOPUS has extensive coverage, it is relatively limited to international publications and do not cover majority of local conference proceedings, seminars and scholarly academic work such as books and thesis. As the research publication landscape of Malaysia is only recently aware of the requirement of publication in journals, the migration of publication destination has yet to occur.

d) Insurmountable publication threshold of SCOPUS Scival Spotlight. The use of SCOPUS Scival Spotlight requires the institutions to have a publication threshold with a minimum number of papers published in a specific research area. Absence of a significant number of publications will prevent the identification of competencies that can be attributed to the institution. For an example, UTM possess a high number of publication related to water research. However, as many of these publications are not indexed by SCOPUS or has yet to reach a certain publication threshold, UTM which a research leader in water research has only managed to be identified as an "emerging competency" on two areas; Competency EC #11 [frequency analysis; flood; flood frequency] and Competency EC #59 [model; weather; rainfall]. Identification of these research competencies attributed to UTM is only based on 15 publications while a simple search of pdf documents with the keywords "water" and "rainfall" on Google pdf search resulted in 2810 documents consisting of thesis, conference papers, reports and proceedings.

e) Subscription basis of SCOPUS. SCOPUS requires a subscription for comparative analysis between institutions (RM 10,000 per institution). As an example, to compare 5 RU requires an institution to pay a subscription fee of RM50,000 making a nationwide comparison a financially unfeasible task.

We have decided to index water resource research publications using a more thorough method using a combination of Google Scholar, SCOPUS and ISI WOS. The resulting analyses are divided into those indexed in SCOPUS/ISI WOS and Google Scholar. This hybrid method would be a more inclusive and comprehensive method compared to the method of sole dependency to SCOPUS to attribute research output and the resulting competency attribution.

3.3.1 General Publishing Trends in SCOPUS/ WOS Indexes

A comprehensive bibliometric analysis on past water research in Malaysia was conducted using the data mined from ISI's WOS and SCOPUS. A basic statistical aspect of the bibliometric analysis was performed, such as citations distribution, publications growth, authors' and institutions' networks. The results are summarised in graphical visualizations to portray the complex bibliographic relationships, trends and patterns. The dataset used for this study covered the data from ISI's WOS (all databases) and SCOPUS and mined using predetermined search terms (Table 3.6).

TABLE 3.6 LIST OF CONTROLLED SEARCH TERMS USED TO RETRIEVE PUBLICATIONS

List of search terms (with Malaysia)	
Eutrophication	Flood
Stormwater	Groundwater
Hydrology	Lake
Reservoir	Pond
Well (thermal/spring)	Rainfall
River	Estuary
Sea	Coast
O□shore	Wastewater
Water and health issue	Water conservation
Water pollution	Water quality
Water analysis	Water resources
Water issue	Water supply
Wetlands	Water

The publications were organised and exported into RIS (Research Information Systems) format. Data was merged in EndNote reference management software with the removal of duplicated items. Additional data were also mined according to the list of (Malaysian) institutions indexed by SCOPUS, mostly institutions of higher learning. Data in ISI was obtained by using all publications in the Water Resource category, filtered by Country=Malaysia. The two datasets were combined and duplications were removed with priority (of retaining the publications) given to publications indexed by ISI. Further filtering of unrelated articles was done in addition to filling in missing information of the published articles (e.g. abstract, authors, keywords, etc.). Institutions' name and authors' name were standardized and additional information were added, specifically, the publications' category and geographical sources (of the water used in the particular publication).

A total of 2516 publications were identified, namely of which 489 were from ISI, and 2027 from SCOPUS. The publications span from the year 1964 to 2012. There are 5277 unique authors from 814 institutions. Unique authors were identified automatically based on the author's name and his/her known affiliations. Authors with unknown institutions (either untraceable or affiliated to a generic street address), is denoted as NULL, which is 495, including unknown authors from unknown affiliations.

3.3.2 Publication Output in SCOPUS/ WOS Individual

The results mark an unhealthy trend where the distribution of publications and citations where more than 3500 authors published only once in water research, and more than 1800 authors have zero citations. A closer inspection of the publications vs citations of the top 20 authors revealed a stark performance contrast between publications and citations (Figure 3.1). There is a shift in the authors' ranking, which suggests that a high number of publications does not always translated into high citations (and vice versa); with only four authors belonging to both top 20's. These low citations with high publications number could be due to excessive 'networking' which published medium to low impact papers. It is expected that majority of authors will generally publish a few highly cited 'breakthrough' publication that are extensively cited by others researchers, with a majority of medium-cited publications, and a 'long tail' of uncited papers.

Examination of the annual new author induction showed a positive correlation and exponential trend between the number of new authors and the number of publications (Figure 3.2). However, the increase of number of new authors is now more that the increase in publications; with the gap becoming significant beginning in 2000. The increasing new author vs new publication ratio suggests that too many authors are sharing the same publications. While some of the research is indeed in a large scale, in which a large number of authors are involved, publications authorship should be limited to those who contribute considerably (based authorship ethics). Pressure from the institutions and individual performance index/ assessment (for salary increment/promotion) maybe reasons for this trend.

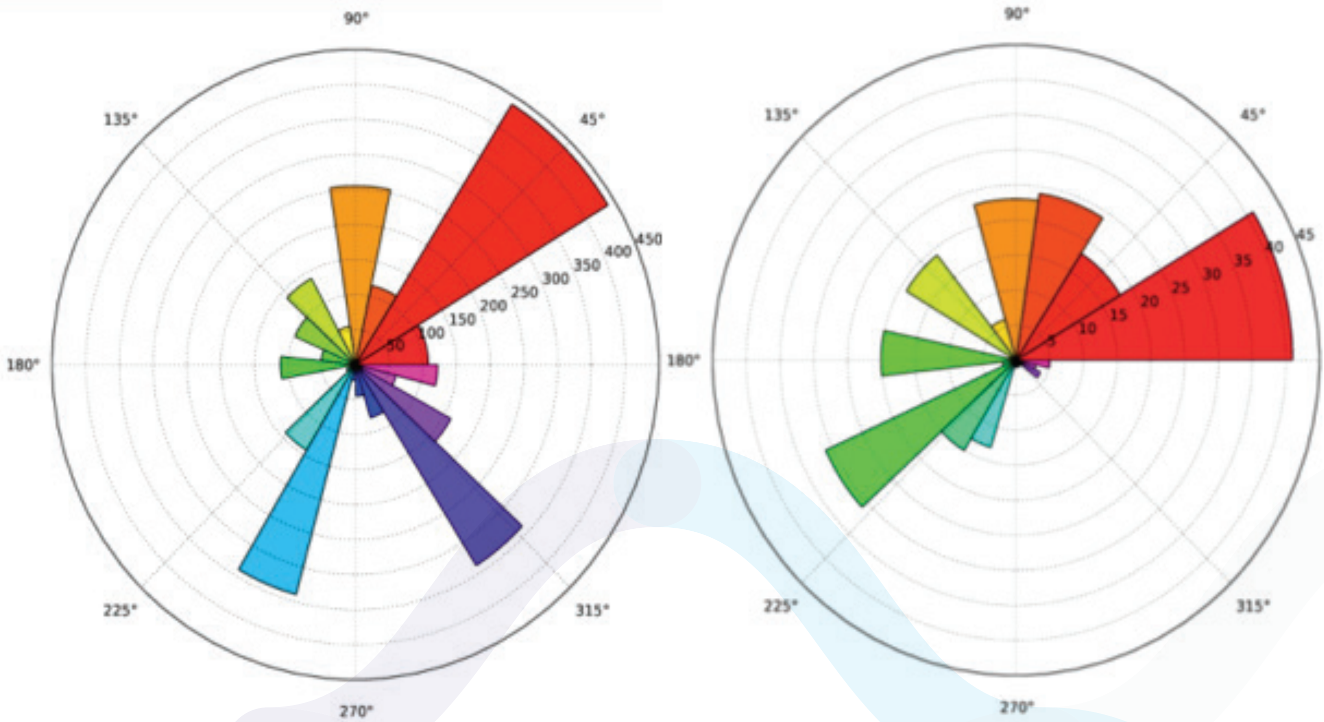


Figure 3.1 (Left) -The top 20 authors, as according to number of publications where the angle of each arc is proportional to the number of publications (of the authors) with the radius proportional to citations (of the authors). (Right) -Top 20 authors in accordance to the number of citations where the arc angle represents the citations and the arc radius represents the number of publications.

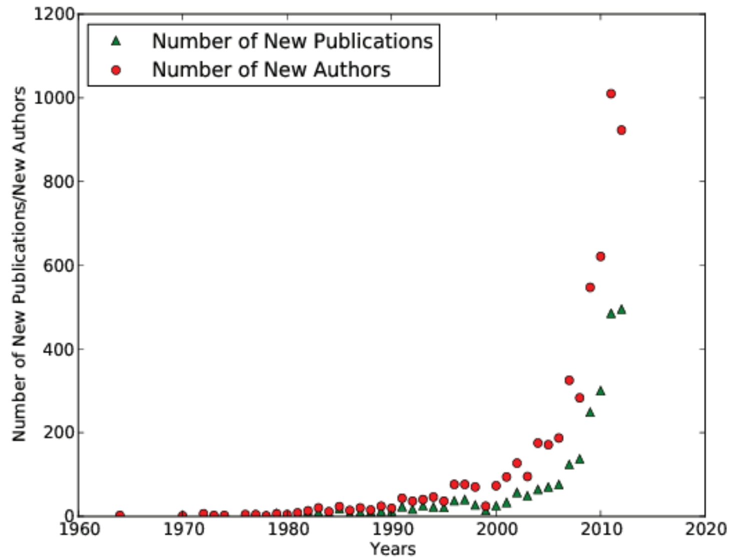


Figure 3.2 New authors and new publications by years.

Gephi network visualisation software (Bastian et al., 2009) was used to visualise and analyse our datasets in terms of authors networking and institutional networking. All the networks are undirected. There are 5277 authors (nodes) with 12227 interactions (edges) in our authors' network with 161 non-interacting authors and 514 authors who only interact once. Nodes' size is proportional to the nodes' degree and all the nodes are coloured according to communities detected via modularity analysis. The largest sub-network consists of 2465 nodes with 7397 interactions.

3.3.3 Collaboration Network in SCOPUS/ WOS Individual

It is found that UKM, UTM and UPM have authors that are ranked top five in terms of inter-institutional collaborators. Prolific authors have been known to adopt a successful collaborative strategy that brings major researchers together thus resulting in even bigger and more solid research network. Highly ranked authors possess high betweenness centrality score exhibit high inter institutional collaborators/ inter institutions ratio, which makes him/her a critical personnel in collaboration across different communities in the research area. The publication pattern also suggests that these authors possess the ability to collaborate with those outside of their local communities. They would serve as the best example of striking a balance intra and inter institutional partnership. Examination of the authors' network in their respective institutions and map the connections between different authors in the particular institution. Relevant nodes and edges were extracted and communities were detected by Gephi before being exported to visualization by Circos (Krzywinski et al., 2009).

The interactions between communities decreased from the highest to the lowest ranked institutions although the number of communities is similar. UPM, USM, UKM and UTM showed good intra collaboration among their respective communities with at least 10% of the communities are interacting among each other (**Figure 3.3**).

Communities in Institutions

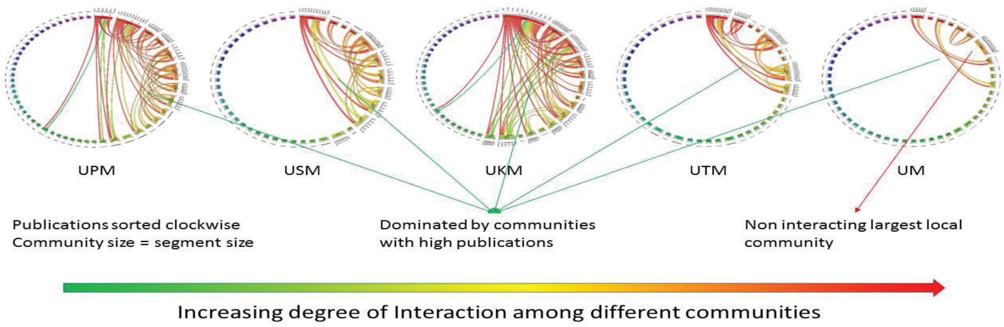


Figure 3.3. Comparison of network of top institutional (local) communities in research universities.

Note: The Outermost ring denotes each community detected by Gephi, and only interlinks (connections to different communities) are shown. Communities without any interactions (i.e. communities with only one member) are discarded. The ring segments are sorted by the cumulative number of publications (starting from 12 o'clock) and the ring size is correlated with community size.

The interactions among communities are driven by the community size and community strength (number of publications) with interactions dominating the right portion of the graph. In the case of UM, although having 51 local communities, the size of each community is small compared to the rest of the RUs. Surprisingly, the largest local community in UM, U63, does not interact outside of itself. This suggests that researchers in UM only collaborate with members in the same community. Although a similar trend is observed in UITM researchers, the situation may be due to the sheer size of the university that consists of a network of universities with branches in almost every State in Malaysia. The lack of interactions among UITM local communities maybe due to geographical limitations with the researchers (although affiliated to UITM) based in different branches of UITM in different states. For IIUM and UMT, interactions exist among communities with high publications number and low publications number although the interactions are still very much community size dependent (**Figure 3.4**).

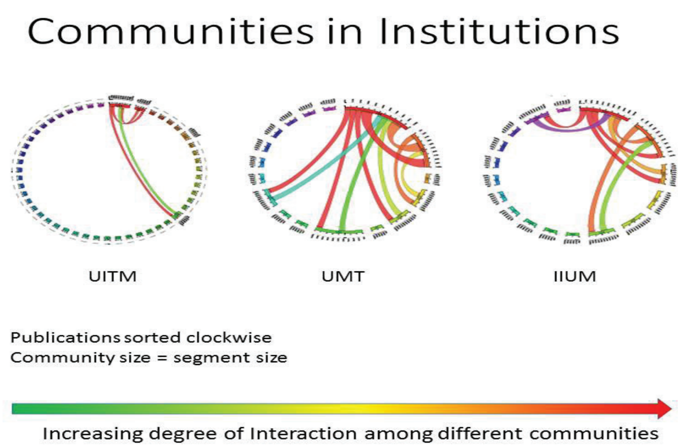


Figure 3.4. Comparison of network of top institutional (local) communities in research universities.

Note: The outermost ring denotes each community detected by Gephi, and only interlinks (connections to different communities) are shown. Communities without any interactions (i.e. communities with only one member) are discarded. The ring segments are sorted by the cumulative number of publications (starting from 12 o'clock) and the ring size is correlated with community size.

Finally, collaborative network among the top 20 authors was also analysed (**Figure 3.5**). The results showed that all top 20 authors are male and relatively senior in their respective institutions. The network analysis indicated that there is a lack of collaborative publication with only five out of the top 20 authors have co-authored together while 11 only collaborate with authors from the same institutions and only four interact with authors from different institutions. This suggested weak inter-institutional collaborations among top authors in water research.

3.3.4 Publication Output SCOPUS/ WOS by Institutional

The analysis of the top 20 institutional publication collaboration networks and publication output clearly indicates that the RUs are in the lead **(Figure 3.6** with **Figure 3.7** as close-up). The National Higher Education Transformation Roadmap by the Ministry of Higher Education (MOHE) describes the inception of a 'research university' that is to be awarded to deserving institutions of higher learning. Thus, recipients such as UKM, UPM, USM, UM and UTM are expected to undergo transformation that departs from the traditional roles of teaching to research and innovation based education. Therefore, the RUs have significantly more research capacities in terms of number of researchers, equipment and budgets.

Figure 3.5 Top 20 authors collaboration network.

Note: Code Authora1 Yap, C.K. [UPM],A2 Aziz, H.A. [USM],A3 Azamathulla, H.M. [USM],A4 Isa, M.H. [UTP],A5 Kamaruzzaman, B.Y. [IIUM; UMT], A6 Ab Ghani, A. [USM], A7 Aris, A.Z. [UMS; UPM], A8 Mokhtar, M. [UKM], A9 Abdullah, K. [USM], A10 Ismail, A.F. [UTM], A11 Mat Jafri, M.Z. [USM], A12 Ismail, A. [UPM], A13 Toriman, M.E. [UKM], A14 Zakaria, N.A. [USM], A15 Hameed, B.H. [USM], A16 Yusoff, I. [UM], A17 Ahmad, A.L. [USM], A18 Jemain, A.A. [UKM], A19 Tan, S.G. [UPM] And A20 Ujang, Z. [UTM]

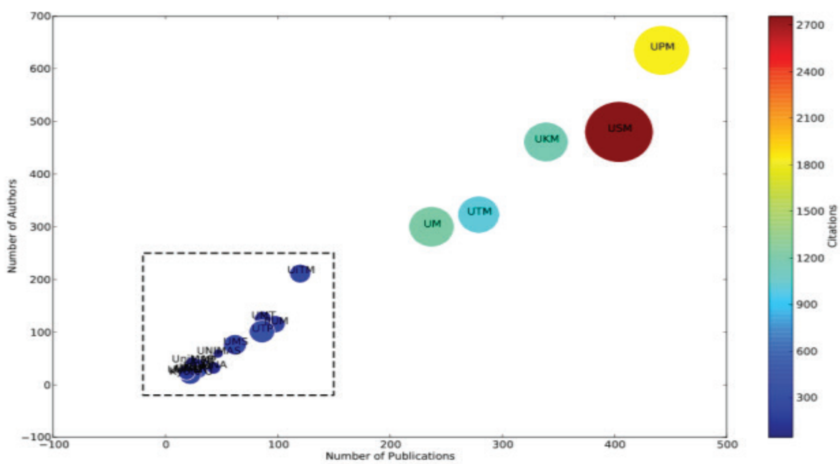


Figure 3.6 Top 20 institutions' trend on number of authors, number of publications and citations, sorted by the number of publications.

Note: The dotted area is enlarged as figure 2. The size of the bubbles correlates to the number of citations (also highlighted as cool-warm colour scheme). A clear split exists between two groups of institutions; those with more than 200 publications and those without.

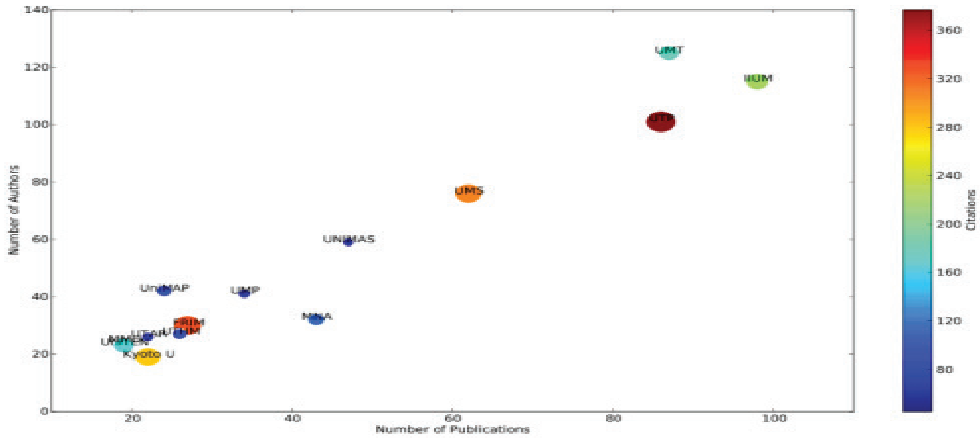


Figure 3.7 Close up of the dotted area in figure 7 showing the smaller of the two groups of institutions in figure 2; those with more than 200 publications and those without.

While the domination of the RU are clearly established, institutions such as UMP, UMT and IIUM, have also impact on water research publication in Malaysia. However, non-public/private institutions can be seen populating the lower rank (**Figure 3.8**), such as Multimedia University (MMU) and Universiti Tenaga Nasional (UniTEN), with the exception of Universiti Teknologi Petronas (UTP). Although funding to these private institutions from the government are relatively limited, research in UTP are partly associated with PETRONAS, the national oil and gas company which owns UTP. A rather unique institution in the top 20 is the Malaysian Nuclear Agency (MNA). Though the main focus of MNA is nuclear research, the publication list revealed a significant number of projects involving heavy metals.

The general trend revealed that the number of authors is directly proportional to the number of publications (an almost linear plot in **Figure 3.6** and **3.7**), with limited exceptions (clearly shown in **Figure 3.7**). Citations trend (bubble colour and size), on the other hand, is less dependent on both parameters. USM, being the institution with the second highest number of publications, tops the citations (six authors with highest citations are from USM). FRIM possesses better citations count than most of the institutions in **Figure 3.8** except for UMS and UTP.

The annual publication trend of the top 20 institutions with highest publications shows that UKM and UM are pioneers in water research with publications as early as 1972. They were joined by UTM, USM and UPM in year 1984-85. The rest of the institutions started to contribute to publications either in late 90s or early 2000s. There is a net positive growth of publications, the top eight institution generally recorded a yearly increment (denoted by the cool-warm colour scheme in **Figure 3.8**).

3.3.5 Research Collaboration Network in SCOPUS/ WOS Institutional

All the RUs, again excel in institutional network, scoring higher networking among different communities and higher sub network connectivity. As far as top 10 institutions are concerned, UPM, UKM and UMS are grouped in the same community (detected by Gephi), USM and UTP are in another community, and, UTM–UITM and IIUM–UMT are in separate communities, respectively. The networking among top 20 institutions is generally diverse , however, has very few unconnected nodes (institutions).

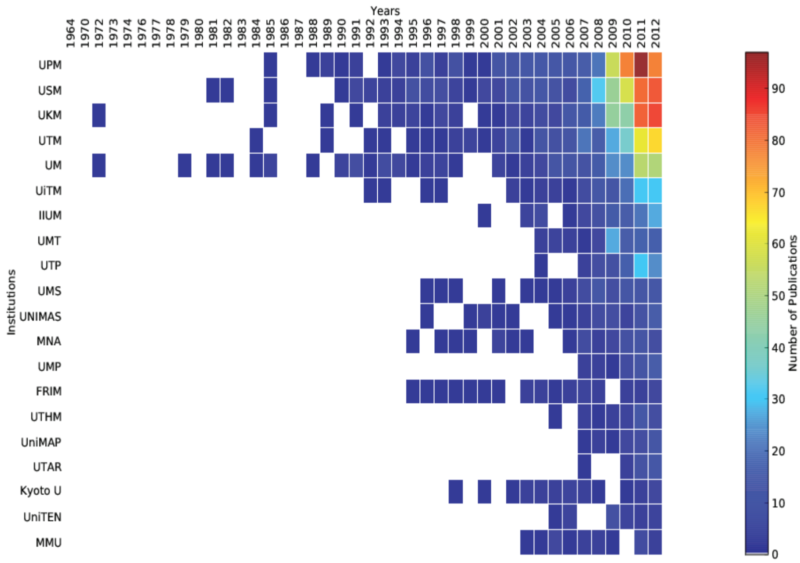


Figure 3.8 Annual publications for top 20 institutions.

Note: with white=no publications. All institutions constantly published once they have started with absence limited from one to four years (from 1990 onwards).

