Sustaining Malaysia's Future

The Mega Science Agenda

AKADEMI SAINS MALAYSIA

Water

A MEGA-SCIENCE FRAMEWORK FOR SUSTAINED NATIONAL DEVELOPMENT (2011 – 2050)

EPILOGUE

1. Introduction

Science has been universally touted as the main engine of economic growth and national development. Science from its Latin name 'scienta' means knowledge. A knowledge-based economy is essentially a science-based economy. New knowledge i.e. "science" is generated by undertaking research, experiments and strategic studies or R&D. R & D and strategic studies provide the means to fulfill market needs and find solutions to various problems. The results and findings are delivered in the form of new or enhanced knowledge, technology and products or services. This results in productive economic activities which contribute to wealth creation and economic growth.

Malaysia, as a country, should adopt the concept of a Mega-Science Framework as a comprehensive vehicle to drive the use of science, technology and innovation (STI) to contribute towards economic growth. Mega essentially means big, therefore the discipline of Mega-Science implies a pervasive (broad-based), intensive (in-depth), and extensive (long period of engagement) use of science or knowledge to produce technologies, products and services for all sectors of the economy to derive economic growth and development. It also calls for extensive investment in research activities to enhance the knowledge base for the targeted sectors. Since knowledge in marketing and finance is equally important in promoting the success of a commercial venture as compared to technical needs, it is envisaged that the Mega-Science approach will require research to be conducted both in non-technical sectors as well as in traditional scientific sectors.

2. A need for national knowledge generating mechanism

As we are aware, national economies are classified into 5 sectors namely: agriculture, mining, manufacturing, construction and services (Table 1). Efforts to generate knowledge by establishing research institutions and universities and centers of excellence to support agricultural, mining and manufacturing sectors are well established. The construction and services sectors are also dependent on new knowledge and technology in order to progress and remain competitive.

R & D and strategic studies are also necessary to drive the development of these two sectors.

Table 1 NATIONAL ECONOMIC SECTORS (% OF GDP)

SECTOR	2010*	2015**
SERVICES	58.5	61.1
AGRICULTURE	7.6	6.6
MINING	7.9	5.9
MANUFACTURING	26.2	26.3
CONSTRUCTION	3.2	2.9

*Source:*Economic Report 2009/2010 (MoF)*
***RMK10 Report (EPU)*

The Mega-Science approach would emphasize the need to strengthen R & D and strategic studies to be undertaken in these non- traditional sectors. For example, to enhance the development of the tourism industry (service sector), dedicated R&D and strategic studies should be undertaken to generate new knowledge that will lead to the delivery of new tourism products, services and innovative strategies which will improve competitiveness of the industry. Similarly, research studies, market surveys and financial models are proposed especially for the services sector as the knowledge created will fulfill a need or solve a problem which eventually will generate revenue and contribute to economic growth. The Mega Science approach therefore identifies R&D and strategic studies as the key enablers to economic growth in all targeted sectors of the economy.

3. A need to invest sufficiently in knowledge creation: R & D and knowledge acquisition

To become a high income developed economy, Malaysia as a country has to intensify knowledge generating capacity by investing in R&D and strategic studies. The expenditure in R & D must reflect the norm usually associated with countries having a developed economy. While past

expenditure in R & D for Malaysia as a developing country has hovered at 0.5% of the national GDP, the present and future rate of spending should be increased to above 2.0% as benchmarked against the rate of spending for countries with developed economies (Figure 1). Towards achieving this goal, it is proposed that the Government formalize the rate of spending of 2% and above through the promulgation of a Science and Technology Act ("S&T Act"), which is long overdue.

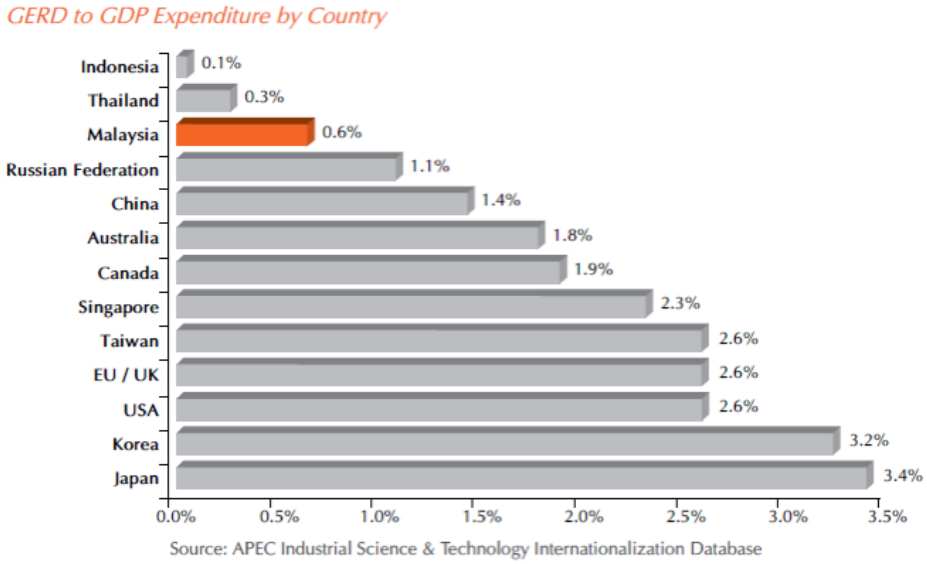

Figure 1 Malaysia's Low R&D Investment

R&D needs a long lead time before beneficial results can be harnessed to contribute to the economy through commercialization of research results and development of expertise (Figure 2). To fulfill the need to have pervasive, intensive and extensive R&D activities and satisfy the long lead time needed for R&D to mature, bold up front investments in R&D spending will be necessary. While this is financially difficult to reconcile, extensive and expensive upfront investment in R & D is necessary and forms a critical dimension of the Mega-Science Framework approach. These long lead times from R&D to Commercialization are amply demonstrated in Malaysia in the rubber and palm oil sectors of agriculture. In rubber, we took some 50 years to see Malaysia "topping the world" in rubber technology since initiating R&D in rubber. Similarly, in palm oil, Malaysia took about 40 years to "top the world".

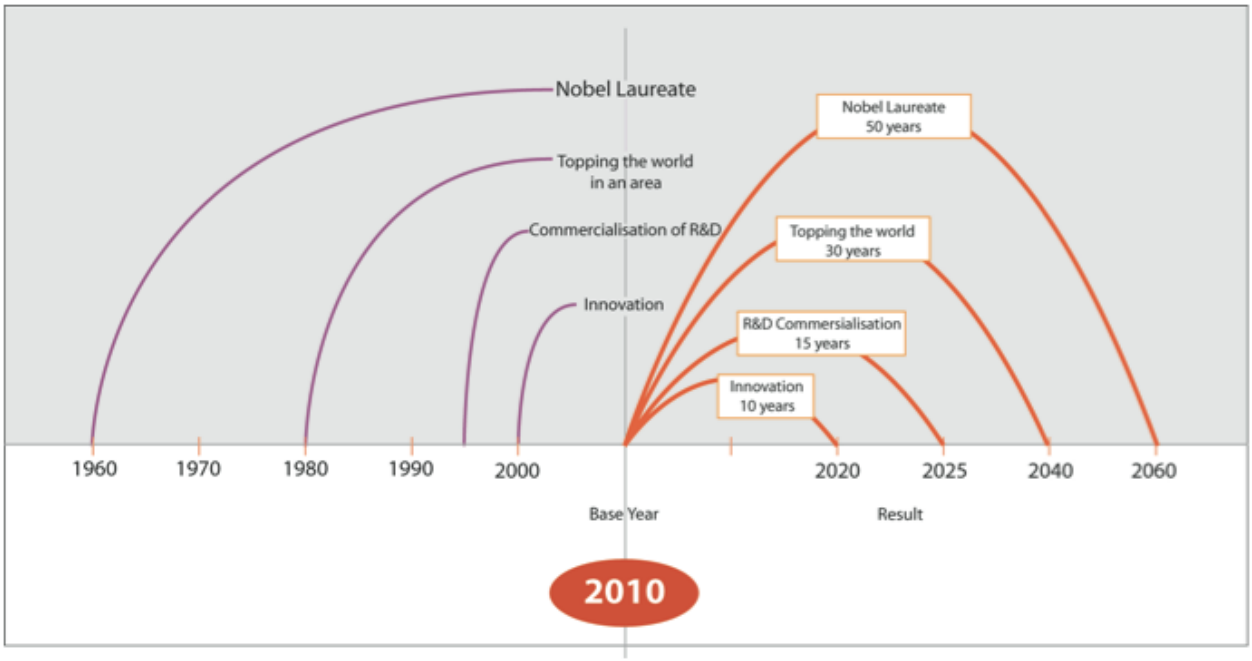

Figure 2 Time Lag on Increase in HR and R&D Investments and the Resultant Key Indicators Stimulating Economic Growth

Although a certain amount of knowledge, technology and research inputs may be imported especially through FDI activities, these are often out-dated or out-of-sync with business and economic needs. Therefore, the process of knowledge renewal and enhancement must continue to be undertaken for the country to remain competitive.

4. A need to manage knowledge generation and acquisition nationally through private and public sector participation

The Mega-Science Framework looks at national efforts in generating new knowledge and STI deliverables. 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 present proposal to establish the National Research Council (NRC) and the National Innovation Unit (UNIK) should be encouraged as these provide the management function of ensuring that funding and management for R & D and strategic studies will be maximized. A significant role of ensuring the timely development and availability of STI deliverables for economic growth must be emphasized. In this respect, the role of MIGHT and other Technology Development Corporations in technology foresight scoping, development and acquisition are highly crucial especially bearing in

mind that some technologies can be obtained through offset programmes of government international tenders.

5. Knowledge gaps in various economic sectors

In the past, economic growth was a function of knowledge (technology) and capital accumulation. Past investments in R&D in the relevant sectors would have generated knowledge to stimulate economic growth. Continuous knowledge enhancement (training) or accumulation of human capital development (expertise) adds to facilitate and accelerate economic growth. The serious lack of researchers in basic and applied sciences has to be urgently addressed such that it does not hamper the generation of knowledge and hamper sustained economic growth of the nation (Figure 3).

Future economic growth may be limited by natural limits to growth effected by population growth and excessive demand for non-sustainable and non-renewable resources. There is the possibility of reaching limits of environmental carrying capacity. Therefore, future economic development may not only depend on accumulation of capital and technology, but also on natural resources including energy and land, and the carrying capacity of the environment. These additional factors of economic growth must be factored in to the future development of the country's economy.

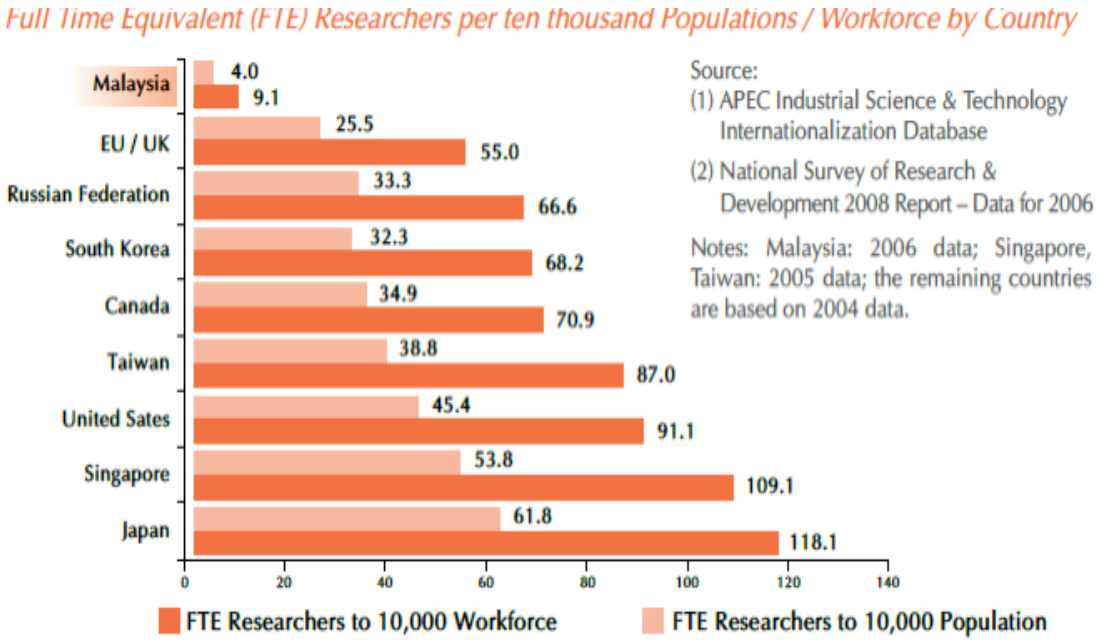

Figure 3 Low FTE Researchers – A Barrier to Sustained Economic Growth

To sustain future economic growth in Malaysia, investment in knowledge creation must be continued or enlarged. The knowledge creation (R&D) function of the Mega-Science Framework will rightly identify and address these needs.

6. Malaysia needs to intensify knowledge generation in niche sectors

Part of the Mega-Science Framework calls for pervasive, intensive and extensive use of science to identify and develop competitive knowledge and STI opportunities for commercialization in various sectors of the economy. Subsequently, another part of the Mega-Science Framework will require prioritizing of sub-sectors so that returns to strategic R&D investments are maximized. This will naturally lead to more efforts being devoted to developing of niche key sectors where Malaysia has certain competitive advantages.

Identification of the niche sub-sectors may employ the process of consultation and short term evaluation of opportunities such as the "laboratory retreats" studies undertaken by the Malaysian government recently. In addition, long term development of niche areas at the national level and the private sector will be necessary. The process is iterative. The more the investment in knowledge (R&D and STI development) the more will be the discovery of niche areas for commercial exploitation where Malaysia has the competitive advantage. But in-depth knowledge developed through the Mega-Science Framework is firstly needed to identify the niche areas.

7. Sectoral knowledge gaps and STI requirements

Studies of various economic sectors have identified the need to invest in knowledge gaps to sustain current and future needs, maintain competitiveness and contribute to the country's economic development. Firstly, cost must be kept optimally low and secondly revenue must be maximized. Ideally, the sector will generate enough commercial revenue to cross-subsidise the need to maintain the sector at minimal cost. For example, in the health and medical sector, knowledge enhancement is continuously needed to maintain the capacity of the sector to provide a high standard of health service. Efforts include promotion of preventive activities which will reduce health treatment in the long run. But there are also opportunities to generate revenue by supplying and exporting competitive health services and products such as health tourism which can contribute directly to economic growth. Similarly, in the Water Sector, ASM's Mega Science Study has identified opportunities in S&T in various niche areas.

In the biodiversity, energy and agricultural sectors which have been subjected to the Mega-Science Framework Studies undertaken by the Academy of Sciences Malaysia (ASM), it was found that the knowledge creation and STI application opportunities and gaps exist in both the home consumption

and exportable components of each sector. The defense sector could similarly fall into the two categories of development, and as more economic sub-sectors are evaluated in the future under the Mega-Science Framework Studies, the pattern will probably be the same: the need to develop both the home consumption and exportable components of the sector in order to improve the country's standard of living directly and to generate revenue for increased income.

Examples of gaps in STI adequacy and niche opportunities have been identified during the Mega-Science Framework Studies undertaken by the ASM recently. The examples clearly show that Malaysia has many niche areas for STI development for commercial exploitation especially for the export component. It is also noted that a sector with well developed export component will also provide for adequate home consumption needs. It implies that developing the export component of a sector should be given greater focus and priority as this will serve to also develop the home consumption sector to bring about improved standard of living while increasing revenue and income.

8. Lubricating the Engine of Growth

The Mega-Science Framework advocates the pervasive use of knowledge and proposes the use of STI as the main engine of economic growth and national development. An engine does not function without lubrication. To facilitate the smooth or lubricated functioning of STI, human resource expertise must be adequately available. Fortunately, the enhancement of expertise of human resource is achieved through the same engagement in knowledge creation process (R&D) and other forms of knowledge enhancement process (training) at universities, research institutes and training centers. The more people are involved in R&D and STI development; the better will be the available expertise of the country. R&D investments therefore contribute to expertise and knowledge enhancement of human resource.

Another dimension of the lubrication process to the engine of growth is the level of income itself. There exists an iterative cycle in the relationship between intensity in investment in R&D and the level of income of the country. The higher the R&D expenditure the higher will be the income level. The higher the income level, the higher will be the R&D expenditure. To break this vicious cycle, it is necessary to adopt a strategy of a high income economy, similar to what the country is currently attempting to do. In the past, Malaysia has adopted a low income and low cost economy with a reasonably high purchasing power parity index compared to other countries. It was found that the low income and low cost economy has severe limitations to promote further growth and consequently, Malaysia was led into the middle income trap. Low income strategies do not attract talents and retention of expertise in the country. Low income strategies also under-exploit the services sector which now becomes a major sector of the economy. Services provided in Malaysia

earn much lower revenue compared to similar services provided by the developed economy countries.

High income economy means high salary which means high costs. Malaysia must be prepared to adopt a high income and high cost economy as this is the norm seen in other developed countries. High cost is inevitable because when looked from the income side, high income means high salary, but the same high salary will mean high cost when looked at from the cost perspective. The big advantage of high income and high cost (salary) economy is that expertise is easier to obtain and retain, and in addition, the services sector such as hotels, tourism, banking, airlines, etc will be charging internationally competitive prices to maximize revenue and income for the country. Furthermore, efficiency will automatically be enhanced when an economy operates on a high income and high cost strategy. Such an economy will also be able to pay international prices and avoid most subsidies. The billions of Ringgit of subsidy money currently provided in the government budget can instead be distributed to increase salary. Leaving it to the high income individuals to buy the unsubsidized goods and services will further improve efficiency and reduce wastages which are often encountered in a subsidized economy.

9. S&T Governance

In Malaysia, Science, Technology and Innovation are being given very high priority. However, Academics and Researchers need to play a very strong role in evidence- and data-based decision-making, while bureaucrats should continue to play a supporting role.

In the Korean example, a high-level National S&T Council, chaired by the President with the Minister of Environment, Science and Technology as the Vice-Chair and the Ministry of Environment, Science and Technology as the Secretariat, has 5 Committees (Figure 4) on Key Industrial Technologies, Large-Scale Technologies, State-led Technologies, Cutting Edge and Convergence Interdisciplinary Technologies and Infrastructure Technologies.

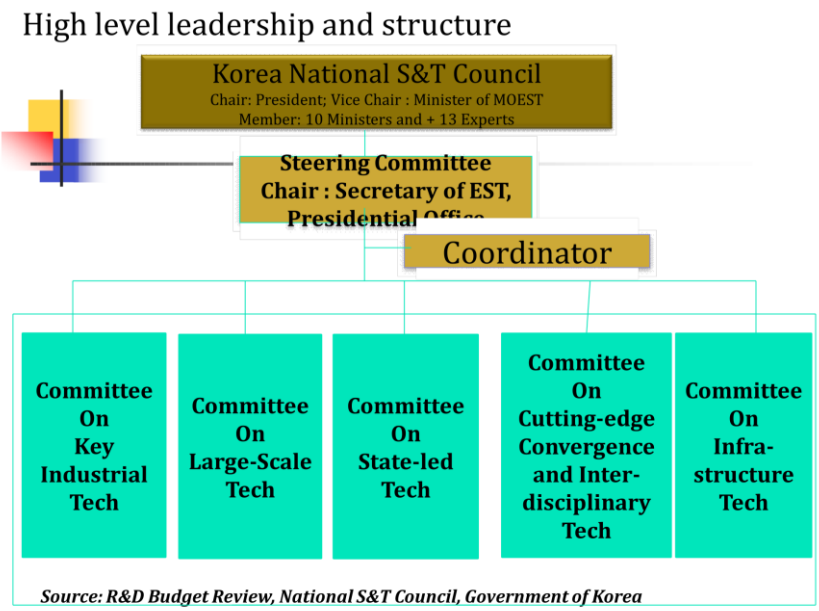

Figure 4 Korean National S&T Council

10. Funding

Malaysia is in the process of improving its science infrastructure to help improve the capacity of the country to use science (STI) as the main engine of growth for its future development. Funding and investment in R&D and strategic studies in all sectors of the economy remain underdeveloped. Such funding is both important and urgent because of the long lead time needed to provide future STI deliverables.

It is proposed that Malaysia makes a 'jump start' and allocates RM 20 billion for an accelerated development of its science industry between now and the year 2020. This fund should be managed by the responsible agencies to ensure both priorities in R&D and strategic studies and the intensification of R&D especially in the private sector can be implemented. Such funding should be increased if necessary during the period of implementation. Commitment to fund the science industry with a RM 20 billion grant would greatly contribute to the achievement of the high income economy strategy as proposed by the government. In comparison, many other countries, both developed and developing, are already providing such mega science grants to invest for their sustained growth in the future. As an example, the Korean Government gave an allocation amounting to US$16 billion to facilitate the R&D programme in the country. UNIK can be authorized to manage, coordinate, distribute and monitor the RM20 billion grant.

As a second option, part of the RM20 billion grant can be created from taxing corporate profits, amounting from ½% to 2%. The corporations will however be exempted from this taxation if they

can show that they are undertaking R&D. UNIK can be authorized to verify and certify that the R&D is being carried out. The exemption will be given to corporations able to show that they are undertaking R&D, Strategic Studies and/or undertaking technological acquisitions to further their R&D capacity and capability. In this way, more R&D, of at least 75%, will be carried out by the private sector.

In essence, the following actions are proposed as part of the functions of UNIK which will be authorized to manage, coordinate, distribute and monitor the grant:

(i) Raise R&D funding, amounting to 2% and above of GDP, through the Government initially giving a "launching grant" amounting to RM 20 billion. The grant can be sustained through taxing corporate profits, amounting from ½% to 2% with the necessary tax exemptions given as described above;

(ii) Prioritise R&D areas with advice from the National Science Research Council; and

(iii) Migrate to improving the R&D activities to be mainly private-sector driven with the ratio being private sector: public sector at 75%:25%.

11. Conclusion

A Mega-Science Framework can be the national vehicle to promote the application of knowledge (science) through STI commercialization to generate better standard of living and new sources of revenue and income to achieve economic growth and national development. The advocacy of science (STI) as an engine of growth can be reinforced through the strong recognition given via the Mega-Science Approach on the need to have extensive investment in R&D and other strategic studies in both traditional 'scientific' sectors and the newly-emphasized services sector.

The scientific STI system as an engine of growth can be further 'lubricated' to deliver the end objectives by the adoption of knowledge enhancement strategies through R&D and training, as well as the adoption of a high income and high cost economic system as practiced by other developed economy countries. By systematically evaluating the knowledge and technology gaps in various sectors and sub-sectors of the economy, it is possible to provide the country with a road map of future opportunities in STI implementation for economic growth and national development. Present studies show many fertile areas of future opportunities exist for the sectors evaluated.

Malaysia's rate of knowledge generation is falling far behind the desired target. It can be concluded that science has not be given the needed funding and urgency to enable it to be truly the engine for sustained national growth for the future. It is hoped that the adoption of a Mega-Science Framework approach will help resolve these limitations and assist in the development of the science industry in the country.

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PREFACE

One of the most frequently asked questions by decision-makers and scientists themselves is “How can Science, Technology and Innovations (S, T and I) contribute more effectively to economic development and wellness in a sustained manner without compromising the environment’s sustainability”. There are good reasons to turn to S, T and I because they have a track record to meet critical challenges posed primarily by the growth of human population and their wants. The eradication of small pox by 1979 saved millions of life, the green revolution in the 1960's staved off global famine, nuclear power help to supplement increasing energy demand and the computer enhanced the dissemination of information for education, research and business. Antibiotics and vaccines dramatically increased life spans and improved health all through S, T & I.

Unfortunately, during the past 30 years, the anthropocentric S, T & I approach changed food production, transportation, communications, education, health and even culture (consumption society) which resulted in unsustainable environments including climate change. Designed for efficiency and driven by profit, S, T & I innovated and produced non-biodegradable plastics, toxic DDT, CFC, harmful nuclear wastes and encouraged a new generation of consumption society through automation and mass production - not to mention sophisticated weapons of mass destruction. Today we face the results of "destructive creation" because the innovators failed to factor in the impact on sustainability and wellness.

Once again no doubt, S, T & I will rise to meet the new challenges in response to the national and global demand to factor towards enhancing quality of life in all products, processes, services and development projects. It is now known that there is no positive co-relationship between the rise in GDP and wellness or quality of life. The new awakening of the global community towards a more ecocentric paradigm will change innovations and business. There are already instruments in place such as "eco-labeling" for tropical timber, traceability for food products in EC and green building index in Malaysia.

The biggest challenge to all scientists is how to use the fixed earth resources (especially water, land and minerals) to produce food, water and goods for human needs without depriving habitats for the millions of other species and destroying the ecosystems. Proven existing technologies must continuously be improved to be eco-friendly whilst the emerging one such as renewable energy, genomics, stem cells, nanotechnology, biotechnology and the novo-ICT must conform to the new order of sustainability, ethical and moral obligations whilst contributing to the economic development of the nation.

Malaysia, with its biodiverse wealth, can turn to nature for many of the answers for a developing innovatively (and of course, sustainably) our economy. Scientists only need to uncover them. We need to turn to the sun - a natural nuclear fusion reactor for all our energy needs and to water (rivers and oceans) to provide the additional food needs to begin our new journey towards a sustainable world for all. This journey for Malaysia must begin now.

At the same time, there are vast opportunities in various sectors of the national economy which can be leveraged upon in an attempt to resolve challenges and problems faced by the populace through innovative approaches in the application of Science, Engineering and Technology (SET). Through identifying and developing various tools through SET, it will go towards ensuring that our economy is not only sustained but sustained in a sustainable manner.

The Academy recognizes the importance of cross disciplines linkages that must be integrated during planning, implementation and monitoring of national programs and projects. Social engineering must be designed to match the rapid technical advances to minimize their negative impacts.

In this series, of the Mega Science Framework Studies for Sustained National Development (2011-2050), undertaken by the Academy of Sciences Malaysia, S, T and I opportunities have been identified and roadmaps provided for the short- to long-terms applications of Science, Engineering and Technology in the critical and overarching sectors such as water, energy, health, agriculture and biodiversity.

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FINAL REPORT

WATER SECTOR

MEGA SCIENCE FRAMEWORK STUDY FOR SUSTAINED NATIONAL DEVELOPMENT 2011 - 2050

2 DEC 2010

CONTENTS

6. OPPORTUNITY DESCRIPTIONS

1. PROJECT BRIEF

1.1 Purpose

To prepare and produce a Mega Science Framework document for National Sustainable Development (2011-2057) to be submitted to the Government that can be used as a basis to formulate appropriate policies and strategies towards achieving national sustainable development. This Framework is for all the Ministries and Central agencies to consider and implement for the period up to 2057 (100 years since Merdeka).

(i) Assessing and analysing the global drivers of sustainable development and the critical role of innovation in national development. Global drivers include the worldwide concern over climate change and its impact on sustainability; the shift towards a knowledge-based economy where the intangibles dominate; growing power of innovation to sustain competitiveness; concern over poverty and the fate of the environment and the millennium development goals.

(ii) Undertaking a review and an analysis of the Government's various development policies such as the 5-Year Development Plans, Industrial Master Plans 2 & 3, Outline Perspective Plans, S&T Policy II, K-Economy Master Plans, National Education Policy, National Higher Education Policy, National Agriculture Policy etc vis-à-vis sustainable development.

(iii) Assessing and determining the economic, social and environmental targets as outlined in the plans and policies so as to reflect the three dimensions of sustainability and the multi-sector nature of sustainable development.

(iv) Addressing policies, strategies and action plans for implementation for the period from 2011-2057 (10^{th} – 18^{th} Malaysia Plans).

1.2 Rationale

The Innovation-led Economy model which was adopted by the Government is a strong take-off point to enable Malaysia to leap-frog into a technologically advanced nation taking into consideration the need for societal well-being and wealth creation through knowledge generation and the development of a skilled (knowledgeable), innovation and balanced human capital resource.

The generation of scientific knowledge has led to remarkable advances that have been of great benefit to humankind but, at the same time, it can lead to environmental degradation and contribute to socio-economic imbalance if the right governance structures are not in place.

Science, engineering and technology are increasingly central to sustainable development. A number of countries, such as Ireland, Netherlands, Finland, Sweden and South Korea, have already incorporated, or are in the process of incorporating, elements of Science, technology and Innovation (STI) into their national sustainable development plans.

Decision makers, at all levels, need timely, reliable access to the knowledge generated by STI to introduce rational policies that reflect a better understanding of complex technical, economic, social, cultural and ethical issues concerning the society, the earth, and its environment.