TABLE 3.7 LIST OF FOREIGN (FOR) AND LOCAL (MAL) COLLABORATED INSTITUTIONS FOR THE TOP 20 INSTITUTIONS

Institutions	FOR	MAL
Universiti Putra Malaysia	111	41
Universiti Sains Malaysia	88	25
Universiti Kebangsaan Malaysia	57	40
Universiti Teknologi Malaysia	70	35
Universiti Malaya	73	33
Universiti Teknologi MARA	22	20
International Islamic University Malaysia	12	21
Universiti Malaysia Terengganu	21	14
Universiti Teknologi Petronas	25	10
Universiti Malaysia Sabah	25	16
Universiti Malaysia Sarawak	7	13
Malaysia Nuclear Agency	4	12
Universiti Malaysia Pahang	14	9

Forest Research Institute of Malaysia	23	4
Universiti Tun Hussein Onn Malaysia	12	4
Universiti Malaysia Perlis	7	9
Universiti Tunku Abdul Rahman	12	5
Kyoto University	24	12
Multimedia University	3	6
Universiti Tenaga Nasional	1	6

RUs generally have more collaboration with foreign institutions than local ones. The lacks of foreign collaborators for other local could be due to the institutions' reputation in water research.

3.3.6 Publishing Trends in Google Scholar

A set of controlled search terms (**Table 3.6**) identical to the ones used earlier were used to query for articles of our interest in Google Scholar. Any duplications to the publications identified in WOS and SCOPUS were removed. Each Google Scholar indexed publications were categorised to themes (biodiversity, climate change, drainage, energy, pollution, water management and others), geological classification (coast, island, lake, rain, river, waste and undefined) and type of the study (science, technology and social).

A total of 1257 articles were collected during the data mining after some filtering and data cleaning. Majority of the articles are found to be of journal articles (988), followed by conference proceedings (173) and the rest (96). This trend is similar with the WOS and SCOPUS's dataset. We manage to tagged 840 authors with their known affiliations while discovering 1537 (potentially) new authors. The years of publications span from 1963 (which is a year before the oldest publication in WOS and SCOPUS's dataset) to 2012. In addition, the Google Scholar's coverage of legacy publications is found to be superior to WOS and SCOPUS with additional years of coverage (1967-1969). In terms of journals/conferences coverage, dataset for Google Scholar shows 556 unique journals/conferences not found in WOS and SCOPUS dataset which constitutes 700 articles. Such observation is significant enough for any of the bibliometric analyses to include data from Google Scholar.

The different dataset of articles mined from Google Scholar has generated the different ranking of the top institutions in water research (**Table 3.8**). Three new institutions were promoted from WOS/SCOPUS ranking to top 20 in Google Scholar; NAHRIM, FFPRI and DID which previously on published 12, 17 and 18 respectively according to WOS/SCOPUS dataset. Minor shuffling occurred throughout the top 20 overall ranking including the 2nd-3rd place swap between USM and UKM and the outgoing of UniTEN, MMU and UTAR. Although the ranking of top contributors were the least affected, we observed newcomers in the range of top 20, hence justifying the need for bibliographic analysis to include Google Scholar's data.

TABLE 3.8 SUMMARY RANKING OF EACH DATASET AND THE FINAL RANKING (COMBINATION OF BOTH DATASETS) OF THE TOP 20 PUBLISHING INSTITUTIONS

WOS/SCOPUS	Pub	Google Scholar	Pub	Total	Pub
UPM	442	UKM	155	UPM	596
USM	404	UPM	154	UKM	494
UKM	339	USM	86	USM	490
UTM	279	UM	63	UTM	342
UM	237	UTM	63	UM	300
UiTM	120	UMS	36	UiTM	144
IIUM	98	FRIM	27	IIUM	118
UMT	87	UiTM	24	UMT	108
UTP	86	UMT	21	UTP	100
UMS	62	IIUM	20	UMS	98
UNIMAS	47	UNIMAS	19	UNIMAS	66
MNA	43	NAHRIM	18	MNA	58
UMP	34	MNA	15	FRIM	54
FRIM	27	UTP	14	UMP	36
UTHM	26	FFPRI	10	UTHM	34
UniMAP	24	JIRCA	10	NAHRIM	30
UTAR	22	UTHM	8	Kyoto U	28
Kyoto U	22	DID	8	FFPRI	27
UniTEN	19	U Tokyo	8	UniMAP	26
MMU	19	U California	7	DID	26

Research categories were used to classify the articles according to the type of water research, whereas geological classifications attempt to differentiate the 'water source' of the publication. In addition, articles were further divided into Science, Engineering and Social based researches. The WOS/SCOPUS dataset shows that 'Pollution' is a favoured topic of research (**Figure 3.9**), whereas, Google Scholar shows that 'Others' is favoured with 'Pollution', and is followed closely (**Figure 3.10**). The categories 'Drainage' and 'Energy' remain the least published-about-research. Examination of publication categorised as "Others" in Google Scholar showed a range between generalised researches, such as water quality to social-based researches. This suggests that miscellany publication which is often found in the "Other" category is relatively harder to be published in WOS and SCOPUS indexed journals/conferences. Geological classification (**Figure 3.11**) and type of research (**Figure 3.12**) for WOS/SCOPUS dataset and Google Scholar dataset indicated a similar trend. The discernible difference is only minor; namely, the WASTE geological class showed less in Google Scholar than in WOS/SCOPUS while the UNDEFINED category is slightly higher in Google Scholar by 8%.

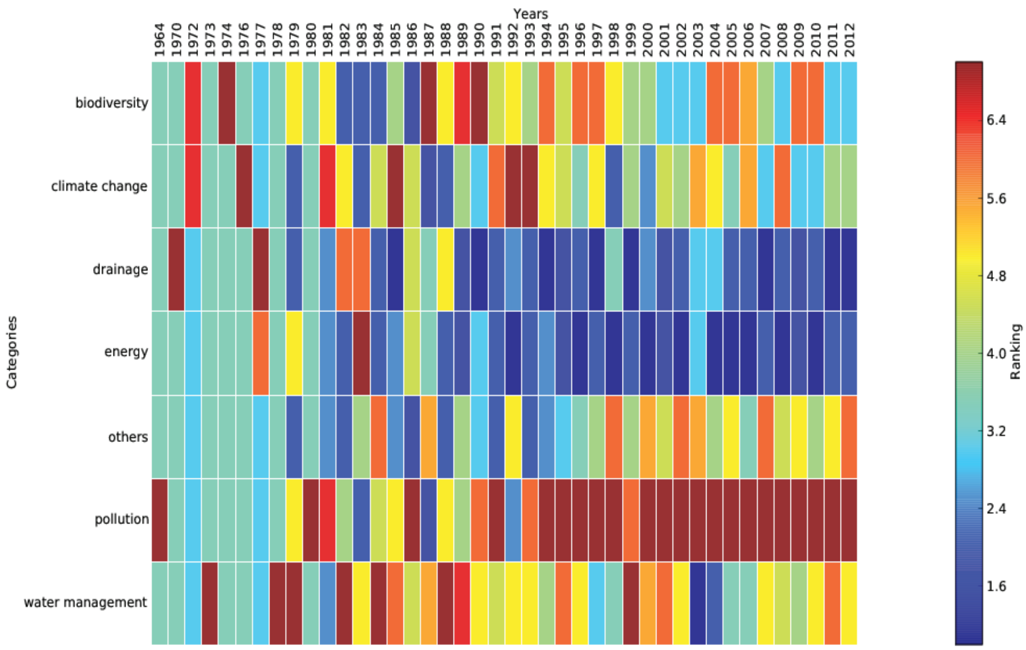


Figure 3.9 Research topic category by year for articles indexed by WOS/SCOPUS.

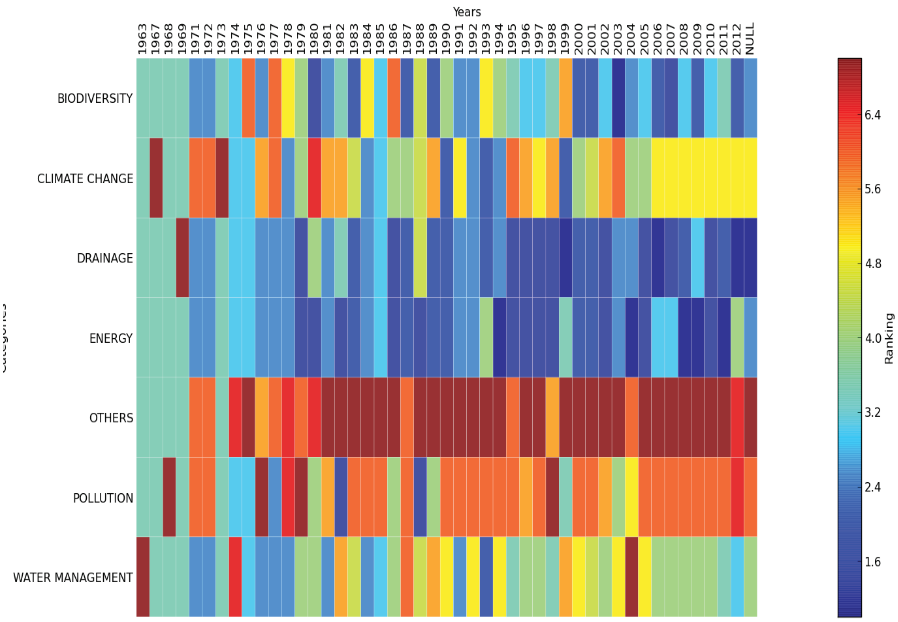


Figure 3.10. Research categories by year for articles indexed by google scholar.

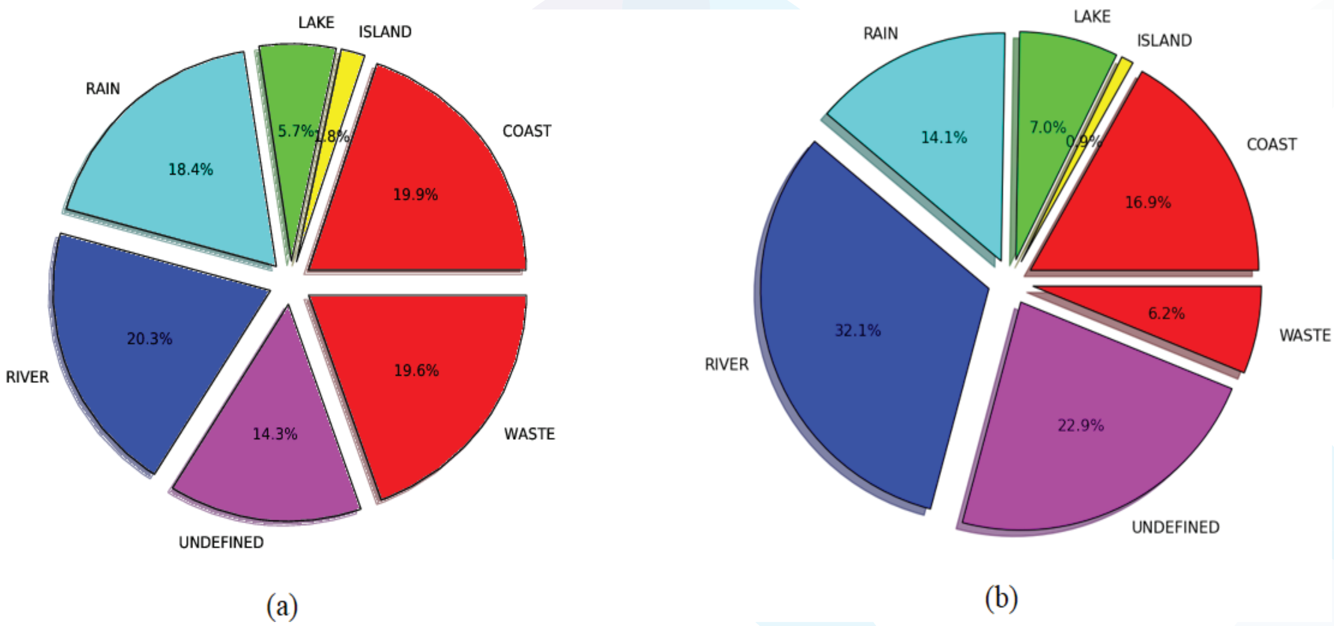


Figure 3.11. Geological classification for (a) WOS/SCOPUS and (b) Google Scholar datasets.

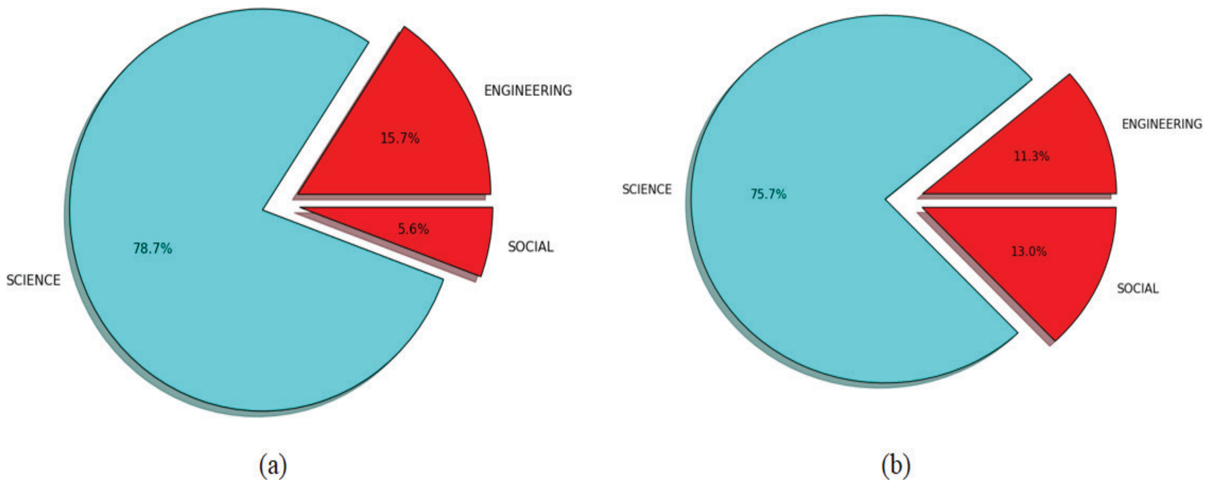


Figure 3.12 Type of research for (a) WOS/SCOPUS and (b) Google Scholar datasets.

Google scholar provides a better representation of bibliometric dataset, due to its wide coverage, particularly those of journals and conference proceedings not indexed by WOS and SCOPUS. The inclusion of such additional information, although only slightly cleaned, affects the institutional ranking and possibly author ranking as well. In the current world of no clearly defined boundaries, the (academic research) information outreach in no longer as controlled or as restricted as before, Google Scholar prove to be a competitive data provider of such by focusing primarily on the 'visibility' of the publications.

3.3.7 Publication Funding Correlation

Among the universities in Malaysia, UTM has obtained the most of grants (cumulatively from MOHE and MOSTI). This is followed by UPM and UMT, Whereas, in the field of publications, UPM is the first, followed by USM and UKM. UKM, being the 3rd in publications, has only managed to secure 26 grants. There are a number of reasons for this. One is that grants obtained from MOSTI are typically larger in term of monetary value. Another reason could be that UKM has managed to obtain a larger portion of MOHE grants prior to RMK-9 (year 2002). RUs, generally are IHL which rank 'better' in publications than grant's standings. **Table 3.9** details the institutes of higher learning (IHL)'s standings in terms of grant and publications.

TABLE 3.9 TOTAL GRANTS STANDING (YEAR 2002-2011) FOR INSTITUTIONS AND THEIR RESPECTIVE PUBLICATIONS STANDING (YEAR 2002-2012)

Grants Standing (Descending)	Publications Standing
Universiti Teknologi Malaysia	4
Universiti Putra Malaysia	1
Universiti Malaysia Terengganu	8
Universiti Sains Malaysia	2
Universiti Teknologi MARA	6
Universiti Kebangsaan Malaysia	3
Universiti Malaya	5
Universiti Malaysia Sabah	10
Universiti Tun Hussein Onn Malaysia	14
Universiti Malaysia Perlis	15
Universiti Malaysia Sarawak	12
Universiti Malaysia Pahang	11
Universiti Tenaga Nasional	18
Universiti Pendidikan Sultan Idris	21
Universiti Islam Antarabangsa Malaysia	7
Agensi Nuklear Malaysia	13
SIRIM Berhad	31
Forest Research Institute Malaysia	17
Universiti Pertahanan Nasional Malaysia	32
Universiti Malaysia Kelantan	28

3.3.8 Publications Citations Correlation

The results indicated that the ‘Pollution’ category is the top contributor to the number of publication and citations, at 981 and 6353, respectively, with an average of 6.48 citations per paper (**Figure 3.13**). Nonetheless, biodiversity, climate change, others and water management, although they shared a similar number of publications, their contribution to citations varies. Distinctively, biodiversity seems to garner more citations than compared to water management, however, the latter has a higher number of publications.

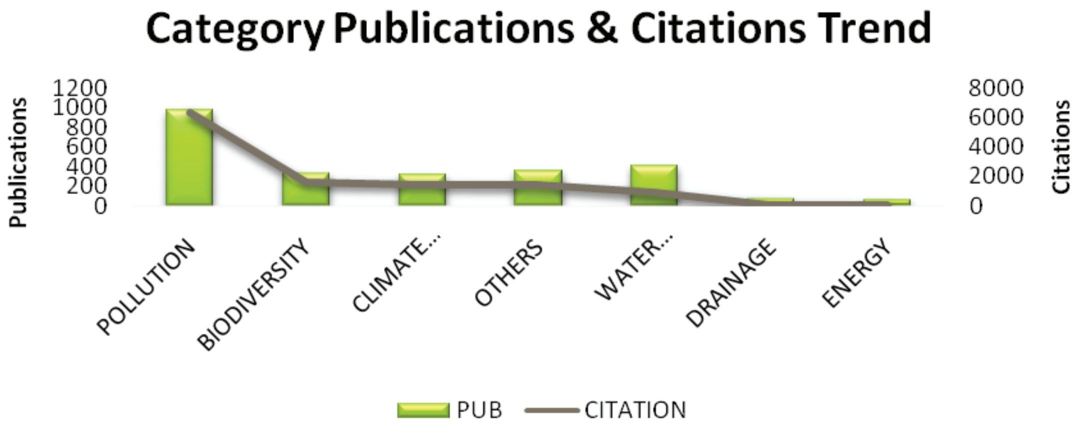


Figure 3.13. Publications and citations trend for different categories.

Similar observation can be found in geological classification (**Figure 3.14**). There is no clear leader in terms of publications with waste, rain, coast and river evenly distributed. However, citations in waste (with an average of 8.03 citations per paper) easily outperformed those of the other three classes. As shown in **Figure 3.15**, science -based research remains the top in total publications (1980) and citations (10450). This observation agrees with the trend of impact factor reported in Journal Citations Reports. For example, top ten journals which offer impact factors from 35.7 to 153.5 belongs to basic science discipline with few exception such as Nature and Nature Materials which sometimes accept technology based articles. In contrary, the top journal in computer system (IEEE Transactions on Neural Networks and Learning Systems) only manage to score 3.77.

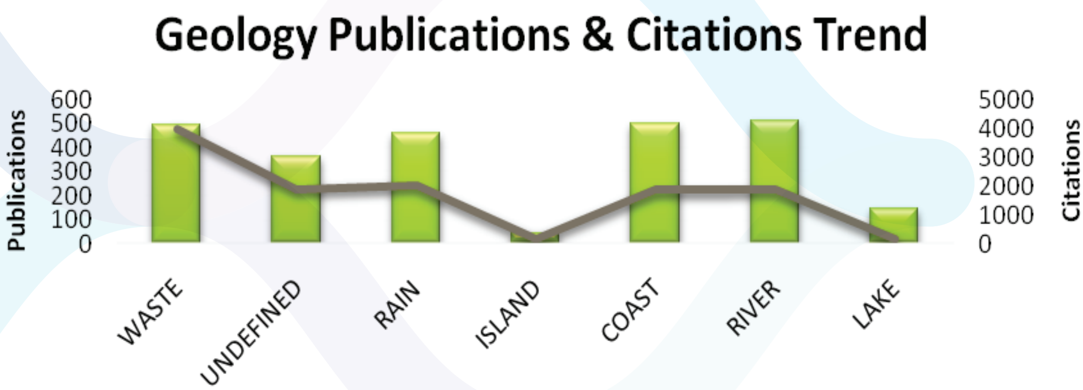


Figure 3.14. Publications and citations trend for different geological classification.

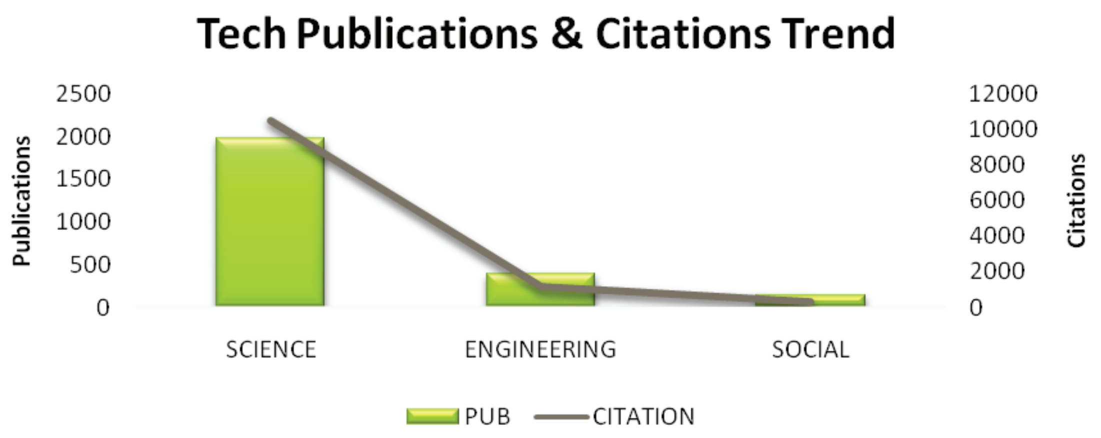


Figure 3.15. Publication and citation trends for different types of research.

3.3.9 Research Classification Relationship

The relationships between categories, geological classifications and types of research were studied as well. Every category, geological classifications and types of research 'interact' among themselves, at least once; except for climate change (category) which "has nothing to do with" waste (geological class). Science, undoubtedly, is the most important node as it has strong relationship, particularly with pollution (category). Lake and island (geological classification), and, drainage and energy (category), do not have any significant relationship with others; whereas, 'others' (category), do not have any prominent relationship with any of the geological class. The most noteworthy 'triangle' is the science – waste – pollution which constitutes around 22.5% of the total 'connections'. Another important relationship is the climate change – rain relationship weighted at 229.

In short, Science-based researches are considered the best "bang-for-your-buck" researches; be it the citation count or the relationship with other categories and geological classification. Regardless of the research area, fundamental (sciences) researches are of utmost critical since they help in understanding the phenomena which in turns encourage the technological development based on the theory. Articles which are science-based-pollution-study-of-waste (intended) are the most frequently published, as far as water research in Malaysia is concerned.

Chapter 4

Water R&D Needs Assessment

4.1 Overview

In the study, a final listing of important Water R&D areas was developed by adopting various steps. The first step was the listing of Water R&D areas from an extensive literature survey. In this step, we had identified 175 different Water R&D areas. As not all identified Water R&D areas were fit for the Malaysian environment and the country's water resource problems, so the listing of 175 Water R&D areas was further tested on the water resource problems in the country. This investigation came up with 95 Water R&D areas which we assume were the most representative for solving water resources problems in Malaysia.

The next step for developing priority listing of Water R&D areas was to design and administer the questionnaire in the Strategic Consultation workshop (SC-1). The questionnaire was distributed in the SC-1 and responses from 22 workshop participants were received. The data was analysed and a new priority listing of 95 Water R&D areas was developed. All the other steps involved in developing final priority listing of major Water R&D areas is shown in **Figure 4.1**. More details on every step are given in the subsequent sections and sub-sections.