For Malaysia to reach a developed nation status sustainably, it is imperative that it develops and harnesses all available scientific knowledge and tools.

The Academy of Sciences Malaysia (ASM) believes that the STI industry can contribute immensely to the future development of Malaysia. The Dream is to have a prosperous, peaceful and progressive country and its people through maximum use of STI in sustaining the country's development in the next 50 years.

In view of the global drivers outlined above, it is imperative that Malaysia urgently address the need to develop an integrated science framework for national sustainable development. This is essential to foster, promote and manage the development and application of scientific knowledge and technological innovation, as well as related skills and expertise, for the attainment and sustainability of the overall national development strategies, objectives and plans. The current approach appears to be sectoral and non-integrated, and does not emphasise Sustainable Development as a national over-arching priority. These include the existing policies and plans such as 5-Year Development Plans, Industrial Master Plans 2 & 3, Outline Perspective Plans, S&T Policy, K-Economy Master Plan, National Agriculture Policy etc.

It is not sufficient to look upon the S&T Community as simply a provider of information on tap when the need arises, but S&T should also be brought into play in framing the issues and contributing to strategic (national) developments. Science and technology are increasingly recognised as central to both the origins of sustainability challenges, and to the prospects for successfully dealing with them.

Sustainability should be conceptualised holistically to include political, institutional and managerial dimensions as well as intangible attainments like peace, contentment, harmony and happiness of the citizens.

It is in the national interest for societal well-being, wealth creation and knowledge generation that Malaysia has to have in place a Mega Science Framework for National Sustainable Development that can be used as a basis to formulate appropriate policies and strategies towards achieving national sustainable development.

To assist in achieving these national aspirations in the next 50 years since independence, the ASM and the Ministry of Science, Technology and Innovation will undertake the Mega Science Framework Study for National Sustainable Development. As problems associated with sustainable development are invariably complex in nature, it is incumbent that multi-sectoral and multi-disciplinary approaches (natural and social sciences) be adopted in the Study.

The Study will examine the following relevant sectors, among others, in the context of Science for Development and Development for Science, which are of crucial importance to national economy and well-being: Water; 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.

As part of the Study, comparative studies will be undertaken with international success stories.

1.3 Goal

(i) To foster, promote and manage the development and application of scientific knowledge and technological innovation for wealth creation, societal (human) well being, knowledge generation and sustainability. This is for enhancing Malaysia's competitiveness is an innovation-led global economic setting.

(ii) Sustainability should be conceptualised holistically to include also political and institutional dimensions in an innovation-led global economic setting.

1.4 Scope

(i) The Framework will need to be considered in the context of the application of "science for development" and "development for science".

(ii) The structure of the document should include the following components :

- *Stocktaking* – where are we at in incorporating STI in national sustainable development plans. Review policies, strategies and plans (towards identifying technological, scientific, educational and governance gaps) such as: National Sustainable Specialized Studies; Federal Policies on Sustainable Development; Vision 2020; 5-Year Development Plans i.e. RMK7-9; Industrial Master Plans 2 & 3; Outline Perspective Plans; NST Plan 2 Policy; K-Economy Master Plan (ISIS); National Agriculture Policy 3; Innovation-led Economy Model; National Higher Education Strategic Plans; National Biotechnology Policy; National Biodiversity policy; 5-Fuel Energy Policy; Water Policy; Health Policy; Any other plans/policy/program.

  Compare Malaysia with other innovation-led countries (e.g. Sweden, Denmark, Netherlands, UK, Ireland, Canada, South Korea, Japan). Review, adopt and adapt international STI Plans.

  Identify drivers of STI.

- *Why it needs to be done* - why S&T?

  Critical Success Factors: (a) Credibility (scientific basis); (b) Saliency (relevance to national/ international/ regional context); (c) Political buy-in.

- *How it needs to be done* – (a) Stakeholder Viewpoints (governments, industries, Professional Institutes, Universities, Civil Societies); methods (workshops, seminars, conferences, interviews, surveys, National/Regional/International/Other Meetings.

- *Aspirations* – Where we want to go

  Develop the nation using STI into an innovation-market driven economy in every sector.

- *Recommendations*:

  - What needs to be done?

  - How to do it (relevant agencies will develop their Strategy Plans and Policies for each Sector over the period 2011-2057)?

- Who should do it?

- *Enabling mechanisms* – mandate, money, manpower, market, infrastructure, technology

- *Obtain national commitment* to recognise Science and Technology as the foundation for future development of the country.

2. EXECUTIVE SUMMARY

2.1 Introduction

The Mega Science Framework for Sustained National Development (2011-2050) aims to identify the future opportunities that water Science, Technology and Innovation (STI) may provide for enhancing Malaysia's economic development. The STI industry can contribute significantly to the future development of Malaysia through the development, adoption and application of new scientific knowledge and tools across most economic sectors. Decision makers, at all levels, need timely, reliable access to the knowledge generated by the STI industry to introduce rational policies that reflect a better understanding of complex technical, economic, social, cultural and ethical issues that will challenge society over the next few decades. This report for the water sector identifies the best STI investment opportunities that will contribute to Malaysia's sustained economic development in domestic, regional and global markets in the foreseeable future. The information presented here has been derived from an analysis of: Malaysia's current economic profile; mapping of the contribution of the water sector across ten other economic sectors; identification of 70 potential investment opportunities across the ten sectors; prioritisation and characterisation of the twenty leading opportunities using the Risk-Return investment tool; and preparation of investment roadmaps for each STI.

2.2 Current Situation

Malaysia is currently classified as a 'high middle-income country', ranked 42nd in the size of its economy with an estimated US$207 billion gross domestic product for 2009 in current prices (IMF 2011). Since the 1970s Malaysia has transformed itself from a producer of raw materials into an emerging multi-sector economy. Malaysia's economic growth is in part supported by a fast growing population (2.1 % in 2009). Malaysia's vision is to achieve developed nation status by 2020.

In regard to the water sector, Malaysia has abundant water resources on a global scale. The annual mean runoff of 566 billion m^3 and 64 billion m^3 in ground water recharge translates into an annual average gross water availability of 28,000 m^3 per capita. The present total water consumption in Malaysia is about 12.5 billion m^3/yr or less than 3% of the available runoff. Malaysia's aquatic environmental assets are similarly abundant.

2.3 Future Challenges and Opportunities

Malaysia's water sector faces a number of challenges and great opportunities in the future. Most of the challenges centre on maintaining or improving the quantity, quality and health of the nation's water resources and increasing efficiency of use. Most of the opportunities arise from more effective economic exploitation of Malaysia's water resources on a sustainable basis. The 'sustaining the resource' challenges and 'creating new wealth' opportunities are opposite sides of the same coin – both are required to sustain future economic development. Recognising this duality, this project has identified the following important investments (in priority order for each of the twin sets) to maximise future economic development potential.

Investment roadmaps have been designed for each opportunity which indicate the nature of the investment, required enablers (such as incentives, research funding) and the outcomes targeted in five to ten periods from 2011 to 2050.

The findings of this project have been developed using a logical and systematic approach and well established strategic and futures tools. The recommended STI opportunities have also been tested and refined through a Stakeholder Workshop.

It is recommended that prior to any future STI investments being made based on the high-level analyses in this report, additional more detailed studies, including ex-ante benefit-cost analyses, be undertaken.

3. BACKGROUND

3.1 Introduction to the Mega-Science Project

The Academy of Sciences Malaysia (ASM) is undertaking a Mega Science Framework Study for Sustained National Development for the period 2011-2050 across a number of economic sectors, including water. The study will examine what might happen over the next 40 years that could create opportunities for enhancing Malaysia's development. The Academy believes that the science, technology and innovation (STI) industry can contribute immensely to the future development of Malaysia. In order for the country to attain developed-nation status, as well as achieve sustainable development within the country, it is imperative that Malaysia makes use of all relevant scientific knowledge and tools. The Academy believes that the STI industry can contribute significantly to the future development of Malaysia both through the development of new scientific knowledge and tools, and adaptation and application of scientific knowledge and tools from outside the country.

It is not sufficient for the STI community to operate simply as a provider of information when the need arises; rather STI should play an active role in identifying how scientific knowledge and tools can help (a) frame development issues and (b) determine what role scientific knowledge and tools can play in contributing to national development. Decision makers, at all levels, need timely, reliable access to the knowledge generated by the STI industry to introduce rational policies that reflect a better understanding of complex technical, economic, social, cultural and ethical issues concerning society, the earth and its environment. The sustainable development of Malaysia should be viewed holistically to include political, institutional, legal and managerial dimensions as well as the attributes of peace, contentment, harmony and happiness of the citizens.

3.2 Malaysia's Economic Base

Malaysia's vision is to achieve developed nation status by 2020. It is currently classified as a 'high middle-income country', ranked 42 in the size of its economy with an estimated US$207 billion gross domestic product for 2009 in current prices. In terms of gross domestic product per capita, Malaysia sits at number 65 in the world. On a gross domestic product based on purchasing-power-parity (PPP) per capita GDP, Malaysia's ranking is 59 in the world. Malaysia in recent years has been achieving high real GDP growth (about 6% per year from 2004-2008) and is recovering quickly from the global financial crisis. Malaysia's economic growth is in part supported by a fast growing population (2.1 % in 2009). It has the 46th largest population globally at 28.3 million (Census Bureau 2009).

Since the 1970s Malaysia has transformed itself from a producer of raw materials into an emerging multi-sector economy. Its current GDP is made up of manufacturing (26%), wholesale and retail trade, hotel and restaurants (15%), finance, insurance, real estate and business services (13%), mining and quarrying (13%), agriculture, forestry and fishing (10%), and other (23%). Malaysia's main exports are electrical & electronic products (49%), palm oil & palm oil-based products (11%), liquified natural gas, crude petroleum and petroleum products (16%), timber & timber based products (4%), and other (20%).

In the last decade the Malaysian government has tried to move the economy further up with focus on the value-added production chain by attracting investments in high technology industries, medical technology, and pharmaceuticals. The government has an active privatisation program and is competing hard with other countries in the region to provide a pro-business environment. The government has also invested heavily in infrastructure to facilitate both efficient business and a high standard of living, particularly in the major centres.

3.3 The Malaysian Water Sector

Globally about two thirds of the world population will live in water stressed catchments by 2025. However Malaysia has abundant water resources with annual mean rainfall for Peninsular Malaysia is 2400 mm, Sabah 2360 mm and Sarawak 3830 mm. This rainfall is equivalent to 990 billion m^3 volumetrically, of which 566 billion m^3 becomes surface runoff and 64 billion m^3 ground water, with the remainder returning to the atmosphere through evapotranspiration. This translates into an annual average water availability of about 28,400 m^3 per capita. The sources of raw water for domestic, industrial and irrigation are almost entirely from surface runoff, comprising 98% of the total supply. The remaining source is from groundwater.

Water supply has been a priority issue in the development agenda for Malaysia. The budget spent for water development has risen considerably in the recent years. In the Ninth Malaysia Plan (9MP) between 2006 and 2010, the government allocated US$ 2.5 billion. This value is more than double than the total spent in the 8MP. Currently there are 47 single-purpose and 16 multipurpose dams with a total storage capacity of 25 billion m^3. In 2008 the water supply coverage for the urban and rural populations was 97.8% and 91.0%, respectively.

The present total water consumption in Malaysia is about 12.5 billion m^3/yr or less than 3% of the available runoff. The demand is expected to increase at about 12% per year due to rapid population increase and industrial growth. The estimated total demand for the whole country is projected to increase to 60 billion m^3/yr by 2040 and 120 billion m^3/yr by 2060. Irrigation will continue to be the

largest consumer but its share is expected to decline as demands for domestic and industrial consumption are growing at a higher rate.

Malaysia's aquatic environmental assets are similarly abundant. About 12 % of the total 330,000 km^2 land area can be categorised as aquatic ecosystems. The surface freshwater ecosystems in Malaysia include the highland forests, forested wetlands and water bodies such as river systems, lakes and reservoirs. These ecosystems provide various kinds of services such as natural resources, biodiversity, habitats for flora and fauna, water purification and flood control. There are currently six Ramsar recognised wetlands in Malaysia.

Malaysia has more than 9,000 km of coastline with 98 % of the total population living within 100 km from the coast. Malaysia has a strong potential to realise economic opportunities in marine and coastal ecosystems and has an area of continental shelf of about 336,000 km^2. Malaysian territorial sea (up to 12 nautical miles) is 152,000 km^2 with Claimed Exclusive Economic Zone of 198,000 km . Malaysia has about 1650 km^2 of mangrove forests that harbour 36 mangrove species and 9 seagrass species. A total of 36 mangrove species can be found in the Malaysian coastal mangrove forest that covers 1,659 km^2 and 7 % of which is protected. The total fisheries production in the year 2007 was 1.65 million tonnes of food fish with valued RM6,467 million which comprised marine capture and aquaculture. Malaysia also produced 558 million pieces of ornamental fish valued at RM647 million.

3.4 Water Sector Challenges

Malaysia's water sector is not without its challenges. Some of the well recognised issues include:

- Rapidly increasing demand on water supply to 2050 and beyond, particularly in the domestic and industry sectors
- Localised water shortages particularly during drought periods
- Low irrigation water use efficiency
- Pollution affecting more than half of Malaysia's rivers
- High rate of non-revenue water
- Climate change increasing temperatures and raising sea-levels, as well as exacerbating climate variability and extreme events
- Institutional and regulatory complexity and inconsistency.

However, compared to other countries, Malaysia is likely to be exceedingly well off, resulting in increasing competitive advantage and economic development opportunities. All these opportunities will require science, technology and innovation to improve feasibility and reduce costs.

4. METHODS

4.1 Approach

This project has been undertaken in the following logical framework:

i. Getting the focal question right
ii. Understanding the current situation
iii. Assessing future drivers of change
iv. Linking water STI to sustainable economic development
v. Identifying opportunities in each relevant economic sector, including international and national case studies
vi. Prioritising STI investment opportunities in a Risk-Return framework
vii. Describing each recommended STI investment in detail
viii. Testing STI investments via a Stakeholder Workshop
ix. Preparing STI investment roadmaps.

Each of these steps is described briefly in the following sections.

4.2 Getting the focal question right

The project team presented the project proposal to the ASM at the outset of the project to ensure the project direction and design was appropriate. Resulting from this, the focal question for the project was agreed as:

'What future investments in Water Mega Science will provide the greatest improvement of STI to generate new sources of growth in sustained economic performance?'

4.3 Understanding the current situation

A detailed *situation analysis* for the Malaysian water sector and its relationship to the broader economy was conducted in the first phase of the project.

The *situation analysis* incorporated economic profiling of Malaysia to ascertain the economic vision, key economic indicators, economy in the global setting, economic production by sector and region, and population and employment trends.

The assessment of water resources in the *situation analysis* included water sources, water use (demand), water supply, water quality, aquatic ecosystems (surface freshwater ecosystems, rivers and floodplains, lakes and reservoirs, swamps, rice fields), and water infrastructure.

Current water issues in Malaysia were described, including supply-demand trends; geographically localised water shortages particularly during drought periods; high irrigation supply losses; river pollution; non-revenue water; climate change; and institutional and regulatory complexity.

The *situation analysis* was used as a reference document for the project team and is not submitted as part of the final report.

4.4 Assessing and Using Future Drivers of Change

A large number of trends and drivers were identified as potentially influencing Malaysia's future. The major future drivers affecting the water sector were considered to be: world population; consumer preferences; food, water and energy security; peak oil; climate change; new world order (geopolitical power); technological advances; water-related health; and water pollution. These trends and drivers were used to help identify future STI opportunities.

A more detailed set of factors that will influence sequential segments of time from 2011 to 2050 were detailed in the social, technological, economic, environmental and political (STEEP) domains for roadmapping STI investments.

4.5 Linking Water STI to Sustainable Economic Development

To meet the requirements of the 'focal question', it was necessary to work out how the water sector contributes to development of other sectors in the broader economy, and then to see how STI supports this development. The team members identified 11 pillars that linked Water STI to sustainable economic development as shown in Figure 1. From the pillar, ten sectors were identified as having important water sector underpinning: ecosystem services, education, energy, fisheries, forestry, health, irrigated agriculture, tourism, urban/domestic, and water management *per se*. For each of these sectors, Malaysia's competitive advantages were first elucidated domestically (Table 1), regionally and globally. The specific roles water could play in sustainably developing each economic sector was then identified for domestically (Table 2), regionally and globally. For each economic opportunity a preliminary assessment of the required STI to realize the benefits was undertaken. This was combined with national and international case study analysis to identify a 'long list' of over 100 potential

investment opportunities. Some amalgamation and sorting reduced the long list to the 70 opportunities shown in Appendix 1.

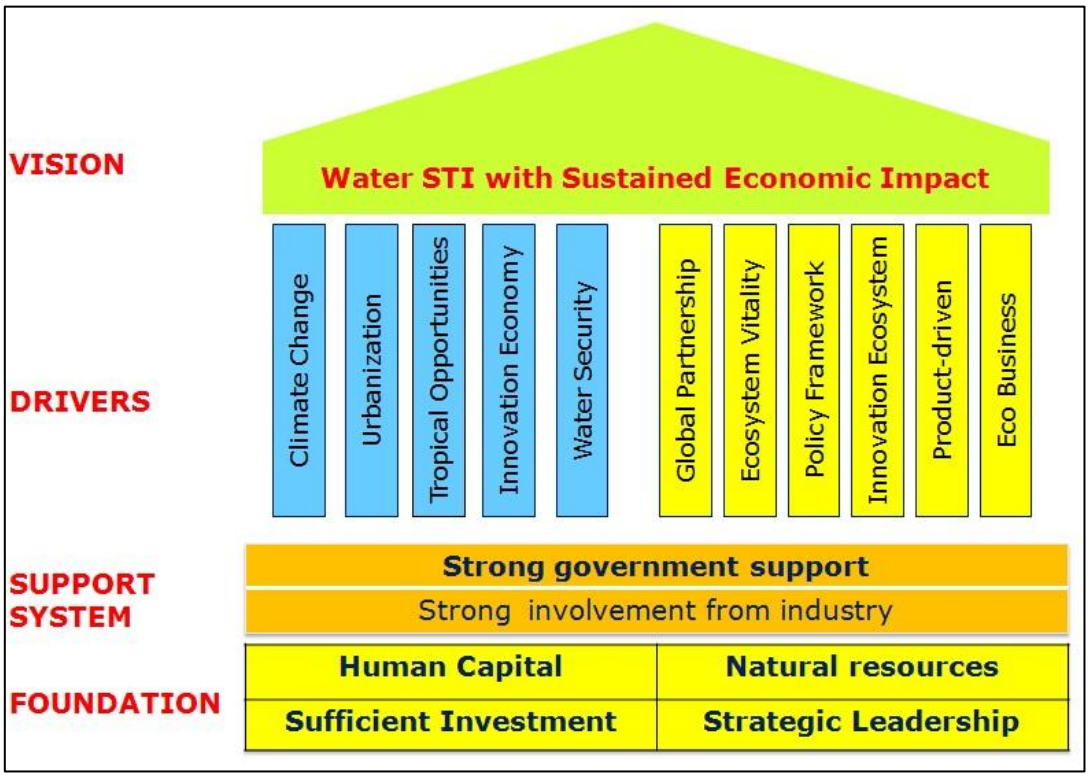


Figure 1: The eleven pillars linking water STI with sustained economic impact

Table 1: Malaysia's domestic competitive advantages by industry sector

Industry sector	Competitive advantages
Agriculture	▪ Large reliable water resource ▪ Government R&D priority in agricultural sector
Energy	▪ Strong manufacturing base ▪ Commercial development pathway ▪ Increasing service sector
Tourism	▪ High quality natural assets ▪ Tourist friendly ▪ Multicultural
Forestry	▪ Tropical forest ▪ Rubber wood as alternative to forest timber ▪ Sustainable forest management ▪ Reforestation program in place
Fisheries	▪ Growing ornamental fish industry for domestic and export market
Ecosystem services	▪ Tropical climate with high rainfalls ▪ Rain-forest as major eco-tourism ▪ Diversity in forest plants and herbs of medicinal value ▪ Government support and policy on eco-tourism
Urban	▪ Prowess in urban design
Health	▪ Already met Millennium Development Goals
Education	▪ Strong interest in S&T education ▪ High quality water education institutions
Water management	▪ Abundance of fresh water ▪ Water management expertise

Table 2: Role of water STI in increasing sector economic performance

Industry sector	Water economic stimulus
Agriculture	▪ Increase crop for the drop (productivity) ▪ Improve water use efficiency (WUE) ▪ Reduce pollution downstream ▪ Sustainable extraction limits ▪ Water-less rice production ▪ Multi-disciplinary approach of agriculture water saving for sustainability in economic, social and ecological aspects
Energy	▪ Improve hydro energy provision ▪ Supply water fit-for-purpose ▪ Manage waste stream
Tourism	▪ Identify sites for eco-tourism and general tourism ▪ Protect sites for their natural values ▪ Design appropriate development and access ▪ Ensure best practice in catchments
Forestry	▪ Forest protection and rehabilitation ▪ Growing stock change
Fisheries	▪ Fresh water and marine fish farming
Ecosystem services	▪ Identify and describe ecosystem services ▪ Protect or enhance these services ▪ Educate population ▪ Ecosystem restoration ▪ Aquatic plant management
Urban	▪ Urban water design ▪ Lakes and pond rehabilitation ▪ Channel to soft engineering ▪ Quality of wastewater discharge ▪ Stormwater management ▪ Flood management
Health	▪ Meet MDGs ▪ Reduce water-borne diseases ▪ Meet or exceed water quality health standards ▪ Reduce flood risks
Education	▪ Educating overseas students ▪ Increasing quality/capacity of Malaysian water science and technology ▪ Cultural change in water use
Water management	▪ Ecosystem approach of water resources management ▪ Regular water quality monitoring program ▪ A centralised agency responsible for water resource management ▪ Improve the industrial discharges standards

4.6 First stage prioritization of STI Opportunities

The project team presented the ASM with the long list of opportunities in its Interim Report. The ASM encouraged the team to prioritise the opportunities and evaluate a short-list in more detail. The prioritization was undertaken by team members using their best judgment to assess the 'potential significance of the STI opportunity to Malaysia'. The importance of each opportunity was rated very high, high, medium and low. At the same time the long list of opportunities were separated into two categories, 'creating new wealth' and 'sustaining the resource'. The long list of opportunities was retained and later submitted to the Stakeholder Workshop to ascertain whether any opportunities not in the short-list should be added, or replace another opportunity in the short-list. As it happens no changes were requested.

The frequency distribution of STI opportunity ratings by economic sector is shown in Figure 2. The sectors attracting the greatest opportunities by rank order were: water management, urban, tourism and ecosystem services.

In the prioritization process the ten highest rating STI opportunities for 'creating new wealth' and ten for 'sustaining the resource' were identified for more detailed assessment.

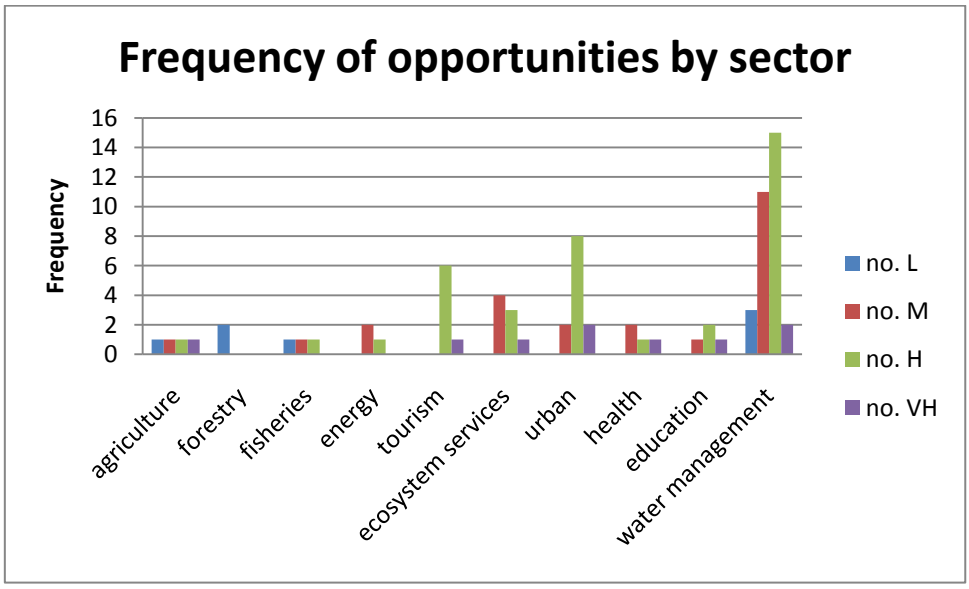


Figure 2: Frequency of STI opportunity ratings by economic sector

4.7 Describing Each Recommended Investment in Detail

The twenty opportunities identified were described in more detail using the structure below:

- Title
- Description of the opportunity and its STI needs
- Return assessment: market potential, potential return on investment, potential to protect or restore ecosystem health, Malaysia's competitive advantage
- Risk assessment: technical barriers, skills and capacity, political or institutional barriers, potential for ecological damage, adoptability, holistic robustness.
- Benchmarking against similar initiatives – in Malaysia and overseas
- Specific potential projects

4.8 Assessing Investment Opportunities in a Risk-Return Framework

The next task was to assess the short-listed opportunities for future incorporation into a STI investment plan for the water sector. The assessment of each STI was undertaken with a Risk-Return tool. To do this, criteria were established for 'potential return on investment of the opportunity' and 'risks to achieving this return'. Each opportunity was then assessed and scored on each criterion by the project team, and the results plotted on the Risk-Return matrix. Further details of this assessment are provided in section 5.

4.9 Stakeholder Workshop

The project brief and background research, along with the twenty short-listed STI opportunities, were presented to a 1-day workshop of stakeholders (see list of stakeholders in Appendix 2). The formal presentation, which included the Risk-Return results, was followed by questions and two break-out sessions to facilitate more discussion about the STIs, answer queries and identify any additional ideas. The outputs from the workshop were fed back into refinements in the STI descriptions. No changes to the STL list were requested.

The final step in this project has been to prepare an investment Roadmap for each STI.

4.10 Investment Road mapping

Each Roadmap consists of a timeline of proposed investments, enablers and outcomes achieved within a specific period of time. The timeline segments are mostly the same for each STI opportunity, so that investments can be aligned, compared and synergies assessed. The time segments are 2010-2015, 2015-2020, 2020-2030, 2030-2040, and 2040-2050.

The STI investments have been designed to be achieved over the 2010-2050 timeframe. Whilst this seems a long investment period, it is noted that many environmental and infrastructure outcomes take substantial periods of persistent effort to achieve real benefits. For example the Thames River restoration project has just won the Theiss International River Prize after four decades of sustained effort and continuous improvement, demonstrating real improvements in water quality and species habitat.

A second reason for the apparent long timeframes is that a large number (twenty) of major investments has been proposed, all of which would constitute a substantial injection of funding and human resources. Hence further prioritisation (as conducted in the Risk-Return analysis) and time are required for realistic achievements.

For each investment proposed within a time segment, the enablers to achieve a desired outcome are specified. The enablers were drawn from the list in Table 3.

Table 3: Potential enablers that may be required to achieve STI outcomes

Enabler	Comment
Visioning	A grand statement like 'we'll land man on the moon in 10 years'
Policy	Highest level of government action
Legislation and regulation	Follows setting of clear policies
Standards and guidelines	Specifies minimum requirements or in some cases 'best practice'
Administration	Processes and means for implementing policies or legislation
Governance	Specifies roles, responsibilities and decision-making rules
Institutional arrangements	Specifies roles and responsibilities of agencies which have carriage of task
Programs and/or projects	Provides the framework for specifying outcomes, targets, resources, ongoing monitoring and evaluation, reporting requirements etc
Planning requirements	Meet planning requirements for example of local government
Funding	May be government, private, philanthropic, in-kind etc
Public-private partnerships	PPPs can be designed with different levels/roles of 'partnership'
Private sector	Private sector investment for commercial outcomes
Philanthropy or corporate social responsibility (CSR)	Suitable for some parts of the private sector and may attract tax benefits
Incentives	Range of potential government incentives
Knowledge and capacity building	Specific programs designed to build a suitable workforce in a short timeframe
Expertise, skills	Specialist expertise is required in most major projects
Suitable technologies	Soft engineering, high tech treatment etc
Research and development	Address knowledge gaps or novel situations
Ex-ante cost-benefit evaluation	Important part of establishing the business case and maximising multiple benefits from a single investment
Community participation	Projects that require community consultation, learning or assistance

The final Roadmap component for each time segment is specification of the 'outcome' to be achieved by the completion of that time segment. Outcomes are designed such that benefits will begin to flow

incrementally through the longer term projects. The basic time segment unit is 5-years to match the Malaysia Plans.

The Roadmaps provide a strategic overview of STI opportunities and how they may be implemented over time. Clearly more detailed assessment is required before any investment is commenced. This involves a careful and more detailed evaluation of the opportunities and barriers, benefits and costs, and a plan for implementation.

Finally is should be noted that most of the STI Roadmaps presented could be accelerated if the government assigns special priority and resources to specific opportunities.

5. RISK-RETURN ASSESSMENT

The Risk-Return Framework is a simple but effective tool for assessing future investment opportunities providing good information is combined with a quality assessment team. The framework is essentially qualitative, although a scoring system is used to assist the assessment. The framework can be applied to any size or type of investment and can be used to compare 'apples and oranges'. The framework can be used either for prioritisation or assessing investment options, for example whether the opportunity is market ready or there are hurdles to be overcome.

'Return' is a measure of the potential return from the investment while 'Risk' is a measure of the barriers to achieving the return. Criteria are established for the topic in question and weights adjusted depending on the emphasis sought. In this project the following criteria and weights were applied.

Return		**Risk**	
Criteria	**Weight**	**Criteria**	**Weight**
Market potential	0.4	Technical barriers	0.17
Potential to protect or restore ecosystems	0.3	STI skills and capacity	0.17
Competitive advantage	0.3	Holistically robust	0.17
		Political or institutional barriers	0.17
		Potential for ecological damage	0.17
		Adoptability	0.17

The results of applying the Risk-Return assessment are shown in Table 4 and Figure 3 for 'creating new wealth opportunities'. Figure 3 has four quadrants, the top left showing the 'best' opportunities, that is those with highest return and lowest risk. Most of the opportunities assessed are seen to fall in this category – this is to be expected given the short-listing of the long list down to twenty. The numerical Return and Risk values are shown in Table 4, along with a combined risk-return value (sum of squares) that can be used for ranking.

Table 4: Risk-Return Assessment for Opportunities for Creating New Wealth

Opportunity	Return	Risk	Combined risk-return & rank
Eco-tourism around high ecological value sites	8	2.7	117
Urban water-based tourism	8.4	3.5	113
Market and export high quality water	8.1	3.3	111
Clean water for aquaculture Industry	7.4	2.8	107
Malaysian brand for domestic water purification unit	6.9	2.5	104
World leading tropical aquatic research and education	7.4	3.2	101
Knowledge export	7.4	3.3	100
Downstream Water Tapping	7.7	4.2	93
Rainwater harvesting	7.4	4.3	87
Zero pollutant discharge	6.8	6.2	61

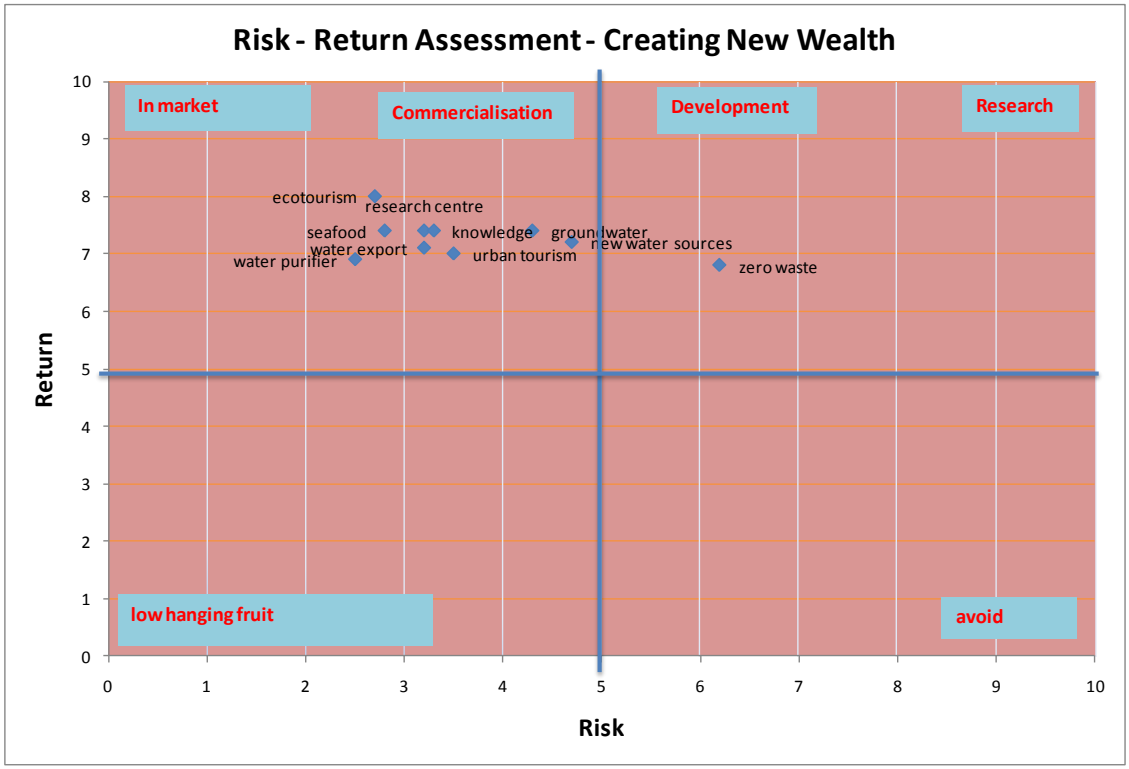


Figure 3: Risk-Return Assessment for Opportunities for Creating New Wealth

The results for *sustaining the resource* opportunities in Table 5 are plotted on the Risk-Return quadrants in Figure 4.

Table 5: Risk-Return Assessment for Opportunities for Sustaining the Resource

Opportunity	Return	Risk	Combined risk-return & rank
Exploit groundwater further as a resource and drought protection	7.7	2.3	119
Improve flood forecasting and mitigation	7.7	2.3	119
Reform Water Education Approach	8	3.8	102
Improve ecosystem protection from point and non-point pollution	7.9	4	98
Clean-up and rehabilitate waterways in highly visible locations to improve aesthetics and ecological functioning	7	3.5	91
Irrigation water use efficiency	5.7	3.2	79
Community (including decision-makers, planners, and politicians) values ecosystem services for Malaysia	5.8	3.8	72
Advanced water and wastewater treatment	6.3	4.7	68
Wetland ecosystem repair	6.2	4.8	65
Water management planning to improve resilience with uncertain climate future	6.2	5.2	62

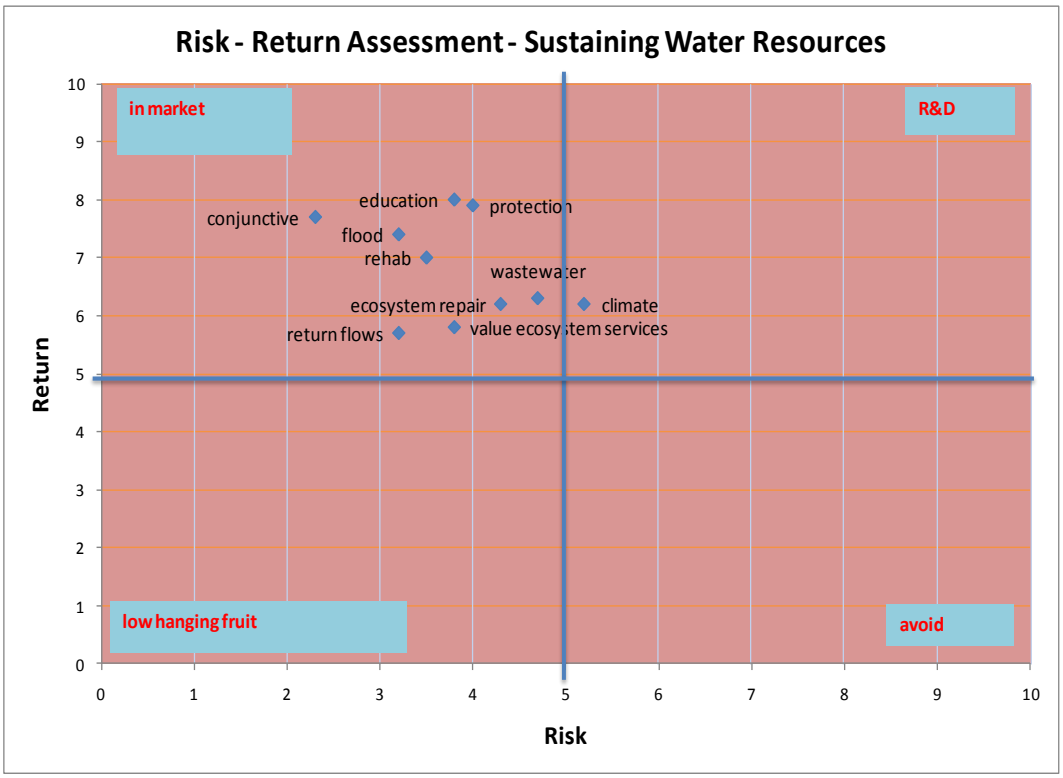


Figure 4: Risk-Return Matrix for Sustaining the Resource Opportunities

Section 6 provides in-depth information on each of the STI opportunities, their Risk-Return ratings and investment roadmaps. The Risk Return rating for all the opportunities are included in Appendix 3.

6. OPPORTUNITY DESCRIPTIONS

6.1 Creating New Wealth Opportunities (2011-2050)

6.1.1 Develop Eco-Tourism around High Ecological Value Sites

Economic Sector: Tourism and Development

Description of the Opportunity

It is already recognized that Malaysia has a wealth of natural ecosystem assets. What is often not so apparent in the relationship between these assets and the potential for eco-tourism.

Some of the opportunities are:

- rivers (e.g. canoeing, rafting)
- reservoirs (e.g. sailing)
- waterfalls (e.g. sight-seeing)
- wetlands (e.g. bird spotting, aesthetics)
- rainforests (e.g. walking)
- beaches (e.g. swimming, beachcombing, cruising)
- inshore marine (e.g. diving, snorkelling)
- outer marine (e.g. recreational fishing)
- waterscapes (e.g. holiday accommodation).

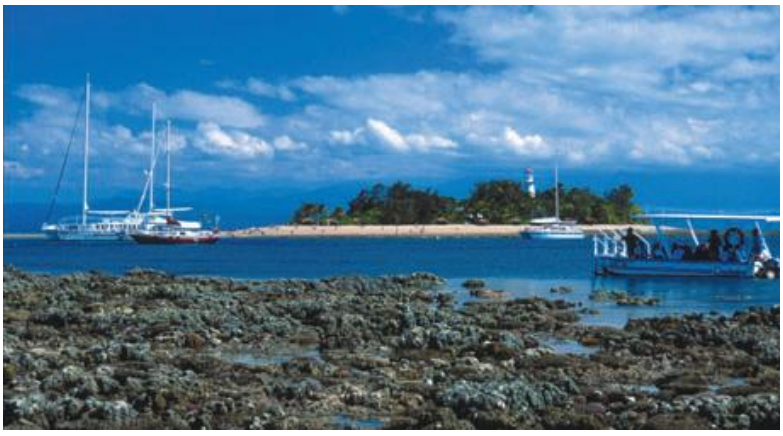
Risk Return Analysis

The return scores is calculated as 8 and the risk scores is 2.7

Economic Feasibility

Tourism is fast becoming the second most important sector for Malaysian economy. Despite the scare of the September 11, 2001 attack on the United States and global economic downturn, over 12.7 million tourists visited Malaysia last year, generating over RM24 Billion revenue to the economy, an RM7 Billion jump compared to the figure of 2000 (Badaruddin Mohamed, 2002). Prior to this. Malaysian tourism had enjoyed quite an impressive average growth of 9.26% between 1981 and 2000. WWF Malaysia estimates that Malaysia gains RM655 million per year from ecotourism.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)



The Great Barrier Reef, which stretches for more than 2,300 km along the Queensland coast, is one of Australia's most popular attractions for international tourists. As a World Heritage Area, the Reef is

considered to be an outstanding example of 'a major stage of the earth's evolutionary history' and attracts at least 1.9 million visitors every year. The health of the Reef is vital for supporting its associated tourism industry; however, a number of other smaller industries (such as fisheries) depend upon the health of the Reef.

The Great Barrier Reef is estimated to be worth almost $6 billion per year in economic activity, and supports approximately 63,000 jobs. The tourism industry accounts for approximately $5 billion of this income. With such a significant economic contribution coming from tourists, swimming, sailing and diving in and around the Reef, and maintaining the health of the Reef is essential from a purely economic perspective.

Recent work has also been undertaken by scientists to determine the value of the Great Barrier Reef's ecosystem services. This includes the value of services directly 'consumed', such as recreation, and those which are indirectly consumed, such as the value of seagrasses to prawn fisheries. Work on a comprehensive valuation of the Reef's ecosystem services is still emerging, with estimates ranging up to $51 billion.

The Reef itself provides a habitat for numerous protected and migratory species, including a number of endangered species. The Reef falls within the Great Barrier Reef Marine Park, which restricts activities permitted within the Park and provides a means for regulating tourism operators and their activities. The Great Barrier Reef Marine Park Authority (GBRMPA), who is responsible for managing the Park, seeks to do this in line with the principles of ecological sustainable development.

The health of the Reef, however, faces a number of naturally-occurring and anthropogenic threats. Naturally-occurring threats include coral bleaching from high temperature events and crown of thorns starfish, along with anthropogenic threats such as climate change and pollution from agricultural runoff. Assessment and management of these risks is therefore dependent upon scientific understanding of the complex ecosystems of the Great Barrier Reef.

Research into the effects of agricultural runoff on the Reef has identified the intense agricultural land use as a serious threat to ongoing reef health. High levels of nutrients, herbicides and suspended sediments are exported to the Reef every year, primarily due to sugarcane farming immediately adjacent to the Reef, and cattle grazing higher up in the catchments running into the Reef. Scientific research and knowledge also has an important role to play in minimising the runoff of these

pollutants. This includes improving existing understanding of pollutant transport (i.e. how pollutants are mobilised from the soil) and strategies for reducing the rate of pollutant runoff, such as tail water retention wetlands and improving pasture cover. Scientists also have an important role to play in accurately estimating pollutant loads and in establishing a relationship for the impacts associated with different levels of pollutants.

Scientific understanding of the impacts on the Reef of agricultural pollution is another important consideration, given the complex interactions with Reef ecosystems. The type, timing and load of pollutants entering the Reef will have differing impacts on Reef health, and understanding these impacts is crucial for targeting mitigation activities. Significant research has been conducted into the effects of these pollutants on Reef ecosystems and demonstrates a host of consequences, including algal blooms, reduced ecosystem resilience and loss of marine life.

The threats posed to the coral reefs of the Great Barrier Reef by climate change vary depending upon the emissions scenario used, but indicate that warmer ocean temperatures will increase the extent and frequency of coral bleaching events. While such events do occur naturally, the projected increase in frequency and intensity, combined with the threat posed by agricultural runoff, need to be carefully assessed and mitigated in order to protect the Reef. Climate change is also predicted to lead to acidification of the world's oceans, due to an increase in dissolved carbon dioxide concentrations.

Scientific research and understanding is essential for quantifying these combined risks, which in turn can be used to target management responses. Scientists have an important role to play in formulating appropriate management responses that can address these risks and adequately protect the health of the Reef.

Potential Project

Malaysia has 54 protected areas of more than 1,000 hectares, totaling 1, 483 million ha. or about 4.5 % of the land surface of the country. They include 28 district nature reserve.

Among main national parks are:

- Bako National Park
- Crocker Range Park
- Endau-Rompin
- Gunung Mulu National Park
- Kenong Rimba Park
- Kinabalu National Park
- Kuala Gula Bird Sanctuary
- Niah National Park
- Rantau Abang Turtle Hatchery
- Sepilok Orang Utan Sanctuary
- Taman Negara
- Tuanku Abdul Rahman National Park

Kinabalu Park recently joined rank with other 630 sites worldwide as a Unesco's World Heritage Site. Peninsular Malaysia on the other hand, has over the years been establishing a network of protected areas for the conservation of biological diversity. Some of these national parks, wildlife reserves and sanctuaries, nature parks, birds' sanctuaries and marine parks have been established since 1930's. Peninsular Malaysia's largest national park covering 434, 351 ha was gazette as early as 1939, which comprises mainly virgin forests of various forest types according to altitudes and soils. Currently, Peninsular Malaysia has 0.74 million ha of conservation area protected by legislations. Of these, 0.55 million ha are located outside the Permanent Forest Estate, whilst another 0.19 million ha are within the Estate (Badaruddin Mohamed, 2002).

STI Involved/ Technical Feasibility

Mapping of unique ecosystems across Malaysia is required to identify potential ecotourism sites and activities. Once sites are identified, the eco-tourism potential should be assessed in a triple bottom line format, blending local/indigenous interests with commercial interests for mutual benefit. At the same time full ecological assessments should be completed.

Summary of STI

Objectives	• Increase revenue by attracting foreign tourist to high ecological value sites
Science, Technology and Innovation	Short terms: • National mapping and identification of potential high ecological sites for ecotourism purposes. Medium terms: • Research into Biodiversity Inventory of the identified and assessed eco-tourism sites involving Ecosystem management science and technology education Long terms: • Malaysia as the nation which demonstrate ecological and biodiversity conservation and promotes high-tech ecotourism management
Key Area	• Eco-tourism at high ecological sites

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **investment**	National mapping of potential high value ecotourism sites. Assessment and research. Identification of unique values and attractions of Malaysian ecosystems potential. Assessment of direct and indirect benefits of the identified sites in a triple bottom line format, blending local/indigenous interests with commercial interests for mutual benefit, research on climate change impacts on eco-tourism in Malaysia tourism market	Research into Biodiversity Inventory of the identified and assessed eco-tourism sites. Ecosystem management science and technology education	Green technology (energy source, transportation, buildings, etc.), research and education	Demonstration of ecological and biodiversity conservation Chemical free water treatment and processing	Green technology application Malaysia as the hub for biodiversity, high-tech ecotourism management
Enablers	Commitment of various government agencies. Coordination between various government agencies. Financial and institutional support. High-tech marketing and promotion of eco-tourism including packages.	Creation of "Sustainable Trail Initiatives (STI)" voluntary groups e.g. friends of an ecosystem	Extensive ecosystem science for the development of detailed code of practice for tourism operators to minimise damage	60% of population in urban - education and promotion, higher temperatures encourage people to take refuge in cooler places including eco-tourism areas	People appreciate green technology, research funding, ecological laws in full force.
Outcomes	National maps of high value ecotourism potential sites. Complete full ecological assessments of the	Highly valuable biodiversity inventory of Malaysian eco-tourism sites Local	Demonstration of fully green technology in action in and around the eco-tourism sites, critical mass professional	Highly valued biodiversity and ecological attractions for high valued customers/tourists	Tropical forest and wetland base and marine base eco-tourism as the main attraction

	identified ecological sites. High values and appreciation of ecosystems for and ecosystems	community and national economic benefits of the eco-tourism	eco-tourism guides and managers. Specialized eco-tourism sites (birds watching/water sports/mountain climbing/marine recreational fishing, etc)		

6.1.2 Urban Water-Based Tourism

Description of the Opportunity

Develop urban tourist water facilities such as river walks, lakes, water parks, and special features, along with commercial waterfront development, has been a growing activity in North America, Europe and leading Asian nations over the last decade. Improved water-based living and working places in a rapidly urbanizing world is seen as vital to human development and welfare. The popularity of tourism worldwide has driven urban riverfront development dramatically in recent decades. Riverfront developments often include convention centers, hotels, retail and entertainment facilities, housing, and sometimes an aquarium or discovery centre. With the emergence of riverfront parks, land near rivers is becoming highly desirable.

"It has become apparent that urban waterfronts, whether natural or artificial, are now prime pieces of real estate, essential ingredients in forming a community image, valuable stages for architectural display and great places for public recreation." GRADY CLAY, 1998.

Risk Return Analysis

One of the largest service industries in the United States is travel and tourism, two broad categories which involve approximately 17 million jobs. Total travel and tourism expenditures in the United States for the year 2000 reached $582.5 billion, while total revenue was $99.5 billion. In increasing numbers, domestic and foreign travelers are visiting theme parks, natural wonders, and points of interest in major

U.S. cities. Worldwide, tourism annually generates over $3.5 trillion dollars, a significant percentage of which involves water-related tourism.

Cleaning up, rehabilitating and/or redeveloping urban waterways will in most circumstances be highly beneficial for ecosystem health.

Malaysia has substantial natural water assets in its urban centres which provide a unique opportunity for generating tourism locally and internationally, whilst improving the health and lifestyles of its citizens.

Most technologies are available. A new rehabilitation green industry can be match with commercial and business acumen already available in Malaysia. Political support will be required to establish a vision for Malaysia's urban centres as beautiful water-based tourist centres. The potential for adopting a waterfront development paradigm is emerging but requires fostering by government in consultation with business. The proposed STI is holistically robust as it supports sustainable, liveable and progressive cities. The return scores is calculated as 8.4 and the risk scores is 3.5.

Economic Feasibility

Malaysia can be called as a water rich nation because of have number of rivers with great potential for wealthy recreation. Malaysia is bounded by the river flows from the northern to southern part of Malaysia, as well as Sabah and Sarawak. History shows many towns and cities in Malaysia were established nearby water areas including river and ex- mining area (such as Kuala Lumpur, Malacca and Perak). In a recent interview survey on the importance of river, majority of respondents agreed that river is significantly important and related to human for several reasons. They were believed that river's function and significance value will be remaining important for the entire country for various reasons. However, development and redevelopment process was the major contributor towards declining waterfront in Malaysia (Azlina Md. Yassin, 2010).

Benchmarking against similar initiatives (in Malaysia and overseas)

After abundance for many years, Malaysia has begun to redevelop waterfront areas (along the riverbank) and Kuching city which is located in Sarawak has been selected to initiate this project. The project was proposed by Chief Minister of Sarawak mainly for recreational purpose in year 1989 and proceeds for development granted in

year September 1993. The project is fully funded by the state government of Sarawak and managed by the Sarawak Economic Development Corporation (SEDC) (Sarawak subsidiary) (Sarawak Economic Development Corporation (SEDC), 1990). After being completed in year 2003, Kuching riverfront has become a benchmark for waterfront development projects in Malaysia. The next phase (which expands from the existing waterfront) will be continued in the year 2008 mainly focusing on river upgrading and beautification. Up to date, many waterfront developments has been developed in Malaysia, such as Malacca waterfront and Kuantan waterfront and more are forecasted to be continued for the future (Azlina Md. Yassin, 2010).

Specific Potential Projects

One of Malaysia's ongoing urban waterfront development is the Iskandar Waterfront Development Project. The expansion of Iskandar Waterfront Development (IWD) is within Iskandar Malaysia (IM), a national project driven by the Federal Government and the Government of the State of Johor. IWD is a Government-linked company (GLC) through the shareholding of Iskandar Investment Berhad (IIB) at 51.2% and Kumpulan Prasarana Rakyat Johor (KPRJ- an investment arm of the State Government) at 12.3%. The balance of 36.5% is held by Danga Bay Sdn. Bhd., a private enterprise. This project is expected to attract more international tourist with the proposed project of a rapid transport system which will connect Johor Bahru and Singapore, making travel between the two places more painless. A joint development of eco-tourism and river-cleaning is being planned between these two cities towards what is called as a "wellness township" which is expected to be launched within a year. It is expected, more STI will be needed for this project to be successful.

Besides developing new waterfront projects, old and historical water-related sites should also be developed. One such site is the Penang Botanic Gardens, also known as the "Waterfall Gardens" because of the cascading waterfall nearby. This is a public park situated on Jalan Air Terjun (Waterfall Road) on Penang Island, Malaysia. The original gardens were established in 1884 from an old quarry site, under the supervision of Charles Curtis, who was the first superintendent. However, recently there were reports and complaints because of "lack of monitoring by the state's policy makers".

STI Involved / Technical Feasibility

The science and technology of urban water-based tourism has developed substantially over the last 10-20 years, with a number of well respected guides and manuals available to practitioners. Most of the work has been conducted in the US and Europe, but increasingly in Asia in more recent times. Tourism projects *per se* emphasise high amenity, aesthetics and good water quality. Genuine ecological outcomes prove more difficult in urban situations, and further long term research and development is required.

Summary of STI

Objectives	• Develop urban water based tourism
Science, Technology and Innovation	Short terms: • Identify potential urban based tourism plan and location. Also assessment of restoration potential on water quality and ecosystem functions Medium terms: • Research and development on the adaptation and development techniques applicable to tropical urban system Long terms: • Service industries in the application of science and technology to implement restoration plan with specialised Malaysian consultants.
Key Area	• Large cities which have water-fronts

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI	Assessment of restoration potential on water quality and ecosystem functions	Adaptation and development techniques applicable to tropical urban system	Application of science and technology to developing restoration plans	Application of science and technology to implement restoration plans	Specialised training facilities
Enablers	Vision and commitment	Research and development funding	Critical mass of restoration skill	Funding and competent implementer	Service industries with specialised Malaysian consultant
Outcomes	Identify potential urban based tourism plan and location.	Restoration techniques applicable to Malaysia's urban rivers	plans for restoration project with target benchmark	5 flagship urban water based tourism projects completed	Export services to other tropical countries

6.1.3 Market and Export High Quality Water

Economic Sector: Urban/Domestic

Description of the Opportunity

Nowadays, bottled water is a common phenomenon in our daily life. Mainly due to the doubt on the quality of the potable water supplied by the public water supply companies, people has either use home water purifying unit or turn to bottled water for their daily consumption.

While there are many bottled water in today's market, there are certain types of bottled water which are quite exclusive and priced higher than other local bottled water products. These include Evian and Perrier (both are products of France) which are commonly found in Malaysia. They are well known for their clean sources of natural spring water which made them popular all over the world.

There are many types of bottled mineral water in Malaysia. They are tapped from groundwater located at different sites in Malaysia. In general, they are all considered as ordinary bottled mineral water priced similar to bottled drinking waters.

While the Alps countries are proud with their source of spring water, Malaysia is not deprived from such resources. The Taman Negara rain forest in Malaysia is said to be the world's oldest rain forest. Untouched by ice age glaciers, the rain forest has stayed essentially the same for the last 130 million years. Hence, the groundwater held by the forest is as virgin as the forest, which special qualities still unexplored.

With proper management by the authorities, this virgin water can be exploited to generated income the country – "virgin spring water from the untouched tropical forest".

Risk Return Analysis

The scores for the return and risk are 8.1 and 3.3, respectively. Based on the current market of bottled water, this activity has very high market potential. In addition, as the activities rely highly on the quality of the water, indirectly it will require the protection of the water resources. As the water will be extracted from the beneath of the tropical forest, competition in terms of water source is expected to be low.

The risk is mainly on the technology and skills required for the production of the water ensuring the high water quality product at low carbon footprint and minimum overall environmental impact.

Economic feasibility

The groundwater from the virgin tropical forest and other groundwater sources in Malaysia can be exploited to benefit the country's economy as has been achieved by companies such as Danone. The global bottled water market valuation grew by 7% in 2006 to reach a value of US$60,938.1 million. The volume of bottled water grew by 8.1% in 2006 to 115,393.5 million liters. In 2011, the market is forecast to have a value of US$86,421.2 million, an increase of 41.8% since 2006. In 2011, the market is forecast to have a volume of 174,286.6 million liters, an increase of 51% since 2006 (King, 2008). The global rate of consumption more than quadrupled between 1990 and 2005 (Li, 2007). Purified water is currently the leading global seller, with

U.S. companies dominating the field, and natural spring water, purified water and flavored water being the fastest-growing market segments (IBISWorld, 2008).

As the extracted water is clean and pure, the technology which will be required is to ensure the sustainability of the water resources, and the ability to produce the water ensuring the high water quality product at low carbon footprint and minimum overall environmental impact.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Danone Water *(http://www.danone.com/)*

With a total of roughly 18 billion litres of packaged water marketed in 2008, Danone is the world's second largest producer, with a global market share of approximately 11%. Danone's waters division's sales amounted to €2.9 billion in 2008: Europe accounted for 47% of this total, Asia 31% and the rest of the world 22%. Its ability to sustain the sales mainly owing to the division's ability to promote its brands, its expertise in neighbourhood retailing and concerns of consumers, opting for safety in the absence of clean drinking water in some countries.