4.2 Stakeholders Survey and Findings

In order to know which Water R&D fields are important to the stakeholders, a consultation workshop was held on 26 March 2013, at NAHRIM, where about 30 stakeholders participated. The project team distributed a questionnaire to the workshop participants. A total of 22 responses were received. A copy of questionnaire is shown in **Appendix A**. It is important to mention that the comprehensive literature review on Water R&D fields resulted into 175 different Water R&D fields. These Water R&D fields are shown in **Table 4.1**.

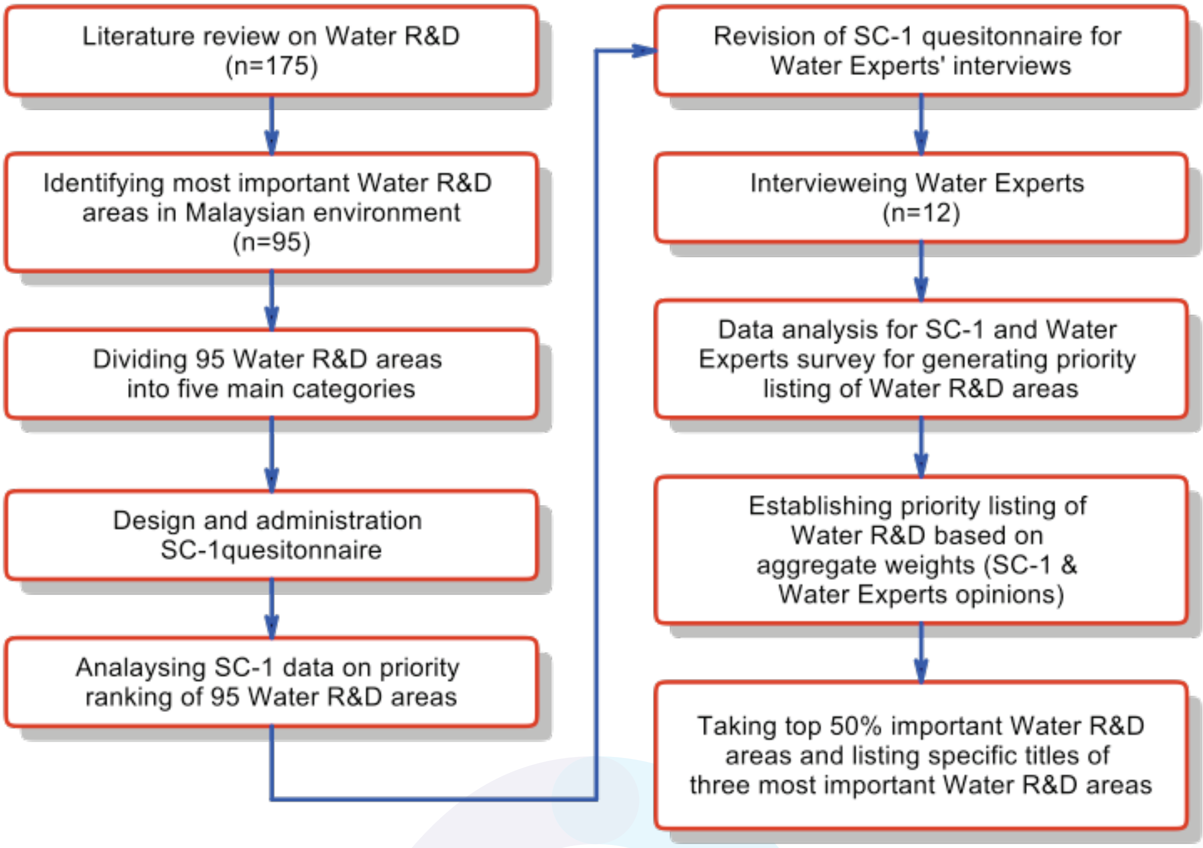


Figure 4.1. Procedure followed in developing priority listing of Water R&D areas.

TABLE 4.1 IDENTIFIED IMPORTANT WATER R&D FIELDS (N=175)

Sr. No.	Water R&D Field	Sr. No.	Water R&D Field	Sr. No.	Water R&D Field
1	Absorption and Remediation	60	Advance flood warning system	119	Alternative water resources
2	Bio-remedial treatment	61	Brackish Water Biodiversity and Conservation	120	Capacity building and awareness
3	Climate change impacts	62	Cloud Seeding Technology	121	Coastal Ecology
4	Conjunctive use of water	63	Corrosion	122	Cumulative watershed effects
5	Disaster Management	64	Drainage technologies and water logging issues	123	Drinking Water Quality Standards

6	Ecological Engineering	65	Ecology of water resources, including groundwater	124	Eco-tourism
7	Environmental Policy, Legislation and Standards	66	Environmental Protection and Health Impact	125	Environmental Risk Assessment and Bionomics
8	Estuarine Ecology	67	Flood control and management	126	Flooding and erosion control
9	Freshwater and saline water interface	68	Freshwater Biodiversity and Conservation	127	Freshwater Ecology
10	Groundwater Assessment	69	Groundwater contamination and pollutant transport	128	Groundwater Hydrology
11	Impacts of climate change on flow regimes	70	Impacts of uncertain population growth, climate change, and transboundary issues on water supply	129	Improving flood carrying capacity of rivers
12	Integrated catchment management	71	Integrated Water Resource Management	130	Isotope Hydrology
13	Management of water resources and water provision	72	Mangrove Ecology	131	Marine Ecology
14	National Biodiversity Policy	73	Natural Resource Management	132	New emerging pollutants
15	Organic contamination in water	74	Palaeoecology	133	Partnership in water resources management
16	Policies and Regulations about water	75	Polluter pays principle	134	Population Ecology
17	Restoration of urban river channels	76	River and coastal flood management	135	River Basin Management
18	Rural Hydrology	77	Sea Water/Salt Water Intrusion	136	Seasonal Climate Forecasting
19	Service efficiency and effectiveness	78	Social engineering	137	Socio-economic impacts of sea level rise and increased river flooding
20	Storm Water Management	79	Sullage	138	Surface Water Hydrology
21	Sustainable Sanitation	80	Sustainable use of water	139	SWIFT methods for monitoring water quality
22	Urban and Rural Water Policy	81	Urban Hydrology	140	Urban runoff utilisation
23	Waste assimilation	82	Waste Bioremediation	141	Waste Management

24	Water and Wastewater Treatment Technology	83	Water Availability	142	Water Bodies
25	Water Enrichment	84	Water Filtration	143	Water Footprints and Virtual water calculations
26	Water policy and governance	85	Water Pollution	144	Water quality criteria and standards
27	Water Resources Development	86	Water Resources Management	145	Water resources security
28	Water Security	87	Water Services and Utilities	146	Water supply and distribution
29	Waterborne Diseases	88	Watershed Ecosystems	147	Watershed protection
30	Zero-Discharge Technology	89	Watershed vulnerability index	148	Wetlands
31	Aquatic and Marine life	90	Arsenic cycling in lakes	149	Bio-indicators
32	Carbon Sequestration (Carbon Conversion)	91	Catchment Management	150	Climate change adaptation policies
33	Coastal hydrodynamic processes	92	Coastal Management	151	Coastal pollution
34	Decision Support System in water resources	93	Decision support systems in watershed management	152	Degradation of aquatic ecosystem
35	Drought Management	94	Dyes and Pigments	153	Ecohydrology
36	Emerging environmental pollutants	95	Environmental and eco-system services	154	Environmental flow in rivers
37	Environmental Standards	96	Erosion Control	155	Estimation and Modelling of Precipitation
38	Footprint of water	97	Formulation, establishment & implementation of water policy, legislation & institutions	156	Fresh Water and Estuarine Environment
39	Geographical Information System (GIS) in watershed management	98	Global Warming/Climate Change	157	Greywater systems

40	Hazardous Waste Management	99	Hydraulic System	158	Hydrology, Hydrogeology and hydrometeorology
41	Industrial Effluent Treatments	100	Industrial Water Management	159	Institutional and water governance
42	Karst Ecology	101	Landscape Ecology	160	Limnology
43	Marine Water Quality Standards and Criteria	102	Molecular Ecology	161	Monitoring, remediation and conservation of water resources
44	Non-revenue water (NRW)	103	Nutrient Removal Process	162	Optimization of water
45	Physiological Ecology	104	Plant and Water Relation	163	Point and non-point source pollution
46	Rainwater Harvesting	105	Reclamation, Reuse and Recycling	164	Remote Sensing
47	River ecosystem functions	106	River management and rehabilitation	165	Role of woman in enhancing water use efficiency
48	Seawater and Sediment Chemistry	107	Seawater Chemistry	166	Sediment Transport and Silting
49	Soil Bioremediation	108	Solid Waste Management	167	Storm Water Harvesting
50	Sustainability of watersheds	109	Sustainable agriculture	168	Sustainable decision-making for urban water systems
51	Toxic and Hazardous Waste	110	True economic value of water	169	Trust building with stakeholders
52	Urban water regulation and planning	111	Urban watershed remediation	170	Virtual water concept promotion
53	Waste Water Management	112	Water and Health	171	Water and wastewater treatment
54	Water Body Management	113	Water Delivery System	172	Water demand management
55	Water governance	114	Water Meters	173	Water policy
56	Water Quality Simulation Modelling	115	Water related Rules, Policies, Laws	174	Water resource assessment
57	Water resources sustainability	116	Water rights/permits/ trading	175	Water Sanitary
58	Water tariff and subsidies	117	Water Treatment		
59	Watershed sustainability index	118	Water, as a Green solvent/ Reaction Medium		

Later on, all of these 175 Water R&D fields were discussed in various meetings of the project team, and it was short-listed to only 95 Water R&D fields which were deemed to be important for Malaysian water resources and related research fields. These 95 Water R&D fields were included in the questionnaires used in the Consultation Workshop (SC-1) and the Expert Opinion Survey. All these 95 Water R&D fields were distributed into five sections of the questionnaire, depending on their relevance to a particular section. These five sections of the questionnaire are as follows:

1. Water Resources and Watershed Management;
2. Water Supply and Demand;
3. Irrigation and Drainage;
4. Sanitation, Wastewater Treatment & Environmental Issues; and
5. Water and Climate Change.

In the survey, the rating of 1 to 5 (1 being 'Least Important' and 5 being 'Most Important') was utilised to determine the level of importance of the sub-topics in different five sections of Water R&D fields. The list of short-listed (amended) Water R&D fields is given in **Table 4.2**.

TABLE 4.2 IMPORTANT WATER R&D FIELDS (N=95)

Sr. No.	Water R&D Field	Sr. No.	Water R&D Field	Sr. No.	Water R&D Field
1	Advanced and innovative technology for industrial wastewater treatment	33	Advanced dam technology	65	Advanced water treatment process
2	Alternative unconventional urban sanitation systems	34	Alternative water resources (ground water, rainwater harvesting, etc.)	66	Assessment of freshwater withdrawal
3	Assessment of water use and availability	35	Balancing water supply versus demand	67	Carbon footprint of water and wastewater treatment system
4	Catchment/river basin management	36	Climate change and aquatic invasive species	68	Climate change and hydrologic cycle
5	Climate change and rainfall modelling	37	Coastal ecology	69	Coastal erosions
6	Coastal habitat management	38	Conservation and preservation of water resources	70	Consumer and corporate water footprint assessment
7	Dam modelling construction	39	Decentralised sanitation system	71	Development of best drainage design and practices that enable crops to use shallow groundwater efficiently

8	Drainage for ecosystem and conservation	40	Drainage, water logging and salinity control	72	Drinking water quality standards
9	Drinking water quality versus public health	41	Ecohydrology	73	Electromechanical equipment
10	Energy and water efficient cities/ township	42	Environmental and indigenous people related issues	74	Environmental and social impacts
11	Environmental effects of nutrients carried in drainage discharge	43	Environmental flow versus climate change issue	75	Environmental impacts assessment of effluent discharge to environment
12	Environmental water requirements	44	Erosion and sedimentation	76	Eutrophication
13	Flood management and mitigation	45	Fresh water ecology	77	Ground water quality
14	Groundwater hydrology	46	Hydrometeorology	78	Impacts of climate change, increased population and changing human demographics on watersheds
15	Impacts of climate variability on wetlands ecosystem	47	Impacts of irrigation on environmental and health	79	Improved and innovative irrigation technology (for water use reduction)
16	Integrated coastal zone management	48	Integrated urban water management	80	Integrated water resource management
17	Low carbon and energy efficient treatment system	49	Marine biodiversity, conservation and management	81	Marine ecology
18	Marine pollution	50	Micro drainage system for small scale farming	82	Modelling climate-related water resource stressors
19	Newly emerging water pollutants	51	Nutrients removal and management	83	Phytoremediation/ Bioremediation technology
20	Policy and legislative instruments	52	Policy and legislative issues	84	Protected conservation areas in marine environment
21	Public awareness and participation in water resources conservation	53	Public participation in watershed management	85	Quality waters and wastewater reuse for irrigation
22	Rainwater harvesting for irrigation purpose	54	Risk assessment	86	River morphology
23	River rehabilitation	55	Rural hydrology	87	Salt/sea water intrusion

24	Seawater and sediment chemistry	56	Social and environmental costs of watershed degradation	88	Storm water management
25	Surface water hydrology	57	Sustainable and integrated watershed management	89	Sustainable water supply management in rural areas
26	Technologies for controlling and monitoring non-point source pollution	58	Technologies for monitoring, controlling and removing diffuse and point source pollution	90	Terrestrial atmospheric pollution and water quality
27	The adaptation of urban water supply to climate change	59	Urban hydrology	91	Water and sanitation hygiene in rural areas
28	Water demand projection and forecasting	60	Water footprint	92	Water quality Information management and modelling
29	Water quality modelling	61	Water resource assessment and accounting	93	Water security challenges and mitigation measures
30	Water supply and demand for industry	62	Water supply and demand for livestock and agriculture	94	Waterborne pathogens and microbial risks
31	Water-energy-food security nexus	63	Water-use efficiency	95	Wetland modelling
32	Wetlands and lakes restoration	64	Zero discharge technology		

4.2.1 SC-1 Survey Data Analysis

A total of 22 responses were analysed, and from that priority ranking of sub-topics in each category of Water R&D was developed. The priority ranking is based on the preference weights calculated from the survey responses. An example of survey results is shown in **Table 4.3**. More results on SC-1 data analysis are presented in **Appendix B**.

TABLE 4.3 PREFERENCE WEIGHTS AND PRIORITY RANKING OF SUB-TOPICS IN SECTION 1 (WATER RESOURCES AND WATERSHED MANAGEMENT) OF SC-1 QUESTIONNAIRE

Section-1 (Priority Listing)	Preference weights (%)	Rank
Climate change and hydrologic cycle	26.7	1
Terrestrial atmospheric pollution and water quality	26.5	2
Coastal erosions	26.2	3
Integrated coastal zone management	25.1	4
Coastal habitat management	24.4	5
Coastal ecology	24.4	5
Climate change and rainfall modelling	23.8	6
Hydrometeorology	23.0	7
Risk assessment	22.6	8
Environmental and indigenous people related issues	21.9	9
Wetlands and lakes restoration	21.4	10
Sustainable and integrated watershed management	21.3	11
Marine biodiversity, conservation and management	21.3	11
Marine pollution	21.1	12
Impacts of climate variability on wetlands ecosystem	20.4	13
Policy and legislative issues	20.2	14
Impacts of climate change, increased population and changing human demographics on watersheds	20.0	15
Dam modelling construction	20.0	15
Protected conservation areas in marine environment	19.9	16

Fresh water ecology	19.8	17
Eutrophication	19.6	18
Marine ecology	19.5	19
Public participation in watershed management	19.3	20
Social and environmental costs of watershed degradation	19.1	21
Advanced dam technology	19.1	21
Wetland modelling	18.8	22
Seawater and sediment chemistry	18.3	23
Conservation and preservation of water resources	17.9	24
Catchment/river basin management	17.2	25
Integrated water resources management	17.2	25
Electromechanical equipment	16.5	26
Water resource assessment and accounting	16.4	27
Alternative water resources (ground water, rainwater harvesting, etc.)	16.0	28
Storm water management	15.4	29
Flood management and mitigation	11.0	30
Environmental water requirements	10.8	31
Erosion and sedimentation	10.6	32
River rehabilitation	10.4	33
Urban hydrology	10.2	34
Surface water hydrology	10.1	35
Rural hydrology	9.9	36
Groundwater hydrology	9.3	37
Ecohydrology	9.1	38
River morphology	8.7	39

4.2.2 Rating Scale Problem in SC-1 Questionnaire

As mentioned earlier, we used a rating scale of 1-5 (5 for the most important Water R&D field and 1 for the least important Water R&D field). However, ratings 5 and 4 were dominating in the survey and this was not our purpose to apply rating in the survey questionnaire. We assumed that the survey participants will assign uniform rating to different sub-topics according to their importance within that topic of water research field. For example, rating 5 to the most important Water R&D field and 1 to the least important Water R&D field. However, the survey participants assigned higher ratings to almost all Water R&D fields, which indicate that all Water R&D fields presented in the questionnaire were most important to the majority of the participants and which should not be practically valid. An example of improper use of rating scale is given in **Figure 4.2**.

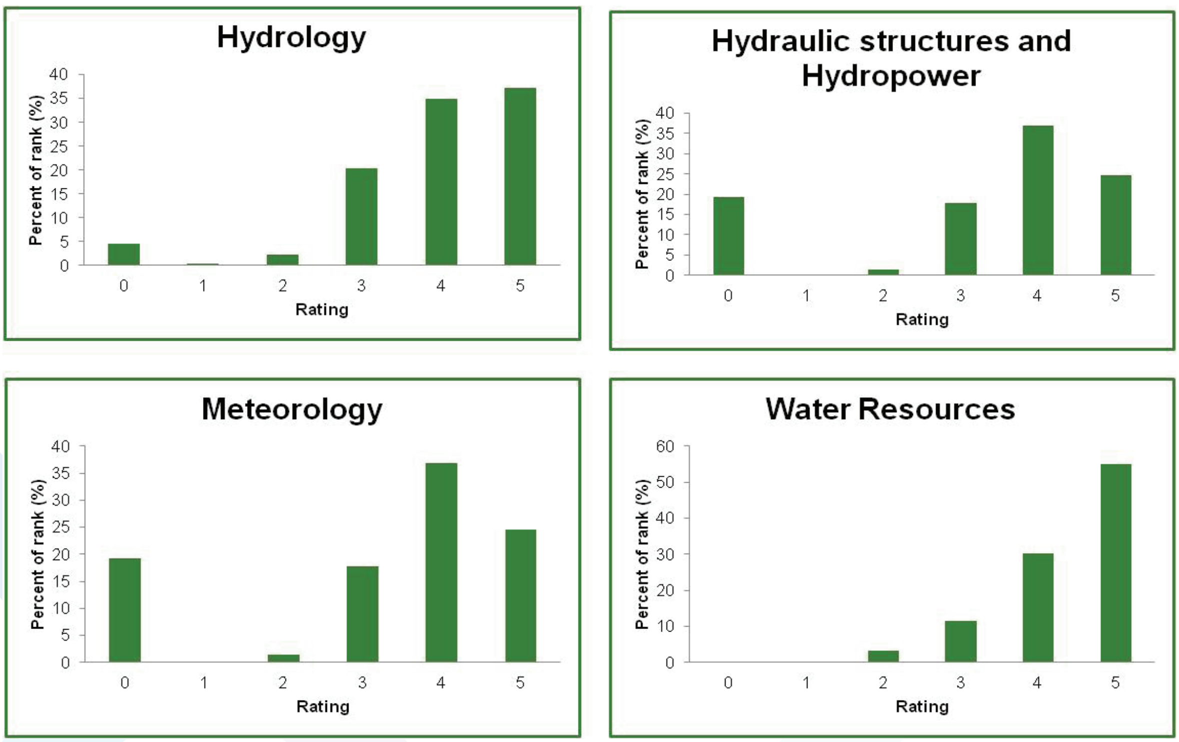


Figure 4.2 An Example of Improper Utilisation of the Rating Scale.

Based on the findings of SC-1 results, we removed the rating scale from the second questionnaire which was used in an expert opinion survey. We asked water experts to choose any three sub-topics in a particular category of Water R&D field, and assigned them numbers 1, 2, & 3 where 1 carries more weightage than 2 and 3. Similarly, 2 carries more weightage than 3.

4.2.3 Expert Opinion Survey Data Analysis

The same questionnaire was used in the expert opinion survey with a change in rating scale only. In this survey the experts were asked to choose any three most import Water R&D fields and assign numbers 1, 2, and 3. The sub-topic assigned with number 1 by an expert is considered to be the most important sub-topic within a Water R&D category.

Compared to SC-1 survey results, the expert opinion survey data analysis produced stable sets of preference weights which can be trusted and used with great confident in future studies. For example, a very low preference weightage (0%) was given to the least important sub-topic in 'Water Resources and Watershed Management' category of Water R&D, and 42.22% of preference weight was calculated for the most important sub-topic of 'Water Resources and Watershed Management' category of Water R&D. An example of priority ranking of sub-topics in Section 1 of the questionnaire (Water Resources and Watershed Management) is given in **Table 4.4**. More expert survey results are given in **Appendix C**.

TABLE 4.4 PREFERENCE WEIGHTS AND PRIORITY RANKING OF SUB-TOPICS IN SECTION 1 (WATER RESOURCES AND WATERSHED MANAGEMENT) OF THE EXPERT OPINION SURVEY QUESTIONNAIRE

Section-1: Water Resources and Watershed Management	**Preference weights (%)**	**Rank**
Integrated coastal zone management	42.22	1
Sustainable and integrated watershed management	38.33	2
Risk assessment	35.83	3
Terrestrial atmospheric pollution and water quality	34.44	4
Environmental and indigenous people related issues	33.33	5
Wetlands and lakes restoration	31.67	6
Climate change and hydrologic cycle	30.00	7
Integrated water resources management	30.00	7
Marine biodiversity, conservation and management	30.00	7
Marine pollution	30.00	7
Fresh water ecology	29.17	8
Climate change and rainfall modelling	26.67	9
Coastal erosions	25.56	10
Protected conservation areas in marine environment	23.33	11
Conservation and preservation of water resources	22.00	12
Impacts of climate variability on wetlands ecosystem	21.67	13
Social and environmental costs of watershed degradation	20.00	14
Policy and legislative issues	19.17	15

Advanced dam technology	18.33	16
Eutrophication	17.50	17
Water resource assessment and accounting	17.33	18
Environmental water requirements	17.04	19
River rehabilitation	16.67	20
Catchment/river basin management	16.67	20
Coastal ecology	16.67	20
Erosion and sedimentation	16.30	21
Surface water hydrology	16.30	21
Coastal habitat management	15.56	22
Impacts of climate change, increased population and changing human demographics on watersheds	14.17	23
Flood management and mitigation	13.33	24
Marine ecology	11.67	25
Alternative water resources (ground water, rainwater harvesting, etc.)	11.33	26
Dam modelling construction	9.17	27
Hydrometeorology	8.89	28
Public participation in watershed management	8.33	29
Ecohydrology	7.04	30
River morphology	6.67	31
Seawater and sediment chemistry	5.00	32
Groundwater hydrology	3.33	33
Urban hydrology	3.33	33
Electromechanical equipment	3.33	33
Storm water management	2.67	34
Rural hydrology	0.00	35
Wetland modelling	0.00	35

4.2.3 Aggregate Preferences Weights and Priority Ranking of Water R&D Sub-topics

In order to get generic sets of preferences weights of sub-topics within a Water R&D category, preference weights obtained from both surveys (SC-1 and Expert Opinion) were aggregated. The aggregate preference weights are more stable than the SC-1 and Expert Opinion survey weights if they were considered separately. An example of aggregate preference weights of sub-topics in Water R&D is given in **Table 4.5** where sub-topic 'integrated coastal zone management' was given 67.4% of the aggregate preference weights and considered to be the most important Water R&D field for government investment and research. Conversely, sub-topic 'river morphology' was the least important Water R&D field to the both groups of survey participants as it has been given 8.7% of the aggregate preference weight. Aggregate preference weights (shown in second last row and last column of **Table 4.5**) provide higher range of preference weights (range of preference weights is equal to maximum preference weights within a Water R&D category minus minimum preference weights of that particular Water R&D category) which can be interpreted as stable sets of preference weights. Aggregate preference weights calculated for all five categories of Water R&D are given in **Appendix D**.