In addition to water production, Danone is one of the players that is most directly concerned by the long-term production of this resource. It has invested heavily in its preservation (in terms of quantity) and protection (in terms of quality). In 2004, DANONE formalised its commitments with regard to water in a Charter for the Protection of Groundwater Resources. The prime principle underlying this Charter is to avoid making excessive demands on the hundred or so group springs and not to use more water than nature can produce naturally. The water cycle is studied and demands on springs are limited in order to maintain groundwater levels. Danone has also committed to reduce its own consumption at production sites and not discharge waste water into the natural environment. This is the goal of the Danone Water Footprint programme which has helped save over 3.5 billion litres of water in the past five years.

Danone has always been a pioneer in the promotion of recycling. In the 1970s, it initiated litter collection campaigns such as "Vacances Propres" in France. The aim was to encourage tourists to adopt environmentally friendly gestures by picking up their litter and putting it in easy to find litter bins. Danone has also invested in more than 20 organisations in France specialised in recycling packaging. Six years ago,

Danone decided to go one step further by taking action at the source of the problem; reducing by 10% the overall weight of product packaging over 10 years. Each subsidiary has to ensure that packaging gets lighter for identical product weight. Results have been very encouraging, especially for flagship products. In just a few years, the weight of an Actimel bottle has fallen from 11 to 6.5 grams and that of an Evian bottle from 43 to 30 grams.

Specific Potential Projects

The identification of potential sites for the tropical forest groundwater extraction should be initially carried out. The selection of the site should be based on the high quality of the groundwater (similar to Alps spring), sustainability of the water resources, low cost of production, low carbon footprint and minimal environmental impact.

Studies also need to be conducted to determine the nutritional benefit of the groundwater of the tropical forest. Promotions on the source of water and its nutritional benefit are important aspect in marketing the bottled water.

Domestically, the use of big bottles (up to 20 L size) should be promoted.

STI involved/technical feasibility

Since the extracted groundwater is expected to be of high quality, no treatment is necessary except disinfection. To avoid the use of chemicals, disinfection can be carried out through ultra-filtration process or ultra-violet (UV) disinfection. Both technologies are available in the market but are normally imported from abroad.

As mentioned earlier, the technology which will be required is to ensure the sustainability of the water resources, and the ability to produce the water ensuring the high water quality product at low carbon footprint and minimum overall environmental impact.

Since some countries and NGOs are discouraging the use of bottled water, technology in packaging the water will play important role in sustaining the bottled water business.

Summary of STI for export of high quality water

Objectives	To exploit high quality groundwater from virgin forest of Malaysia – "virgin spring water from the untouched tropical forest".
Science, Technology and Innovation	Short terms: • Identification of potential sites for the tropical forest groundwater extraction - high quality of the groundwater (similar to Alps spring), sustainability of the water resources, low cost of production, low carbon footprint and minimal environmental impact • Studies to determine the nutritional benefit of the groundwater • Promotions on the source of water and its nutritional benefit Medium terms: • Production and export of the groundwater. Long terms: • Development of green containers – in terms of materials, printing and packaging
Key Area	• Development of human resource • Enhancement of R, D & C aspects of the technologies • Education and awareness programmes

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI investment	Mapping potential source of high quality virgin spring water from the untouched tropical forest Ecofriendly packaging	Develop quality standard and regulation	Ensuring sustainable extraction of bulk waters	Advanced bulk water transport technology	Major player in water export technology
Enablers	Ecofriendly marketing advantage	SME to develop niche water market	Private sector investment- 2 billion people facing water scarcity	Private sector investment - 3.5 billion people facing water scarcity	Private sector investment - 9 billion people facing water scarcity
Outcomes	Niche market water sources known	Export water industry developed	Malaysia enters the bulk water export market	Malaysia is an established world player	Malaysia is a prominent water exporter

6.1.4 Clean Water for the Aquaculture Industry

Economic Sector: Fisheries

Description of the Opportunity

Fisheries commodity has been contributing to positive balance of trade, for Malaysia for the last 15 years. The fisheries sector comprises three sub-sectors, namely the capture fisheries, aquaculture and processing. Capture fisheries directly involved the exploitation of natural resources in the inshore as well as offshore marine waters.The total fisheries production in the year 2008 was 1.6 million m.t with values amounting to RM5.1 billion which is lower compared to 2007 where it was valued at RM6,467.40 million. In 2008, the fisheries sector has provided 110,547 employment with a surplus of RM0.6 billion contribution to Agro-food Balance of Trade. The production of ornamental fish in 2008 were valued RM458 million with 679 million

pieces. This is also lower compared to 2007 where Malaysia produced 558,178,294 pieces of ornamental fish valued RM647.05 million (http://www.dof.gov.my).

Risk Return Analysis

Generally, the Malaysian seafood industry has a high return potential and low risk. Fisheries and seafood industry have a high market potential and return of investment, simply because of increasing global food demand. However, the success strongly depends on good management to ensure a sustainable future and the prevention of over-fishing. The return factor is 7.4 whereas the risk factor is at 2.8. It is related to political or institutional barriers where human factor has been identified as the highest risk. The fisheries export to EU and US must comply with the hygiene and safety standard guidelines.

Economic Feasibility

The seafood industry is the country's second largest food export earner. Main trading partners are USA, Australia, EU, China, Japan, S Korea, ASEAN and West Asia Countries where export values amount to RM2.4 bill with the main commodity being shrimp products and marine finfish. Since May 2010, EU have lifted its ban on seafood products from Malaysia, therefore this will lead to increase in business opportunity. The promoted areas of investment includes (Junaidi Che Ayub, 2010):

- **Aquaculture**
  - AIZ (49 sites covering 27,000 ha. of land and water bodies)
  - Shrimp, marine finfish & freshwater fish
  - Aquaculture Hatchery (Marine Finfish)
  - Domestic & export market.

- **Ornamental Fish**
  - Production technology & trade.

- **Fish-based Processing Industry**
  - Regional source of raw materials
  - Surimi-based Fish Processing Industries
  - Harmonization of Products Certification.

- **Capture Fisheries**
  - Downstream & upstream industry
  - Tg. Manis Integrated Fishing Port, Sarawak
  - Tok Bali Integrated Fishing Port

- **Seaweed Farming**
  - To explore east coast of Malaysia for seaweed farming.

The commodity of interest for commercial aquaculture species includes

- **Freshwater aquaculture:** Tilapia (*Oreochromissp*.), Catfish (*Clariussp., Pangassiussp*.), and Freshwater Prawn (*Macrobrachiumrosenbergii*).

- **Marine aquaculture:** Finfish: Sea bass, grouper, snapper, Crustaceans: Black tiger shrimp (*Penaeusmonodon),*white shrimp (*P. vannamei),B*ivalve – cockle, mussel and oyster, Seaweed –*Euceuma cottonii*

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

In Malaysia black tiger shrimp has continued to be the leading species for the last 5 years at a value of USD 160186. Prior to 2008, Kerpan shrimp farm in Kedah was almost an abandoned farm due to poor disease control. Currently it is beginning to net in the harvest, and employs about 500 people. It has 226 grow-out ponds with capacity to produce 1,500 tonnes of black tiger prawns or 4,000 tonnes of whiteleg prawns. Kerpan is also big on technology and innovation, where R&D is given priority. The farm has a laboratory to test, among other things, diseases, the growth rate of the shrimps, and cleanliness of the ponds. Efforts are ongoing to put in place a hatchery and processing plant to bring about vertical integration of the operations, and these are expected to be in place by the middle of this year. The shrimp farm is expected to take off in a big way once it is fully integrated, with the ability to supply shrimp to markets in the European Union, Japan and the US.

Thailand is currently the biggest exporter of shrimp worldwide. In 2009, shrimp export volumes are estimated to hit US $1.37 billion, up 5% from 2008 levels. In 2010, export targets are set at $1.5 billion, +9.5% over 2009 levels. The existence of suitable biophysical conditions, a well-developed irrigation system, and government

support for export-based agricultural development fuelled the expansion of shrimp farming in Chao Phraya Delta. These same conditions are also present in other deltaic regions of tropical Asia (Szuster, 2003)

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Figure 5: Low Salinity Shrimp Farming in Chao Phraya Delta (Szuster, 2003)

Canada is one of the leading countries with huge seafood and fisheries industry. Both the government and corporate sectors placed high priority to ensuring sustainability and management of the world's canning grade seafood species (including tuna, salmon, sardines and clams). Scientific based approaches are being employed for the industry stock assessments involving various national and international research bodies. A number of criteria included in the assessment are:

- Assessment of the target stock status.
- Assessment of the impact on non-target stocks and related eco-systems.
- Review of on-going fisheries management platforms currently in place.
- Review of enforcement practices and compliance measures.
- Development of recommendations to improve fishery management practices.

In addition to local efforts, fishery industry is also supported by the STI partnership via the International Seafood Sustainability Foundation (ISSF), which is a global partnership among scientists, the fishery industry and environmental non-governmental organizations.

Its mission is to undertake science-based initiatives for the long-term conservation and sustainable use of fish stocks, reducing by-catch and promoting ecosystem health. ISSF's goal is to ensure targeted fish stocks will be sustained at or above levels of abundance capable of supporting maximum sustainable yield in a healthy ecosystem upon which they depend. These initiatives will not only help ensure the long-term sustainability of the seafood species, but also address waste reduction and resource conservation throughout the global operations in order to better manage the carbon, water and overall environmental footprint.

Specific Potential Projects

The future prospects and sustainability of the seafood and fisheries industry are highly depending on the STI investments by the government and private sectors. Areas of concern for investment may include:

- Boosting seafood and aquaculture productivity through new technology and improvements in fishery and fish-farming practices
- Building human capital and skills and attracting young people to seafood and fishery industry
- Boosting R&D for better understanding and managing of climate change impacts on the fishery and seafood industry
- Strengthening the management aspects of the industry
- Helping fish-farming and fishermen families to secure their futures
- Developing new fish and seafood products and securing new markets
- Transporting of products to market
- Organic aquaculture (OA) for black tiger shrimp. This project is based on The Improved Market Access for Organic /Aquaculture Products from Asia project which was approved by the CFC in 2005 (PEA: INFOFISH). OA Promotes sustainability in terms of protection and reforestation of mangroves and no application of pesticides, herbicides or antibiotics

Science, Technology and Innovation Needs

In response to the increasing demand of seafood products, aquaculture seafood farming is seen as an alternative to satisfy consumer demand. Indeed, aquaculture now produces half of the world's seafood. Seafood aquaculture industry is not without challenges due to unsanitary practice which may cause breeding of bacteria, viruses, and parasites that forced the producers to use antibiotics and chemicals to prevent disease outbreaks.

Residues of these chemicals may end up in the fish which causes sickness when consumed by humans. Furthermore, transport of seafood imports over long distances presents opportunities for contamination and decomposition due to improper handling and refrigeration. A sustainable seafood and fishery industry is therefore highly dependent on the state of the art STI to ensure clean water to minimise bioaccumulation of metals etc; sustainable fishing technology; sustainable marine aquaculture; and zero discharge.

STI for Clean Water Aquaculture Industry

Objectives	• Ensure clean water to minimise bioaccumulation of metals etc; sustainable fishing technology; sustainable marine aquaculture; and zero discharge. • Experience and knowledge in developing and applying the technology that can be exported to other developing country.
Science, Technology and Innovation	Short terms: • Recycling water technology to ensure high standard and high quality of marine and fresh water for aquaculture industry Medium terms: • Development and installation of state-of-the-art technologies which include application of smart sensors for aquaculture industry Long terms: • Future technologies should be directed towards fully automated aquaculture industry
Key Area	• Enhancement of R & D aspects of the technologies in water recycling and clean water for aquaculture • Development of human resource to ensure hygiene and technological advancement in aquaculture industry.

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI Investment	Recycling water to a standard for a guaranteed high quality product	Application of smart sensors	Synthetic marine water for optimization of location and design of aquaculture facilities	Fully automation using robotics system	Design of sustainable large scale aquaculture enterprises
Enablers	Importation and adaptation of existing technology	Nanotechnology research	Land/ water use capability assessment	Application of robotics technologies	Collapse of global fisheries and increasing global water scarcity
Outcomes	Disease prevention	Real time monitoring water quality for quality control	Aquaculture optimally located for optimal human, economic and environmental benefits	Sustainable, reliable, efficient and high quality water supply for eco label aquatic product	Exploiting Malaysia's abundant water resources to upscale aquaculture for high value exports

6.1.5 Malaysian Brand for Domestic Water Purifier

Economic Sector: Urban/Domestic

Description of the Opportunity

Similar to bottled water, domestic water filters or purifiers are also very common nowadays. They are almost in every home and office with prices ranging from less than RM100 to several thousands RM according to the capacity of the system.

Domestic or home water filters can be categorized into two types, depending on their point of use. They are Point-of-Enty (POE) water filters and Point-of-Use (POU) water filters.

The POE water filters are those that are installed at the point where water from the public water supply enter the house pipe system. While some are bulky in size, some are rather simple. Their main purpose is to remove the dirt, sediment and rust from

the water that is supplied to the whole house. The medium of filtration ranges from sand to membrane and the filtration system is normally equipped with backwashing, either manually or automatic.

The POU water filters are installed at one of the kitchen tap that are dedicated for consumption. They are small in size with medium ranging from ceramic filter, cellulose filter, activated carbon, ion exchange resin and other medium which are the trade secret of the supplier. Depending on the medium use, the POU water filters aim at removing dissolved contaminants such as inorganic metals, odor, chlorine and dissolved organics which include trihalomethanes (THMs).

There are many types of home water filters throughout the world. In Malaysia, there are more than 150 companies (http://superpages.com.my) dealing with water filters. While some claim that they manufacture their own products, others are just product distributor. In many cases, the filtering medium, pumps, valves are imported from overseas.

The demand for the home water filters is expected to increase world-wide due to the increasing concern on health and safety of the drinking water supply. This is a great global business opportunities for Malaysia. However, due to competition from other supplier countries, export of the product should emphasize on the countries where Malaysian companies are more acceptable these days such as the Middle-east and countries with high Muslim population. With Malaysia's reputation as Islamic country and with the products that are certified as *halal* and *toyyibah*, Malaysia home water filters should be more marketable in those countries.

Risk Return Analysis

The scores for the return and risk are 6.9 and 2.5, respectively. Based on the current market of water filters, this domestic water purification unit has very high market potential and is important for the protection of human health. However, as there are many water filter products available in the market, competition would be very high. The advantage for Malaysia would be to market the products to Islamic countries with certification of *halal* and *toyyibah.* As the technology for the production of the water filters is quite common, the risk is also low.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Fairey Industrial Ceramics Limited *(http://www.faireyceramics.com/)*

Fairey Industrial Ceramics Limited (FICL), based in the United Kingdom, is the sole manufacturer of the world-famous range of Doulton® and British Berkefeld® ceramic drinking water filters (Figure 6). With over 150 years continuous manufacturing experience and Doulton® and British Berkefeld® in use in home water filtration systems in 140 countries world-wide, FICL is a global leader in water purification, helping to provide safe, clean, filtered drinking water to millions of people every day. To service the needs of their customers, FICL has set up a world-wide distribution network and has Regional Sales Managers based in various key territories around the globe.

Figure 6: Different types of ceramic filters produced by FICL

Fairey Industrial Ceramics Limited takes serious effort to ensure the quality of their products. All stages of FICL's drinking water filter production process adhere to the stringent quality standards. The ability to produce consistently high-quality, effective drinking water filters is what makes FICL different. Fairey Industrial Ceramics Limited holds the coveted NSF® and WRAS certificates, demonstrating that their drinking water filters have passed the highest international testing standards.

Fairey Industrial Ceramics Limited drinking water filters have been so successful globally because they have a variety of advantages over other products in the market. These include highly effective barrier to particles and pathogens, long life, self sterilizing, natural, long term value, possible combination with other filter media and no power requirement.

Specific Potential project

The initial stage would be to identify the Malaysian home water filters currently available in the market which may include RX-water, Bio-Aura, and Diamond. These products need to be certified as *halal* and *tayyibah* by the authorized party (i.e. JAKIM). Promotion for these products needs to be carried out in the Islamic countries and also to countries with high Muslim population.

In addition, new home water filters could also be developed. Different types of water filter, either POE or POU can be designed and fabricated. The important part of this development is to ensure that every component of the filter, particularly the media is *halal* and *tayyibah*.

STI involved/technical feasibility

The STI involved in these types of product would be the filtration system, the filter medium, the valves, piping, etc. Local filter media have also been developed in the universities and also industries. These media and the filtration system will require certification not only from JAKIM, but also from technical certification bodies locally and internationally. The design and packaging of the system also need to be attractive and convincing. This is important in order to gain confidence from the international market. Table below summarises the STI involved under domestic water purifier.

Summary of STI for domestic water purifier

Objectives	To develop and export Malaysian brand domestic/home water purifier under the flag of *halal* and *tayibah*
Science, Technology and Innovation	Short terms: • Identification of existing local products in the market • Development of operating procedures for *halal* and *tayibah* certification • Promotion of local products at the global market Medium terms: • R, D & C on filter medium and other auxiliaries Long terms: • Development of green technology on domestic water purifier and its components
Key Area	• Development of human resource • Enhancement of R, D & C aspects of the technologies

Investment Roadmap

	2010-15	2015-30	2030-40	2040-50
STI investment	• Identification of existing local products in the market • Development of operating procedures for halal and tayibah certification	• Development of local and innovated produts of filter medium and other auxiliaries • Promotion and export of local products at the global market	Green technology on domestic water purifier and its components	
Enablers	Government and private initiative	Government and private initiative	Government and private initiative	
Outcomes	Certification procedures	New and improved products	Eco-friendly products	

6.1.6 World Leading Tropical Aquatic Research and Education

Economic Sector: Education

Description of the Opportunity

Malaysia's aquatic environmental assets are abundant. Situated in the tropics with 12 % of the total 330,000 km^2 land area categorised as aquatic ecosystems and more than 9,000 km of coastline, the potential for both formal education and research in tropical marine and coastal ecosystems is strong. With a number of local universities already having courses focusing on aquatic ecosystems, the potential of Malaysia to become leaders in this area and attract overseas students is high.

The aquatic ecosystem research is basically the study of the complex interactions between aquatic and terrestrial systems. The structure of the upland and the activities occurring there play an important part in regulating community structure and ecosystem processes in streams. Aquatic ecosystems perform numerous valuable environmental functions. They recycle nutrients, purify water, attenuate floods, augment and maintain stream flow, recharge ground water, and provide habitat for wildlife and recreation for people. Aquatic resources are vulnerable to the effects of human activities such as land use alteration and this cause irreversible damage (e.g. introduction of new species or extinction of certain species) or give rise to cumulative long term, large scale biological or cultural consequences. Rapid population increases in many parts of the country, accompanied by intensified industrial, commercial, and residential development— have led to the pollution of surface waters by fertilizers, insecticides, motor oil, toxic landfill leachates, and feedlot waste. At the same time that water pollution and releases of nutrient-laden municipal sewage effluents have increased, water consumption has also increased, thus reducing the flows available for the dilution of wastes.

Risk Return Analysis

The global education market is substantial, forming significant components of developed world economies. Rapidly developing countries such as Malaysia increasing have the opportunity of attracting overseas students in niche education areas such as tropical aquatic science and engineering. Enhanced education facilities will lead to improved environmental awareness in Malaysia with flow-on benefits for ecosystem protection. Malaysia is technologically advanced, politically stable and culturally sensitive. It has a vibrant university sector.

Malaysia will need to expand its education sector to fully capitalise on the international education market. A specialist tropical aquatic research and education centre and network would provide a cornerstone to capacity development. Political support will be required to establish a vision for Malaysia as an international centre for advanced education. The potential for adopting a new international education model is high as has been demonstrated successfully in other countries. The proposed STI is holistically robust as it supports Malaysia's vision as an advanced developed nation built on cutting edge science and technology.

Risk Return Analysis

The total return score calculated is 7.4 and the total risk score is 3.2.

Economic Feasibility

Tropical aquatic research is a dynamic and exciting field of research, but opportunities for students to undertake undergraduate and postgraduate studies is limited. As the critical component of this education strength is the use of field and laboratory based classes, Malaysia is most suitable and has got the strength since this country has is situated in an ideal physical environment.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

eWater CRC

As a Cooperative Research Centre (CRC) established with government, industry and academic funding, eWater CRC develops water management tools for its partner organisations as well as national and international markets. eWater is currently developing a number of software packages to support water planning and management activities, with a focus on water management in eastern Australia. A number of early versions of eWater products are currently being tested in the field, with their stormwater modelling software 'music' recently released on the market.

The Cooperative Research Centre program provides funding from the Australian government to tertiary institutions for research programs. However, in order to receive federal funding, each CRC must partner with representatives from industry, who also provide funding for the activities of the CRC. As part of this relationship, CRCs tailor their research to meet the needs of partner organisations. In the case of eWater CRC, its 47 partner organisations are beneficiaries of the products developed through eWater's research.

As mentioned above, eWater has recently released music v4, the latest iteration of the music software for modelling urban stormwater improvement concepts that was initially developed by the CRC for Catchment Hydrology. music simulates the effects of different stormwater improvement devices, allowing planners to test the select the most appropriate and cost effective option. The software can be used to simulate a range of stormwater improvement options, including bio-retention systems, swales and wetlands. Pollutants such as total suspended solids, total phosphorus and total nitrogen are modelled, with calibration tools to ensure accurate outputs from the modelling.

Music is the product of sustained research and development into stormwater hydrology, with leading Australia knowledge incorporated into a discrete product. The software is designed to inform management decision making by governments and private consultants, and it is hence marketed to these groups both nationally and internationally.

While eWater offers a number of tools as free software, it is also currently developing other software products that it intends to bring to market. eWater is building new tools, as well as upgrading existing tools, in four categories according to their purpose:

- Tools for ecological management, including monitoring & assessment or restoration of freshwaters and floodplains;
- Tools for forecasting and managing catchment water yield and quality in variable and changing climates and land-uses;
- Tools for integrated management of urban water, including water security;
- Tools for managing and operating rural river systems and water supplies.

These 'next-generation' software tools link water management to land-use practices, at a range of scales - from small (down to lot-scale in urban areas) to very large.

eWater Innovation is the commercial arm of eWater CRC. eWater Innovation is a wholly owned subsidiary of eWater Ltd and was started in October 2008. Its purpose is to sell products, provide support, train users and focus on product development of eWater products launched in the market.

Potential Project

Malaysia established its National Biodiversity Policy in 1997, four years after the agreement of the international Biological Diversity Convention (BDC) came into force. The policy states its vision as: to transform Malaysia into a world centre of excellence in conservation, research and utilization of tropical biological diversity by the year 2020. In the same year, the Sarawak State Government enacted the **Sarawak Biodiversity Centre** Ordinance and set up the Sarawak Biodiversity Centre (SBC) the following year to initiate programmes for the conservation, utilization, protection and sustainable development of biodiversity in the state. The state government also enacted the Sarawak Biodiversity Regulations in year 1998. Back then, the Centre's role was primarily inventory and regulatory – often known as the gatekeeper to Sarawak's rich biodiversity to those who wanted access to and collection of biological resources in the state for research or commercial purposes. In our view, the same approach can be set up for Tropical Aquatic Research Centre which can be set up in few countries in Malaysia such as Sarawak, Sabah, Terengganu, Pahang and Johor. Certain government research centers for eg. the Institute Penyelidikan Perikanan which are already doing research in fishers for example can be upgraded to such centres.

Science, Technology and Innovation Needs

The fundamental goal of aquatic ecosystem restoration is to return it to a condition that resembles its natural pre-disturbance, state as closely as possible. Achievement of this goal entails restoration of the target ecosystem's structure and function both locally and within its broader landscape or watershed context. To measure the degree of success in achieving restoration goals, physical, chemical, and biological evaluation data are necessary to verify that an ecosystem is performing as it should. In the light of STI, this can be achieved by via education (formal or informal) and continuing research. Malaysia's aquatic environmental assets are abundant. Situated in the tropics with 12 % of the total 330,000 km^2 land area categorised as aquatic ecosystems and more than 9,000 km of coastline, the potential for both formal education and research in tropical marine and coastal ecosystems is strong. With a number of local universities already having courses focusing on aquatic ecosystem, the potential of Malaysia to become leaders in this area and attract overseas students are high.

The current and future trends in the aquatic ecosystem research is the employment of modern instrumentation such as Geographical information systems (GIS), image processing technology and spatial statistical techniques where it allows quantitative assessment of lateral, longitudinal and vertical components of the landscape that interact at several spatial and temporal scales to influence streams. When GIS is used in concert with geostatistics, multivariate statistics, or landscape models, complex relationships can be elucidated and predicted. This suite of tools has improved the ability of aquatic ecologists to examine relationships and test theories over larger, more heterogeneous regions than were previously possible.

Summary of STI

Objectives	• To be a world leader in tropical aquatic research and education
Science, Technology and Innovation	Short terms: • To identify centres or institute that to be the world leading tropical aquatic research and education centre recognising Malaysia's abundant aquatic/ecosystem resources Medium terms: • Course development completed with fully enabled virtual learning Long terms: • Understand science, research and education needs across many tropical countries
Key Area	• Research and Education in Tropical Aquatic fields

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI Investment	Design of world leading tropical aquatic research and education centre recognising Malaysia's abundant aquatic/ecosystem resources	Real-time testing of facilities as they come online. Course development completed with fully enabled virtual learning.	Course and research programs rolled out across Malaysia	Understand science, research and education needs across many tropical countries	Monitoring and evaluation plan for centre's impact on sustainability designed and implemented
Enablers	Business model presented and agreed with government and partners	Funding, virtualisation technologies	Highly skilled professional staff attracted	International marketing; international reputation	Funding for impact assessment
Outcomes	Business model and development plan in place that is futuristic to match foreseen technology advances over 50 year lifespan and incorporates appropriate level of commercial features (e.g. Australian CRC model)	Facility built in physical and cyberspace	Recognised leading research and education centre in Malaysia	Recognised as a leading institution across all tropical regions with real and virtual nodes established in many countries and cornerstone of capacity development	Impact of centre on sustainability of tropical regions recognised and results fed back to continuously improve effectiveness of centre. Export earnings amongst best for special centres in Malaysia.

6.1.7 Knowledge Export

Economic Sector: Education

Description of the Opportunity

The knowledge economy and the STI industry will be the main driver of the global economy in the future, where advanced technology products, knowledge resources such as know-how and expertise are as critical as other economic resources. It is therefore timely that Malaysia embarks on the New Economic Model (NEM) where STI will play a significant role in transforming the Malaysian economy to become one with high incomes and quality growth by 2020. The goal of NEM is to stimulate economic growth by improving worker productivity across all sectors of society, in part through an improved system of affirmative action, with an eye towards sustainability. Greater emphasis on the role of STI and focus on sustainability in the NEM is expected to generate indigenous new knowledge and technology and the development of expertise among local scientists, engineers and managers. This is where the ASM Mega Science Framework Study is very relevant for sustained development until 2050. For Malaysia to reach a developed nation status sustainably, it is imperative that it develops and harnesses all available scientific knowledge and tools. The STI industry can contribute immensely to the future sustainable development of Malaysia.

Risk Return Analysis

STI will be the global driver of the future economy. The development of an integrated science framework for national sustainable development will foster, promote and manage the development and application of scientific knowledge and technological innovation, as well as related skills and expertise, for the attainment and sustainability of the overall national development strategies – the outcomes of these are in the forms of knowledge, IP, quality products, skilled workers, and world experts. The return-risk analysis generally indicates favourable return on investment with a low risk score. The main risk component of the knowledge export generally lies in the STI and human capital outcomes of the implementation of the Mega Science Framework. The total return scores calculated as 7.4 whereas the total risk scores calculated as 3.3.

Economic Feasibility

One of the long term objectives in water sector STI should be to export the home grown products, the expertise and technology for the national economic return. There are examples where successful STI in water sector has produced strong knowledge from the country as demonstrated by Australia and Israel. Israel, for example managed to emerge from recent global economic crisis faster than others, partly due to knowledge export in water sector that contributes $2.5 billion in water technology annually by 2011 (Reuters, 2009).

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

The generation of scientific knowledge has led to remarkable advances that have been of great benefit to humankind, as well as improving the environment and contributing to a socio-economic balance through appropriate governance structures. Science, Technology and Innovation (STI) are central to sustainable development. A number of countries, such as Ireland, Netherlands, Finland, Sweden and South Korea, have already incorporated, or are in the process of incorporating, elements of Science, Technology and Innovation (STI) into their national sustainable development plans. They also export their knowledge and STI for profitable economic return.