TABLE 4.5 AGGREGATE PREFERENCE WEIGHTS OF WATER R&D FIELDS

Sub-topics of "Water Resources and Watershed Management"	Preference weights from SC-1 Survey (%)	Preference weights from Expert Survey (%)	Aggregate Preference weights (%)
Integrated coastal zone management	25.1	42.2	67.4
Terrestrial atmospheric pollution and water quality	26.5	34.4	60.9
Sustainable and integrated watershed management	21.3	38.3	59.7
Risk assessment	22.6	35.8	58.4
Climate change and hydrologic cycle	26.7	30	56.7
Environmental and indigenous people related issues	21.9	33.3	55.2
Wetlands and lakes restoration	21.4	31.7	53.1
Coastal erosions	26.2	25.6	51.7
Marine biodiversity, conservation and management	21.3	30	51.3
Marine pollution	21.1	30	51.1
Climate change and rainfall modelling	23.8	26.7	50.4

Fresh water ecology	19.8	29.2	49.0
Integrated water resources management	17.2	30	47.2
Protected conservation areas in marine environment	19.9	23.3	43.2
Impacts of climate variability on wetlands ecosystem	20.4	21.7	42.1
Coastal ecology	24.4	16.7	41.0
Coastal habitat management	24.4	15.6	39.9
Conservation and preservation of water resources	17.9	22	39.9
Policy and legislative issues	20.2	19.2	39.4
Social and environmental costs of watershed degradation	19.1	20	39.1
Advanced dam technology	19.1	18.3	37.4
Eutrophication	19.6	17.5	37.1
Impacts of climate change, increased population and changing human demographics on watersheds	20	14.2	34.2
Catchment/river basin management	17.2	16.7	33.8
Water resource assessment and accounting	16.4	17.3	33.8
Hydrometeorology	23	8.9	31.9
Marine ecology	19.5	11.7	31.2
Dam modelling construction	20	9.2	29.2
Environmental water requirements	10.8	17	27.8
Public participation in watershed management	19.3	8.3	27.6
Alternative water resources (ground water, rainwater harvesting, etc.)	16	11.3	27.3

River rehabilitation	10.4	16.7	27.0
Erosion and sedimentation	10.6	16.3	26.9
Surface water hydrology	10.1	16.3	26.4
Flood management and mitigation	11	13.3	24.3
Seawater and sediment chemistry	18.3	5	23.3
Electromechanical equipment	16.5	3.3	19.8
Wetland modelling	18.8	0	18.8
Storm water management	15.4	2.7	18.1
Ecohydrology	9.1	7	16.1
Urban hydrology	10.2	3.3	13.5
Groundwater hydrology	9.3	3.3	12.6
Rural hydrology	9.9	0	9.9
River morphology	8.7	0	8.7
Maximum	**26.7**	**42.2**	**67.4**
Average	**18.2**	**18.0**	**36.2**
Minimum	**8.7**	**0.0**	**8.7**
Max. Difference (Range)	**18.0**	**42.2**	**58.6**

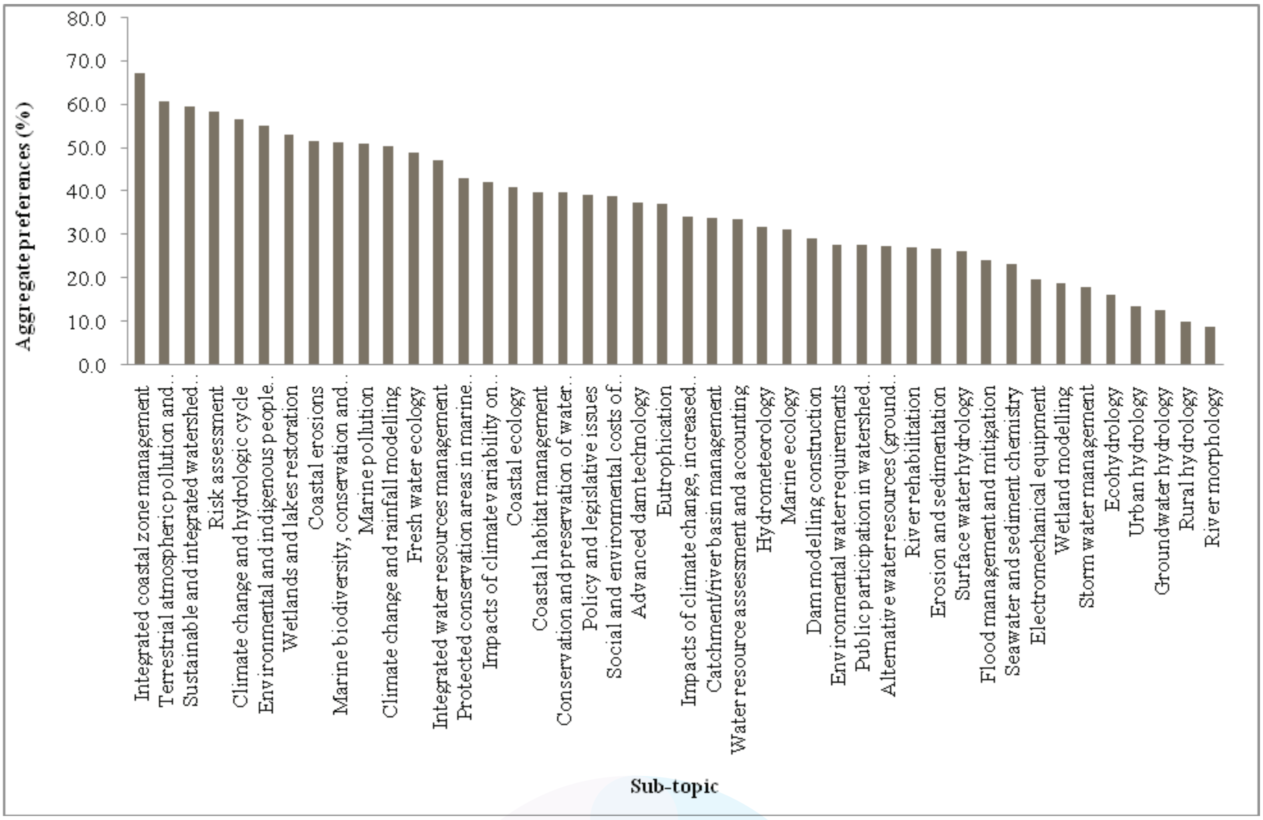
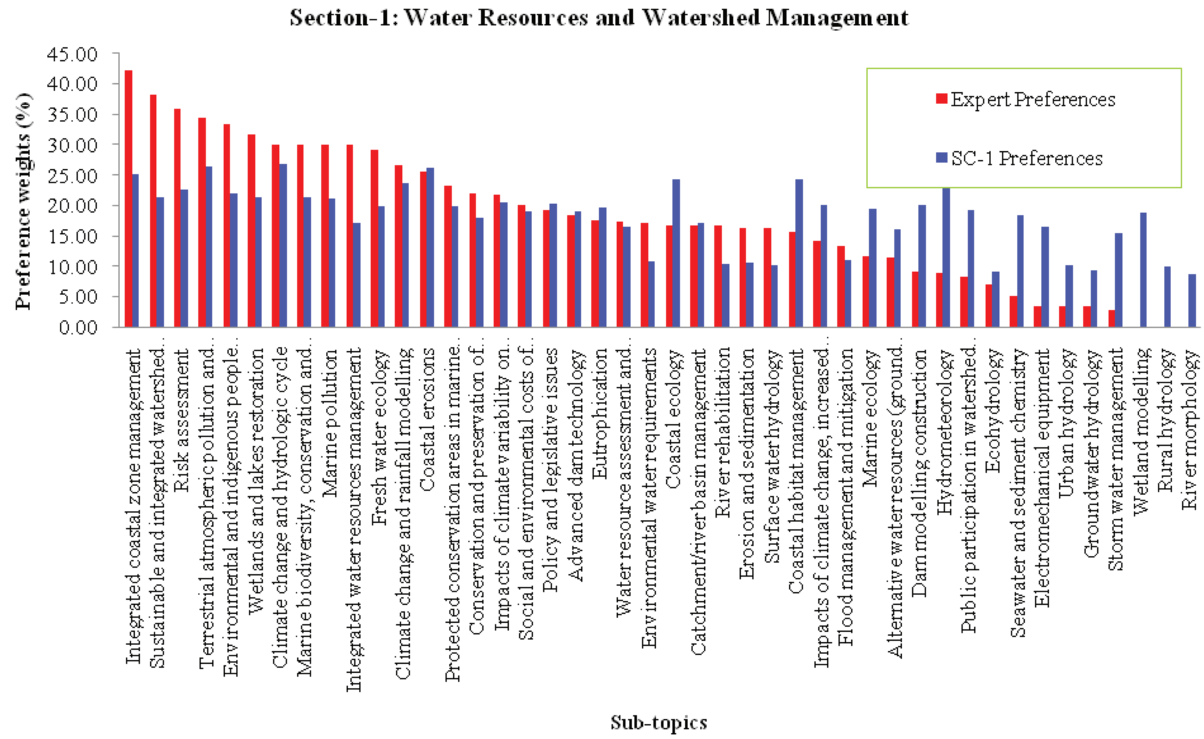


Figure 4.3. Aggregate preference weights of Water R&D fields in Section 1 (Water Resources and Watershed Management)

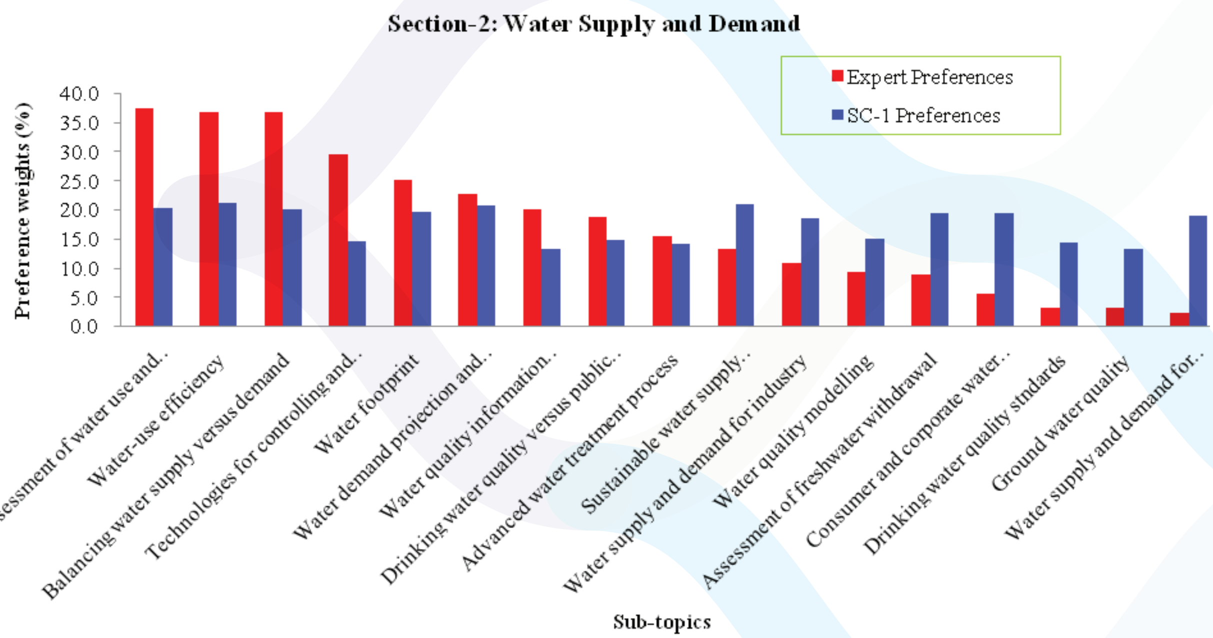
4.2.5 Comparison between SC-1 and Expert Opinion Surveys Results

The survey data analysis for both surveys reveals that the water experts assigned larger preference weights to almost all sub-topics of Water R&D fields compare to SC-1 survey participants. For example, the top most important sub-topic in 'water resources and watershed management' category of Water R&D was given 42.2% of preference weightage by the water experts, and ironically, in contrast, the least important sub-topic in the same Water R&D category was given zero preference weights. Conversely, the participants of the stakeholder consultation workshop assigned 25.1% of preference weights to the most important sub-topic in 'water resources and watershed management' Water R&D category and 8.7% preference weights to the least important sub-topic in this Water R&D category.

We believe that higher the difference between the highest preference weight and the lowest preference weight is better and generates more stable weights compare to lower range in preference weights. This flexibility of preference weights in SC-1 was not visible and that could make very confused to decision makers and water managers for applying these findings in real-world water problem solutions. A comparison of preference weights obtained from SC-1 survey data analysis and the expert survey data analysis are plotted in **Figures 4.4** to **4.8**.



Figures 4.4. Comparison of preference weights for SC-1 and Expert Surveys (Section 1)



Figures 4.5. Comparison of preference weights for SC-1 and Expert Surveys (Section 2)

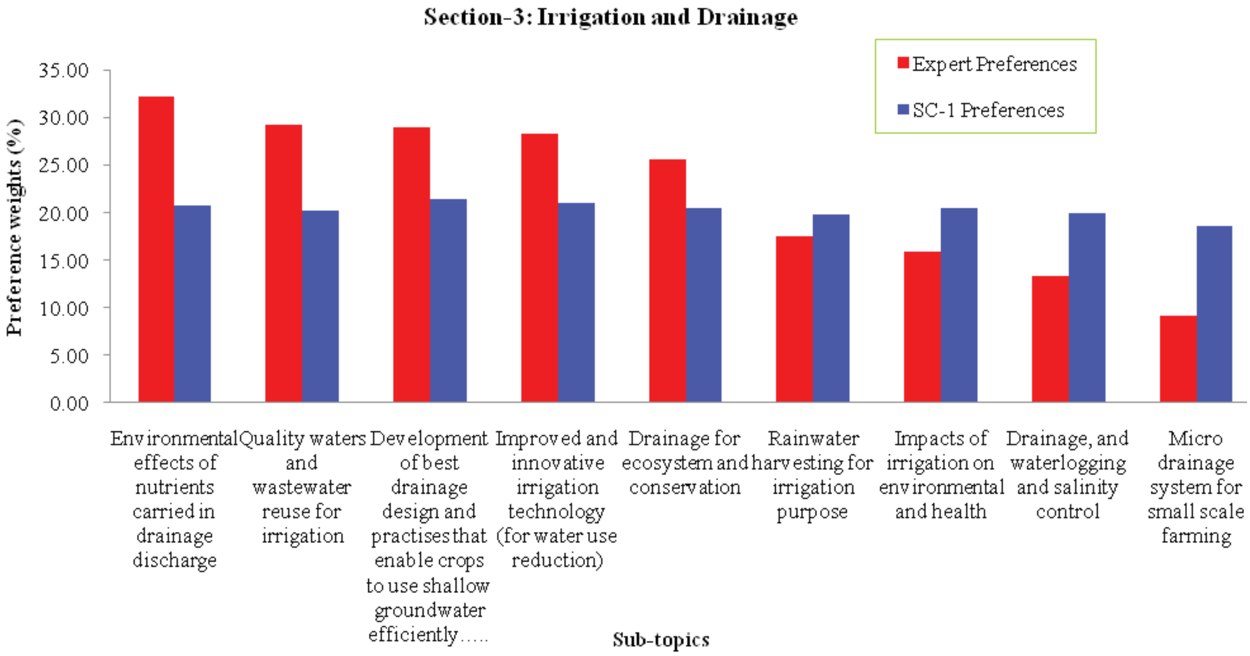


Figure 4.6 Comparison of preference weights for SC-1 and Expert Surveys (Section 3)

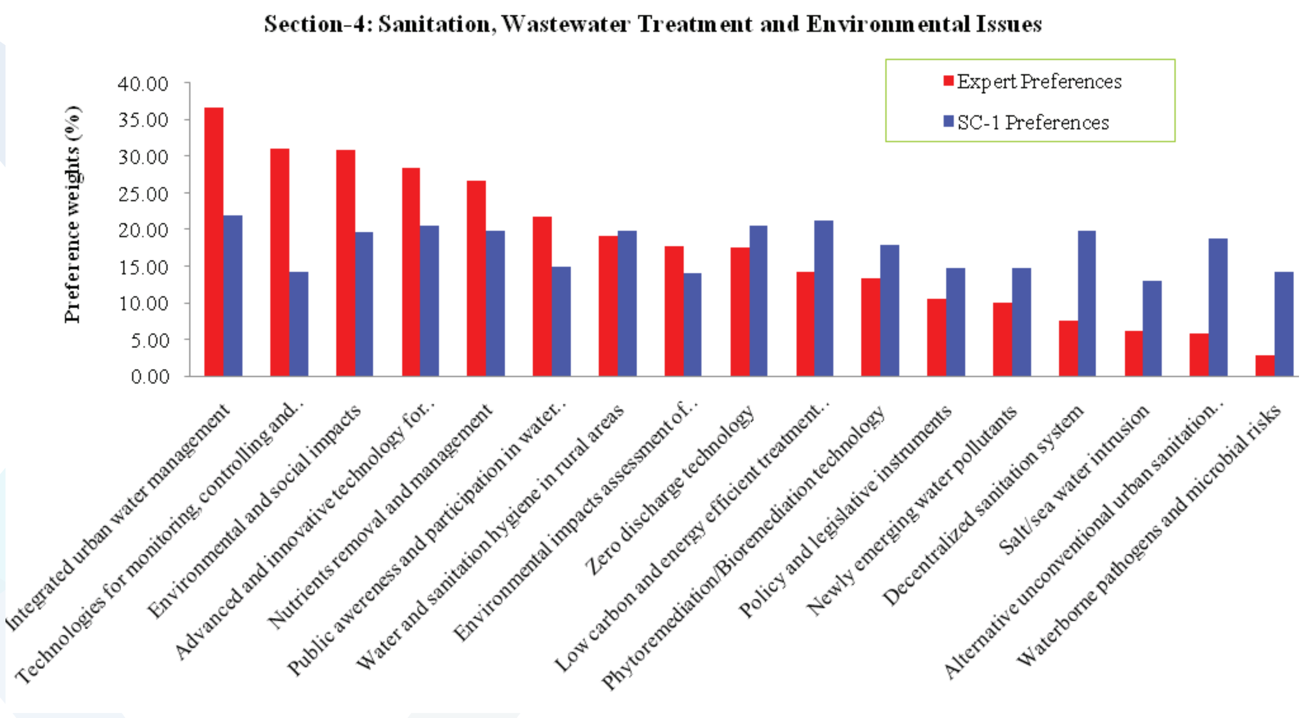


Figure 4.7 Comparison of preference weights for SC-1 and Expert Surveys (Section 4)

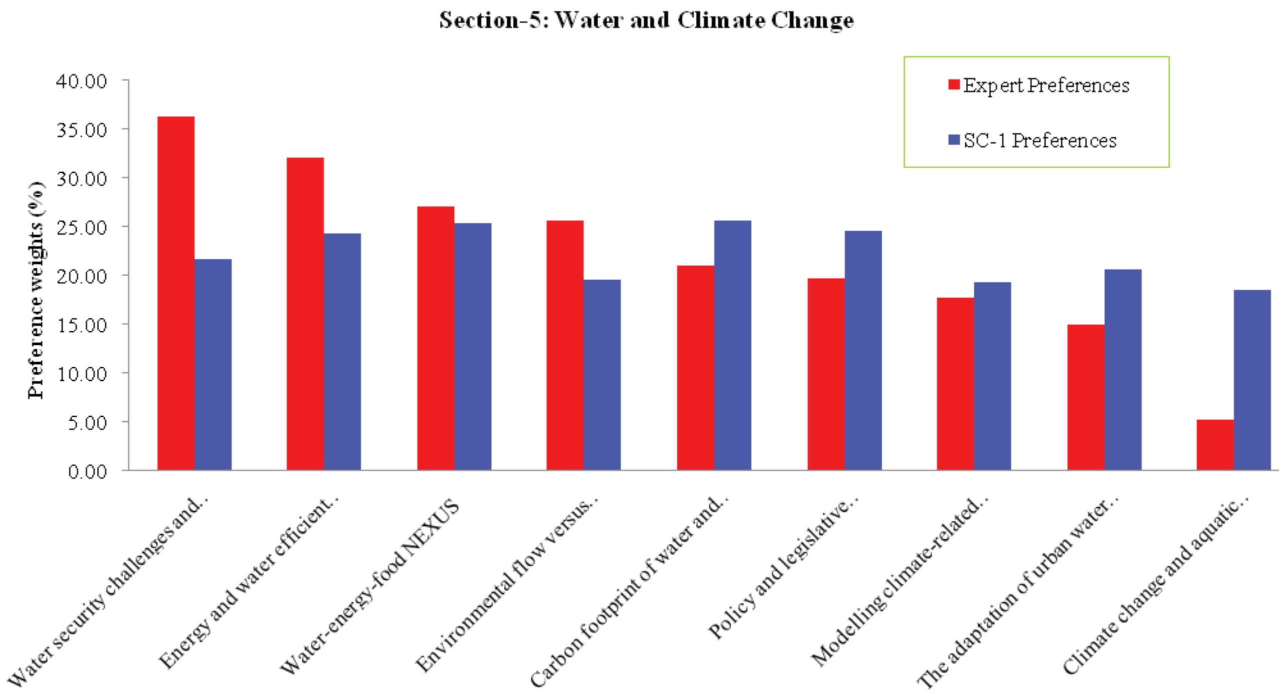


Figure 4.8 Comparison of preference weights for SC-1 and Expert Surveys (Section 5)

4.3Listing of Water R&D Topics

This is imperative to declare that two different formats of questionnaire were distributed in SC1 and Expert Opinion surveys. In the SC1 format, the questionnaire was consisted of five sections separate for each major field of Water R&D. In this format, the survey participants were asked to show their preferences on ranking scale on the sub-topics of Water R&D of the each section. The analysis of survey data shows that ranking scale was not properly utilised by the participants. Therefore, from the expert opinion survey questionnaire, we changed the questionnaire format. In this questionnaire, we assigned different sub-topics for each Water R&D field. A total of 97 sub-topics were distributed into five sections. Here, we used ranking scale but the water experts were asked to select only 3 sub-topics which they assume that are most important within a specific Water R&D (1 for most important, 2 for second most important, and 3 for third most important sub-topic of Water R&D). Below are the five sections along with list of sub-topics presented to the water experts in the survey:

Section I: Water Resources & Watershed Management

1. Surface water hydrology
2. Rural hydrology
3. Urban hydrology
4. Erosion and sedimentation
5. Flood management and mitigation
6. Ecohydrology
7. Groundwater hydrology
8. Environmental water requirements
9. River morphology
10. River rehabilitation
11. Environmental and indigenous people related issues
12. Electromechanical equipment
13. Advanced dam technology
14. Risk assessment
15. Dam modelling construction
16. Hydrometeorology
17. Climate change and hydrologic cycle
18. Climate change and rainfall modelling
19. Terrestrial atmospheric pollution and water quality
20. Water resource assessment and accounting
21. Alternative water resources (ground water, rain water harvesting, etc.)
22. Catchment/river basin management
23. Storm water management
24. Integrated water resource management
25. Conservation and preservation of water resources
26. Impacts of climate change, increased population and changing human demographics on watersheds
27. Public participation in watershed management
28. Social and environmental costs of watershed degradation
29. Sustainable and integrated watershed management
30. Policy and legislative issues
31. Eutrophication
32. Fresh water ecology
33. Impacts of climate variability on wetlands ecosystem
34. Wetland modelling
35. Wetlands and lakes restoration
36. Integrated coastal zone management
37. Coastal erosions
38. Coastal habitat management
39. Coastal ecology
40. Protected conservation areas in marine environment
41. Seawater and sediment chemistry
42. Marine pollution
43. Marine ecology
44. Marine biodiversity, conservation and management

Section 2: Water Supply and Demand

1. Water-use efficiency
2. Water supply and demand for industry
3. Water supply and demand for livestock and agriculture
4. Sustainable water supply management in rural areas
5. Balancing water supply versus demand
6. Water footprint
7. Assessment of freshwater withdrawal
8. Water demand projection and forecasting
9. Consumer and corporate water footprint assessment
10. Assessment of water use and availability
11. Water quality modelling
12. Drinking water quality standards
13. Ground water quality
14. Advanced water treatment process
15. Water quality Information management and modelling
16. Technologies for controlling and monitoring non-point source pollution
17. Drinking water quality versus public health

Section 3: Irrigation and Drainage

1. Improved and innovative irrigation technology (for water use reduction)
2. Quality waters and wastewater reuse for irrigation
3. Impacts of irrigation on environmental and health
4. Micro drainage system for small scale farming
5. Rainwater harvesting for irrigation purpose
6. Drainage, water logging and salinity control
7. Environmental effects of nutrients carried in drainage discharge
8. Development of best drainage design and practices that enable crops to use shallow groundwater efficiently, while reducing the use of agricultural chemicals and reduce flood flow
9. Drainage, and waterlogging and salinity control
10. D\rainage for ecosystem and conservation

Section 4: Sanitation, Wastewater Treatment and Environmental Issues

1. Water and sanitation hygiene in rural areas
2. Environmental and social impacts
3. Decentralised sanitation system
4. Integrated urban water management
5. Alternative unconventional urban sanitation systems
6. Low carbon and energy efficient treatment system
7. Nutrients removal and management
8. Phytoremediation/Bioremediation technology
9. Zero discharge technology
10. Advanced and innovative technology for industrial wastewater treatment
11. Public awareness and participation in water resources conservation
12. Policy and legislative instruments
13. Salt/sea water intrusion
14. Waterborne pathogens and microbial risks
15. Environmental impacts assessment of effluent discharge to environment
16. Technologies for monitoring, controlling and removing diffuse and point source pollution

17. Newly emerging water pollutants

Section 5: Water and Climate Change

1. Climate change and aquatic invasive species
2. Modelling climate-related water resource stressors
3. Water security challenges and mitigation measures
4. The adaptation of urban water supply to climate change
5. Environmental flow versus climate change issue
6. Policy and legislative instruments
7. Energy and water efficient cities/township
8. Water-energy-food nexus
9. Carbon footprint of water and wastewater treatment system

In assigning research titles to the specific sub-topics of Water R&D, it was important to select only few sub-topics which were deemed to be important to the experts and SC1 participants. For that, the project team agreed to select 50% of the sub-topics of Water R&D and assign research titles matching with the Malaysian environment and need of immediate research and exploration. The task of assigning titles to the sub-topics by the individuals was distributed according to their field of research and expertise. Below are specific titles for each sub-topics within each section of Water R&D.

Section 1: Water Resources and Watershed Management

1. Integrated coastal zone management

I. Biological indicators and their role in integrated coastal management.

II. Hydrological and oceanographic considerations for integrated coastal zone management.

III. The use of remote sensing and GIS in the sustainable management of coastal ecosystems.

2. Terrestrial atmospheric pollution and water quality

I. Critical levels of atmospheric pollution in forest and lake ecosystems

II. Impacts of future air pollution mitigation strategies

III. Terrestrial and oceanic influence on spatial hydrochemistry and trophic status in subtropical marine near-shore waters

3. Sustainable and integrated watershed management

I. Determination of environmental flow for important river basin

II. Development of integrated watershed management schemes for an intensively urbanized region in Malaysia

III. An index-based robust decision making framework for watershed management in a changing climate

4. Risk assessment

I. Development of 21st Century Water Risk Management

II. Risk Management of Water Resources in Malaysia in the Face of Climate Change

III. Risk Assessment of Public Drinking Water Source Areas

A 5. Climate change and hydrologic cycle

I. imulations of the martian hydrologic cycle with a general circulation model

II. Selection of hydrologic modelling approaches for climate change assessment

III. Assessment of climate change impacts on hydrology and water quality with a watershed modelling approach

6. Environmental and indigenous people related issues

I. Indigenous Peoples: Environmental Exposures and Sustainable Development

II. Indigenous Water Issues

III. Exploring different options for displaced indigenous people for rehabilitation

7. Wetlands and lakes restoration

I. Biodiversity in wetland ecosystem of tropical climate

II. Use of wetland-based nutrient farming for water quality protection

III. Effectiveness of nutrient loading reduction in shallow lake restoration in the tropic.

8. Coastal erosions – coastal person

I. Study on integrated approach to coastal rehabilitation in Malaysia.

II. Tsunami sedimentation on the West Coast of Malaysia.

III. Mangroves as indicators of coastal erosions

9. Marine biodiversity, conservation and management

I. Management strategies to conserve marine biodiversity.

II. Connectivity, biodiversity conservation and the design of marine reserve networks for coral reefs

III. Roles of experimental marine ecology in coastal management and conservation

10. Marine pollution

I. Study on impacts of pollution on coastal and marine ecosystem in Malaysia.

II. The application of biomarkers in marine pollution monitoring.

III. Fish disease as a monitor for marine pollution.

11. Climate change and rainfall modelling

I. Prediction of future rainfall affected by climate change

II. Rainfall disaggregation technique

III. Water resources availability and climate change connection in tropical climate

12. Fresh water ecology

I. Effect of urban stream syndrome

II. Effect of climate change driven changes

III. Ecotoxicology of freshwater bodies

13. Integrated water resources management

I. Conjunctive use of water especially between surface and groundwater uses

II. Sustainable Integrated Water Resources Management for Energy Production and Food Security in Malaysia

III. Imagined communities, contested watersheds: Challenges to integrated water resources management in urbanized watersheds

Groundwater assessment, GW modelling and related studies?

14. Protected conservation areas in marine environment

I. Effect of climate change driven changes

II. Effect of zonation and species assemblages

III. Marine spatial planning and sustainable development strategy

15. Impacts of climate variability on wetlands ecosystem

I. Impacts and Adaptation of Climate Variability and Changes on Wetlands

II. Modelling the Impacts of Climate Change on Wetland Ecosystems

III. Climate Change Impacts on the Livelihood of Wetland and Lakes Ecosystem

16. Coastal ecology

I. Effects of engineering activities on coastal ecology in Malaysia.

II. Diversity of methanogenic Archaea in mangrove sediment.

III. The impacts of climate change in coastal marine systems

17. Coastal habitat management

I. Ecological engineering for successful management and restoration of mangrove forests.

II. Landscape modelling of coastal habitat change.

III. Applications of remote sensing for the assessment and management of tropical coastal resources.

18. Conservation and preservation of water resources

I. Water foot print analysis for increasing production efficiency

II. Water recycling and reuse for industrial and commercial premises

III. Development of water quality standard dedicated for sensitive/important ecosystem

19. Policy and legislative issues

I. Exploring policy and legislative tools for environmental flow allocations in different rivers of Malaysia

II. Development of a decision support system to guarantee stakeholders engagement in managing the Malaysian watersheds and river basins

III. Framing groundwater management and abstraction policy for sustainable use of the resource

20. Social and environmental costs of watershed degradation

I. The economics and scope of community watershed management initiatives in Malaysia

II. Multiple environmental serves as an opportunity for watershed rehabilitation

III. Cost-benefit analysis as a tool for rehabilitation of urbanized watersheds in Malaysia

21. Advanced dam technology

I. Realistic and Computational Efficient Evaluation of Temperature and Stress Development in Large Dams

II. New Developments in Dam Safety – Feasibility Evaluation on Risk

III. Hydraulic Simulation and Flood Protection in Large Dams

22. Eutrophication

I. Effect of land use activities on eutrophication of the tropic water bodies

II. Assessment and control of eutrophication in the raw water source impounding bodies

III. Water treatment for treating eutrophic water

Section 2: Water Supply and Demand

1. Water use efficiency

I. Assessment of water use efficiency and productivity for industrial development in Malaysia

II. Priority listing of important water use efficiency and productivity indicators for sustainable water conservation and saving

III. Development of a precise and logical link between water pricing and water use efficiency for urban water supply in Malaysia

2. Assessment of water use and availability

I. Assessment of water resources availability and demand in the Major river catchments of Malaysia

II. Temperature and food availability affect risk assessment

III. Availability assessment of a reverse osmosis plant: Comparison between Reliability Block Diagram and Fault Tree Analysis Methods

3. Balancing water supply versus demand

I. Implications of Future Water Supply Sources for Energy Demands

II. Modelling of water supply systems for optimal control and responses to anomalies

III. Spatial and Temporal Variation in Water Supply and Demand

4. Water footprint

I. Comprehensive Assessment of Water Footprint of Energy Sector

II. Quantifying and Assessing the Environmental Degradation of Manufactured Product (can be specific on the chosen product here)

III. Water Footprint Benchmark for Crop Production

5. Technologies for controlling and monitoring non-point source pollution

I. Non-point source water pollution management: Improving decision-making information through water quality monitoring

II. Seasonal change of non-point source pollution-induced bio-available phosphorus loss

III. Least-cost management of nonpoint source pollution: source reduction versus interception strategies for controlling nitrogen loss in Johor River Basin

6. Water demand projection and forecasting

I. Decreasing Climate-Induced Water Supply Risk through Improved Water Demand Forecasting

II. Development of Advanced Water Forecasting Methodology for Malaysia Incorporating Climatic Aspects

III. Evaluating the Sustainability of Projected Water Demand

Section 3: Irrigation and Drainage

1. Environmental effects of nutrients carried in drainage discharge

I. Effect of nutrient enrichment on river ecosystems

II. Development of nutrient objectives in Malaysian rivers and impounded water bodies

III. The fate of nutrients and nutrient carrying capacity of rivers in Malaysia

2. Development of best drainage design and practises that enable crops to use shallow groundwater efficiently

I. The effect of salinity on water productivity of paddy above shallow groundwater

II. The effect of saline shallow ground and surface water under deficit irrigation in paddy fields

III. Integration of SWAP and MODFLOW for modelling groundwater dynamics in shallow water table areas of Malaysia

3. Improved and innovative irrigation technology (for water use reduction)

I. Scope and opportunities of sprinkler and drip irrigation systems in Malaysia: A valuable tool for improving irrigation water productivity

II. Investing in advanced irrigation application systems in Malaysia: Reviewing past and looking to the future

III. Modelling for improved irrigation water management in a tropical climatic conditions

4. Quality waters and wastewater reuse for irrigation

I. Domestic treated wastewater reuse for agriculture irrigation using aerobic membrane technology.

II. Study on wastewater reuse potential using anaerobic membrane bioreactor.

III. Wastewater quality and reuse for irrigation in Malaysia using membrane technology.

5. Drainage for ecosystem and conservation

I. Domesticated ecosystems: Challenges for the management of large rivers in Malaysia

II. Multi-attribute evaluation of ecosystem management for the major river basins of Malaysia

III. An ecohydrological model for studying groundwater-vegetation interactions in shallow groundwater areas

Section 4: Sanitation, Wastewater and Environmental Issues

1. Integrated urban water management

I. Multi-Criteria decision assessments using Subjective Logic: Methodology and the case of urban water strategies in Malaysia

II. Vulnerability of water quality in intensively developing urban watersheds

III. Developing a decision support system for sustainable option selection in integrated urban water management

2. Environmental and social impacts

I. Equity, efficiency and regulation in the sanitation sector in Malaysia

II. Effective water and sanitation policy reform implementation: Need for systemic approach and stakeholder participation

III. Assessment of environmental and social impacts of existence and non- existence of wastewater collection and sanitation facilities in urban and semi-urban areas of Malaysia

3. Advanced and innovative technology for industrial wastewater treatment

I. Combination of advanced oxidation processes and biological treatments for industrial wastewater treatment.

II. Advanced ozone treatment and biological treatments of palm oil mill effluent.

III. Biologically pre-treated industrial wastewater using advanced UV irradiation.

4. Nutrients removal and management

I. Nutrient removal as tools in water quality management.

II. Nutrient removal mechanisms in constructed wetland and sustainable water management.

III. Nutrient removal by constructed wetlands: Implication for water management and design.

5. Technologies for monitoring, controlling and removing diffuse and point source pollution

I. Decision support for diffuse pollution management

II. Remediation technologies for heavy metal contaminated groundwater

III. Comparative study of two models to simulate diffuse nitrogen and phosphorus pollution in a medium-sized watersheds of Malaysia

6. Water and sanitation hygiene in rural areas

I. Study on water and sanitation hygiene in rural area.

II. Water supply, sanitation and hygiene awareness in rural area.

III. Water sanitation hygiene and child health in rural area.

7. Zero discharge technology

I. Treatment of palm oil mill effluent using membrane technology to achieve zero discharge.

II. The application of zero discharge system in treating industrial wastewater.

III. Treatment of domestic wastewater using biological process integrates with membrane to achieve zero discharge.

8. Public awareness and participation in water resources conservation

I. A Case Study on Public Awareness and Participation for the water resources Conservation of a Tropical Urban River

II. Conservation, Development and Management of Water Resources: An Experience in Malaysia

III. Developing a Water Conservation Public Awareness Programme: A Guide for Utilities

9. Low carbon and energy efficient treatment system

I. Low carbon assessment for ecological wastewater treatment by a constructed wetland.

II. A microbial fuel cell–membrane bioreactor integrated system for cost- effective wastewater treatment system.

III. Industrial wastewater treatment and simultaneous electricity generation using microbial fuel cells.

Section 5: Water and Climate Change

1. Water security challenges and mitigation measures

I. Water Security and Climate Change Adaptation in Malaysia River Basins

II. Water Security Index for Malaysia

III. Improvement of Urban Water Security

2. Energy and water efficient cities/township

I. Malaysia’s energy security in fast development activities: The perspective of energy users

II. Understanding household energy consumption patterns: Are religion, race, and location playing role in energy consumption trends?

III. Comparison of low and high income households in energy and water usage efficiency: Different tariffs for different types of income households

3. Water-energy-food NEXUS

I. Considering the energy, water and food nexus: Towards an integrated modelling approach

II. Basin perspectives on the Water–Energy–Food Security Nexus

III. Policy and institutional dimensions of the water–energy nexus

4. Carbon footprint of water and wastewater treatment system

I. Analysis of Embodied Energy and Carbon in Water and Wastewater Treatment Systems

II. Modelling Carbon Footprint

III. Identifying energy and carbon footprint

5. Environmental flow versus climate change issues

I. Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis

II. Climate and narrative: Environmental knowledge in everyday life

III. The importance of population, climate change and CO_2 plant physiological forcing in determining future global water stress

Chapter 5

Setting a National Agenda for Water Research

5.1 Brief Overview of IWRM Concept

Sustainable water management is required to guarantee that a sufficient quantity and quality of freshwater resource is always available in meeting the human demand for water, as well as in maintaining hygienic living standards. Sharp (2009) found that many universities were addressing sustainability in a ‘piecemeal manner’ which generally fails to achieve the comprehensive organisational transformation necessary for a sustainable water consumption and usage. One of the approaches for managing scarce freshwater resources to a sound sustainability level is through the Integrated Water Resource Management (IWRM). Integrated water resource management, is defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2000). Rahaman (2005) affirms that the IWRM is a recommended approach for sustainable water management. The IWRM covers all important aspects of water resources which directly or indirectly affecting management strategies of water resources in Malaysia. Different fields of research covered in IWRM are shown in **Figure 5.1**.

Figure 5.1 Different fields constituting IWRM.

The application of IWRM in Malaysia is still in the early stages. Thus, there is dire need of boosting this field of research and identify tools and methods to bring IWRM concept from paper to field for solving actual water research problems in the country.

5.2 Mega Science Framework – ASM Study

In 2010, the Academy of Sciences Malaysia (ASM) had completed a study on the need for development of a framework that could capture R&D investments in Science, Technology, and Innovation (STI) sector. The Mega-Science Framework was the first effort of this type in generating new knowledge and STI deliverables. The study concludes that the country's science infrastructure must exist to help deliver the desired results. The science infrastructure should also ensure the evolution of more R&D to be undertaken by the private sector vis-à-vis the public sector as is typically found in a developed country economy.

The study also proposed for the establishment of the National Research Council (NRC) and the National Innovation Unit (UNIK) as these would provide the management function of ensuring that the funding and management for R&D and strategic studies are maximised. The study indicated that Malaysia invests much less in R&D field as compared to other developed nations.

5.3 R&D Investment and Knowledge Acquisition

Malaysia has to intensify knowledge generating capacity by investing more in R&D to be a developed country in 2020. The expenditure in R&D must reflect the norm usually associated with countries having a developed economy (Mega Science Framework, 2010). Current expenditure in R&D by the Malaysian Government is about 0.6% of the national GDP (Gross Domestic Product). The ASM study suggests that government investment in R&D should be increased to 2.0% of the GDP. The current R&D investment in Malaysia and other countries is shown in **Figure 5.2**.

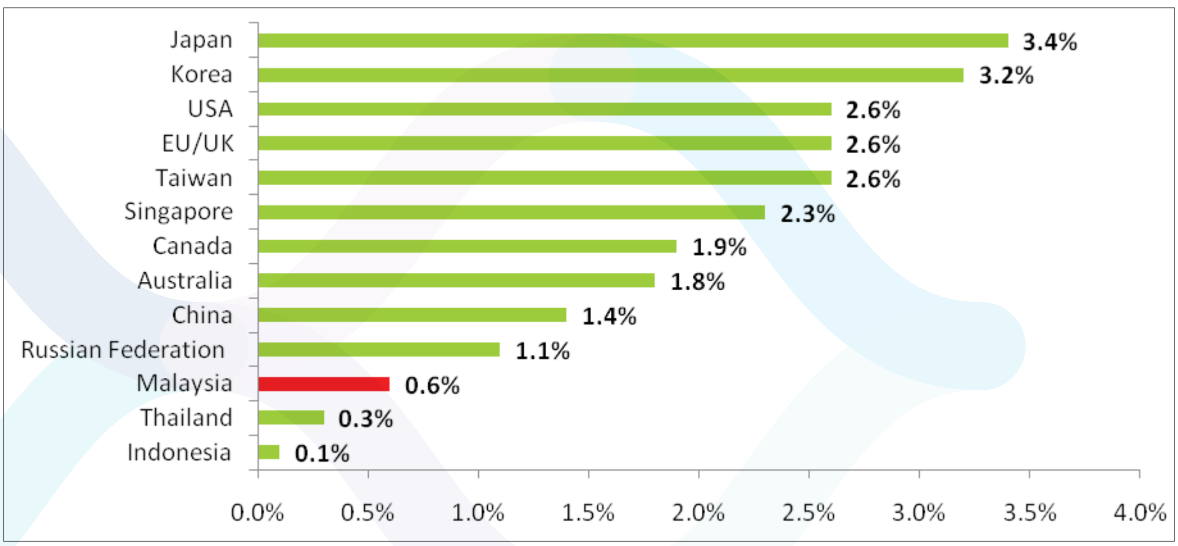


Figure 5.2 Malaysia's Low R&D Investment.

Source: ASM Mega Science Framework, 2010

5.4 Knowledge Gaps in Various Economic Sectors

In the past, economic growth was a function of knowledge and capital growth. Past investments in R&D in the relevant sectors would have generated knowledge to stimulate economic growth (Mega Science Framework, 2010). Continuous knowledge enhancement or human capital development contributes to facilitate and accelerate economic growth. The serious lack of researchers in basic and applied sciences, however, has to be urgently addressed such that it does not hamper the generation of knowledge and hamper sustained economic growth of the nation. The number of full time researchers in Malaysia is very low as compared to other developed nation (**Figure 5.3**).

The low number of researcher in the country results in low number of publications in high impact journals. **Figure 5.4** shows that in the year 2008, Malaysian researchers produced only 1,351 articles as compared to small population countries like Singapore, whose researchers managed to publish 4,187 research articles during the same period.

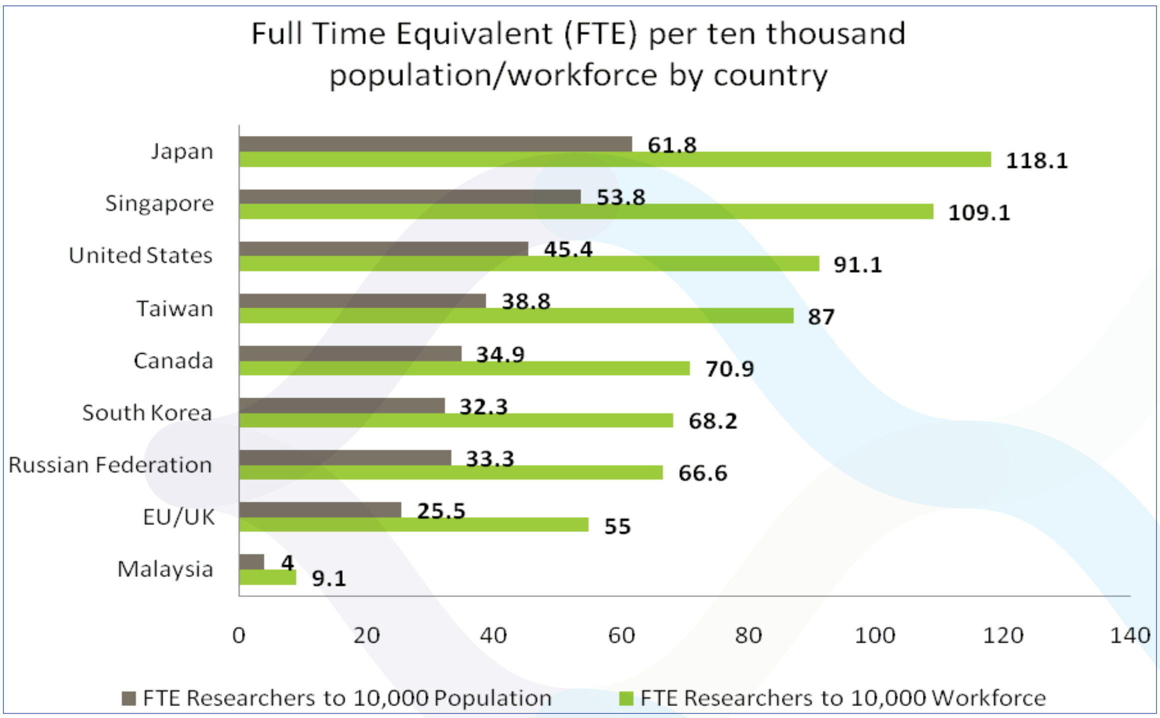


Figure 5.3 Low FTE Researchers.