Australian eWater CRC is an example of where research agency and the government established a cooperation that develops water management tools for its partner organisations as well as national and international markets. For example, eWater has recently released music v4, the latest iteration of the music software for modelling urban stormwater improvement concepts that was initially developed by the CRC for Catchment Hydrology. Music simulates the effects of different stormwater improvement devices, allowing planners to test and select the most appropriate and cost effective option. The software can be used to simulate a range of stormwater improvement options, including bio-retention systems, swales and wetlands. Pollutants such as total suspended solids, total phosphorus and total nitrogen are modelled, with calibration tools to ensure accurate outputs from the modelling.

Another example of Australian knowledge export is the Water Industry Alliance, a group of approximately 250 South Australian-based companies and organizations formed as a means of marketing South Australian water sector expertise, and combines research & development, consultancy, engineering, technology, manufacturing and education experience. Alliance members aim to promote leading

skills and tender for projects on the basis that clients will receive world class solutions. The Alliance provides a vehicle for consolidating and marketing South Australian expertise, and positioning Alliance teams as a leading group of consultants. Rather than a specific economic outcome, the Alliance is a vehicle for promoting members' capabilities and developing business opportunities. The Water Industry Alliance is currently assisting its members to expand into Asian markets.

Specific Potential Projects

The STI developed can be exported to developing neighbouring countries and other parts of the world where the STI are needed. Malaysian experts can serve and provide their expertise elsewhere around the globe.

Science, Technology and Innovation Needs

The future economic drive is to link the economic growth with sustainability of the ecosystem utilization and generation of new wealth based on ecosystem services. Sustainability focuses on how to reduce the amount of resource (e.g. water, energy, or materials) needed for the production, consumption and disposal of a unit of good or service, and whether this can be achieved from improved economic management, product design, new technology etc.

Summary of STI

Objectives	• To generate new wealth based on export of knowledge, technology and expertise in water STI
Science, Technology and Innovation	Short terms: • Human resource development specializing in water sector • Improvement of experts and expertise directory Medium terms: • National research alliance on water STI • Demonstration of successful R&D and commercialization of Water STI Long terms: • Government and private partnership in water STI • Malaysian companies on water STI operating overseas
Key Area	• Human capital development in water sector STI

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Focus on human resource development specializing in water sector Improvement of experts and expertise directory	National research alliance on water STI	Demonstration of successful R&D and commercialization of Water STI	Government and private partnership in water STI	Malaysian companies on water STI operating overseas
Enablers	Strong policy directive towards water STI	Strong legal and policy support to potential products/ technology and expertise	International partnerships and collaborations	International satellite offices	International trade promotion and legal supports
Outcomes	Enhanced interest in the water sector STI Increase number of human resource trained in water STI	Enhanced R&D and commercialization Increase in international partnerships and collaborations	Intensified R&D and commercialization of water STI including overseas markets	Increasing trend of national income generated overseas from the water based products/ technology and expertise.	Significant contribution from water based technology/ products and expertise to national income generated overseas

6.1.8 Downstream Water Tapping

Economic Sector: Urban/Domestic

Description of the Opportunity

Water demand in Malaysia is expected to double for every two decades. At present 98% of the water supply is sourced from surface runoff. All potential sites for water resources development in highly populated areas like Kelang Valley and Penang have been developed. At the moment, the conventional option to enhance supply is through inter-state water transfer which is very costly and may pose severe environmental damages. For example the total cost for water transfer and treatment facilities project from Pahang to Selangor is about RM 9 billion. Of which RM3.9bil

will be for the construction of pipelines and the tunnel (44.6 km) and RM4.4bil for the water treatment plant in Hulu Langat and its distribution system (Mohamad, 2010; http://www.kettha.gov.my/en/). Once completed, the scheme will pump 1,890 mil litre/day of raw water from Sungai Semantan in Pahang to the Hulu Langat water treatment facility in Selangor.

Inter basin or inter-state water transfer is no longer a viable option in the future especially when the distance from source is far. Other more innovative methods that are affordable and sustainable need to be explored. Two potential STIs are identified. The first is river bank filtration (RBF) and the second is urban runoff tapping.

Risk Return Analysis

The total return score is calculated as 7.7 and the risk score is 4.2.

Economic Feasibility

In many countries, river bank filtration technology has been proven very cost effective. Reduction in cost is associated with simpler and smaller construction facility, lower treatment cost as the raw water is naturally treated by the layer of sand and aquifer above the streambed, and lower maintenance cost. On the other hand the technology for urban runoff tapping require not only physical structure but also investment on social engineering and education as good quality urban runoff can only be realised through catchment wide river quality improvement and control program. However, when implemented, this STI can induce multiple socio-economic benefits.

Benchmarking

River Bank Filtration

Riverbank filtration (RBF) is a low-cost treatment technology that has been used for over a century especially in Germany and the USA. Bank filtration and infiltration have been widely used in Germany (Sontheimer et al. 1978; Sontheimer 1980). Today, approximately 16 % of all drinking water in Germany is produced by bank filtration, groundwater contributes 64% and river water only 1% (Schmidt et al., 2003). It is a cost-effective as it treats raw water naturally through the aquifer media instead of using chemicals as in most of the conventional treatment methods (Figure 7). The bank filtration technique takes advantage of existing geologic formations adjacent to water bodies to filter drinking water. Wells are dug in fine, sandy

sediments next to water bodies and water is extracted from these wells. Water in the water bodies filters through the sediments removing contaminants. The water obtained is often of much higher quality than the raw surface water. The natural media is not only effective in removing suspended solids and turbidity but also effectively removes toxic chemicals and pathogen including Cryptosporidium (Clancy and Stendahl, 1997). Substantial reduction in the organic precursor was achieved in RBF technique, thus reduce the formation of Disinfection Byproduct (DBP). One of the common DBPs when the raw water contains high concentration of natural organic matter is trihalomethanes (THMs) which is produced during chlorination process. THMs is known to contain carcinogens. However it's still hard to find alternative to chlorine. Another major advantage of RBF is its ability to avoid sudden load of pollution due to spill or accident (Schmidt et al., 2003). In fact, concentration of pollutants in RBF water during event of spill was found to be remarkably lower than in the river water (Kühn, 1999).

Underground passage as water treatment procedure combines particle removal, pathogen removal, organic and inorganic chemical removal, peak smoothing in spills, temperature equalization, reduction in DBP formation, and production of a more biologically stable water. Locally, RBF has been tested at Sungai Langat in Selangor and Sungai Jeli in Kelantan. Significant improvement in water quality after undergoing the RBF system was observed (see Figure 8).

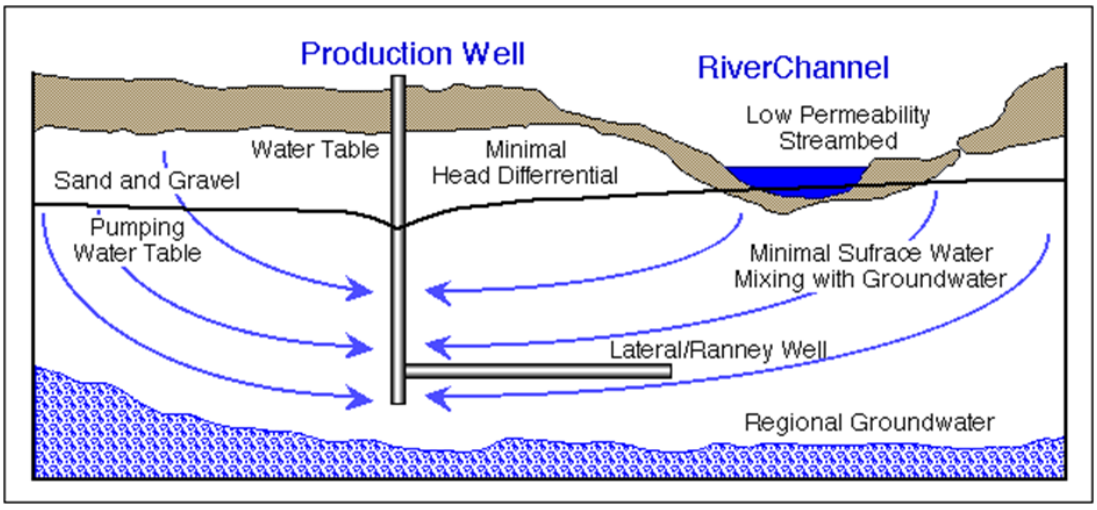

Figure 7: Schematic diagram of a River Bank Filtration (RBF) system

(Source: http://www.wrrc.hawaii.edu/bulletins/2000_08/filtration.html)

Figure 8: Water quality of raw water (left) and extracted from river bank

Filtration system at Sungai Langat (courtesy of NAHRIM)

Manchester Water Works (Smith, 2009)

RBF was used as a pretreatment technology for Manchester Water Works (MWW) in New Hampshire to supplement 57-million-liter-day (MLD) drinking water supply at Merrimack River. Hydrogeologic investigation indicated that the technology was a potentially viable pretreatment technology and an alternative to a direct surface water intake.

The RBF investigation involved aquifer exploration utilizing seismic reflection profiling, subsurface angle intake modeling, pumping tests, detailed water quality analysis and bank filtration modeling. Onshore and offshore geophysical and test well exploration studies identified a potential high-yield sand and gravel aquifer beneath the Merrimack River.

In this study, a 21-degree angled well design was used to explore the possibility of developing a 45.6 MLD future RBF supply. The low-angle gravel well, 50.3 m in length, was drilled beneath the river and pumps tested for six days at 2.35 m^3 per minute. A detailed groundwater flow model with a rhodamine dye time-of-travel

analysis was conducted, and a detailed water quality laboratory analysis was conducted.

RBF was shown to be an excellent barrier against microorganisms. A log credit removal of at least 2 for bacteria, viruses and aerobic spore-forming bacteria could be assigned. It removed organic precursors by an average of 63%.

Induced infiltration from the river was estimated to range from 53% to 64%. The design of a unique offshore well construction and pumping system allowed the utility to take advantage of the raw water source, positioning it to meet projected supply needs. By utilizing the technology, MWW may eliminate the need for filtration as well as reduce chemical, operational and treatment facility construction costs.

Tapping of Urban Runoff - Marina Barrage Singapore
(http://www.pub.gov.sg/marina/Pages/default.aspx)

Marina barrage is a sophisticated dam that provides three main benefits: a tidal barrier and pumping station for flood control, a reservoir for augmenting water supply, and new lifestyle attractions in and around the reservoir. The complex includes extensive user-focused lifestyle benefits, including the visitor gallery, iconic architectural treatment, and parkland features. The construction cost was USD 167 million.

The Marina Barrage was designed to simultaneously protect Singapore from devastating floods, address the city-state's need for safe drinking water through beneficial capture and reuse, while supporting its plans to stimulate the local economy and the people's interest in environmental conservation. In addition to improving water quality, the barrage anchors a tropical botanical park extending from downtown and along the reservoir, which enhances Singapore's reputation as a garden city.

The barrage is an iconic structure in Singapore's downtown landscape, visually and functionally linking the east and west arms of the Marina Reservoir shoreline. The site has proven a popular destination for local residents and tourists alike. Its premier location makes the reservoir an ideal venue for international water sport competitions, cultural performances, and recreational activities.

Marina Barrage also offers an attractive model for other low-lying coastal cities confronting climate change, flooding, and demand for new water supply. Other

coastal cities, like Hong Kong, New Orleans, and Dublin, are interested in the concept, and Dublin has recently undertaken preliminary studies for a tidal barrage across Dublin Bay.

The barrage steadies the upstream waterways of the Singapore and Kallang rivers, significantly enhancing urban development and shoreline recreational activities. Some USD 7 billion of development is underway in the immediate neighbourhood - all enhanced by the ability of the barrage to stabilize water levels.

Figure 9: **Besides providing new sources of water, Marina Barrage creates opportunity for urban water based activities and awareness on water conservation**
(http://www.pub.gov.sg/marina/Pages/default.aspx**)**

Figure 10: Marina Barrage also increases the property values in the surrounding areas
(http://www.pub.gov.sg/marina/Pages/default.aspx)

Specific Potential Projects

Installation of RBF system can be carried out along any major river, but preferably in the downstream in order to achieve a bigger volume. The technology is already available locally. However, further improvement is still necessary to increase the water yield and improve the water quality.

This kind of project can be implemented in well planned growth areas with strong emphasis on environmental protection and management such as Nusajaya Malaysia which is one of the flagship zones to be developed under the Iskandar Malaysia. It is the most strategic flagship zone to be transformed as Asia's foremost city under the World in One City concept. The development of Nusajaya Flagship Zone will include Johor State administrative centre, medical hub, educity, international destination resorts, and industrial clusters which encompasses an area about 1/6 the size of Singapore as a single privately owned Southern Industrial Logistic Cluster (SiLC) covering 1300 acres (Khazanah Nasional, 2007). The proposed flagship zone is envisaged to cover 23,875 acres of contiguous, development ready land, the business-friendly authorities as well as world-class infrastructure and facilities. Through its integrated planning and implementation, Nusajaya Malaysia will offer a secure, unique, enhanced and enriched lifestyle.

Sustainable water and sewerage management are two major issues in ensuring the success of development in Nusajaya Malaysia and Iskandar Malaysia as a whole.

Unless new sources of water are established, Iskandar Malaysia may experience water shortage by year 2025 or sooner.

Through adherence to stringent environmental regulations the runoff quality in this growth region is expected to achieve at least Class IIB standard which is suitable as sources of raw water and enhancement of ecological functions.

Science, Technology and Innovation Needs

Tapping of urban runoff as a new source of water supply requires a holistic approach for controlling point source and non-point source pollution over an entire catchment. This requires innovative technology, stringent regulation and high environmental awareness among the public. Modelling of runoff quality to understand the cumulative impact of pollutant loading into the newly created water body is also necessary. Preferably construction of barrages should also take into consideration impact of climate change locally and sea level rise.

Summary of STI

Objectives	• Increase the nation capacity in meeting future water demand
Science, Technology and Innovation	Short terms: • Installation of River Bank Filtration demonstration unit Medium terms: • A holistic approach for rehabilitation of river quality Long Terms: • Utilization of urban runoff for water supply in selected well planned development areas
Key Area	• Water supply, river rehabilitation, tourism

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of demonstration unit of RBF system along major rivers Mapping off urban runoff potential for water supply Public awareness campaign on total protection of water resources	RBF is widely accepted for large scale implementation Design of smart barrage that can automatically regulate flow Flood risk modelling for potential site which incorporate climate change impact	Show case of urban water collection system for water supply Public awareness campaign on total protection of water resources	Tapping urban runoff technology is implemented in high water demand areas Realization of integrated river basin management	Enhancement of urban water facilities for eco-tourism and conservation
Enablers	Policy statement, Hydraulic modeller	Availability of fund and technical resources	Private investment, Incentive from the government, enforcement	Private investment, Flexible water supply policy	Private sector, greater public ownership/ participation
Outcomes	Public acceptance of RBF system Documented urban runoff potential	Acceptance by potential investor and the public RBF provides cleaner water	Cleaner river, wider acceptance by the public	New source of freshwater in urban area Reduced cost for water transfer Cleaner urban runoff through public participation Improved river habitat	Healthier river ecosystem Increase property values Increase tourism revenue

6.1.9 Rainwater Harvesting

Economic Sector: Urban/Domestic

Description of the Opportunity

Rainwater harvesting is a strategy of reducing water demand from public water supply by providing an alternative water resource. Rainwater or precipitation is

relatively pure, except at some industrialized locations where acid rain could pose a threat. If heavy rainfall persists for a long period, only the initial part of the rainwater is significantly polluted while the remainder is of acceptable quality. Guidelines for installing a rainwater collection and utilization system in Malaysia has been launched in 1999. On March 27, 2006, the Prime Minister announced that rainwater harvesting would be made mandatory to large buildings. In August 2006, the Town of Country Planning and Development has formulated the National Urbanization Policy (NUP). The policy in particular stresses that cities need to improve water management efficiency by emphasising the use of alternative, non-conventional sources such as rainwater harvesting and water recycling. Unfortunately, acceptance by developers and the public is still poor despite the potential benefit to lessen dependence on tap water and minimise impact of flash floods.

The paradigm of rainwater utilization in Malaysia must change from small scale for residential houses to large scale projects for industries, public buildings and urban communities. Besides reducing the water bill and lessening the dependency on traditional water sources, the socio-economic benefit of rainwater harvesting must take into consideration reduction in flash flood occurrence and its associated damages. Further incentive can be given to private sectors which invest in rainwater harvesting projects by allowing them to sell rainwater to water companies. Rainwater collection systems might be economically more attractive especially when the full cost recovery for providing raw water from rivers, reservoirs and inter basin transfer is considered.

Risk Return Analysis

The total return score is calculated as 7.4 and the risk score is 4.3.

Economic Feasibility

Rainwater harvesting is a cost effective option for high water use industries and commercial complexes. The future scenario is even more promising as water is becoming a scarce resource and its tariff is expected to increase from time to time. Therefore the future return of investment (ROI) will be shorter. Rainwater harvesting technology is available locally and therefore with right incentives this program can be successfully implemented.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

One-Utama Commercial Complex in Malaysia

The rainwater harvesting system is composed of 29, 160 m^2 roof area, 3248 m^3 storage cistern and water distribution systems (http://www.sun2surf.com/article.cfm). The cistern is located at the basement of the building and equipped with sensor to detect the storage level. When the water level drop to a certain level, the sensors will trigger pumps to extract water from tube wells. There are four tube wells constructed in the system, acting as back up when rainwater is not sufficient. The system is also connected to public water supply in case both rainwater and tube wells are not able to meet the water demand. Rainwater from the cistern is pumped to the second tank that will distribute the water to the consumers. The rainwater is used for toilet flushing, cooling system and watering the landscape. The rainwater harvesting system is working fine with 81% reliability. It is able to reduce water bill by 30% with a payback period of 4.5 years.

Figure 11: The Rooftop Garden at One Utama Building is Watered Using Rainwater

Singapore

(http://www.unep.or.jp/Ietc/Publications/Urban/UrbanEnv-2/9.asp)

Singapore, which has limited land resources and a rising demand for water, is on the lookout for alternative sources and innovative methods of harvesting water. Almost 86% of Singapore's population lives in high-rise buildings. A light roofing is placed on the roofs to act as catchment. Collected roof water is kept in separate cisterns on

the roofs for non-potable uses. A recent study of an urban residential area of about 742 ha used a model to determine the optimal storage volume of the rooftop cisterns, taking into consideration non-potable water demand and actual rainfall at 15-minute intervals. This study demonstrated an effective saving of 4% of the water used, the volume of which did not have to be pumped from the ground floor. As a result of savings in terms of water, energy costs, and deferred capital, the cost of collected roof water was calculated to be S$0.96 against the previous cost of S$1.17 per cubic meter.

A marginally larger rainwater harvesting and utilisation system exists in the Changi Airport. Rainfall from the runways and the surrounding green areas is diverted to two impounding reservoirs. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The water is used primarily for non-potable functions such fire-fighting drills and toilet flushing. Such collected and treated water accounts for 28 to 33% of the total water used, resulting in savings of approximately S$ 390,000 per annum.

Tokyo, Japan

(http://www.unep.or.jp/Ietc/Publications/Urban/UrbanEnv-2/9.asp**)**

The Ryogoku Kokugikan Sumo-wrestling Arena, built in 1985 in Sumida City, is a well-known facility that utilises rainwater on a large scale. The 8,400 m^2 rooftop of this arena is the catchment surface of the rainwater utilisation system. Collected rainwater is drained into a 1,000 m^3 underground storage tank and used for toilet flushing and air conditioning. Sumida City Hall uses a similar system. Following the example of Kokugikan, many new public facilities have begun to introduce rainwater utilisation systems in Tokyo. At the community level, a simple and unique rainwater utilisation facility, "Rojison", has been set up by local residents in the Mukojima district of Tokyo to utilise rainwater collected from the roofs of private houses for garden watering, fire-fighting and drinking water in emergencies. To date, about 750 private and public buildings in Tokyo have introduced rainwater collection and utilisation systems. Rainwater utilisation is now flourishing at both the public and private levels.

Seoul, South Korea

Rainwater utilization has been strongly promoted within government, academic circles, and non-governmental organizations in the Republic of Korea. Some local governments, such as the Seoul Metropolitan Government (SMG), enforced an act to require installation of a rainwater utilization system for newly constructed buildings and also developed an incentive program to promote rainwater utilization. Rainwater management is also considered as an important measure to prevent natural disasters such as flooding and/or drought. A new regulation on the installation of a rainwater harvesting system was enforced in December 2004. The purposes are i) to mitigate urban flooding and ii) to conserve water. Citizens are asked to cooperate by filling and emptying rainwater tanks according to directions from the disaster prevention agency.

A special feature of the new system is the provision of a network for monitoring the water levels in all water tanks at the central disaster prevention agency in the City Office, which are gathered from each Gu-office, which is a regional organization in the City. Depending on the expected rainfall, the central disaster prevention agency may issue an order to building owners to empty their rainwater tanks, either fully or partially. An incentive program is planned for those who follow the order and some penalties for those who do not. After a storm event, the stored water can be used for fire fighting and/or miscellaneous purposes such as toilet flushing and gardening.

The buildings included in the regulation are as follows:

- All public buildings: compulsory for new buildings and recommended to the
- extent possible for existing buildings.
- New public facilities such as parks, parking lots, and schools: to the extent possible.
- Private buildings: recommended for new buildings subject to building permission (floor area larger than 3000 m^2).
- Large development plans such as new town projects: installation of a rainwater management system as a first priority.

Star City Project in Kwangjin-Gu

(http://ecowaterinfra.org/knowledgebox/documents/)

A specific rainwater system was designed for a recently constructed building (Figure 12) at the Star City Project in Kwangjin-Gu, Seoul. A 3000 m^3 rainwater tank was installed in the basement and divided into three sections of 1000 m^3 each. The first section collects rainwater from the unpaved ground surfaces. It should be kept empty most of the time except when there is heavy rain. The second 1000 m^3 section collects rainwater from the roof, which should be used for toilet flushing and landscaping purposes. The third 1000 m^3 section should be filled with fresh water and used for supply during emergencies such as fire fighting or accidents.

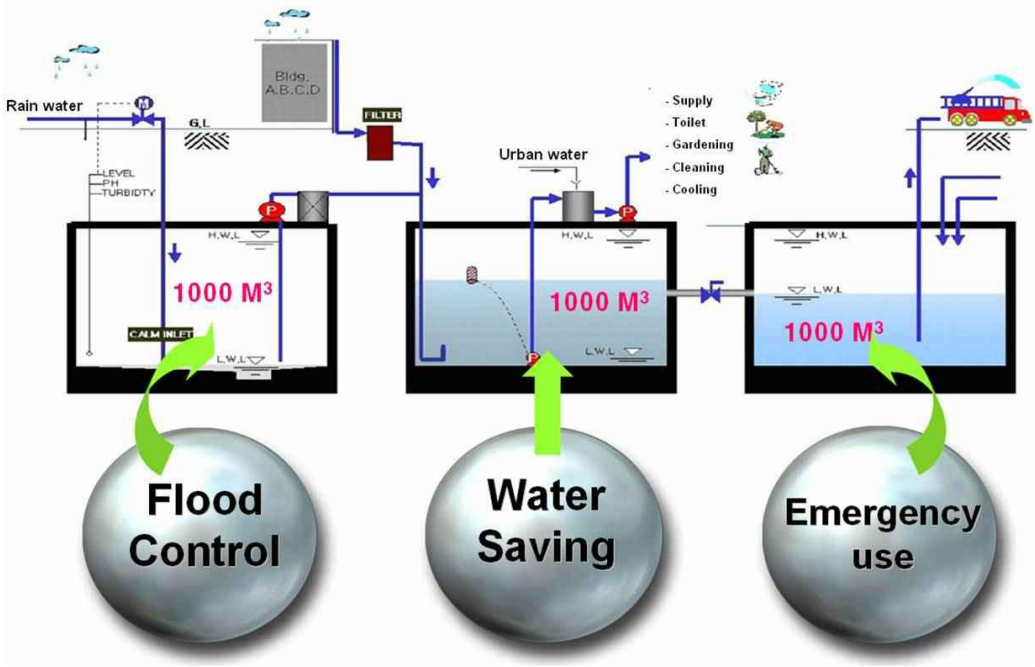

Figure 12: Rainwater Harvesting System Comprising Three Large Tanks for Flood Control, Water Saving and Emergency Use. (Source: **http://ecowaterinfra.org/knowledgebox/documents/)**

Specific Potential Projects

Rainwater harvesting is recommended for public and commercial buildings, heavy water use industries, new buildings and new residential areas.

Science, technology and innovation needs

Rainwater harvesting is basically an old technology that has been practiced over many centuries and therefore the technology involved is quite straight forward. There remains however some questions around quality from a health perspective when used for drinking water. It is also useful to model the benefit of rainwater harvesting project in reducing flash flood and reduction in damage loss.

Summary of STI

Objectives	• Supplement water supply and reduce dependant on river water
Science, Technology and Innovation	Short terms: • Rainwater harvesting system in government, commercial building and heavy water use industries Medium terms: • Show case of large scale rainwater harvesting system. Long terms: • Rainwater technology is supported with right policies for water supply system
Key Area	• Policy, Water Supply, Flood Control, Green Technology

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Rainwater harvesting for new public & commercial buildings and heavy water use industries	Rainwater harvesting system is implemented in 30% of new residential areas and compulsory for heavy water use industries	Show case of large scale rainwater harvesting system In all new housing areas	Treated rainwater for domestic and industrial used	Widely accepted technology for using rainwater in water supply system
Enablers	Enforcement of the existing policy, incentive	Enforcement of existing policy, higher industrial and domestic water tariff	Private investment, right government policy and incentive	Private investment, higher water tariff for domestic and industrial use	Private investment, strong policy and enforcement
Outcomes	Reduced water bill	Reduced dependency on tap water and minimise flash flood	Additional source of raw water Reduced flood risk	Cost saving from delayed construction of major water resources infrastructure	Rainwater as major source in water supply system Significant reduction in flash flood and urban runoff pollution

6.1.10 Zero Discharge

Economic Sector: Urban/Domestic

Description of the Opportunity

Zero discharge is a term that is normally applied to a wastewater treatment facility. Theoretically, zero discharge means that there is no discharge of any kind of pollutants from the treatment facility into the environment. However, as this is impossible in most cases, the term zero discharge is loosely used to define the absence of liquid discharge into the environment. So, quite often, zero discharge and zero liquid discharge are used interchangeably.

For all practical purposes, the concept of zero discharge necessarily means the followings:

- Recovery of reusable water/other materials from wastewater
- Minimization or, no discharge of polluting substances into the environment away from the wastewater treatment facility

The main objectives are to see that the processes utilized for wastewater treatment does not generate any additional pollutants, the production of waste is minimized by suitable selection of unit processes and adjusting operating parameters, and recovery of reusable materials, especially water, is achieved.

Zero discharge system is similar to other conventional waste water treatment systems. However, in addition to primary treatment and secondary treatment, tertiary treatment is normally employed. The applications of appropriate treatment processes are required in order to achieve the objectives of zero discharge system.

Risk Return Analysis

The scores for the return and risk are 6.8 and 6.2, respectively. The return is mainly on ability of the developed technologies and experience to be exported to other developing countries and the ability of the technologies to protect or restore the environment. Similar to advanced water and wastewater treatment, most of the technologies are readily available and thus, the competition is expected to be high.

The risk is on the commitment from the government and the industries in implementing zero discharge. Furthermore, as zero discharge will require the application of advanced treatment processes, the technology, local skills and capacity, and adoptability of the existing (imported) technology will be the factors that hinder the progress of the

Economic feasibility

The main benefits of applying zero discharge are the preservation and protection of the environment and minimization of natural water resources utilization. This will have significant effect on other water-related economy generating sectors. Furthermore, the installations of these facilities are economy generating activities and

the experience and knowledge in development and application of the technology can be exported to other developing countries.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

NEWater, Singapore *(http://www.pub.gov.sg/NEWater)*

NEWater project in Singapore is a good example of zero discharge application for a sewage treatment plant. All the sewage discharged into the treatment plant is transformed into potable water through stringent purification and treatment process using advanced dual-membrane (microfiltration and reverse osmosis) (Figure 13) and ultraviolet technologies. The NEWater is used for wafer fabrication processes, non-potable applications in manufacturing processes as well as air-con cooling towers in commercial buildings. Additionally, NEWater is mixed and blended with reservoir water and then undergo conventional water treatment to produce drinking water.

The NEWater Factories at Bedok and Kranji Water Reclamation Plants was commissioned at the end of 2002. Following that since Feb 2003, NEWater has been supplied to wafer fabrication plants at Woodlands and Tampines/Pasir Ris and other industries for non-potable use. In Jan 2004, another milestone in the NEWater initiative was accomplished with the commissioning of the third NEWater Factory at Seletar Water Reclamation Plant which began supplying NEWater to the wafer fabrication plants at Ang Mo Kio. The total capacity of the 3 NEWater factories is 92,000 m^3/day or 20 MGD. Public Utility Board of Singapore has introduced 3 MGD of NEWater (about 1% of total daily water consumption) into thier raw water reservoirs. The amount will be increased progressively to about 2.5% of total daily water consumption by 2011.

Figure 13: Membrane technology used in the production of NEWater

Siemens Power Generation, Germany (Mürau and Schöttler, 2005)

Siemens Power Generation has adapted Zero Discharge Concept at one of their plants in Germany. Water losses which have been considered are disposals coming from the clean drains system of the water/steam cycle including the one termed as HRSG. The Zero Discharge Concept was designed to collect all kinds of clean drains and blowdown routing and send them to condensate polishing plant. The regenerated condensate is fed back to the water/steam cycle.

The Zero Discharge system saves more than 90% waste water compared to a conventional water/ steam cycle. Beside the environmental aspect the Zero Discharge Concept enhance the project profitability by life cycle cost reduction.

Specific Potential Projects

Zero discharge system can be applied to most wastewater treatment facilities, either domestic or industrial. As water recovery can be achieved through the installation of such system, it can possibly be emphasized in water stress areas such as Kelang Valley and Melaka. Alternatively, the system can also be implemented in areas where high natural water body quality is to be maintained, such as upstream of tourism site, where discharge of effluent is to be minimized.

In general, the technologies for water recovery are well established. The uses of technologies such as evaporation, membrane filtration, and chemical oxidation have been reported. Research on these technologies in local universities has been going on

for many years. However, the collaboration between the local researchers and the practitioners are still lacking. Hence, most of the advanced technologies currently employed are imported particularly from the developed countries.

Summary of STI for zero discharge

Objectives	• To ensure that the processes utilized for wastewater treatment does not generate any additional pollutants, the production of waste is minimized by suitable selection of unit processes and adjusting operating parameters, and recovery of reusable materials, especially water, is achieved. • To protect and preserve water environment • Significant impact on other water-related economy generating sectors which include tourism, ecosystem services, and health • Experience and knowledge in developing and applying the technology can be exported to other developing country.
Science, Technology and Innovation	Short terms: • Installation of effective tertiary treatment for water recovery at wastewater treatment facilities, either domestic or industry + Emphasized in water stress areas such as Kelang Valley and Melaka + Also implemented in areas where high natural water body quality is to be maintained, such as upstream of tourism site, where discharge of effluent is to be minimized Medium terms: • Development and installation of state-of-the-art technologies for manufacturing processes and end-of-pipe tertiary wastewater treatment Long terms: • Future technologies should be directed towards recovery of materials other than water.
Key Area	• Development of human resource • Enhancement of R, D & C aspects of the technologies • Improvement in the policies and regulations pertaining to zero discharge implementation. Lucrative incentive should be provided to promote the industry to go for zero discharge

Investment Roadmap

	2010-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of effective tertiary treatment for water recovery at wastewater treatment facilities, either domestic or industry Emphasized in water stress areas such as Kelang Valley and Melaka Also implemented in areas where high natural water body quality is to be maintained, such as upstream of tourism site, where discharge of effluent is to be minimized	Local development and installation of state-of-the-art technologies for manufacturing processes and end-of-pipe tertiary wastewater treatment expansion of zero discharge application to other areas	Export knowledge of wastewater treatment Recovery of materials other than water, e.g. energy	Low carbon footprint technologies
Enablers	Incentives, policy, Stringent regulation & enforcement	Incentive and policy Private & institutional initiatives	Private & institutional initiatives	Political commitment and concern for global warming
Outcomes	Water saving. Hence reduce water stress Improvement of water quality and human and ecosystem health at sensitive areas	Wealth creation Water saving. Hence reduce water stress More improvement of water quality and human and ecosystem health in the country	Wealth creation Eco-friendly industry	Support national low carbon policy

6.2 Opportunities for Sustaining the Resource

6.2.1 Exploit Groundwater Further as a Resource and Drought Protection

Economic Sector: Water

Description of the Opportunity

Groundwater is a natural resource that is being under-utilised in Malaysia, given the fact that the average rainfall in Malaysia is around 3000 mm per year. With groundwater recharge between 200 – 300mm per year, the total groundwater storage is approximately 5,000 billion m^3. Despite the estimated safe yield of 14.7 billion m^3 per year particularly available in Peninsular Malaysia, the groundwater usage is only 2-3% of the total water supply in Malaysia. It is very often the case that the provision of public water supply could barely cope with the rapid and immediate water demands, especially in the areas that experience rapid population growth and socio-economic developments. Issues such as high transfer cost and higher cost of raw water treatment generally hinders the potential growth of the water supply infrastructure and indirectly impedes the growth of new development projects.

Thus, groundwater can play a pivotal role to complement and cater for overall water supply needs (immediate, emergencies or future) as it is:

- generally not affected by severe drought
- not subjected to abrupt interruption or change due to water supply cut or rationing
- closer to the point of demand
- cheaper to develop as it requires minimum treatment as it is usually of good quality
- effective in reducing water bills as it can supplement the municipal water supply

Groundwater is a major source of water in many countries. For example 98% of Denmark's water consumption is sourced from groundwater, Austria 98%, UK 85%, Thailand 80% , China 78% and Germany 65%. In Malaysia, in the state of Kelantan, groundwater contributes 70% to the total consumption. During droughts, groundwater is used to supplement supply from surface water in densely populated areas such as Kelang Valley.

A large scale exploration of groundwater has been attempted by Sime Darby in Batang padang District. The pumping test revealed promising results with sustainable yield up to 5000 Mil Litre/day from fractured rock and alluvial aquifer systems and up to 5 Mil Litre/day from other rock aquifer systems

(http://www.simedarby.com/Sime_Darby_Unveils_Its_Pilot_Groundwater_Project_In_Perak.aspx).

It is recommended that groundwater is to be used in conjunction with surface water to reduce heavy dependence on rivers, reservoirs and lakes. Groundwater is also suitable for consumption by industries that need high quality water. As groundwater supply is not interrupted during dry spells, it can relief water supply problems during drought periods.

Risk Return Analysis

The total return score is calculated as 7.7 and the risk score is 2.3.

Economic Feasibility

Raising the portion groundwater consumption in the overall water supply is a strategic move especially to minimise severe socio-economic impacts from prolonged drought. In the future groundwater investment can be more attractive because of the high cost for transferring water and increasing river pollution.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Management of Groundwater Resources in Denmark.
(http://www.unep.org/gc/gcss-viii/Denmark.IWRM.pdf)

Protection of ground water is so vital in Denmark because it provides almost all water supply for domestic and industrial uses. Since 1888, all geological information from groundwater drillings are being reported and stored on a national level under the Ministry of the Environment. Despite pressures from pesticide use and other contamination, it has been possible to maintain a high quality of water, which does not need special treatment or purifying before drinking or other use.

A new law on Environmental and Ecological Objectives including groundwater was issued in 2003. The assignment of clear responsibilities is very important. In Denmark the state is responsible for the international obligations, the overall administration and establishment and adjustment of the legislative framework. Also research and development are under the state's responsibility. The regional level is responsible for issuing permits on groundwater abstraction based on detailed mapping and planning. The permits are based on a political prioritisation based on plans for development of the society and its water demands and environmental objectives. The

regional level is also responsible for exercising protection of the groundwater resources and regional monitoring. The local level is responsible for planning of the water supply for the municipality and the inspection of the technical standard at the Water Supply plants and the quality of the drinking water, and the Water Supply Plant is responsible for the quality of the drinking water.

Stakeholders and public participation at various levels of management is central for achieving the objectives and huge efforts are used on information for making the groundwater conditions transparent for the society.

In 1987 a nation-wide groundwater-monitoring network was established. Partly based on the existing wells from more than 4500 Water Supply plants and partly on more than 50 special monitoring fields representative for the Danish groundwater conditions. Annual reports from the monitoring program supports the awareness of the quality of the drinking water and the protection of the groundwater is maintained.

Specific Potential Projects

The Department of Mineral and Geoscience has identified sites with high potential of groundwater yield. Groundwater resources are being explored in various parts of Kelantan which include Pengkalan Chepa, Tanjung Mas, Kubang Krian, Bachok, Wakaf Baru, Tumpat and Rantau Panjang; Kampung Kepong in Terengganu, Cuping in Perlis, Sg Ular and Rompin in Pahang. In Sarawak, groundwater is important source of water supply for many coastal villages. A large reserve of groundwater reserve was recently found in Batang Padang district.

Science, Technology and Innovation Needs

Technology for groundwater exploration is already available locally and can be further strengthened by incorporating foreign technology. The present rate of groundwater consumption of only 2% should be increased to at least 20% in order to benefit from the high groundwater quality and relief possible water stress especially during dry periods. An important issue to be addressed is determining the sustainable ground water yield. This can be done by undertaking hydrogeological investigations that include describing and characterising the aquifers, determine key hydrologic parameters and using groundwater models.

Summary of STI

Objectives	• Increase groundwater consumption to 20% in order to reduce dependent on surface runoff and ensure sufficient water even during prolonged droughts.
Science, Technology and Innovation	Short terms: • Detailed mapping of the country's groundwater resources Medium terms: • Wider exploration of groundwater resources especially in highly populated area Long terms: • Conservation and monitoring of groundwater yield and quality
Key Area	• Hydrogeology, water supply

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Intensive assessment of current and future water resources and demand in all states	Complete mapping of Malaysia's aquifer systems and its capacity Study of Ground water physico-chemical characteristics and propose treatment	Design and installation of large scale groundwater plant to supplement water in 3 major areas (KL, Penang, Johor Bahru)	More groundwater plant to be installed to supplement water in major areas	Technology is fully developed for large and small scale groundwater plant
Enablers	KeTTHA, NAHRIM, JMG	KeTTHA, NAHRIM, JMG	KeTTHA, NAHRIM, JMG, State Gov	KeTTHA, NAHRIM, JMG, State Gov and private investment	Private investment
Outcomes	Updated reliable water supply and demand data for Malaysia known	Updated, reliable Malaysia's aquifer system and its physi-chemical quality known	Increase groundwater usage to 10%. Reduce surface water usage thus cut down treatment cost and river water quality downstream	Increase groundwater usage to 20%. Reduce surface water usage thus cut down treatment cost and river water quality downstream	Groundwater can be a main source for areas far away from water supply

6.2.2 Improve Flood Forecasting and Mitigation

Economic Sector: Water

Description of the Opportunity

Globally, flood causes billions of dollars of losses to properties, human beings and ecosystems. The extent of the impacts is expected to be more severe in the future due to climate change and sea level rise. Developing countries especially in humid

tropical climates would suffer the most because the rainfall there is more torrential and their ability to cope with disaster is limited.

There are huge opportunities to help solve flood problems globally especially in the developing countries. This can be done by offering training and consultancy services, and construction of flood mitigation structures. Being located in one of the wettest regions, Malaysia has vast and long experience in conducting research, planning and management of floods.

Risk Return Analysis

The total return score is calculated as 7.7 and the risk score is 2.3.

Economic Feasibility

The market potential is huge but competition is also high especially from established international companies such as the Danish Hydraulic Institute (DHI), WL Delft Hydraulics, Edenvale Young Associates Ltd and HR Wallingford. In Malaysia there are already local companies involved in hydraulics modeling work such as Dr Nik & Associates Sdn Bhd. Due to a lower operating cost, Malaysian companies are expected to be able to offer similar quality of work but at a more competitive price.

Benchmarking against similar initiatives (in Malaysia and overseas)

Danish Hydraulics Institute (DHI)

DHI is an independent, international consulting and research organisation which focuses on advanced technological development and competence within the fields of water, environment and health. DHI offers a wide range of consulting services and leading edge technologies, software tools, chemical / biological laboratories and physical model test facilities as well as field surveys and monitoring programmes. DHI has more than 950 employees worldwide. DHI has expanded considerably over recent years and is today a truly global organisation with a strong regional presence world-wide. The continuing success of DHI is attributed to the increased importance of water, the environment, health aspects of water use, climate change and industrial production and products now on the global agenda.

Specific Potential Projects

Developing countries especially in the wet tropical region

Science, technology and innovation needs

The nature of ST&I opportunities in this field is more on knowledge economy by exporting our expertise and services. Development of Malaysian brand hydraulics and hydrological softwares for predicting flood and designing mitigating structures is needed. The solution must be integrated by incorporating GIS and satellite mapping technology which can offer real time monitoring.

Summary of STI

Objectives	• Strengthen knowledge economy in water sector by providing solutions to tropical problems
Science, Technology and Innovation	Short terms: • Application and adaptation of flood forecasting and mitigation models Medium terms: • Improved flood prediction technique and perfection of early warning system Long terms: • Development of local brand hydraulic and hydrological softwares.
Key Area	• Hydrology, Hydraulics, Modelling, Resources Economy

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Application and adaptation of flood forecasting and mitigation models	Perfection of flood early warning system Technique for predicting future rainfall and flood	Adaptation measures to flood associated with climate change	Development of local brand hydraulic and hydrological software specializing in tropical environment	Technology is fully developed and ready for market
Enablers	Sufficient numbers of professionals	Investment on state of the art technology	Private investment	Critical mass of professionals	Private investment
Outcomes	Capable of using models and up to date software	Minimization of flood damage	Reduced risk of extreme flood associated with climate change	Malaysian global player	Market services

6.2.3 Reform Water Education Approach

Economic Sector: Education

Description of the Opportunity

Education is seen as the principal mechanism for creating the generational change required for a sustainable future. A well-informed and well educated public will demand a transition to environmentally benign industries and protection of Malaysia's substantial ecosystem and water resources for future generations to use and enjoy.

Risk Return Analysis

The total return score is calculated as 8 whereas the total risk scores is calculated as 3.8.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Many countries have advanced significantly in delivering environmentally sustainable education at all levels. Occasionally this causes a backlash from vested interests who oppose a 'green agenda'. In Malaysia, river clean-up programs includes the *Cintailah Sungai Kita (Love Our Rivers) Campaign (Malaysia)*. In this programme River Brigades consisting of high school students undertook river clean-up programs. The brigades removed debris, stabilized the bank of the small rivers and replanted them. A competition was organized to select the most "beautiful" river.

Rivers Alive (Canada, USA and China) is another initiative aiming to involve students in both research and action. Data of water quality sampling, invertebrate analysis, vegetation surveys and site mapping are collected and compared, for example, in rivers and estuaries. Marsh restoration was completed in several areas. Youth learned more about wetlands in a series of workshops. Rivers Alive '96 helped youth to gain first-hand experience in environmental analysis, work together to compare and exchange ideas, and most importantly, develop a sense of stewardship for estuarine environments. In the future, research results and general information will be shared globally with other youth groups.

Specific Potential Projects

Currently water awareness or education in school and colleges are championed by NGO's. Therefore the content or curriculum is diversified according and based on different group interest. Therefore it is proposed to develop a courseware on water awareness using animation and cartoon both in Bahasa Malaysia and English. The courseware should also include a programme on how to monitor our rivers and pollution prevention.

Science, Technology and Innovation Needs

STI requirements include curricula development for primary, secondary and tertiary education levels; public environmental awareness campaigns; support for river and

wetland local volunteer communities with suitable education materials; media campaigns; websites education portals; film and video documentaries.

Summary of STI

Objectives	• To ensure that Malaysian citizens are environmental conscious starting from a young age. • To ensure water education be embedded in curricula for primary, secondary and tertiary.
Science, Technology and Innovation	Short terms: • Development of local based water module or curricula. Medium terms: • Establishment of water care group and unification of NGO's related to water and environmental awareness • Long terms: • Future technologies should be directed towardsonline water education.
Key Area	• Improvement in the education policies to promote water education and awareness in school and at tertiary levels.

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Development of local based water module/curricular	Establishing water care groups	Online water education	Integration of education and awareness system	
Enablers	Education Ministry together with all agencies related to water sector	Community based national program	Web 3.0 - intelligent web	Convergence of all good quality education material with information access and strong community involvement	
Outcomes	Incorporate water education in primary, secondary and tertiary education	Experiential learning	Universal access to water information	Whole population values water	

6.2.4 Improve Ecosystem Protection from Point and Non-point Pollution

Economic Sector: Ecosystem Services

Description of the Opportunity

Malaysia's rapid economic and population growth has resulted in the loss of many ecosystem services due to land use change. Current ecosystem protection and conservation in Malaysia are mostly focusing towards biodiversity such as endangered plant and animal species, but lack of focus on the protection of ecosystem services. There are constraints and opportunities for the integration of ecosystem services into ecosystem protection. Nevertheless an appropriate framework for planning for protection and conservation of ecosystem services is a matter of urgency.

Risk Return Analysis

Protected ecosystem services are marketable, particularly in watershed protection, carbon emission offsets, and biodiversity conservation. Potential buyers in watershed protection are the industrial and agricultural water users because they depend on a secure and stable water supply. The municipal water utilities and consumers are willing to pay for quality water and cost reduction. Payment for ecosystem protection can also be expected from the agencies managing environmental risks (e.g. floods). Carbon emission offsets can be traded to industries seeking to comply with carbon rules and by agencies and municipalities seeking to improve air quality or to avoid deforestation. Market value in relation to biodiversity conservation may come from the conservation agencies & NGOs working on private lands, tourist industry, for landscape beauty or protection of key species, from land developers (to offset for damage, or for amenity values), and from farmers (to protect pollinators, sources of wild products). There are several areas of concern in ecosystem protection and conservation in Malaysia which include technical and market information, limited experience throughout the value chain, inadequate legal and institutional frameworks, suspicion of markets for securing "public goods", and equity. Political and institutional barriers may represent the major obstacle due to lack of understanding and appreciation of the ecosystem services values to the general well-being of the community.

Economic Feasibility

Ecosystem services such as carbon sequestration, wildlife habitat for species with commercial and cultural significance, or erosion control that maintains water quality do not have tangible economic or market values. In other words, many ecosystem services suffer from what economists describe as market failure, or inability to be sold or exchange in a market. This is because, partly, due to the fact that people who have not paid for a service, such as the services available from a clean stream of river, cannot be prevented from enjoying the benefits of the service. Those who pollute the river do not suffer direct economic consequences. One person's use or enjoyment of a resource, e.g. the flood mitigation by riparian areas, does not prevent or preclude others from enjoying the service. Information on the impacts of urban development on the values of affected ecosystem services in land-use decisions must be coupled with market driven information.

Unfortunately, most non-absolute value of ecosystem services in the country is yet to be discovered. Economic study to identify and quantify components of ecosystem service values are necessary for a preliminary assessment of their magnitude so that they may be incorporated into frameworks of decision making.

Ecosystem services, as a whole, have infinite use value because human life could not be sustained without them. There is a need, therefore, to estimate the tradeoffs the society will bear that requires estimation of marginal value of ecosystem services to determine the costs of losing – or the benefits of preserving – a given amount of quality of services. Although the information needed to estimate marginal values is difficult to obtain and is presently unavailable for many aspects of the services, even imperfect measures of their value, if understood as such, are better than simply ignoring the ecosystem services altogether.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

The New York City drinking water supply system is the largest unfiltered water supply in the US that provides approximately 1.2 billion gallons of high quality drinking water to nearly one-half the population of New York State every day. In order to safeguard this irreplaceable natural resource a comprehensive and innovative watershed protection plan was generated in January 1997. The watershed protection program, at the cost of $1 billion, managed to avoid the need for costly filtration of $8.0 - $10.0 billion to construct the facility and approximately $1.0 million each day to operate and maintain the filtration plant. The Great Barrier Reef in Australia is an example where application of STI has driven government investment and protection which also include establishment of new legislation to non-point discharge and multi zoning of the marine park with restricted use of each zone. Extensive ecosystem science provided the foundation for the development detailed code of practice for tourism operators to minimise the ecosystem damage, enabling a sustainable eco-tourism industry.

Specific Potential Projects

Malaysia is rich in tropical ecosystems (forest, freshwater, and marine). These include forest reserves and national parks. Many of these ecosystems are facing threats from human intervention due to tourism and land-use change. The need for protection and conservation planning and action is imminent. New conservation approach of ecosystem services is evolving from the National Park system to

Integrated Conservation and Development Projects (ICDPs) and newly emerging Compensation and Reward for Environmental Services (CRES) and Payment for Environmental Services (PES) which form part of the market-based management tool of the environment. Decisions to protect and conserve a specific ecosystem may involve the following aspects:

a) developing the scientific base for understanding ecosystem services, identifying threats, and determining priority areas;
b) promoting innovative policies that support human development and the conservation of freshwater and ecosystem services; and
c) conducting field programs to test new approaches on the ground.

Science,Technology and Innovation Needs

Ecosystem protection implementation requires an assessment that involves identifying spatial priorities for conservation action (i.e. area selection) and the development of an implementation strategy with the involvement and collaboration of the stakeholder, i.e., the agencies who will take implementation of the plan forward. Ecosystem services to be captured in the protection assessment and planning may include regulatory, provisioning, supporting, and cultural.

Summary of STI

Objectives	• Protection of ecosystems from point and non-point pollution sources so that services by the ecosystems can be optimised.Assimilative capacity; species-based water quality standards & targets, Reserves Plan
Science, Technology and Innovation	Short terms: • Developing a national scale ecosystem services assessment protocol Medium terms: • Application of online sensors and satellite technology • Advanced wastewater treatment, zero discharge, best management practice, precision farming for efficient use of agriculture chemical. Organic farming is widely practised Long terms: • Design of sustainable ecosystem management • Scientific demonstration/ establishment ecosystem benefit compared to unsustainable practices
Key Area	• Wastewater treatment, precision and organic farming

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Developing a national scale ecosystem services assessment protocol	Application of online sensors and satellite technology	Advanced wastewater treatment, zero discharge, best management practice, precision farming for efficient use of agriculture chemical. Organic farming is widely practised	Design of sustainable ecosystem management	Scientific demonstration/ establishment ecosystem benefit compared to unsustainable practices
Enablers	Political will and funding, overcoming institutional barrier	funding and adaptation of existing technology	Polluters pay scheme strategy is fully enforced	Best practise policy, guidelines and implementation	Massive loss of biodiversity elsewhere in the world. Malaysia is less impacted by climate change
Outcomes	Nationwide prioritisation of ecosystem services and risk protection requirement	Fully established national scale assessment and monitoring	Improvement in overall water quality	Potential of ecotourism is fully realised	Malaysia recognised as a global resource of biodiversity and genetic resources

6.2.5 Clean-up and Rehabilitate Waterways in Highly Visible Locations to Improve Aesthetics and Ecological Functioning

Economic Sector: Tourism and Development

Description of the Opportunity

Besides being a water source, rivers also provide numerous kinds of service to the population. In less urbanized areas, significant portions of the rural dwellers are directly affected by rivers, culturally, socially and economically. Rivers support the livelihoods of riverine communities. Rivers serve as feeding and breeding grounds for a wide range of riverine biodiversity that lives in the river as well as in the river-fringing vegetation. It plays an important role as food resources including various

kinds of freshwater fish, shrimps, etc. In many remote areas rivers are still utilised as means of transport and navigation routes.

In Malaysia, water pollution originates from point sources and non-point sources. Point sources that have been identified include sewage treatment plants, manufacturing and agro-based industries and animal farms. Non-point sources are mainly diffuse ones such as agricultural activities and surface runoff. Some of the river systems in Malaysia suffer from acute levels of pollution due to urban and industrial development. River that flow through densely populated areas including towns and housing estates are often polluted with solid wastes and eroded soil resulting in pollution levels incapable of sustaining aquatic life and blockages that cause flash flood. Soil erosion caused by land development in the surrounding areas and untreated waste discharges from nearby factories further contribute to the high pollution levels. These wastes not only destroy aquatic life but also the surrounding vegetation, flora and fauna due to its highly acidic levels.

In 2008, the major pollutants detected were biochemical oxygen demand (BOD), ammoniacal nitrogen and suspended solids. High BOD is attributed to untreated or partially treated sewage and discharges from agro-based and manufacturing industries. The main sources of ammoniacal nitrogen were livestock farming and domestic sewage while the sources of suspended solids were mainly from earthworks and land clearing activities (Malaysia Environment Quality Report, 2008). Figure 14 shows the trend of water quality in rivers from 1987 to 2008.

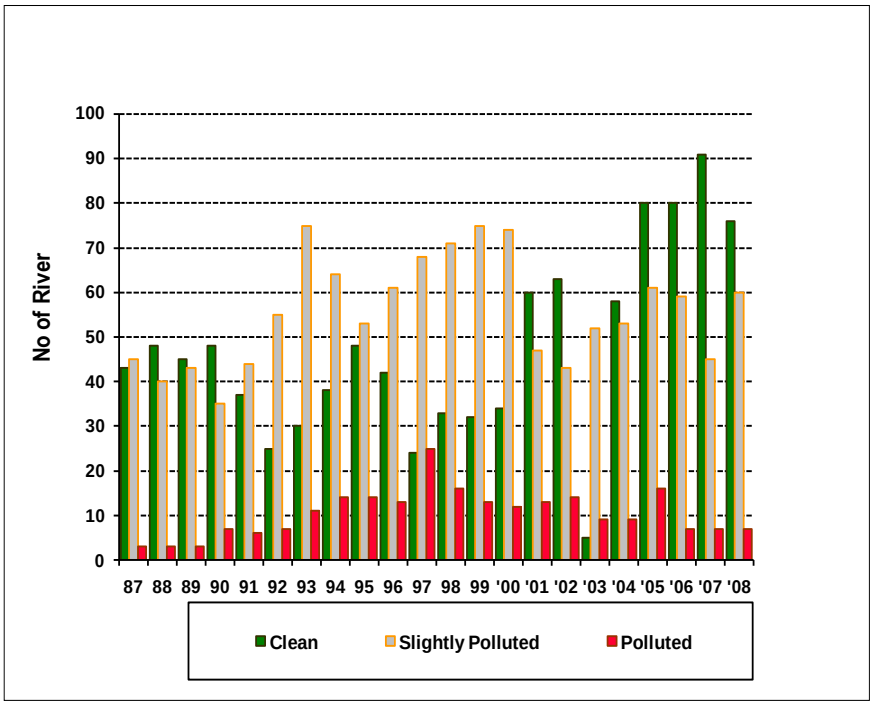

Figure 14: Water Quality Trends in Malaysian Rivers from 1987 to 2008.

Risk Return Analysis

The scores for the return and risk are 7.0 and 3.5, respectively. The return is mainly on the high cost market potential. Potential to protect or restore ecosystems would also involve hard to return ecological function. The risk is on political or institutional barriers where human factor has been identified as the highest risk.

Economic Feasibility

Clean water contributes to the recreation and tourism industry worldwide by accentuating beautiful beaches, white-water rivers, mountain lakes, and aquatic ecosystems such as coral reefs. Water has a powerful attraction for people. When people decide to plan vacations and travel for recreation, instruction, and pleasure, many have a strong tendency to head to the water. For example, a day at the beach provides recreation, relaxation, and a chance to renew the spirit. A third of all Americans visit coastal areas each year, making a total of 910 million trips while spending about $44 billion. Coastal tourism supports businesses like hotels, resorts, restaurants, outdoor outfitters, chartered fishing services, and travel agencies.

Benchmarking River Rehabilitation Locally, Regionally and Internationally

River Rehabilitation in Malaysia

Currently, there have been some fragmented efforts from the authorities and the public for river restoration and rehabilitation in Malaysia. The Drainage and Irrigation Department has initiated a program to clean up the Kelang River, i.e. to clean the river of solid waste and silt, to improve water quality to Class III (recreational purposes without body contact) and to beautify strategic stretches of the river for recreational purposes. So far, it has had mixed results. Some stretches in the cities are showing good results as more attention has been focussed there but elsewhere the river is as dirty as ever.

The rehabilitation and beautification of rivers has proved to benefit both the economy and the environment. Since its heyday, the Malacca River has slowly degenerated from an important historical lifeline to a large sewage drain filled with rubbish that nobody wants to see. Today, the Malacca River has been cleaned up and rehabilitated. The rehabilitation work was completed after 6 years in 2007 and the total cost was RM 200 million. Smart looking cafes line its banks and now the tourists can take a river cruise and see the highlights of Melaka's heritage, when it was a key port of the peninsula. Rehabilitation of the Melaka River has enhanced property values and increased the number of tourists to the historic city. Properties that ranged from 200 to 5,000 sq ft in the old town area, like Jonker Street, Heeren Street and Lorong Hang Jebat, were valued at RM300,000 to RM400,000 before the river was rehabilitated. Values have since increased to RM800,000 and more. Melaka has also attracted a lot of investors due to the increase in tourists (http://www.escpile.com/map/Malaysia_039.pdf).