Source: ASM Mega Science Framework, 2010

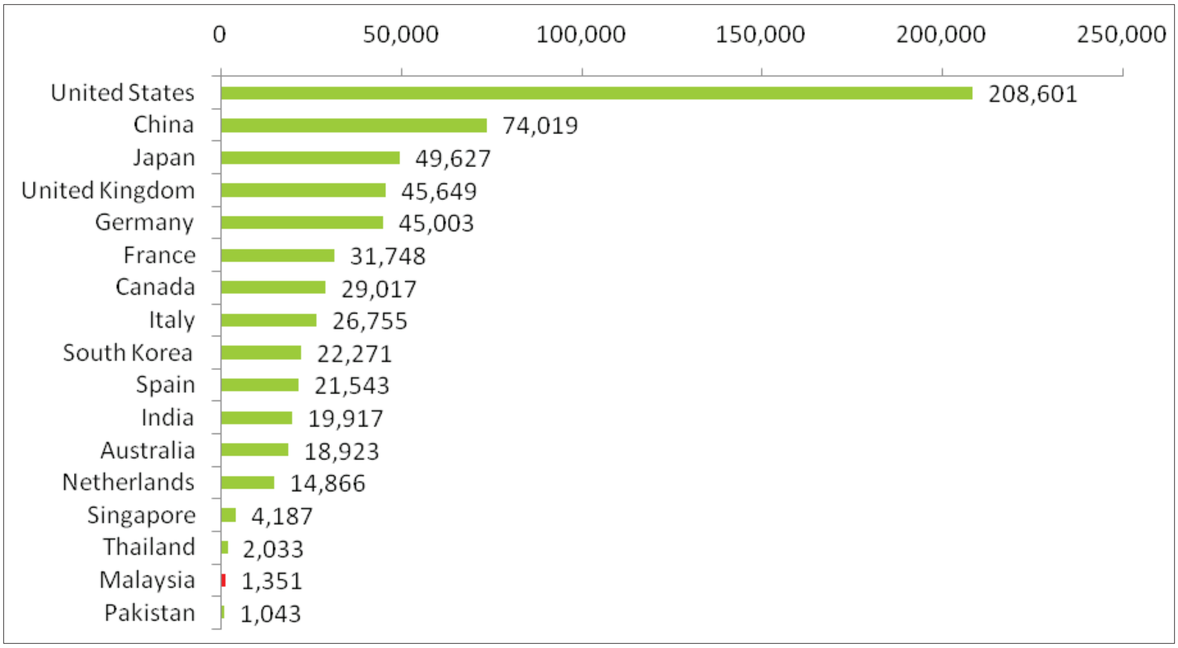


Figure 5.4 Scientific and technical journal articles.

5.5 Duplication in R&D Investment in Malaysia

In the current set up water resources management and planning in Malaysia is fragmental as many departments and agencies are doing some similar research in different Water R&D fields. For example, watershed management studies are being conducted by Department of Irrigation and Drainage (DID), Department of Environment, NAHRIM (National Hydraulic Research Institute of Malaysia), etc. Further duplication in Water R&D and ultimately in Water R&D investment can be seen in **Table 5.1**.

TABLE 5.1 SOME FUNCTIONAL RESPONSIBILITIES OF WATER RELATED AGENCIES/BODIES

DEPARTMENT/AGENCY	Water Supply	Water Sanitation	Irrigation	Hydropower	Flood Control	Water Quantity Regulation	Water Quality Regulation	Watershed Management	Integrated Area Development	Data Collection	Research	Ports and Navigation	Fisheries	Recreational
Economic Planning Unit								■	■					
Ministry of Natural Resources and Environment					■	■	■	■	■	■	■			■
Department of Irrigation and Drainage					■	■		■		■	■			
Department of Environment							■	■		■	■			■
PERHILITAN								■		■	■			■
NAHRIM										■	■			
Forestry Department, Peninsular Malaysia								■		■	■			
Department of Director of Lands and Mines									■	■				
Jabatan Mineral dan Geosains	■					■				■	■			
Marine Park Department									■	■	■			■
Ministry of Energy, Green Technology and Water	■	■		■						■	■			
SPAN	■	■												
Water Supply Department	■													
Sewerage Services Department		■												
Ministry of Agriculture and Agro-based Industry			■							■	■		■	■
Department of Agriculture			■							■	■			
Fisheries Department										■	■		■	■
Ministry of Housing and Local Government							■	■						
Ministry of Health							■			■	■			

Ministry of Rural and Regional Development														
Ministry of Works														
National Water Resources Council														
Tenaga National Berhad														
Ministry of Transport														
Marine Department Malaysia														

Source: NWRS, 2011

5.6 Mechanism to Identify Priority Water R&D Areas

Currently, there is no formal or informal framework/ mechanism in the country for identifying the nation's water research and development priorities or even for prioritizing the nation's water problems on a unified basis. More than a dozen Federal agencies are involved in water research programmes in addition to some State and private agencies. Despite the number of Federal programmes for water research, there is no single catalogue of Federal funds directed to these purposes. Moreover, commonly acceptable structure for categorizing types of water research is missing. The existing funding in Water R&D is not in very specific, but rather, it is split into various research areas such as earth science, environment, regulation, planning, ecosystem, pollution, climate change, etc. This funding mechanism could not capture all the amount put on Water R&D by the government and other public and private agencies. As a consequence, this type of funding mechanism may also cause duplication of funding for the same Water R&D area by the various departments and agencies. Added to that, many research agencies are not forward-looking or focussed on the future water problems, but rather focusing on short-term and operational research projects. Hence, these short-term research projects may not help government to identify water problems in future., but instead hamper government policies as these policies may not be adequate for long-term planning in water resource management.

Nonetheless, some may favour the *laissez faire* approach in setting Water R&D funding and argues that this type of approach will serve the nation well and that what is needed is a massive infusion of research funding. However, the main problem with the *laissez faire* approach is that the competition for research (in terms of money input) is far more intense now than it was at any time in the 20th century (NRC Report, 2001). Thus, it is imperative that we be more systematic and strategic in planning water research if credible arguments for more resources are to be mounted.

A coordinated water research programme in which researchers and policy-makers can be accountable to the public will require an alignment of State and Federal Governments, research universities, users and suppliers/vendors, NGOs, and public interest groups. These groups will need to ally to identify and support the future water research agenda. Although the notion that the water research agenda should be set in a decentralised fashion may have much appeal, recent experience suggests that decentralised agenda-setting has been reactive and sometimes neglectful of long-term water issues. One consequence of this has been that the environmental impacts of many engineering works were neglected or misunderstood. Both multidisciplinary and interdisciplinary research should help to avoid a repetition of this kind of mistake.

A more viable mechanism is needed for setting and overseeing the water resources research agenda in the country and this research agenda should be based on the following main principles:

- The R&D activities must aim at supporting the recently launched NWRP. The policy statement spell out the need for the security and sustainability of water resources to be made a national priority to ensure adequate and safe water for all, through sustainable use, conservation and effective management of water resources enabled by a mechanism of shared partnership involving all stakeholders. Thus all the three NWRP principles as spell out in section 2.6.1.3 are highly relevant for charting the Water R&D framework;

- The water research effort should be aligned towards sustaining the existing resources and towards creating new wealth as discussed in ASM Mega Science Framework;

- Specific policy for Water R&D is needed to guarantee that the nation is benefited from the State-of-arts available techniques and tools;

- Concept of Integrated Water Resources Management (IWRM) should be promoted and applied in the country for managing water resources in most holistic and efficient way;

- The core research agenda should develop (1) greater understanding of the basic processes—physical, biological, and social—that underlie environmental systems at different scales, (2) appropriate environmental monitoring programmes, and (3) research tools to identify and measure structural and functional attributes of aquatic and related ecosystems;

- The national water resources research effort should be coordinated to reduce duplication and to ensure that gaps in water research do not occur; and
- The research effort should be multidisciplinary and interdisciplinary.

5.7 Establishing a Water R&D Centre (WRDC)

In the first phase of developing water research agenda in the country, we had proposed for the improvement of NAHRIM (see Chapter 7). However, we strongly believe that in far future, this set up may not be able to cover all problems associated to the Malaysian water resources research. Thus, there will be a need for the creation of a Centre that could specifically deal with all aspects of Water R&D in the country. In this study, we provide outlines of the proposed Centre in this chapter which may be required in future.

The proposed Water Research and Development Centre (WRDC) would be responsible for establishing and overseeing the national water research agenda. The WRDC would be charged with the ongoing task of developing a strategic and anticipatory national water research agenda. The WRDC would consist of representatives from stakeholders from the public and private sectors as well as academic representatives — the people who best understand water problems in their areas. The proposed WRDC would help to ensure that there is adequate balance among disciplinary, multidisciplinary, and interdisciplinary water research.

The WRDC would provide a relatively simple, centralised system of setting water research priorities. The appropriate implementation of those priorities could provide the necessary assurances and accountability for additional funding in water resources research. Because existing water research is so fragmented and even approximate estimates of the total annual funding in such water research is difficult to estimate precisely. Indeed, one of the first tasks the WRDC would be to determine the current level of funding and the additional funds needed in Water R&D.

5.7.1 Mandates of WRDC

The mandate of the proposed WRDC may include:

- Promoting co-ordination, co-operation and communication in the area of water research and development;
- Establishing water research needs and priorities;
- Stimulating and funding water research according to priority;
- Promoting effective transfer of information and technology; and
- Enhancing knowledge and capacity-building within the water sector.

The proposed Water Research & Development Centre (WRDC) will be a world class integrated applied research platform that will further innovation in the water sector within Malaysia and internationally. This will be the first such initiative of its kind in Malaysia to bring in multiple disciplines within the same cluster including – Research & Academia, Government, Industry and Civil Society. The proposed WRDC will provide a holistic solution that accelerates knowledge transfer across different domains: from research to industry and from global centres of water research and innovation to Malaysia.

5.7.2 Centres of Excellence under WRDC

The project team proposes that the WRDC will have five centres of excellence which can be established in phases. The brief outlines and mandates of each centre of excellence are given as below:

1. Research & Innovation (focus on core research and innovation)

- Scientific Research
- Engineering Research
- New product/technology development and innovation

2. *Water Quality & Resource Management (focusing on collecting data and developing cutting edge models)*

- Watershed management
- Data gathering
- Mapping
- Modelling
- Measurement

3. *Social & Economic Models (focusing on the water equality and new economic models)*

- Socio-economic research for urban and rural settings
- Water economic modelling and research for urban and rural settings
- Water policy development
- Water pricing models

4. *Industry Solutions (bringing solutions to real world and focusing on various other parts of implementation)*

- Technology transfer
- Technology testing and verification
- Training
- Standards
- Incubation centre
- Venture Capital and Private Equity
- Project Finance
- Water quality testing
- Testing Labs management
- Water Foot-printing and efficiency solutions
- Water instrumentation and technology manufacturing hub
- Consulting

5. Big Impacts Centre (develop and implement model projects)

- Smart Grid
- Water Quality Trading
- Water livelihoods
- Water Nexus (water/food; water/energy; water/health)

The proposed WRDC will be home to a world class integrated platform that will further applied research, development and demonstration in the water sector through academic, government and industry collaboration. The WRDC will accelerate knowledge transfer from research to industry and focus on addressing the challenges faced in Malaysia.

5.8 Concluding Remarks

Based on the above discussion, we propose that Water R&D may focus on six broad water research areas which we believe are most important for efficient use and development of the country's water resources. These broad water research areas are as follows:

1. Research on water availability should focus on the development of supply-enhancing technologies, on understanding the threats to water quality, on developing means for preventing further degradation in water quality, and on developing

means and methods of enhancing water quality. In order to conduct research on these fields, data need to be available in real time and should characterise water quantity and quality for both surface and groundwater waters. The monitoring of water quantity and water quality will also be important in assessing whether water policies and management efforts are working.

2. Research of water use should focus on developing a better understanding of the problems of consumptive use, the importance and scale of water uses by all sectors (industries, domestic, agriculture, environment, etc.). Research on the technologies and infrastructure for water recycling will be critical to meeting future water needs.

3. Research leading to the development of improved water management institutions should receive much more emphasis in the country's water research agenda. Research should focus on legal and economic institutions, and researchers from other social science disciplines in water resources research should be involved.

4. Research on adoption of Integrated Water Resources Management (IWRM) in the country should get more focus and needed funds should be allocated to satisfy demand of fresh water by the growing population and fast development activities to be a developed nation in 2020.

5. Malaysia needs to promote innovation in Water R&D to remain competitive. The literature suggests that our neighbouring countries have made considerable progress on enhancing their capacities (water storage capacity and increased skilled human resource). Nevertheless, in general, Malaysia still lags behinds the neighbouring countries in Water R&D investment and research.

6. We realise that the States cannot deal with certain societal challenges in isolation as these challenges are of a transnational in nature and should be only addressed through cooperation between all stakeholders (Federal, states, private and government NGOs, private and public research institutions, etc.).

Chapter 6

Water Research Fund

6.1 Introduction

Malaysia is facing threats of a lack of sufficient water, while water quality and availability issues are becoming more acute. Many parts of the country require immediate attention following the intensifying water shortage problems due to the dry spell that has hit the nation. It is deemed to be of national importance to generate new knowledge and to promote the country's water research purposely, owing to the recurrent critical water situation in Malaysia.

At present, there is no research coordination and an apparent neglect of some key research fields. In addition, there is little strategic direction that would provide for the identification of priority areas or appropriate water technology transfer. To address these issues, the government has established R&D activities to promote sustainable management of water research studies. As water management problem and related issues are getting increasingly more complicated and the solution demands integration of various water-related knowledge, the government is committed to direct and fund research on critical water issues. However, the source of funds is scattered. The administration of R&D funds is largely related to the MOSTI and MOE.

6.2 Water Research Funds Availability

6.2.1 Research Priority Areas by MOSTI

The R&D funds related to MOSTI cluster focus on areas including Biotechnology, ICT, Industry, Sea to Space and S&T Core under 4 types of funds: *(i) ScienceFund; (ii) TechnoFund; (iii) InnoFund; (iv) Flagship Programme*.

ScienceFund is a type of grant provided by MOSTI to carry out R&D projects that can contribute to the discovery of new ideas and the advancement of knowledge in applied sciences, focusing on high impact and innovative research. The selected project should produce clear and measurable expected output, outcome and impact in line with National Key Economic Areas / National Key Result Areas (NKEA/NKRA). TechnoFund is a grant scheme which aims to stimulate the growth and successful innovation of Malaysian enterprises by increasing the level of R&D and its commercialisation. The scheme provides funding for technology development, up to pre-commercialisation stage, with the commercial potential to create new businesses and generate economic wealth for the nation. InnoFund is a grant scheme which funds the development or improvement of new or existing products, processes or services with elements of innovation. The project must have economic value and improves the societal well-being of the community. InnoFund can be categorised into Enterprise InnoFund (EIF) and Community InnoFund (CIF).

Research priority areas for MOSTI ScienceFund, TechnoFund, InnoFund are as follows:

1. Life Sciences
2. Computer Sciences and Information and Communication Technology (ICT)
3. Agriculture Sciences/ Agricultural Engineering
4. Environmental Sciences
5. Advanced Materials Science
6. Chemical Sciences
7. Physical and Mathematical Sciences
8. Engineering
9. Medical and Health Sciences
10. Social Sciences and Humanities.

The research priority areas for ScienceFund, TechnoFund and InnoFund by MOSTI do not indicate Water R&D as an important research area. As these funds are offered by the government to academic institutions and various industrial players, it is suggested that Water R&D should be included as one of the research priority areas.

The Flagship Programme is a special grant scheme programme provided by MOSTI to fund research in areas identified to have an impact on the development of STI and aligned with the New Economic Model (NEM). The Flagship Programme is a top-down approach and the National Science and Research Council (NSRC) sets the research priority areas and particular niches that need to be implemented for the sustainability of current Government initiatives. Water R&D is highlighted as one of the research priority areas for Flagship Programme as outlined below. However, the flagship funds may only be used for a multi-disciplinary project, which involves pilot plant/ prototype equipment and supporting infrastructure which is directly related to the pilot plant, therefore limiting the number of successful applicants for this fund.

The flagship research areas are as follows:

1. Biodiversity (sustainable utilisation and conservation)
2. Cyber security (Information security and autonomous system)
3. Energy Security (Harnessing alternative resources and improving the efficient use of energy especially in the areas of renewable energy)
4. Environment and Climate Change (Ecosystem management, protection and improvement to mitigate flood, drought & air pollution; biosurveillance for environmental protection; Eco-tourism)
5. Food Security (Improvement of food crops, livestock & animal feedstock; Exploitation of biodiversity for food/ feed; Post harvest physiology & technology Production System and Precision Agriculture; Improvement of biosecurity biosurveillance and Sanitary & Phytosanitary (SPS) measures for animal and plant genetic resources)
6. Medical and Healthcare (Diagnostic, prevention and treatment to enable the ability to mitigate the burden of lifestyle diseases; new and emerging diseases; Cancer; biosurveillance in medical and healthcare.)
7. Plantation Crops and Commodities (increasing the productivity and utilisation, focusing on Oil Palm, Timber, Rubber, Cocoa, Kenaf, Tobacco & Pepper)
8. Transport and Urbanisation (Enabling the use of alternative energy sources and energy efficiency vehicles for environmental friendly transport; Design and engineering in vehicle, infrastructure, systems and facilities; Efficient urban waste management (Reuse, recycle & reduce))

9. Water Security (Sustainable sources and processing, treatment & distribution of water)

6.2.2 Research Priority Areas by MOE

MOE also provides R&D funds including (i) Fundamental Research Grant Scheme (FRGS); (ii) Long Term Grants Scheme (LRGS); (iii) Prototype Research Grant Scheme (PRGS). Fundamental research involves the exploration of new ideas, concepts or theories which will be the backbone to new discoveries, expansion of knowledge and sophisticated and State of the art inventions.

In this respect, under the Ninth Malaysia Plan, the MOE (formerly MOHE) has allocated RM200 million to fund fundamental research projects in Public of Higher Education Institutions. The Ministry offered applications for the FRGS for the first time in 2006. The evaluation and recognition process for each Public of Higher Education Institutions fundamental research project application is conducted by a group of FRGS Evaluation Committee comprising of experts from Public of Higher Education Institutions. The fundamental research projects are generally classified into six areas as follows:

1. Pure Science
2. Applied Science
3. Social Sciences and Literature
4. Medical Science, Technology and Engineering
5. Natural Science
6. National Heritage

Water R&D is not highlighted as significantly important by MOE as the research project areas in FRGS, hence limiting the positive outcomes of water research areas.

In line with core application for Research and Innovation, the research funding has increased to RM741 million for 2011 and 2012, under the Tenth Malaysia Plan. This provision is for five research programmes including the LRGS. LRGS is research that is fundamental, involving more extensive research scope requiring longer research period and a strong commitment. LRGS may produce theories and new ideas to the forefront of strategic research niche to expand the knowledge boundaries. Through LRGS, it is hoped that research activities may increase via multi-institutional and multi-disciplinary collaborative work. The research programmes in LRGS focus on seven strategic research niches in Malaysia. These research areas are identified as high impact research areas spearheaded by five RUs. Water security is outlined as one of the research niches as follows:

1. Global warming
2. Infectious disease
3. Tropical medicine
4. Energy and water security
5. Adequacy of food
6. Advanced manufacturing and added-value
7. Information and communication technology (ICT)

Apart from the seven niches that have been identified, institution other than RUs may also suggest different research niches according to their own research expertise.

PRGS is a new programme under MOE. PRGS is created to bridge the gaps between laboratory discoveries and research up to its pre-commercialisation towards the creation of new technologies in line with K-Economy and the New Economic Model. This includes proof of concept, evaluation, up-scaling, pre-clinical and field testing.

Chapter 7
Water Research Governance

7.1 Introduction

In this chapter, we will discuss the current set up of water governance in Malaysia and propose a new set up that can overcome the implementation, as well as other management and water governance issues caused by the lack of comprehensive strategies necessary for efficient management and governance of our water resources. In the first part of the chapter, we have briefly highlighted the issues relevant to the water governance in Malaysia. In the second part, we have proposed a new set up of water governance. The new set up takes decentralised and centralised concepts of water management in Malaysia. The important points of the both systems (centralised and decentralised) have been taken into account while proposing the new set-up of water governance.

7.2 Water Governance

7.2.1 Definition

The Global Water Partnership (GWP) defines 'water governance' as *"…the range of political, social, economic, and administrative systems that [are] in place to develop and manage water resources, and the delivery of the services, at different levels of society."*

The Global Water Partnership (GWP) Framework for action declared that, *"the water crisis is often a crisis of governance"* and all Governments should put more focus on "effective water *governance"* for solving water crisis. This GWP Framework was later reviewed at the Hague in 2000, when the Ministerial Declaration called for *"governing water wisely to ensure good governance, so that the involvement of the public and the interest of all stakeholders are included in the management of water resources"* (NWRS, 2011).

Governance is of utmost importance in determining whether a country succeeds or fails in its water management. This is especially so when a country moves from abundant water availability towards scarcity (Mesdaghinia, 1997). The World Bank defines two types of water governance regimes: First, there is 'Good governance' which is epitomised by "… predictable, open and enlightened policymaking, a bureaucracy imbued with professional ethos acting in furtherance of the public good, the rule of law, transparent processes, and a strong civil society participating in public affairs." (Santiago, 2005). In terms of "Poor governance", conversely, the World Bank says it is "…characterised by arbitrary policy making, unaccountable bureaucracies, un-enforced or unjust legal systems, the abuse of executive power, a civil society unengaged in public life, and widespread corruption." Elsewhere, the UNDP defines governance in the following way: It is "… among other things participatory, transparent and accountable. It is also effective and equitable. And it promotes the rule of law." In short, governance is about the exercise of power in managing a nation's affairs, in this case the management of water resources. UNDP's activities at the 3rd World Water Forum in Japan in March 2003 highlighted the importance of water governance. UNDP together with its partners committed to continue the Dialogue on Effective Water Governance, among other things, to follow up actions as a part of the Type II Partnership for Effective Water Governance. Such a level of governance is experienced in Penang State whereby Water Watch Penang is working in close partnership with the government and the private sector in ensuring good governance of the water sector (Chan, 2007).

7.2.2 The Situational Background

Water, is a State matter under the Malaysian Constitution. However, when it comes to water resources development, utilisation and management, both the Federal and State Governments are involved. This is because the responsibility for water resource administration is fragmented and is shared among a number of Federal and State agencies, each of them having their own specific involvement in water-related issues (Elfitrie et. al., 2004). The jurisdiction and legislative power in the aspect of water distribution between Federal and State Governments is in accordance to the Legislative Lists of Federal Constitution which comprises Federal List, State List and Concurrent List. Their interest in water-related matters could be viewed as from any one or more of the following three aspects: (i) the aspect of planning, development and management of water resources; (ii) the aspect of protection and conservation of water; and (iii) the aspect of land-use control and watershed management.

The administration of rivers and water resources in this basin is being carried out by the Federal and various State Government agencies. The Federal agencies are generally responsible for the studies, planning and development of the water resources. The State agencies are responsible for water supply infrastructure development including financing, operation and maintenance. The Federal Government agencies include the Department of Environment (DOE), Malaysian Meteorological Service (MMS), Public Works Department (PWD), Health Department, Department of Agriculture (DOA) and the National Hydraulic Research Institute Malaysia (NAHRIM). The State Government agencies include Water Supply Department (JBA), Forestry Department, Selangor Water Management Authority (LUAS), Local Authorities (PBT) and Land Office. Agencies which were established both at the Federal and State levels include the Department of Irrigation and Drainage (DID), Department of Town and Country Planning (JPBD), Fisheries Department, Wildlife Department and Veterinary Department.