Figure 15: Before and After Photographs of Sungai Melaka Rehabilitation Programme (http://www.escpile.com/map/Malaysia_039.pdf)

Figure 16: Property Image and Values were Significantly Improved with the Sheet Piling and Associated Works (http://www.escpile.com/map/Malaysia_039.pdf)

River Rehabilitation of Singapore River

In 1977, The Singapore government initiated an action plan on The Clean-up of the Singapore River and Kallang Basin. It involved the development of infrastructure such as housing, industrial workshops and sewage; massive resettlement of squatters, backyard trades and industries and farmers; re-siting of street hawkers to food centres; and phasing out of pollutive activities. Industries located by the river were removed and squatters were resettled into flats. Refuse was collected daily for incineration, while hawkers were issued licenses and provided specified areas with proper sewerage amenities. The dredging of the river bed and the removal of hundreds of tons of debris which had been piled up over the years helped marine life to return to the tidal river.

River Rehabilitation of Cheonggyecheon River

Cheonggyecheon River project in Seoul, South Korea is the most talked about river rehabilitation which cost 386 billion won (RM927 million). Once an unsightly and smelly river, it was completely roofed by a highway in the 1960s to ease growing traffic congestion and to hide it from public view. In 2003, the highway was tear down to bring the river back to life. The government planned to develop the areas around the stream, not only to restore the ecology but the history, culture, and economy of the neighbourhood. The project re-purposed more than 75 percent of the dismantled highway material for reconstruction and rehabilitation of the stream's banks and commercial corridor. It has also allowed a number of birds, fish, and insects to return to the area. It has also decreased the temperature by 3.6^{o}C in the hot summer months.

Figure 17 shows the Cheonggyecheon river where it is a vital part of the city's commercial and tourism sectors. The project has also proven that environmental restoration can revive culture and community as well. With the completion of the project in 2005, the tourism industry has also improved. In 2008, it was recorded that 75.5 million people visited the area. About 18.1 million, or 24%, were foreigners. Property prices have also increased 30% to 50% in areas along the river depending on the location.

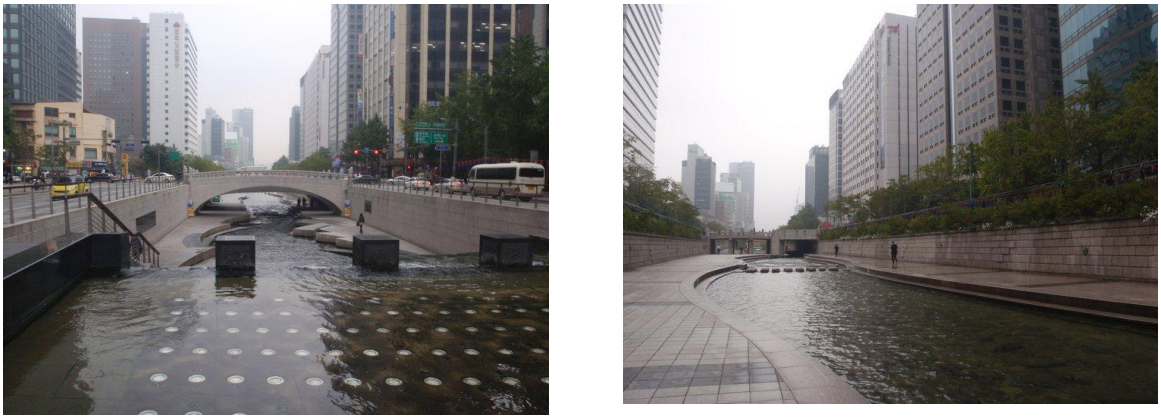

Figure 17: Cheonggyecheon River in Seoul, South Korea *(photo courtesy of Mohd Ismid Mohd Said)*

Specific Potential Projects

Project: rehabilitation of Sungai Segget

Implementation:

- Soft engineering rehabilitation techniques
- improve waste effluent disposal standards and enforce
- provide public access
- re-stock fish and re-establish habitat
- rubbish capture and removal

Reason: The rehabilitation of Sungai Segget will enhance and bring back the significance of Sungai Segget as an integral part and the heart Johor Baharu city centre. It will also increase the price of real estate and attract tourist to the area.

Science, Technology and Innovation Needs

Cleaning and rehabilitating rivers requires a multi-pronged approach, including catchment management, pollution source control (e.g. STPs) and in-stream habitat repair. Most STI is already available but implementation can be a problem due to the integrated nature of the problem, lack of system understanding, and inadequate analysis of best return on investment. Hence STI should be more focussed on integrating existing tools than developing new ones.

Summary of STI

Objectives	• To protect and preserve rivers via river rehabilitation projects • Implementation of cleaning and rehabilitating rivers using available methods with focus on integration approach
Science, Technology and Innovation	Short terms: • Design of national river rehabilitation program Medium terms: • Mapping and prioritisation of site including producing tropical river rehabilitation manual. Long terms: • Future technologies should be directed towards river rehabilitation knowledge and export to other tropical countries.
Key Area	• Improvement in the integration and implementation of river rehabilitation using available methods.

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Design of a national river rehabilitation program based on best available science and proven green and soft engineering techniques. Green jobs initiative supported by river restoration short courses.	Careful mapping and prioritisation of sites based on transparent TBL criteria and public consultation. World best practice river rehabilitation manual for tropical river systems developed. Imaginative new sustainable public access and enjoyment facilities tested in virtual landscapes. Flood mitigation, navigation and real estate developments optimised.	Project initiation and implementation technical supervision and guidance, with before and after evaluation sites established. Restoration sites used effectively in primary, secondary and tertiary and third age education.	Tropical river rehabilitation knowledge packaged for export to other tropical countries, supported by regular 'science tours' of icon projects.	Malaysia submits most successful river rehabilitation project to the International River Prize following best example of pre/post evaluation.
Enablers	Program business plan presented to government	Public support. Business joint ventures. Government financial support.	University staff and/or consultants to supervise projects. Community, local government and local industry tangible support.	Knowledge packaging. Overseas marketing. Growth of Malaysian-based consulting companies.	River prize application.
Outcomes	National river rehabilitation program initiated including 'green jobs' initiative	Priority sites identified. Techniques established. Guidelines for tropical systems finalised. Riverine landscaping concepts and planning for new business opportunities completed.	Six major projects completed for R1billion. Ecosystem functioning restored and iconic species restocked. Local pollution sources controlled. Urban and rural dwellers flock to new tourism sites which emphasised encouraging human sharing of river environments in novel but sustainable ways. Learning outcomes achieved across all sectors of the community.	Tropical river rehabilitation knowledge and skills exported to tropical countries earning Malaysia export income.	Malaysia wins international riverprize ($500,000) that provides impetus to overseas 'twinning ' projects.

6.2.6 Irrigation Water Use Efficiency

Economic Sector: Irrigated Agriculture

Description of the Opportunity

Agriculture is the single largest user of freshwater resources in Malaysia, accounting for about 65 – 70% of the total consumptive use of water. Irrigated agriculture will continue to be the largest water consumer for the foreseeable future. In Malaysia, paddy is the only crop for which extensive irrigation facilities are provided. The method of irrigation is basically basin irrigation where small ridges surround individual lots in which paddy is grown in a depth of standing water. There are 564 000 hectares of wet paddy land in Malaysia, 322 000 hectares of which are capable of double cropping through the provision of irrigation facilities. Irrigation efficiency is about 50 percent for the larger schemes, though some of the smaller schemes operate at an efficiency of perhaps less than 40 percent. (Ref: FAO Corporate Repository: The FAO-ESCAP pilot project on national water visions. From vision to action).

Except for water lost through evapotranspiration, irrigation water is recycled back to surface water and/or groundwater. However, agriculture is both a cause and victim of water pollution. It is a cause through its discharge of pollutants and sediment to surface and/or groundwater, through net loss of soil by poor agricultural practices, and through salinisation and waterlogging of irrigated land. It can be a victim through use of wastewater and polluted surface and groundwater which contaminate crops and transmit disease to consumers and farm workers. Agriculture exists within a symbiosis of land and water and, as FAO (1990a) makes quite clear, "... *appropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired."*(FAO Corporate Repository: Control of Water Pollution Through Agriculture (1996)).

Agriculture is the single largest user of freshwater on a global basis and is a major cause of degradation of surface and groundwater resources through erosion and chemical runoff worldwide. The associated agrifood-processing industry is also a significant source of organic pollution in most countries. Aquaculture is now recognised as a major problem in freshwater, estuarine and coastal environments, leading to eutrophication and ecosystem damage. At the same time sustainable food production to meet a growing population is under pressure. Hence STI will have a

broad-based market domestically, regionally and locally. STI has the potential to reduce water quality impacts related to irrigated agriculture, and hence play a role in restoring affected ecosystems and returning impaired ecosystem services. Malaysia is well placed to develop and implement technologies to reduce irrigated agriculture water quality impacts in tropical environments. Such technologies will have application in other tropical regions globally and may potentially be modified to non-tropical environments.

There should be few technical barriers for common water quality issues such as sediments, nutrients and pathogens. However more specialised water quality issues such as endocrine disruption present some technical barriers. Malaysia has adequate personnel skills and capacity to address common water quality problems. Additional skills and capacity would be required to address more complex problems. The potential for adopting new technologies to control water quality impacts of irrigated agriculture is moderate, as such measures has been successfully utilised in other countries. The proposed STI is holistically robust as irrigated agriculture and downstream users will be well served by improved quality of water supplies and return flows. No system-wide downsides are apparent.

Risk Return Analysis

The total return score calculated is 5.7 and the total risk score is 3.2.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Australia is implementing a A$13 billion *Water for the Future* program that includes A$6 billion for improved efficiency for irrigated agriculture. This work is taking place in an environment of decreasing water resources and declining irrigation industry, but should provide greater water security for irrigation businesses that remain after the rationalisation. Most of the funds are directed to sealing irrigation channels, especially in leakage 'hotspots' and assisting farmers convert to more efficient on-farm water application technologies.

Science, Technology and Innovation Needs

The recommendations for action to minimise the degradation of water qualities due to agricultural activities are as follows:

- establishment and operation of cost-effective water quality monitoring systems for agricultural water uses
- prevention of adverse effects of agricultural activities on water quality for other social and economic activities and on wetlands, *inter alia* through optimal use of on-farm inputs and the minimisation of the use of external inputs in agricultural activities
- establishment of biological, physical and chemical water quality criteria for agricultural water users and for marine and riverine ecosystems
- prevention of soil runoff and sedimentation
- proper disposal of sewage from human settlements and of manure produced by intensive livestock breeding
- minimisation of adverse effects from agricultural chemicals by use of integrated pest management
- education of communities about the pollution impacts of the use of fertilisers and chemicals on water quality and food safety.

Summary of STI

Objectives	• To improve water efficiency in irrigation system
Science, Technology and Innovation	Short terms: • Intensive assessment of current and future irrigation water use and water auditing in all states Medium terms: • Application of smart sensors to control water supply Long terms: • Full development of local brand hydraulic and hydrological software specializing in tropical environment
Key Area	• Development of gadgets for Irrigation Water control system

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Intensive assessment of current and future irrigation water use and water auditing in all states	Application of smart sensors to control water supply	Adaptation measures of Irrigation water supply with climate change	Full development of local brand hydraulic and hydrological software specializing in tropical environment	Technology is fully developed and ready for market
Enablers	ministry of agriculture	Sufficient number of professionals to focus on artificial Intelligence research	Integration of data on optimise water use and climate change	Application of fully automation in irrigation sector	Private investment
Outcomes	Irrigation of current and future water needs known	Real time monitoring optimisation of water use	Minimization of water loss	Malaysian global player in Irrigation system	Market services

6.2.7 Community Values Ecosystem Services

Economic Sector: Ecosystem services

Description of the Opportunity

Community (including decision makers, planners, politicians) understanding on the values of ecosystem services is critical for maintaining sustainable benefits of the services. Of late, more evidences are emerging that past unsustainable approach of development that seemed highly profitable by damaging or eradicating natural ecosystems in the end costs even more to the society. Currently, most ecosystem services, such as those provided by the forest, are considered public goods and property rights are not well defined. Previous economic evaluation of forest ecosystem services in Malaysia focused mostly on timber and market goods in a given forest ecosystem and compartment level. Economic evaluation of Non-timber-forest-products (NTFPs) focused mostly on plant resources, but lacked economic values to indicate environmental resources and non-plant resources.

Risk Return Analysis

As the public better understands and values natural ecosystem services, their interest in protecting and conserving these ecosystems will increase, as will their wisdom in exploiting the ecosystem services sustainably. Healthy ecosystem services will give Malaysia better competitive advantage for creating opportunities of marketing the ecosystem services such as eco-tourism. Concern about global warming and other aspects of losses such as biodiversity loss, is shaping the emphasis on investment towards green technology and reduction of greenhouse gasses release into the atmosphere. Lack of clear and consistent institutions (rules, rights and responsibilities) with respect to management of the natural environment inhibits investment in the maintenance of natural resources and encourages abrogation of responsibilities. The total return score was calculated as 5.8 whereas the risk return score was calculated as 3.8.

Economic Feasibility

Ecosystem services values can be considered from the biophysical, economic and community perspectives. However, the value of ecosystem services from community perspective is rarely considered for conservation and environmental management. Ecosystem services must be properly accounted for the long term environmental and community benefits in economic analysis. When analysing the ecosystem services that may be impacted by a particular action or policy, an expansive perspective should be adopted, recognizing the values from those services that provide direct benefits to society, as well as those that provide indirect and non-use benefits. The economic feasibility of community values ecosystem services will be enhanced by successful demonstration of such efforts that may involve evaluation of stormwater control in an area prone to flooding and analyzing ecosystem services to help determine the public benefits of each. Stormwater control may involve an engineered project that includes construction of detention areas. The natural approach, on the other hand, may involve restoration of riparian areas. It should be able to demonstrate the changes in the values of affected ecosystem services for each alternative approach of ecosystem valuation, including water purification, precipitation interception and storage, flood mitigation, biodiversity maintenance, recreational opportunities, and other amenity benefits. It is then possible to demonstrate an overall economically favourable return of investment by adopting the natural plan over a longer term than shorter timeframe.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Ecosystem services evaluation has been implemented in the major policy documents of the US and Australia. In the US, for example, President Bill Clinton commissioned a report by eminent scientists, industry representatives and bankers which identified a set of questions that need to be addressed to allow an efficient, effective and equitable balance between economic development and ongoing delivery of ecosystem services. In Australia, ecosystem services evaluation of the Great Barrier Reef (GBR) has established its full economic value and drives government investment in ecosystem protection initiatives. The GBR ecosystem services utilisation has provided a huge economic return from the tourism industry, estimated to be worth almost $6 billion per year, and supports approximately 63,000 jobs. Recent scientific studies and comprehensive valuation of the Great Barrier Reef's ecosystem services, including the value of services directly 'consumed', such as recreation, and those which are indirectly consumed, such as the value of seagrasses to prawn fisheries, give estimates ranging up to $51 billion.

Specific Potential Projects

The three major ecosystems in Malaysia are rainforest ecosystem, freshwater ecosystem and marine ecosystem. Assessment of total values of these ecosystem services (regulatory, provisioning, supporting, and cultural) should be focusing in the following areas:

- Estimation of economic values of the natural ecosystems (forest, freshwater, and marine) for local, national and global communities;
- Establishment of a national database of values for Malaysian ecosystems services;
- Scenario analysis of long term economic changes in values of various ecosystem services and impacts of land use and population increase;
- Risk assessment of ecosystems development and linking with values of ecosystem services using GIS (benefit-cost analysis, zoning, environmental impact assessment, satellite image assessment, biodiversity, comprehensive value of ecological services, spatial analysis);
- Formulation of market-based instruments for long term ecosystem sustainable development planning;

- Legal implications of capturing the economic values of ecosystems services (who pays, who gets benefits, whose preference count).

Science, technology and innovation needs

Methods employed include market-based, revealed preference, and stated preference. Future evaluation of the ecosystem services will need to involve the application of valuation in benefit-cost-analysis (BCA), natural resource accounting (NRA), resource pricing, and economy-wide policies. An effective and comprehensive ecosystem services evaluation would also need the application of geographical information system (GIS) and remote sensing technologies for spatial data analysis.

Summary of STI

Objectives	• To enhance community, including politicians and decision and policy makers, values ecosystem services
Science, Technology and Innovation	Short terms: • Developing a national scale ecosystem services valuation protocol Medium terms: • Application of latest technology (e.g. online sensors and IT) for immediate dissemination of ecosystem conditions • Best practise policy, guidelines and implementation Long terms: • Application of latest management technology based on ecosystem wealth to drive national economy and development
Key Area	• Evaluation of ecosystem services

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI	Developing a national scale ecosystem services valuation protocol	Application of latest technology (e.g. online sensors and IT) for immediate dissemination of ecosystem conditions	Best practise policy, guidelines and implementation	Application of latest management technology based on ecosystem wealth to drive national economy and development	
Enablers	• Human resource capacity. • Research, education and awareness programs targeted towards general public, politicians and decision makers. • Institutional and financial support.	• Strengthening the aspects of ecosystem services in school and university curriculum. • Extensive awareness programs. • Legislation enforcement on protection of identified ecosystem services	Community involvement in ecosystem services conservation (e.g. Friends of Ecosystem Sustainable Trail Initiatives). Financial and legislation	Government and private institutional commitments and involvement, including universities and research centres, NGOs, etc.	
Outcomes	• Fully established national scale ecosystem services valuation protocol. • Extensive data on the values of Malaysian ecosystem services	Changes of attitudes towards ecosystem services values among the general public, politicians and decision makers	Malaysians are highly knowledgeable and appreciative of the values of ecosystem services evidenced by better ecosystem conservations.	Significant ecosystem services contribution to the economy and development	Ecosystem services as one of the main economic and development drivers

6.2.8 Advanced Water and Wastewater Treatment

Economic Sector: Urban/Domestic

Description of the Opportunity

The wastewater treatment industry in Malaysia started in early 1960s when septic tank was introduced to treat domestic wastewater from individual houses. Today, the domestic wastewater treatment in Malaysia is mainly operated by Indah Water Konsortium Sdn. Bhd. (IWK). In 2007, (Figure 18) there were approximately 1 million individual septic tanks, 4,400 communal septic and imhoff tanks, 3,700 mechanical treatment plants, 440 oxidation ponds and 155 aerated lagoon operated by IWK (IWK, 2007).

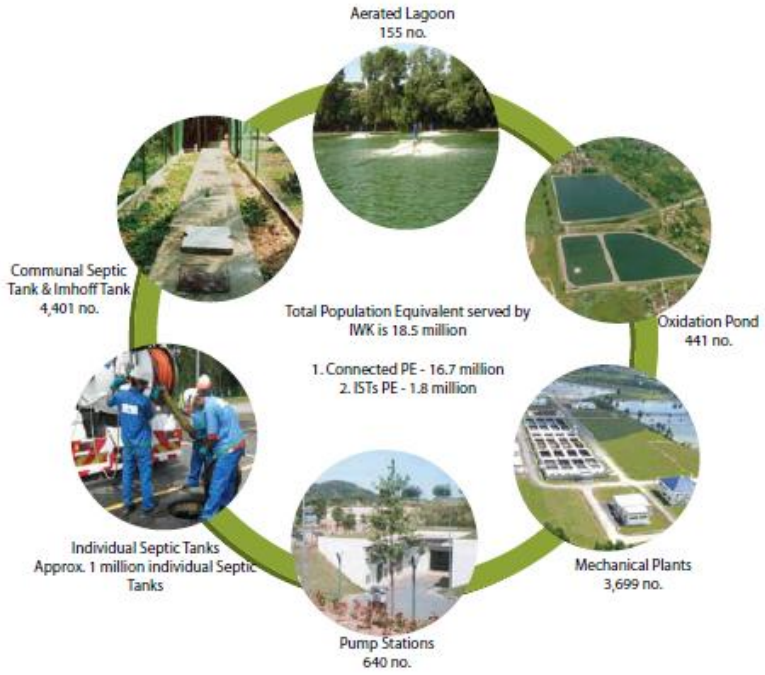

Figure 18: Distribution of sewage treatment plant in Malaysia (IWK, 2007)

Currently, industrial wastewater is being treated individually on-site by the industry. The types of treatment plant highly vary depending on the type of wastewater generated. Generally, biological processes are preferable as they are cheaper to operate while chemical processes are being employed when necessary.

The effluent of the wastewater treatment plants were previously regulated by Regulations in Environmental Quality (Wastewater and Industrial Effluent), 1978. In 2009, the Regulations were amended and separated into two, namely Environmental Quality Regulations (Sewage), 2009 and Environmental Quality Regulations (Industrial Effluent), 2009. The new changes on the sewage effluent standards include but not limited to:

- division based on date of installation and type of treatment system (eg. septic tank, oxidation pond, mechanized system),
- addition of new parameters to the list which include nitrogen and phosphorus compounds,
- the new COD standard has been increased from 50 mg/L (Standard A) to 120 mg/L - 300 mg/L (Standard A) depending on the date and type of installation, and
- the new BOD values for Standard A range from 20 mg/L to 200 mg/L, depending on the date and type of installation.

As for the industrial effluent standard, among the changes are:

- addition of color as one the parameters to be monitored, and
- increase in COD value from 50 mg/L (Standard A) to 80 mg/L - 400 mg/L (Standard A) depending on the type of industry.

Although the new standards have become less stringent with respect to certain parameters, the standards have addressed new contaminants that were not previously regulated, i.e. nitrogen, phosphorus and color. The implementation of the new regulations will therefore require the existing treatment plants to install advanced treatment process in order to meet the new requirements.

Furthermore, in addition to the national effluent standards, more stringent standards should be formulated and implemented specifically to sensitive areas such as tourism areas, urban areas, and environmentally protected areas. The provision of such standards is crucial in the environmental protection of such areas and will also require the installation of advanced treatment system.

In water treatment industry, the application of advanced treatment processes in essential in order to ensure that the potable water provided to consumer is safe and free from micro-contaminants.

Risk Return Analysis

The scores for the return and risk are 6.3 and 4.7, respectively. The return is mainly on ability of the developed technologies and experience to be exported to other developing countries and the ability of the technologies to protect or restore the environment. However, as most of the technologies are readily available, the competition is expected to be high.

The risk is on the commitment from the government in executing the new regulations. This will be the driving force for the implementation of advanced treatment processes in the water and wastewater treatment plants. There will be some form of technical barriers, STI skills and capacity as we currently rely on technology from developed countries.

Economic Feasibility

The applications of advanced water and wastewater treatment will ensure the protection and preservation of water environment. While the installations of these facilities are economy generating activities, they are also important for other water-related economy generating sectors which include tourism, ecosystem services, and health as they have significant effect in enhancing the environmental quality. Furthermore, the experience and knowledge in developing and applying the technology can be exported to other developing country.

Benchmarking Against Similar Initiatives (in Malaysia and overseas)
Sewage work in Osaka, Japan *(http://nett21.gec.jp/GESAP/themes/themes4_5_2.html)*

Sewerage system in Osaka City served almost all the city area and all of 12 sewage treatment plants in the city provide secondary treatment. After the wastewater is treated in the treatment plants, BOD concentration is reduced from130 mg/L to 10 mg/L and then treated effluent is discharged to public water bodies. The water quality of rivers in Osaka City has been dramatically improved since 1970's when sewerage system construction was promoted rapidly. However, some rivers still do not meet the Environmental Water Quality Standards and red tide sometimes occurs in Osaka bay. Therefore, construction of advanced treatment facilities projects has been implemented in order to achieve and maintain the Environmental Water Quality Standards and to create the beautiful waterfront where citizens can enjoy.

Hirano Sewage Treatment Plant has adopted advanced wastewater treatment method using rapid sand filtration facility in order to improve water quality of nearby rivers. The treated water is also partially pumped into the Ima, Koma, and Hosoe Rivers, which have no particular water source, thereby restoring clean streams (Figure 19). In some other wastewater treatment plants, the anaerobic-aerobic activated sludge process has been introduced to enhance the removal of phosphorus.

Figure 9: Hosoe River after restoration

In-Cheon International Airport Wastewater Treatment Plant, South Korea *(http://www.water-technology.net/projects/in_cheon/)*

The Korean Airport Construction Authority (KOACA) has installed a wastewater treatment facility at the new In-cheon International Airport in South Korea. This is in the northern part of the country, close to Seoul. The plant can accommodate 20,000 m^3/day of flow after Phase 1. This is envisaged to expand one and a half times in the future, although the timing and extent of such an expansion have yet to be determined. The plant encompasses a totally enclosed wastewater treatment system. Construction at the site started in 1998, although the contract was signed earlier. The new facility was completed in time for the opening of the new Incheon Airport in March 2001. The $5.5 billion airport facility was built to improve tourist access to South Korea in time for the 2002 World Cup.

The plant is in an international business site, which has required particular modifications. The visual appearance of the plant has been adapted to the setting to be more aesthetically pleasing. As it is highly visible from the airport access highway and over-flying aircraft, it is especially important that visitors' first impressions are good. The construction concept is also very compact in order to save space, which makes future expansion possible.

Odour control is also a key issue. Advanced technology has been used to minimise the problems inherent in wastewater facilities. The treatment plant is totally enclosed and incorporates sophisticated odour control technology compatible with public access to tennis courts located on top of the wastewater treatment system.

The plant is needed as there is high demand for treated wastewater reuse (up to 65%) in toilets hosing, and for irrigation. Tertiary treatment by activated carbon filtration and disinfection allows treated wastewater to be reused. The plant includes an advanced biological nutrient removal system, for nitrogen and phosphorous, which is achieved in a constant level modified sequencing batch reactor process (MSBR).

Specific Potential Projects

In general, applications of advanced wastewater treatment will be needed to fulfil the current regulatory requirements. Emphasis and priority of implementation should be given to the treatment plants discharging effluent to sensitive and important areas such as tourist centre, urbanized area, and environmentally sensitive areas.

STI involved/technical feasibility

There are many advanced water and wastewater treatment available nowadays. These include nitrogen and phosphorus biological removal, membrane bioreactor, biogranules treatment system, membrane filtration, advanced oxidation processes, etc. Most of the technologies are basically mature and applicable with R & D efforts still going on to improve them. However, while several local universities are actively involved in the R & D of the technologies, local experts from the consultant and operation sides are still scarce. Most of the technologies and materials (eg. membrane) are still imported from other countries (eg. China, Europe, Australia). Furthermore, the policies and regulations in certain areas need to be more stringent in order to urge the implementation of advanced treatment processes for the protection of the environment.

Future technologies should be directed towards low carbon footprint with minimum impact to the environment.

Summary of STI for advanced wastewater treatment

Objectives	• To ensure the protection and preservation of water environment • Significant impact on other water-related economy generating sectors which include tourism, ecosystem services, and health • Experience and knowledge in developing and applying the technology can be exported to other developing country.
Science, Technology and Innovation	Short terms: • Installation of N and P biological removal system at sewage treatment plants at sensitive areas such as tourist center and environmentally sensitive areas • Installation of effective tertiary treatment for organics removal at sewage treatment plants and industrial wastewater treatment plants at sensitive areas such as tourist center and environmentally sensitive areas Medium terms: • Development and installation of state-of-the-art technologies which include membrane bioreactor, biogranules treatment system, membrane filtration, advanced oxidation processes, etc. Most of the technologies are basically mature and applicable with R & D efforts still going on to improve them. Long terms: • Future technologies should be directed towards low carbon footprint with minimum impact to the environment.
Key Area	• Development of human resource • Enhancement of R, D & C aspects of the technologies • Improvement in the policies and regulations pertaining to wastewater and effluent discharges. In some areas in Japan, the BOD limit has been reduced to 3 mg/L.