7.2.3 Water Governance in Malaysia

If a country has bad water governance, its water resources would not be managed sustainably (Alam et al., 2007). In general, water governance is not merely a case of managing water resources, either by government, private sector or other institutions. According to UNDP, water governance refers to the range of political, social, economic, and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society. Hence, water governance compromises the mechanisms, processes, and institutions through which all involved stakeholders, including citizens and interest groups, articulate their priorities, exercise their legal rights, meet their obligations and mediate their differences in relation to water (http://www.undp.org/water/about_us.html accessed on 04/03/14).

Water problems in Malaysia are not an issue of scarcity as much as it is an issue of governance. To substantiate this point, the authorities have used the water problems as an excuse to shift the governance of the water sector from government control to private hands. Ineffective institutional arrangements amongst public sector organisations are given as the excuse (Chan, 1998). Hence, privatisation of water supply and raising water tariffs were preferred governance options as privatisation was seen as the panacea to all of Malaysia's water woes (Chan, 2006b).

Many states have privatised some or all of their water supply functions. However, this form of water governance has not yielded the success that it claims but on the other hand has led to losses and failures in the privatisation (Chan, 2004). Hence, the civil society has argued strongly against privatisation (Santiago, 2005).

The authorities need to employ a more "people friendly" approach by allowing the public, including

NGOs, to play a greater role in water management via consultation and participation in all developments relevant to water (Chan, 2009). Water is everybody's business and everyone's responsibility ranging from the government to water corporations, water authorities, water companies, consultants, industries, businesses, NGOs, and the general public (Chan, 2006a). All should work together in a partnership to ensure that water resources are used sustainably in the best economic manner that does not harm the environment but guaranteeing everyone access and protecting the need of future generations with adequate and clean water.

One example of bad water governance in Malaysia can be deduced from the facts on Non-Revenue Water (NRW) reported by Suruhanjaya Perkhidmatan Air Negara (SPAN). The SPAN reported that Peninsular Malaysia has an average NRW of 36%, with a peak of 53.2% (Negeri Sembilan) and a low of 16.9% (Penang). SPAN also reported that the NRW reduction for Selangor between 2003 and 2008 is from 43.9% to 33.9% (Yassin et al., 2013).

The Federal government distributes water resources and supply management to several departments under different ministries. **Table 7.1** shows that there are too many departments involved in the water sector. And hence, many guidelines need to be complied.

TABLE 7.1 WATER ADMINISTRATION UNDER FEDERAL GOVERNMENT

Departments	Tasks/Responsibilities
The Department of Irrigation and Drainage (DID)	Hydrology, river management, flood mitigation, coastal management and storm water management
The Public Works Department (PWD)	Domestic and industrial water supply
Department of Environment (DOE)	Quality of rivers, reservoirs or any water catchment areas
The Ministry of Health (MOH)	Quality of raw water supply especially for drinking water purposes
The Ministry of Energy, Green Technology and Water	Setting water supply and sanitation policies

Source: Saimy and Nor Ashikin, 2013

7.2.4 Sustainable Water Governance in Malaysia

In Malaysia, the majority of water development projects were proposed by the Government and private developer in recent years. Hence, there is a number of government agencies involved in managing the initiated project; especially during the pre-development stage. However, the problem of corporation and participation among the responsible agencies remains a big issue towards the achievement of sustainable of water development practice in this country (Yassin et al., 2013).

According to Weng (2005), involvement of all stakeholders in natural resource management, such as water management are essential in every stage. However, in some cases, the State government and Federal government do not cooperate and support each other, and as a consequence, the situation becomes more complicated in terms of natural resources management and development (DID, 2007).

On the other hand, inadequate regulation for control water development also contributes to the unsustainable development problem (Yassin et al., 2013). Malaysia has no direct laws aimed at controlling development near to water area, though there are laws that are indirectly linked such as The Land Conservation Act 1960 (Revised 1989), The Land Acquisition Act 1960, The EIA Order 1987 and others. Nevertheless, they have been largely ineffective due to poor enforcement and poor governance by those in charge (Weng, 2009). **Figure 7.1** summarises constraints factors in achieving sustainable water governance in Malaysia.

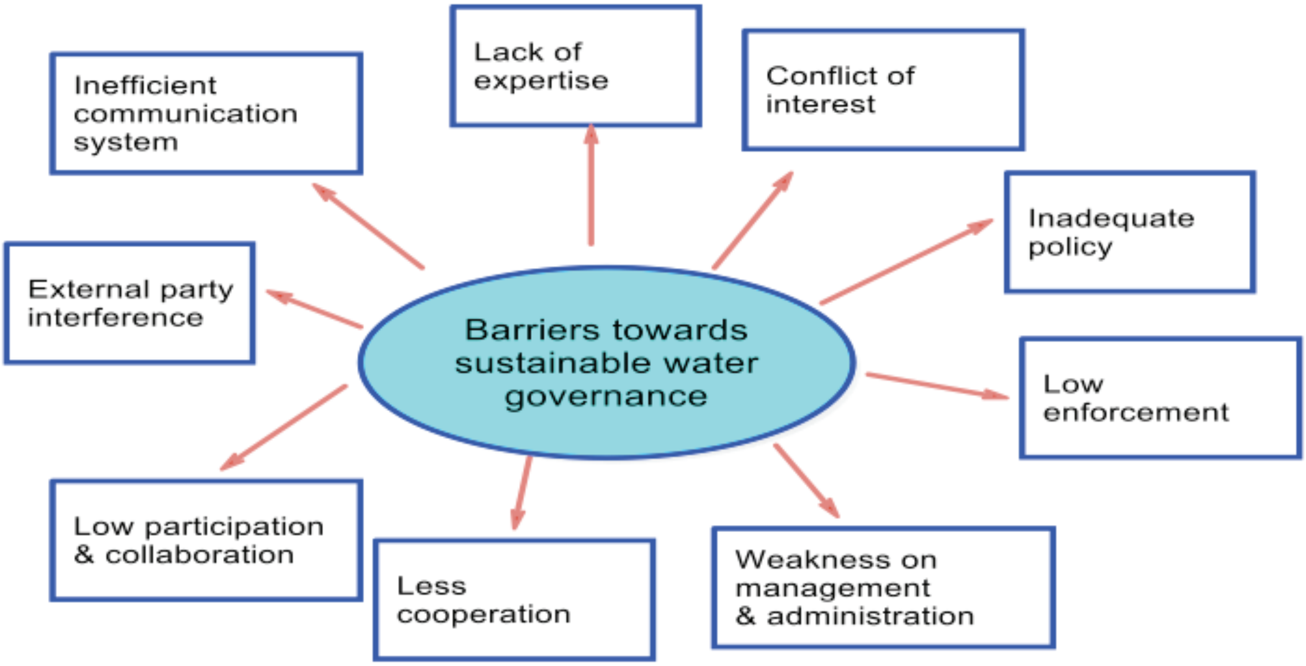


Figure 7.1. Constraints in sustainable water governance

Source: Yassin at al., 2013

The message of the international water organisations is clear regarding the effective governance of water resources. The following points can be considered while improving governance of water resources in Malaysia:

i. If water crisis is to be averted, effective water governance is necessary;

ii. Governments should give top priority to effective governance of water resources and reduce non-revenue water (NRW) as much of water is lost from the system leakage and theft;

iii. In order to have effective water resources governance, public participation needs to be encouraged and the interests of stakeholders should be protected;

iv. Unsustainable exploitation of water resources needs to be stopped and a global effort is required on emergency basis;

v. Governments should develop water management strategies for regional, national, and local levels which promote equitable access and adequate supply of water to the all users and at all times; and

vi. Integrated water resources management (IWRM) concept should be promoted and applied in drawing up water efficiency plans in the country.

All the above points should be applied in managing the country's water resources. This will ultimately affirm our commitment with the international community regarding sustainable management of water resources.

7.3 S&T Contribution in the Growth of Malaysian Economy

Developing a country with strong science and technology background requires heavy investment in research and development (R&D) activity. According to Lall (2009), R&D enables Malaysia to assimilate and develop technological capability. It also allows the country to diversify its industrial base by identify critical technologies needed. Research & Development (R&D) is the core of productivity and is of fundamental importance for Malaysia in sustaining its economic growth (Rasiah, 1999). The R&D activity is important for long-term economic returns and is necessary in sustaining technological growth.

Overall, R&D in Malaysia has shown positive progress since it was announced during the Fifth Malaysia Plan (1986-1990). Between 1986 and 1990, R&D contributed an average of 0.8 per cent to gross national product (GNP). The contribution of public sector in R&D expenditure was more than 80 per cent, whilst private sector input was very low. In the Sixth Malaysian Plan (1991-1995), R&D contributed about RM541.9 million or 0.2 per cent to the gross domestic product (GDP), with 55 per cent contributed by the public sector and the balance by the private sector (Rasiah, 1999). The situation, however, has shown some improvement after 1996. In the Seventh Malaysian Plan (1996-2000), the expenditure for R&D increased to RM1,671 million or 0.5 per cent of GDP. Since then, the amount keeps increasing in other Malaysian Plans.

In terms of employment, in 1989, it was estimated that 13,605 researchers were involved in R&D activities or the equivalent of four researchers per 10,000 workers. However, the numbers slightly decreased for the period 1991-1995. During the period, there were only 8,300 researchers and 12,450 technicians in Malaysia. The lower output of science stream graduates was one factor that affected the number of workforce available for R&D activities. It was reported that during the same period science graduates were only 38 per cent of overall graduates (Seventh Malaysia Plan, 1996). During the Seventh Malaysia Plan (1996-2000), the number of researchers increased to 23,262 after drastic efforts were taken by the government, such as doubling the allocation for education and training development and increasing the intake for vocational education (Danabalan, 1997; Omar, 1997). Five years later, about 27,500 researchers were involved in R&D activities, or the equivalent of 25 researchers per 10,000 workers (Ninth Malaysia Plan, 2006). More analysis on full time equivalent researchers (FTER) in Malaysia is given in Chapter 5.

7.4 Malaysia's S&T Policy for the 21st Century

Science, technology and innovation are central to success in today's modern economy. They are vital resources and strategic investments for building a more innovative and vibrant economy in order to face the challenges and uncertainties of the 21st century. The Second National Science and Technology Policy (hereafter S&T Policy) will put in place programmes, institutions and partnerships to enhance Malaysia economic position including the quality of life of the people.

7.4.1 S&T Policy Vision

To become a nation that is competent, confident and innovative in harnessing, utilising and advancing S&T towards achieving the goals of Vision 2020.

7.4.2 S&T Policy Goal

To accelerate the development of S&T capability and capacity for national competitiveness

7.4.3 S&T Policy Objectives

- To increase R&D spending to at least 1.5 per cent of Gross Domestic Product (GDP) by the year 2010, in an effort to enhance national capacity in R&D; and

- To achieve a competent work force of at least 60 RSEs (researchers, scientists and engineers) per 10,000 labour force by year 2010 in order to enhance national capability in S&T

7.4.4 New Directions of S&T Policy

The S&T Policy provides a framework for improved performance and long-term growth of the Malaysian economy. The S&T Policy aims to:

- Increase the national capability and capacity for research and development (R&D), technology development and acquisition;

- Encourage partnerships between public funded organisations and industry as well as between local and foreign companies for the co-development of technologies with a view to increasing indigenous technology capability;

- Enhance the transformation of knowledge into products, processes, services or solutions that add value across every industry for maximum socio-economic benefit;

- Position Malaysia as a technology provider in the key strategic knowledge industries such as biotechnology, advanced materials, advanced manufacturing, microelectronics, information and communication technologies, aerospace, energy, pharmaceuticals, nanotechnology and photonics;

- Foster societal values and attitudes that recognise S&T as critical to future prosperity, including the need for life-long learning;

- Ensure that the utilisation of S&T accords emphasis towards approaches that are in conformity with sustainable developmental goals including alignment with societal norms and ethics; and

- To develop new knowledge based industries.

7.4.5 Strategic Thrusts for S&T Development

As a nation with relatively limited resources, Malaysia has to ensure the desired results and high rates of return from every investment made in developing S&T. The allocation of resources should, therefore, be closely aligned to national priorities for the country's transformation into a knowledge-driven economy so as to maximise economic and social returns.

The S&T Policy addresses seven key priority areas:

i. Strengthening research and technological capacity and capability;

ii. Promoting commercialisation of research outputs;

iii. Developing human resource capacity and capability;

iv. Promoting a culture of science, innovation and techno-entrepreneurship;

v. Strengthening institutional framework and management for S&T and monitoring of S&T policy implementation;

vi. Ensure widespread diffusion and application of technology, leading to enhanced market-driven R&D to adapt and improve technologies; and

vii. Build competence for specialisation in key emerging technologies.

7.4.6 Initiatives in S&T Policy

The project team reviewed the Second S&T Policy and found that the policy is comprehensive, though lacking in Water R&D as a focus area. Below is a list of initiatives of the S&T Policy which encompass almost all fields, except for the Water R&D field. Indeed, we are aware that other initiatives in S&T Policy are also indirectly covering Water R&D, however, they are not specifically targeting Water R&D field.

1. Increase public and private sector investments in R&D including infrastructure development;

2. Research and technology development programmes including basic research in the new and emerging technologies to be prioritised regularly through initiatives;

3. Invest in upgrading the infrastructure for S&T development including establishment of new major research/technology development institutions;

4. Launch, jointly with industry associations new programmes in selected sectors to strengthen indigenous technological capabilities of local corporations in existing as well as new and emerging technologies through partnerships with universities and public research institutes;

5. Stimulate private sector investment in R&D technology development;

6. Aggressive and strategic implementation of existing Technology Acquisition Programme under the smart partnership framework;

7. Establish strong linkages with regional and international centres of excellence in collaborative R&D;

8. Establishment of Business Development Unit within MOSTE to develop strategies and programmes aimed at enhancing the commercialisation and diffusion of research findings generated from public funded research organisations;

9. Introduce, in collaboration with Association for Small and Medium Enterprises (SMEs);

10. Incorporate within existing procurement practices, programmes to support innovation and development of indigenous technology development.

11. Apply self-financing targets for all public research institutions (30% by 2005) and universities (5% by 2005).

12. Intensify development of critical mass for S&T.

13. Expand implementation of S&T Human Resource Development (HRD) Fund.

14. Strengthen and expand Teaching Company Scheme and other student attachment programmes to build long-term relationships for technology transfer and training between university and industry.

15. Improve the career prospects and mobility of scientists and research workers;

16. Re-examine programme on Returning Malaysian Scientists to make it more attractive;

17. Review the Skills Development Fund to finance industry-training programmes; Enhance and modernise the existing system of certification of technical personnel and classification of skills;

18. Expand adult and continuing education programmes, particularly in technical subjects, to upgrade the skill base in specific areas;

19. Strengthen the effectiveness of mechanisms to allow industry to contribute to course design and curriculum review in institutions of higher learning and industrial training institutes;

20. Ensure that Malaysian graduates acquire training and skills that are fully relevant to national needs;

21. Enhance and institutionalise linkages for industrial training between industry and educational establishments;

22. Strengthen the role of tertiary institutions in advanced technology research and innovation;
23. Ensure an effective role for institutions of higher learning in all proposed technology parks and innovation centres;
24. Expand the scope and coverage of S&T promotion activities in collaboration with S&T NGOs and industry;
25. Establish five Regional Science Centres by 2010 to elevate S&T awareness among the populace;
26. Promote techno-entrepreneurship;
27. Inspire Science and Technology awareness and appreciation at all levels of government;
28. Raise S&T awareness and appreciation by inculcating S&T culture in the education system;
29. Use the mass media to heighten public awareness and appreciation of Science and Technology;
30. Enhance the scope and coverage of the Science and Technology Week programme and other promotional activities;
31. Encourage the formation and development of centres of excellence in science;
32. Promote the formation of guilds for technical personnel with activities that are specially focussed on technical and professional issues;
33. Support the Malaysia Design Council that aims to create and maintain a fund to be used for encouraging the creation, design, development, financing, manufacture and utilisation of Malaysian inventions, research results including other intellectual property;
34. Strengthen the Ministry of Science, Technology and the Environment (MOSTE) by endowing it with necessary resources to ensure effective S&T policy formulation and implementation;
35. Review the role of Majlis Penyelidikan Kemajuan Sains Negara - MPKSN (National Council for Scientific Research and Development) to ensure effectiveness of S&T advisory and coordination system;
36. Expand efforts to develop effective information gathering, monitoring and evaluation and transmission mechanism to track the nation's performance in S&T;
37. Promote adoption of sound research management practices including intellectual property management and commercialisation of research outputs in all PRIs and universities;
38. Enhance the management of intellectual property rights including patent advisory and other services;
39. Develop mechanisms and codes of practice to ensure that development of S&T accords emphasis to preventive approaches as well as being consistent with acceptable societal norms and ethics;
40. Enhance the management of the technology intelligence and information system;
41. Require public sector R&D institutes to draw up five-year budget plans detailing research programmes and priorities;
42. Enhance the system of contract research as a first step towards corporatisation of all industrial research institutes;

43. Aim for a greater degree of financial autonomy for R&D institutes;

44. Enhance quality awareness and design in industry through ongoing programmes;

45. Form a special technical committee to propose specific and concrete measures to enhance the capability of the engineering and technical services sector;

46. Ensure the effectiveness of the Industrial Technical Assistance Fund;

47. Gear public procurement policy firmly to stimulating innovation and product development for local firms to help them be more competitive in regional and international markets;

48. Strengthen linkages between firms by encouraging R&D and product development programmes between purchasers and suppliers and developing vendor support systems;

49. Undertake a detailed scrutiny with a view to implementation of the product group Action Profiles in the key industry sectors such as Advanced Manufacturing, Advanced Materials, Electronics, Information and Communication Technology and Multimedia Technology, Biotechnology, Energy, Aerospace, Nanotechnology, Photonics as well as other key technologies;

50. Develop a secure knowledge base in the key technology areas to sustain technology support for Malaysian industry;

51. Prioritise research programmes in the new and emerging technologies to ensure focus in areas that yield the highest economic pay-offs;

52. Institute special measures to encourage the formation and development of new technology-based firms engaged in the promotion or commercialisation of technological innovations;

53. Set up national focal points for each of the new and emerging technologies; and

54. Enhance exposure to international developments in the new technologies, and exploitation of foreign research expertise where necessary.

7.5 Water R&D not Captured in the Second S&T Policy

Currently, the third S&T Policy is under preparation with the consultants, so the project team suggests that Water R&D should be specifically given priority in the forthcoming S&T Policy. It is no doubt that water resources play a crucial role in every country's economic development. In addition, availability of water resources equivalent to the minimum demand is government responsibility and guarantees the continuous development activities.

Nonetheless, this may not be easily possible if water resource is not on top agenda in government S&T Policy. The project team alarms that the absence of Water R&D in the country's S&T Policy may cause some hindrance in the country's development targets and ultimately may slow down the pace to be a developed nation in 2020. Thus, the project team strongly recommends that Water R&D should be considered as a focus area of research and development in the forthcoming S&T Policy. Doing that may not be easy as some amendments may be needed in the country's constitution. However, these amendments can be made without prejudice of existing laws and regulations prevailing in the country by the legal team expert in water resources laws and regulations.

This is very important and vivid that to remain competitive in the future, the Malaysian Government must support the development of critical bases for future specialisation and competence in carefully selected areas including Water research.

7.6 Need of a Legislative Framework

Since the independence, water policies in Malaysia are made by individual states on an ad-hoc basis. There are no centralised nor standardised water policies or guidelines for states to adopt. As a result, there are numerous Acts and guidelines on water, as well as multiple agencies are managing them. Good water governance is therefore needed in Malaysia to handle water problems complexity, for a better or efficient water use and management (Saimy and Nor Ashikin, 2013). It is also to ensure economic, social and environmental sustainability.

However, in implementing good water governance, legislation becomes the central mechanisms (Ahmad Fariz et al., 2009). The legal instrument would then support the water policies, programmes or projects. Hefny (2007) implied that ethical frameworks are also necessary to address water issues such as allocation of water resource, efficiency, productivity and valuation. Aros (2009) emphasised that government agencies and State authorities should collaborate more and draw up State and national regulations to ensure proper and sustainable utilisation of water resources. Wolf and Stanley (2011) State the water management needs to be under a single entity, improved planning and continued attention. Unifying water-related activities under one ministry or agency is also a good alternative for good water governance (Melati, 2010). Ahmad Fariz et al. (2009) asserted that the communities, industries and stakeholders should be made aware of the importance of water and take part to protect the natural resource. According to MOSTE (2002), well trained monitoring and enforcement officers are also required to effectively manage and enforce water issues.

7.7 Organisational Change and Management

Based on the findings of this study, contributions to the present and future needs of the water sector requires the continuous development of a workforce which is both adequate in size, capable in skills and strong in leadership. The establishment of a Water Research Consortium is proposed as the way forward to facilitate the centralisation of various organisations, representing the water sector in Malaysia. Furthermore, the formation of the water consortium will serve as a collaborative platform for water research and its nexus in which NAHRIM becomes the nuclei of this consortium. In this regard, NAHRIM has the main responsibility to ensure the coordination between various academic institutions and research organisations in the management of water research.

The objectives are as follows:

1. To strengthen the existing structure of water research institutes and organisations;
2. To coordinate multi-disciplinary research between academic institutions, governmental organisations and NGOs;
3. To identify sources of funding for realisation of water-related research and studies; and
4. To identify potential research needs and niches to consolidate water research expected outcomes.

Restructuring process must consider the following key deliverables:

- Integration of multi-disciplinary research activities conducted by universities and others government agencies in Malaysia.
- Review of critical aspects in regards to research activities by various institutions including supervision of research students, inter-varsity or multi-institution research grants, joint publications, patent provisions etc.

Tables 7.2 and **7.3** list water-related R&D in universities, and government/private sectors, respectively. At the moment, there are 20 water-related R&D centres at local universities, three government organisations and four private institutions. Each institution seems to work independently. There appears to be significant overlapping in research focus areas amongst universities. For example, both Universiti Malaya (UM) and Universiti Sains

Malaysia (USM) focus on river management via Water Research Centre (UM) and River Engineering and Urban Drainage Research Centre (REDAC), respectively. However, several universities such as Universiti Teknologi Malaysia (UTM) and Universiti Kebangsaan Malaysia (UKM) has more than one research centre with specific research areas and disciplines. Hence, a focal organizational change and management is of paramount importance to coordinate Water R&D activities especially amongst universities. Similarly, there is a lack of coordinated effort amongst the private institutions. For example, while SYABAS and SAJ are both involved in water supply, coordination at national level is at best weak. This collaborative effort should represent a portfolio on broad aspects of water research including integrated river basin management, water resources technology, sustainability, water supply, wastewater, etc.

There is a need to form a consortium of major Water R&D players to be led by a national agency. In this regard, NAHRIM position should be elevated in order to play more effective leading roles. At the moment NAHRIM already has a good setup, with more than 100 researchers and equipped with water and hydraulic laboratories. The proposed Water Research Consortium is presented in **Figure 7.2**. It's proposed that NAHRIM to be upgraded to become a statutory body under the Ministry of NRE. As other statutory bodies (e.g. FRIM, MARDI, Malaysian Rubber Board, MPOB), NAHRIM will be governed by board of director that oversees the overall running of the Consortium including matters on resources, financial and staffing. Below the NAHRIM board is the Research Advisory Committee (RAC) which is responsible specifically in charting water research agenda and direction. RAC should meet once a year to review research programmes and suggests the way forward. Members of the RAC should be appointed amongst major stakeholders from other research institutions, universities, private sectors and selected prominent scientists.

TABLE 7.2: UNIVERSITIES' WATER R&D CENTRE/INSTITUTE

No.	Universities	Research Centre	Year Established	Contact	Focus Area
1.	**Universiti Malaya**	Water Research Centre	-	Director Department of Civil Engineering Faculty of Engineering 03-79675202/5357 (Office) 03-79555781/79675318 (Fax)	• Industrial wastewater treatment technology • River basin management river modelling and hydrology • River and marine water quality • Standards and criteria development, • Social and economic impacts of water pollution.
2.	**Universiti Sains Malaysia**	River Engineering and Urban Drainage Research Centre (REDAC)	2001	Director River Engineering and Urban Drainage Research Centre (REDAC) Engineering Campus, Universiti USM, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia. Telephone : +604 – 5941035 Fax : +604 – 5941036 http://redac.eng.usm.my/	• River management • Urban Drainage Management • Environmental Hydraulics Management • Hydro informatics
3	**Universiti Sains Malaysia**	Centre for Marine and Coastal Studies (CEMACS)	1991	Director Centre For Marine & Coastal Studies (CEMACS), Universiti Sains Malaysia, 11800 Penang, Malaysia. Tel: +6048852750 (Ext 101) Fax: +6048852751 http://cemacs.usm.my/	• Mangrove ecosystems • Marine pollution and toxicology • Mariculture • Coral reef ecosystem • Integrated coastal zone management • Marine sciences • Biodiversity conservation

4.	**Universiti Kebangsaan Malaysia**	Institute for Environment and Development (LESTARI)	1994	Director Institute for Environment and Development (LESTARI) Universiti Kebangsaan Malaysia (UKM) Tel: (+603) 89214144 Fax: (+603) 89255104 http://www.ukm.my/lestari	Comprises 4 Research Centres • Research Centre for Sustainability Science and Governance • Research Centre for Environmental, Economic and Social Sustainability (KASES) • Langkawi Research Centre (PPL) • Research on natural Southeast Asia Disaster Prevention Research Initiative (SEADPRI) Core Groups • Geological Heritage of Malaysia • Water, forests and natural resources • Liveable cities and landscape ecology • Socio-economic • Chemical management • Ecosystem change and adaptation • National tropical rock engineering research group

5.	**Universiti Kebangsaan Malaysia**	Institute for Climate Change Studies (IKP)	2011	Director Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia Tel : +603 8921 5555 Fax : +603 8921 4097	Research Cluster 1. Tropical Climate Change • Atmosphere, sea and climate • Ecosystem response and climate change • Data mining and mathematical modelling of climate change 2. Impact and Adaptation of Climate Change • Liveability and climate change • Climate change and adaptation
6.	**Universiti Putra Malaysia**	Tropical Forest Ecosystem Science Research Centre	2008	Head of Research For Tropical Forest Ecosystem Sciences (TROFES) T086-855 473 Fax: 086-855416 seca@btu.upm.edu.my http://www.btu.upm.edu.my/eintrocoel3	• Plant ecology and conservation • Soil Science • Wildlife ecology and conservation • Economics of biodiversity conservation • Water quality • Social science • Biotechnology and ecosystem • Terrestrial and aquatic flora and fauna
7.	**Universiti Putra Malaysia**	Smart Farming Technology Research Centre	2012	Head of Smart Farming Technology Research Centre SFTRC, Level 6 West Wing, Tower Block, Faculty of Engineering, UPM Serdang. 03-8946 6427 sftrc@eng.upm.edu.my http://www.smartfarming.upm.edu.my/	• Precision farming engineering • Agricultural automation & robotics • Irrigation and drainage engineering

8.	**Universiti Teknologi Malaysia**	Coastal and Offshore Engineering Institute (COEI)	1990	Director of COEI Tel : 03-26154370 http://www.coei.utm.my/	• Coastal and offshore engineering • Hydraulic and coastal designs • Offshore and coastal hydraulics • River and urban hydraulics
9.	**Universiti Teknologi Malaysia**	Institutes of Environmental & Water Resource Management (IPASA)	1994	Director Institutes of Environmental & Water Resource Management (IPASA) Tel : 07-5531574 http://www.utm.my/ipasa/	• Environmental chemistry • Eco-hydrology • Water & wastewater treatment • Green technology • Climate change impact • Waste recovery • Impact and restoration of water bodies • Integrated water resources management
10.	**Universiti Malaysia Sarawak**	Centre for Water Research (CWR)	2006	Director Centre for Water Research Email: lauseng@ibec.unimas.my Telephone: +6082 671000 ext. 181 http://www.rimc.unimas.my/index.php/centre-of-excellence/coe/27-rimc/centre-of-excellence/62-cwr	• Engineering hydrology • Wastewater management • Integrated water resource management • Natural aquatic environments

11.	**Universiti Malaysia Sabah**	Borneo Marine Research Institute	1995	Borneo Marine Research Institute (BMRI), Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah. Tel:+6088-320121 Fax:+6088-320261 bmru@ums.edu.my www.ums.edu.my/ipmb	• Aquaculture and marine science • Marine biodiversity • Coastal oceanography • Marine aquaculture, • Marine biotechnology
12	**Universiti Malaysia Sabah**	Water Research Unit	2010	Head of Unit Water Research Unit School of Science and Technology, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah. Tel: (+088) 320000 ext. 5864/5148/5061 Fax: (+6088) 320174 http://www.ums.edu.my/wru	• Environmental • Managerial • Economic and social
13.	**Universiti Malaysia Terengganu**	Institute of Oceanography and Environment	2001	Universiti Malaysia Terengganu 21030 Kuala Terengganu Terengganu, MALAYSIA Tel: +609-6683195 Fax: +609-6692166 http://inos.umt.edu.my/	• Physical & geological oceanography • Biological oceanography & biodiversity • Geochemistry & marine pollution • Satellite oceanography & marin informatics

14.	**Universiti Malaysia Terengganu**	Institut Akuakultur Tropika (AKUATROP)	1979	Institut Akuakultur Tropika (AKUATROP) Universiti Malaysia Terengganu 21030 Kuala Terengganu Terengganu, MALAYSIA Tel : +609-6683502 (Director Office) Fax : +609-6683390 Email : akuatrop@umt.edu.my http://akuatrop.umt.edu.my	• Economics & post-harvest technology • Aquatic animal health • Fish nutrition • Breeding technology • Aquaculture biotechnology • Aquaculture engineering
15.	**Universiti Malaysia Terengganu**	Institut Bioteknologi Marin	2004	Director Institut Bioteknologi Marin Universiti Malaysia Terengganu 21030 Kuala Terengganu Terengganu, Malaysia. Tel. : +609-6683104/3661 Fax. : +609-6683105 http://imb.umt.edu.my/	• Marine biotechnology • Genomic, agriculture, and neutraceutical/pharmaceutical • Biotechnology
16.	**Universiti Sultan Zainal Abidin**	East Coast Environmental Research Institute (ESERI)	2013	Pengarah Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Terengganu, Terengganu Darul Iman, MALAYSIA Tel : +609-668 8888 Fax : +609-666 2566 I Email : pro@unisza.edu.my http://www.unisza.edu.my/eseri/	• Quality Engineering and Modelling • Forensic science environment • Risk assessment and environmental health • Environment and resources • Smart forensic laboratory

17.	**UNITEN**	Centre for Sustainable Technology and Environment	-	Head of Center Centre for Sustainable Technology and Environment UNITEN Putrajaya Campus: Jalan IKRAM-UNITEN, 43000 Kajang, Selangor. Tel: 603-8921 2020, Fax: 603-8928 7166. http://www.uniten.edu.my/newhome/content_list.asp?contentid=4872	• Sustainable Urban Drainage Systems (SUDS) • Urban water system • Rain water harvesting, • Eco-hydrology • River rehabilitation
18.	**UNITEN**	Centre for Storm Water and Geohazard Management	2008	Centre for Storm Water and Geohazard Management UNITEN Putrajaya Campus: Jalan IKRAM-UNITEN, 43000 Kajang, Selangor. Tel: 603-8921 2020, Fax: 603-8928 7166. http://www.uniten.edu.my/newhome/content_list.asp?contentid=3814	• Stormwater • Flood hydrology • Geohazard • Water quality • Environment • Hydropower
19.	**Universiti Tunku Abdul Rahman (UTAR)**	Centre for Biodiversity Research	2001	Dept. of Biological Science Faculty of Science Universiti Tunku Abdul Rahman Malaysia Tel: 605-468 8888 ext. 4501 Fax: 605-466 1676 E-mail: teecs@utar.edu.my	• Aquatic biology

20.	**Universiti Tunku Abdul Rahman (UTAR)**	Centre for Environment and Green Technology	2001	Centre for Environment and Green Technology T +605-466 2323 ext.: 4496 Universiti Tunku Abdul Rahman, Jalan University, Bandar Barat 31900 Kampar, Perak Malaysia Email: sclee@utar.edu..my	• Water & wastewater treatment

TABLE 7.3 GOVERNMENT AND PRIVATE WATER R&D INSTITUTIONS

No.	Research Centre	Year Established	Contact	Research Focus Area
1.	**National Hydraulic Research Institute Malaysia (NAHRIM)**	1990	Director General NAHRIM Lot 5377, Jalan Putra Permai 43300, Seri Kembangan Selangor, Malaysia http://www.nahrim.gov.my/	• Water Resources • River • Coastal • Geohydrology • Water Quality • Water and Environment Management
2.	**FRIM (Forest Research Institute Malaysia)**	1929	Director General FRIM Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor Darul Ehsan, Malaysia T : 603-62797000 F : 603 62731314 http://www.frim.gov.my/	• Water Quality • Forest hydrology
3.	**Humid Tropic Centre**	1999	Director HTC Kuala Lumpur Department of Irrigation and Drainage Malaysia No. 2 Jalan Ledang off Jalan Duta. 50480 Kuala Lumpur, Malaysia. Tel: +603 2095 8700 Fax: +603 2095 3366 Website: www.htckl.org.my	• Water Resources Management & Development • Hydrology • New Drainage Manual (MASMA)

V	**Fisheries Research Institute**	1949	Director Fisheries Research Institute 11960 BatuMaung Pulau Pinang, MALAYSIA Tel: + 604 626 3925/26; Fax: +604 626 2210 www.fri.gov.my	• Sustainable Aquaculture Technology
5.	**Nuclear Malaysia**	1972	Director Bahagian Teknologi Sisa & Alam Sekitar Malaysian Nuclear Agency (Nuclear Malaysia) Bangi 43000 Kajang, Selangor, Malaysia. T 03-89112000 F 03-89253827 http://www.nuclearmalaysia.gov.my/	• Water and Natural Resources Management • Marine
6.	**Indah Water Konsortium**	1994	Chief Executive Officer Indah Water Konsortium Sdn Bhd Level 1-4 Block J, Pusat Bandar Damansara, 50490 Kuala Lumpur, MALAYSIA Tel: +603 2780 1100 Fax: +603 2780 1101 http://www.iwk.com.my/	• Sewerage Management Research and Development • Sewage Treatment Plants Treatment Process Performance
7.	**Syarikat Air Johor**	1999	Chief Executive Officer SAJ Holdings Sdn. Bhd. Jalan Garuda P.O. Box 262, Larkin, Johor Bahru Tel: 07-224 4040 Fax: 07-223 4060 http://www.saj.com.my/	• Water Supply Management • Wastewater management

8.	**SYABAS**	1996	Chief Executive Officer Headquarters Jalan Pantai Baharu 59990 Kuala Lumpur 1-800-88-5252 http://www.syabas.com.my/	• Water Supply

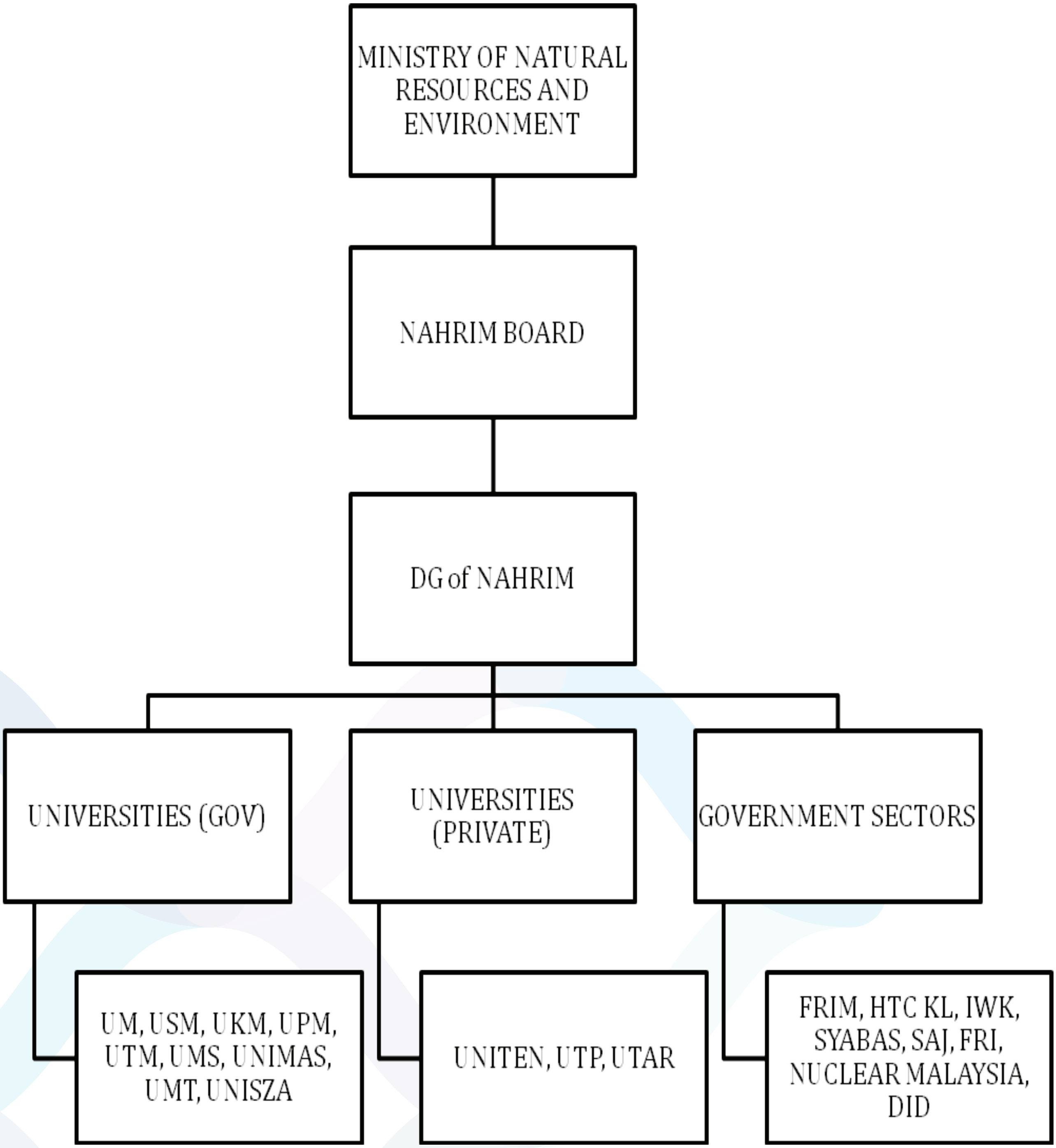


Figure 7.2. Proposed Water Research Consortium to be headed by NAHRIM.

Chapter 8

Conclusions and Recommendation

The Academy of Sciences Malaysia (ASM) had awarded a project titled "Study on the Current Status and Needs Assessment of Water Resources Research in Malaysia" to the researchers of Institut Pengurusan Alam Sekitar dan Sumber Air (IPASA), UniversitiTeknologi Malaysia. The project objectives were three-fold: (1) to compile a complete inventory of past and ongoing research on water and water-related topics, duly classified under distinct categories for ease of reference; (2) to assess Water R&D research needs until the year 2020 of different ministries, departments, agencies, companies and public and private NGO sectors; and (3) to review the overall governance of R&D on water for greater effectiveness and efficiency including the need for the creation of centres of excellence in existing institutions or forming new ones to undertake specialized and integrated research on specific thematic areas. The project team divided the project objectives into these main categories to achieve the given targets:

1. Desktop study to review funding and investment in Water R&D mostly by MOSTI and MOHE;

2. Publications on Water R&D by different institutions and departments;

3. Establishing priority listing of Water R&D from the extensive consultations of stakeholders and water experts;

4. Reviewing water-related policies, rules, regulations, and laws passed by Federal and State Governments to management precious resources and put it into most useful purposes with higher efficiencies.; and

5. Some other water-related issues were also covered but in a fragmented way as full record of the issues were not available in literature. These issues include: groundwater policies, rainwater harvesting scope and opportunities in Malaysia; wastewater State of art techniques tools and methods, etc.

Based on the above categories/classifications, the study conclusions are also prepared separately. There is a growing trend and perception that people usually looking for conclusions of any study in thumps-up and thumps-down fashion. However, in some types of study (e.g. water resources management studies) it is not always possible to answer any problems in 'true' or 'wrong'. Instead, the answer or solution may lies between 'true' and 'wrong' and the solution of a particular water problem may change temporally and spatially. Today's 'true' may be tomorrow's 'wrong' and vice versa. For example, a higher amount of annual rainfall in Sabah could not and should not be projected to Peninsular Malaysia as it is not economically feasible to use rainfall of Sabah to meet the drinking water of Johor Bahru. Thus, the project team realises and concludes that existence of water resources in Eastern Malaysia and Western Malaysia may be assessed separately and different policies should be specifically designed for separate regions.

The project team listed different Water R&D fields successfully and these listings are divided into different five categories of Water R&D: water resources and watershed management; water supply and demand; irrigation and drainage; sanitation, wastewater treatment & environmental issues; and water and climate change. Priority listings of sub-fields of each main Water R&D categories are given in the text of the report. In addition, the Water R&D categories fixed in this project are closely associated to the key core areas of national water resources policy (NWRP) (2012). The key core areas of NWRP are: water resources security, water resources sustainability, and partnership (governance aspects). However, the project team has established priority listing of more than 95 sub-fields of Water R&D. different listings can be viewed in the text of the report. We conclude that the majority of stakeholders and water experts prefer 'water resources and watershed management' and emphasise that this field of research may be given more priority in fund allocation by the Federal and State Governments.

The report has presented brief introduction of various policies including: rainwater harvesting, green technology, urbanisation policy, environmental policies, groundwater policies, national water resource policy, national forest policy, land-use policy, wastewater management policy, etc. However, comprehensive review of these policies was out of the project scope.

Yet, stakeholder engagement in devising water-related policies in Malaysia is not encouraging except in limited involvement of farmers in some irrigation schemes in the country. However, their engagement in decision making process is still required to build confidence between the water operators and users. This type of cooperation will ultimately improve efficiency of water application and reduce non-revenue water (NRW) in the country.

Over the past ten years, Malaysia has spent between 0.5 and 1.07% of its GDP for Research and development (R&D). This is still relatively low compared to the developed nations. Water R&D share in total annual GDP investment is very small compared to energy and other sectors. Water R&D field is diverse and precise estimation of total investment in this field is difficult. However, it can be generally ascertained that the government's expenditure on the Water R&D may be much less than 0.5% of the country's annual GDP. The project team suggests that government investment in Water R&D should increase to explore new techniques and tools for capturing surface runoff, transporting and managing fresh water resources, and disposing off wastewater to safe locations without adversely affecting the country's population and environment. The effects of climate change are still need to be assessed within the country to estimate precise amount of fresh water available in the country and same can be projected by using different climatic models for the next few decades. The precise amount of available water is necessary for long-term planning in the country as most development activities directly or indirectly depend on the reliable supply of fresh water.

The funding information for this study was provided by Malaysian Science and Technology Information Centre (MASTIC) and Ministry of Education (MOE). The awarded grants were categorised according to research theme categories (biodiversity, climate change, drainage, energy, pollution, water management and others), geological classification of the water (coast, island, lake, rain, river, waste and undefined) and the type of research (science, technology and social). The analysis of the MOSTI grants data revealed that Research Universities (RUs) received 56% of the research projects awarded in last decade (from 2001 to 2011), with a total of 139 research projects. We also found that the highest number of research grants related to water research was awarded in the 9th Malaysia Plan

(2006-2010) by MOHE (159 projects) and MOSTI (88 projects).

The strength of any higher education institute could possibly be judged from the number of publications which are being published by its researchers. In this study, a bibliometric analysis on past water research in Malaysia was conducted using the data mined from Web of Science (WOS) and SCOPUS. We performed basic statistical aspects of the bibliometric analysis, such as citations distribution, publications growth, authors' and institutions' networks. The results are summarised in graphical visualisations to portray the complex bibliographic relationships, trends and patterns. The following keywords related to water were used in data mining from WOS and SCOPUS databases: Eutrophication, Stormwater, Hydrology, Reservoir, Well (thermal/spring), River, Sea, Offshore, Water and health issue, Water pollution, Water analysis, Water issue, Wetlands, Flood, Groundwater, Lake, Pond, Rainfall, Coast, Estuary, Wastewater, Water conservation, Water quality, Water Resources, Water supply, and Water. In short, a total of 2516 publications were identified: 489 from WOS, and 2027 from SCOPUS. The publication period is from the year 1964 to 2012. The report presents a number of publications per institution and analysis of popular authors in different specific Water R&D fields.

The concept of Integrated Water Resources Management (IWRM) in Malaysia is still in its early stages, and mostly in theory. Thus, it is proposed that IWRM should be brought out from books into practice to achieve sustainability, effectiveness, and efficiency of the country's water resources.

The second Science and Technology Policy (S&T Policy) does not specifically cover Water R&D - an important field on which the country's development is mostly dependent. Thus, the project team recommends that the new S&T Policy should cover Water R&D as an important field in science and technology development in the country. The necessary arrangements for the inclusion of Water R&D should be made with the consultation of legal departments who are mostly dealing with all laws and regulations related to water resources and its associated fields.

We emphasise that the study findings have some limitations, hence, these should be taken into account while interpreting and employing the study findings in solving any real world water-related problems. These limitations are as follows:

- The study findings are based on the available literature and its findings could not be interpreted as whole depiction of water resources issues in Malaysia.

- The study findings are mainly focussed to the accessible databases to the project team that have been used for mining data for the project. We strongly believe that a bigger range of databases could be available with higher scope and broad covering in future. So, the findings of study may be not complete if the same objectives are being achieved by using new tools and techniques in future.

- Prioritisation of Water R&D fields is based on the responses of limited number of stakeholders and water experts. Higher number of responses and expert opinions may slightly change the listing of Water R&D in future.

- We should also not overlook the growing trend of publications in Water R&D in future as number of research universities (RUs) in Malaysia may increase in future. This will then create more opportunities for water researchers to do research in different Water R&D fields and publish their work.

- The project findings are heavily dependent on the extensive knowledge and expertise of the project team members. In future, if a project team consists of a diverse range of water experts is engaged in a similar type of project may come up with slightly different listing of Water R&D.

- The project team also emphasised that the report is snapshot in time, and thus, proposed that the listing of Water R&D in the future be updated in a span of 5 years as few Water R&D fields are emerging very fast than what was previously thought or deduced.

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