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of advanced water treatment at polluted water sources (WTP) Installation of nutrient removal system at STP Installation of effective tertiary treatment for industries (sensitive areas)	Expansion of the advanced technology application to major cities in Malaysia	Expansion of the advanced technology application throughout Malaysia	Export knowledge of wastewater treatment	Low carbon footprint technologies
Enablers	Incentives, policy, Stringent regulation & enforcement	Incentives, policy, Stringent regulation & enforcement	Incentives, policy, Stringent regulation & enforcement	Private & institutional initiatives	Political commitment and concern for global warming
Outcomes	Improvement of water quality and human and ecosystem health at sensitive areas	Improvement of water quality and human and ecosystem health at major cities	Improvement of water quality and human and ecosystem health throughout Malaysia	Wealth creation	Support national low carbon policy

6.2.9 Wetland Ecosystem Repair

Economic Sector: Ecosystem Services

Description of the Opportunity

Ecosystem services such as dilution of wastewater, erosion control and water purification by riparian vegetation and wetlands ecologies are highly beneficial to people. Malaysia is well endowed with varieties of wetland that include rivers, lakes, reservoirs, swamps, mangroves, estuaries, lagoons and the sea-fronts. Wetlands in Malaysia may include natural as well as man-made lakes. Examples of large natural lakes are Chini and Bera lakes in Pahang and Logan Bunut in Sarawak. Examples of man-made lakes and reservoirs are Pergau in Kelantan, Temenggur in Perak, Kenyir

in Terengganu and Batang Ai in Sarawak. Many natural oxbow lakes, especially in East Malaysia are found along lower reaches of major rivers such as Baram and Limbang in Sarawak, and Kinabatangan, Sugut and Segama in Sabah. There are 51 man-made lakes in Malaysia, 46 of which are located in Peninsular Malaysia, three in Sabah and two in Sarawak. The numbers are expected to rise to meet the increasing demand for water. Freshwater swamps, which have high biodiversity, are common along rivers. Freshwater swamp forests provide an effective form of flood prevention along river valleys.

Peat swamp wetlands are the areas where water-logging and anaerobic conditions partially inhibit vegetation decay gives rise to peat formation. The total area of peat swamp forest in Peninsular Malaysia was historically 6,700 km^2, but had been reduced to 3,400 km^2 by 1991. In Sarawak, peat swamp is the major forest type of the coastal environment with a total area of 7,600 km^2 and was declared as a permanent forest reserve in 1994. While forests provide renewable resource for timber and play important role in flood prevention, globally they play the crucial role of carbon sink. Large areas of peat swamps have been converted to agriculture, especially oil palm plantation, although peat swamps are only of marginal use for agriculture. Mangrove wetlands, on the other hand, were converted to agriculture and aquaculture that rarely produces long-term sustainable results, as the soils are potential acid sulphate soils. When they dry, rapid oxidation of iron sulphites forms sulphuric acid. As the pH decreases, toxic levels of aluminium are also released. Other problems associated with using mangrove as agriculture land include flood and salt water intrusion. The construction of ponds in the inter-tidal zone creates environmental problems due to the destruction and degradation of mangroves and associated mudflats. The cost-benefit analyses of agriculture projects in mangrove areas did not take into account the roles of mangroves in supporting fisheries, forestry values, coastal erosion control, and reduction impacts of tsunami.

Rice fields can be considered as man-made wetlands, mainly because of their characteristics that are determined by paddy plantation activities. They are found mainly in Krian Perak, Kedah, Perlis, Sekinchan and Tanjung Karang in Selangor, and the northern part of Kelantan. In early nineties, almost 2,000 km^2 of wet paddy was planted during the main seasons. Rice field wetlands provide fertile ground for fishes that was an important source of protein for local consumption, but their popularity has declined due to heavy use of pesticides in paddy planting and new

varieties of paddy require a shorter submerged period that is not suitable for rice-cum fish culture.

Malaysia was once the largest tin exporter and tin mining was an important economic activities. Consequently, there are over 4,000 abandoned mining pools, covering an area more than 150 km^2, especially in Perak, Selangor, Johore and Pahang. Some of the mining pools are used for aquaculture, developed into recreational areas, or used as waste disposal grounds.

Wetland ecosystems have been under continuous damaging threat from various sources such as silt from earthwork and land-clearing activities, and organic loadings from sewage and discharges from agro-based and manufacturing industries. Part from natural disasters such as tsunami, these damaging effects mostly come from unsustainable development, manufacturing industries, agro-industries and aquaculture industry. Illegal logging near the natural lakes such as Chini lake, and increasing development around reservoirs increases their vulnerability to eutrophication. The high siltation, caused by mining and logging activities in the upstream, prevents the culture of the most highly valued fish species. The siltation of the reservoir has resulted in rapid proliferation of aquatic macrophytes. Ringlet Reservoir (in Pahang State) was plagued with water hyacinth, costing the government millions of dollars for its control. The long-term prospects for swamp lands also do not look optimistic. The perception that they are wastelands, have made swamps a prime target for reclamation. Already, about 700,000 ha of these wetlands have been converted to agriculture and more are likely to be drained and opened up with growing population pressures.

Recreation and tourism industries require attractive environmental conditions, but these activities, if unregulated, can cause a serious impact and significantly damage the habitats. Coral collection by tourists can significantly destroy the reef. Situation of hotels and resorts on beach fronts and lakes can cause eutrophication of the waters unless the release of sewage and wastewater is completely disallowed into the surrounding ecosystems. Similarly, maintenance of golf courses, which requires heavy use of pesticides and fertilizers cause high concentrations of these chemicals in the receiving waters (Yusoff *et.al*, 2006).

Risk Return Analysis

Successful restoration of damaged wetland ecosystems can provide viable return of investment of the restored ecosystems. Restored healthy ecosystem services also provide the country with a better competitive advantage. The highest risk in the restoration of wetland ecosystem services is from the political/institutional barriers and adoptability which means winning the support of the public and changing the mindset of the stakeholders in particular those decision makers, planners and politicians. Commitment from the Federal Government is critical for the success of initiatives towards restoration of damaged wetland ecosystems. The total return score is calculated as 6.2 and the risk score is 4.8.

Economic Feasibility

Wetland ecosystems and the biological diversity they support are natural assets which can make significant contributions to the national economy. Functional ecosystems represent natural capital upon which the national economy depends for the production of many goods and services. Unfortunately, the benefits of wetland services are often realized only after they have disappeared. Problems with flooding, lost recreational opportunities, reduced fish populations and more costly water treatment are examples of costs understood only after a wetland ecosystem has been degraded or destroyed. Therefore, it is necessary to put economic value on wetland benefits before ecosystem-altering decisions are made so that potential costs up front is well recognised and thereby put wetland-related decisions on a more economically sound footing. Understanding the economic feasibility wetland ecosystem repair is not easy. Different methods of measuring the sociological and economic benefits of wetlands need to be employed before the returns on investment from actions to sustain wetlands and the benefits that may be lost if they are degraded can be demonstrated. Valuing the economic benefits of wetlands can help set priorities and allocate spending on restoration and conservation initiatives. In many ways, the economic benefits received from wetlands are comparable to the benefits received from things such as public schooling, health care and municipal infrastructure.

Benchmarking Against Similar Initiatives

Malaysia has successfully rehabilitated sites where mining operations have stopped. Mining ponds rehabilitation is the restoration of mined land to a natural state and the transformation to alternative, productive land use. Examples are The Mines, The Sunway Lagoon Resort, The Clearwater Sanctuary golf resort, and Lake Titiwangsa. The Mines Resort City was once the world's largest open cast mine and now, it is a tourist destination boasting a 5-star hotel, a man-made beach and a 246-acre golf course.

Specific Potential Projects

Chini lake is the second largest freshwater ecosystem in the country with high potential for eco-tourism attraction. However, this wetland ecosystem is facing threats from increased sedimentation due to activities within the vicinity of the basin such as logging, agriculture and mining. The lake catchment also faces frequent flooding and overflow from the Pahang River during the monsoon season. Preventive measures are needed immediately to curb the periodic increase in sedimentation in Chini lake specifically and the Chini River generally. Other important wetland areas such as Matang Mangrove Forest Reserve, The Belum-Temengor Forest Reserve, and the Lower Kinabatangan-Segama Wetland where various degrees of damage might have taken place due to logging or deforestation activities needs evaluation and immediate action plan of repair and restoration include.

Science, Technology and Innovation Needs

A meaningful success from the wetland ecosystem restoration program can be materialized by the implementation of proper evaluation techniques of restoration success that provide evidence where enhancement of the targeted wetland ecosystem services can be put on display and enjoyed by the nation at large. A fully recovered wetland ecosystem services function can only be made sustainable for ever if they are then managed and protected in a way that both economic and ecosystems are blend together such as those for the ecosystem and development of ecotourism properties.

Summary of STI

Objectives	
Science, Technology and Innovation	Short terms: • Mapping of degraded water ecosystem • Assessment of site specific potential. • Prioritization of wetland for restoration Medium terms: • Appropriate design and technique for wetland restoration. • Implementation of restoration program for priority wetlands • Evaluation techniques of restoration success Long terms: • Managed as protection of the ecosystem and development of ecotourism properties.
Key Area	

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	• Mapping of degraded water ecosystem • Assessment of site specific potential. • Prioritization of wetland for restoration	• Appropriate design and technique for wetland restoration. • Implementation of restoration program for priority wetlands		Evaluation techniques of restoration success	Managed as protection of the ecosystem and development of ecotourism properties.
Enablers	• Expert and government support 2. Rationalization of wetland management	Strong government and local community involvement	Continues program on ecosystem restoration, education and awareness	Budget to support evaluation of restoration success	Committed NGOs
Outcomes	Comprehensive report on degraded wetland	Restoration of degraded wetlands		Enhanced ecosystem services	Managed as protection of the ecosystem and development of ecotourism properties

6.2.10 Water Management Planning to Improve Resilience with Uncertain Climate Future

Economic Sector: Water

Description of the Opportunity

Climate change is one of the basic drivers of change for water, alongside demographic, economic, social and technological forces. Policies, laws and finance also condition the impact of these basic drivers. These factors are interrelated and the outcome is evolving in a dynamic fashion. Climate change can affect water resources directly, but also indirectly through its impact on the other drivers.

What we know now:

- Historic hydrologic patterns can no longer be solely relied upon to forecast the water future;
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management, and ecosystem functions
- Extreme climatic events will become more frequent, necessitating improvements in flood protection, drought preparedness and emergency response
- Water and wastewater managers and customers – businesses, institutions, farms, and individuals – can play a key role in water and energy efficiency, the reduction of greenhouse gas emission and the stewardship of water and other natural resources
- An array of adaptive water management strategies must be implemented to better address the risk and uncertainty of changing climate patterns.

Risk Return Analysis

The return and risk analysis for water planning in an uncertain climate. The risk and return are 6.2 and 5.2 respectively. The highest return involves the potential to protect or restore ecosystem health and the risk includes technology barrier and STI skills capacity.

Economic Feasibility

Significant and ongoing investments must be made in monitoring, researching, and understanding the connection between a changing climate, water resources and the environment

Benchmarking Against Similar Initiatives (in Malaysia and overseas)

Many countries in the world are face of increasing demands for water resources or protection against risk. In the UK, for example, water supply companies currently are pursuing the "twin track" of demand management and supply management in response to potential increases in demand for water. These management strategies also are potentially feasible in the face of climate change. Nowhere, however, are water management actions being taken explicitly and solely to cope with climate change, although in an increasing number of countries climate change is being

considered in assessing future resource management. In the UK, for example, climate change is one of the factors that must be considered by water supply companies in assessing their future resource requirements—although companies are highly unlikely to have new resources justified at present on climate change alone.

Examples of managed retreat and related measures as adaptation to sea-level rise include the following:

- **Canada:** New Brunswick completed remapping of the entire coast of the province to delineate the landward limit of coastal features. Setback for new development is defined from this limit. Some other provinces have adopted a variety of setback
- **Sri Lanka:** Setback areas and *no-build zones* identified in Coastal Zone Management Plan. Minimum setbacks of 60 m from line of mean sea level are regarded as good planning practice.
- **United States:** The states of Maine, Massachusetts, Rhode Island, and South Carolina have implemented various forms of *rolling easement* policies to ensure that wetlands and beaches can migrate inland as sea level rises.
- **Australia:** Several states have coastal setback and minimum elevation policies, including those to accommodate potential sea-level rise and storm surge. In South Australia, setbacks take into account the100-year erosional trend plus the effect of a 0.3-m sea-level rise to 2050. Building sites should be above storm-surge flood level for the 100-year return interval.

Specific Potential Projects

Based on the World Climate Conference 3 held on Sept 2009 in Geneva, the adaptation to increasing climate variability and climate change in the water sector needs to be guided by building resilience to ongoing climate variability and future climate change calls. Adaptation has to start now by addressing existing problems in land and water management (http://www.wmo.int/wcc3).

Recommendations:

- To take up proactive adaptive management approach by:

  - Vulnerability assessment of water infrastructure
  - Increased oversight, inspection and regulation of infrastructure during operation and maintenance
  - Life cycle management of aging infrastructure
  - Development of forecasting methods for implementation of improved 'soft measures' in water management, such as better reservoir and emergency operations
  - Strengthen emergency management and preparedness plans for managing risks associated with extreme
  - Risk based planning and design of new infrastructure to account for climate uncertainties
  - Development of new generation of risk-based design standards for infrastructure responding to extreme events.

- The focus of climate studies must begin to shift from generic global information to local, particularly river basin (sub-basin) level to understand impacts and assessments of more focused adaptation and response options.

- Climate models cannot replicate droughts and the inherent persistence in those phenomena. Drought Early Warning is essential, especially for the large regions of rainfed agriculture. Flood and drought preparedness, warning and response planning are the essential elements of adaptive management.

- Floods serve as important water resource and enhance various environmental services. They need to be managed in a manner that addresses the vulnerability of the societies through robust policies such as Integrated Flood Management with appropriate emphasis on both soft and hard solutions at various stages of the risk management cycle, including residual risks.

- Continued operation of long-term monitoring networks and improved sensors deployed in space, in the atmosphere, in the oceans and on the Earth's surface are essential for understanding the current climate variability, hydrologic trend analysis, quantifying climate change and its impacts, improvements in

the accuracy of forecasting method. The effectiveness of adaptation strategies and actions require continuous feedback and adjustments based on the information provided by monitoring networks.

Summary of STI

Objectives	• To provide up to date projections to improve resilience with uncertain climate in the future
Science, Technology and Innovation	Short terms: • Invest in current climate models Medium terms: • Apply climate change projection to coastal area at risk around Malaysian coastline. Long terms: • Application of latest management technology based on science adaption of slow moving climate change and extreme events.
Key Area	• Improve climate projection for Malaysia using models and to evaluate catchment and coastal risk assesment

Investment Roadmap

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Invest in acquiring leading international climate science and modelling to provide up-to-date projections for Malaysia, whilst training up local scientists for ongoing applications.	Apply climate change projections to the coastal assets at risk around the whole coastline of Malaysia, completing a risk assessment that takes into account sea-level rise, storm surges, changing ocean temperatures and acidity, and tropical storms and cyclones.	Couple climate forecasts to hydrological and hydraulic models with better computing power to provide integrated catchment by catchment risk assessments.	Science-based adaption strategies that cater for slow moving climate change and extreme events such as heat wave impacts on sensitive thermal tolerances of aquatic tropical species, sea defences against rising sea levels, dam splillway design for new flood risks, and refined logging practices to minimise risk of landslides.	Re-assess climate projections with latest quantum computing models and better knowledge of global response to reducing greenhouse gas emissions and incorporate across integrated e-planning systems.
Enablers	Access to world class climate science and modelling expertise. Recent Malaysian climate science graduates/PhDs and modellers.	Robust climate change projections combined with the best local knowledge of coastal processes and competent risk assessment.	Use rapidly increasing computer power (e.g. Optical computing) to apply next generation of climate models that couple with land surface processes and feed into hydrological and hydraulic models.	Well developed emergency plans and well considered adaptations at regional and local levels. Strong support from provinces and local utilities.	Quantum computing, e-planning
Outcomes	Improved climate projections for Malaysia covering temperature, precipitation and evaporation, with best estimates of extreme events risks to water resources and dependent communities, industries and environments	Coastal vulnerability assessment completed for all coastal regions of Malaysia including local communities, coast-based industries and coastal ecosystems such as mangroves and estuaries.	Detailed assessments of climate change risks arising from increasing temperature and evapotranspiration , changing rainfall patterns, changing soil moisture, altering flow regimes and extreme events such as heat waves, forest fires, storms, cyclones, and droughts.	Improved triple bottom line resilience through carefully planned adaptations and emergency response guidelines.	Planning systems support reduced long term impacts of Climate Change

7. CONCLUDING REMARKS

This project was undertaken through a close and beneficial collaboration between the University of Technology Malaysia (UTM) and Sinclair Knight Merz (SKM) under close guidance of the Academy of Science Malaysia (ASM) and input from relevant stakeholders.

The output from the project has been the identification of twenty Science Technology and Innovation (STI) opportunities to enhance Malaysia's sustainable development in social, cultural, environmental and economic terms over the 201102050 period. The project team has used a logical and systematic approach and qualitative methods to reach and support its findings. The results have been tested on a wide-ranging Stakeholder Group.

Readers of this report should be aware of several caveats when considering the findings:

- This assessment is strategic in nature and additional more detailed assessments, including benefit-cost analyses, should be conducted prior to investment
- The prioritisation of the twenty STI opportunities has been based on a Risk-Return paradigm. The Malaysian government may well have other reasons for according higher priority to specific opportunities, for example to meet social objectives
- Some of the opportunities that have a high return but a high risk are ranked lower when both return and risk are taken into account. High return - low risk projects may be taken up or partially supported (e.g. in a joint venture) by the private sector, whereas the high return – high risk opportunities may attract greater attention from government which is willing to invest (e.g. in research and development) to reduce the risk.
- The assessments conducted in this project have relied heavily on the extensive knowledge and judgment of the project team members and priorities may need to be modified when other perspectives or more detailed analyses are included
- The results of this report reflect a snapshot in time. Any strategic assessment of priorities should be regularly updated, at least every five years (and more often in fast-moving sectors)
- A future timeframe of 40 years in a *very long time* in today's accelerating technological world. This means that the further one looks into the future, the greater the uncertainty is for STI investment and planning. However this should not be a barrier to investment, but rather a call to awareness to maximise flexibility, agility and adaptability when navigating towards a longer tern vision.

APPENDIX 1: Opportunities Long List

Sector	Opportunity for sustaining economic development 2011-2050
Agriculture - irrigated	Water wastage from open channel leakage can be dramatically reduced, providing significant long term cost savings
	Manage irrigation supply during drought
	On-farm water use efficiency (distribution and application) can be improved , providing significant long term cost savings
	Water can be supplied to farms with quality matched to crops grown, avoiding unnecessary expensive treatment costs (e.g. reuse of treated wastewater)
.	Irrigation return flows impact on water quality (agrochemicals) and ecosystem services, leaving water available to other uses and users
Forestry	Water yield can be actively managed through forestry and silviculture
	Erosion/ sediments impact on water quality and ecosystem services can be reduced
Fisheries	Can reduce impacts of aquaculture on water quality and ecosystem services, leaving water available to other uses and users
	Can reduce probability of alien fish species release from aquaculture and other sources into native ecosystems.
	Increasing export of seafood products
Energy & mining	Water is a major future renewable energy source via hydroelectricity and micro-hydro, geothermal, wave, tidal and bioenergy
	Solar energy to run smart water systems
	Reduce energy use in pumping, piping and desalination
	Rehabilitate old mining ponds and wetlands
Tourism & development	Develop urban tourist water options (river walks, lakes, parks, features) and waterfront development
	Clean-up and rehabilitate waterways in highly visible locations to improve aesthetics and ecological functioning
	Develop eco-tourism around high ecological value sites
	Design tourism development to withstand climate change eg coastal resorts
Ecosystem services	Community (including decision-makers, planners, politicians) values ecosystem services for Malaysia
	Dams & river infrastructure can be designed with the capacity to release environmental flows to meet the needs of fish and other species
	Work out where it is more cost-effective to repair ecosystem services (e.g. improve catchment management) than treat water

Sector	Opportunity for sustaining economic development 2011-2050
	Identify options for multi-service provision (multi-use)
	Improve ecosystem protection from point and non-point pollution
	Payments for Environmental Services (PES) or incentives
	Create water market value for tangible and intangible goods by policy regulation and offset schemes
	Ecosystem services conservation programs
	Ecosystem services knowledge packaged for ease of use by key stakeholders, policymakers, and business decision makers
Urban/ domestic	Development of non-traditional water sources
	Pay-for-use water tariffs to encourage efficient water use
	Introduction of water conservation technologies
	Advanced water and wastewater treatment to meet new WQ standards and regulations
	Zero waste
	Polluter pays principle & pollution trading
	Management of sullage and leachates
Health	Increase tap water supply (or safe alternative) to 100% of population
	Increase water supply treatment to meet drinking water quality standards for 100% of population
	Awareness campaigns to reduce mosquito borne disease vectors
	Market & export high quality water
	Malaysian brand for domestic water purification unit
Education	Assistance in implementing better water practice (domestic and industry)
	World leader in tropical aquatic ecosystem research, management and education
	Reform water education approach
	Improve public participation in decision-making
	Export knowledge products
Water management	
resource assessment	Groundwater resources can be fully assessed and more effectively utilised
	Hydroclimatic monitoring system could be expanded/intensified
	Real-time monitoring capacity could be expanded
	National water data management protocols for improved assessment and reporting
	Better public access to water information and data
	Surface groundwater interactions assessment
supply	Surface/groundwater plus other sources conjunctive use schemes assessed

Sector	Opportunity for sustaining economic development 2011-2050
water sharing	Sustainable diversion limits (SDL) assessment
water quality	Water quality monitoring could be expanded for additional parameters including pesticides and EDCs
water tools	New generation water resource models could be adopted
	Improved climate and hydro climate prediction models
water infrastructure	Single and multi-dam design, use, impact and EIAs
	Water asset management - infrastructure
	Smart water grids
Flood control	Improve flood forecasting and mitigation
water environment	Asset-based ecosystem management
	Better understanding of forest and ecosystem interactions
	Site specific management plans to maintain values at icon sites
water treatment	Wastewater 'fit-for-purpose' treatment technologies
	Low footprint (green) technologies
water policy	Legislation to protect water supply catchments and high value ecosystems
water planning	Water supply planning to improve resilience with uncertain climate future
	Catchment water sharing plans (describes how the water resources are to be shared amongst different consumptive users and the environment)
water markets-trading	Water markets and trading
water systems	IWRM systems thinking and systems methods and optimisation
Climate change response	Salt water intrusion

Appendix 2: Stakeholder Workshop Attendees

`MEGA-SCIENCE FRAMEWORK STUDY FOR SUSTAINED NATIONAL DEVELOPMENT (2011-2050) - WATER SECTOR' WORKSHOP FOR STAKEHOLDERS (1ST JULY 2010) PARTICIPANTS

No	Name	Position	Org.
1	HJ. ISHAK SAMSUDDIN	JURUTERA DAERAH	JPS , PETALING
2	HJ. AZMI MD. JAFRI	TIMBALAN PENGARAH , BAH. PENGURUSAN SUMBER AIR HIDROLOGI	JPS
3	HJ. MD. KHAIRI SELAMAT	TIMBALAN PENGARAH, BAH. KORPORAT ,	JPS
4	EN. TAN TEOW SOON	TIMBALAN PENGARAH , BAH . PENGURUSAN LEMBANGAN SUNGAI DAN ZON PANTAI	JPS
5	EN. YUSNAN ABD RANI	PEGAWAI LAUT	JAB LAUT SEM MALAYSIA
6	EN. MOHD. ARMA NORAMIN ABD . RASHID	PEGAWAI LAUT	JAB LAUT SEM MALAYSIA
7	PROF. MADYA DR. WAN NOR AZMIN SULAIMAN	TIMBALAN DEKAN (SISWAZAH, PENYELIDIKAN & PEMBANGUNAN)	UPM
8	DR. AHMAD ZAHARIN ARTS	PENSYARAH KANAN	UPM
9	PROF. MADYA DR. MOHAMAD PAUZI ZAKARIA	PENSYARAH	UPM
10	IR . HJ. MOHAMED HANIFFA HJ ABD HAMID	PENGURUS BESAR	INDAH WATER KONSORTIUM S/B
11	CIK LIM PEK BOON	PENGURUS	INDAH WATER KONSORTIUM S/B
12	EN. KHAIRUL ANAM MUSA ® MAHMUD	PEGAWAI PENYELIDIK	NAHRIM
13	EN. NOOR AZME OMAR	PEGAWAI PENYELIDIK	NAHRIM
14	DEVENDRAN RAJANGAM	DP	KPDNKK
15	EN. MOHD. RIDHUAN SPAN ISMAIL	PENGARAH EKSEKUTIF (BAH . KAWALSELIA PEMBETUNGAN)	SPAN

No	Name	Position	Org.
16	EN. MARZUKI MOHAMMAD.	PENGARAH (BAH PENYELIDIKAN, PEMBANGUNAN & INDUSTRI)	PAN
17	IR. JASENI MAIDINSA	PENGURUS BESAR	PERBADANAN BEKALAN AIR P . PINANG S / B
18	EN. MOHD. FAUZI OMAR	PENGURUS	PENGURUSAN ASET AIR BERHAD
19	EN. ZAMRI HASSAN	PENGURUS	PENGURUSAN ASET AIR BERHAD
20	PN. KHASIFAH MUHAMAD	PEGAWAI PENYELIDIK	MARDI
21	DR. KALITHASAN	RIVER CARE COORDINATOR	GLOBAL ENVMNT CENTRE
22	IR. ABD AZIZ ABAS	KETUA JURUTERA	HSS INTEGRATED S/B
23	EN. ISHAMUDDIN MUSTAPHA	EKSEKUTIF	SAJ HOLDINGS
24	HJH. AZLIN HJ. SELAMAT	EKSEKUTIF	SAJ HOLDINGS
25	CIK INA TISHA MERICAN.DIN MERICAN	PENOLONG S/U , BAH PENGURUSAN BIODIVERSITI DAN PERHUTANAN	NRE
26	EN. MOHD. BADZRAN MAT TAIB	KETUA PENOLONG	JMG
27	PN. HABIBAH TAHIR	PEGAWAI KAJIBUMI KANAN	JMG
28	CIK DARIA MATHEW	KOORDINATOR TEKNIKAL	WWF MALAYSIA
29	EN. SAW HIN SEANG	PERUNDING TEKNIKAL	ASIA WATER & ENVIRONMENT SIB
30	EN. DAVID TAN TEONG CHYE	MANAGER	GRUNDFOS PUMPS S/B
31	EN. MD. ABDULLAH ABRAHAM HOSSAIN	GRADUATE RESEARCH ASSISTANT	LESTARI
32	CIK LAVANYA RAMA IYER		
33	DATO' DR. HASHIM ABDUL WAHAB	PROJECT LEADER, AGRICULTURE SECTOR	ASM
34	DR. MOHAMED ARIFF OMAR	MEMBER, AGRICULTURE SECTOR	UPM
35	PN. ISMAHANI ISHAK	PEG TEKNOLOGI MAKLUMAT	MITI

No	Name	Position	Org.
36	IR.DR. AZUHAN MOHAMED	KETUA PEGAWAI EKSEKUTIF	SIME DARBY
37	DATO' TEO YEN HWA	CEO	SPAN
38	ROZITTA SULAIMAN	SENIOR PROGRAMME COORDINATOR	INTAN
39	ACADEMICIAN TAN SRI DATO' IR. HJ. SHAHRIZAILA ABDULLAH	SENIOR FELLOW	ASM
40	ACADEMICIAN TAN SRI DATO DR. AHMAD MUSTAFFA BABIEE	SENIOR FELLOW	ASM
41	DR. AHMAD IBRAHIM	FELLOW	ASM
42	PROFESSOR EMERITUS DATO' WIRA IR. DR. MOHAMMAD NOOR HJ. SALLEH	FELLOW	ASM
43	IR AHMADF RASLAN	SENIOR ENGINEER	MBPJ
44	DEVENDRAN RAJALINGAM	DP	**KPDNKK**

APPENDIX 3: List of table

Table 1: Creating New Wealth Opportunities (2011-2050)

Opportunity	**Primary economic sector**	**Markets**
Eco-tourism around high ecological value sites	Tourism	Domestic, regional and global
Urban water-based tourism	Tourism	Domestic, regional and global
Market and export high quality water	Water	Regional and global
Clean water for aquaculture Industry	Fisheries	Domestic, regional and global
Malaysian brand for domestic water purification unit	Water	Domestic, regional and global
World leading tropical aquatic research and education	Education	Domestic, regional and global
Knowledge export	Education	Regional and global
Tapping urban water	Water	Domestic
Rainwater harvesting	Water	Domestic
Zero pollutant discharge	Wastewater	Domestic

Table 2: Opportunities for Sustaining the Resource

Opportunity	Primary economic sector	Markets
Exploit groundwater further as a resource and drought protection	Water	Domestic
Improve flood forecasting and mitigation	Water	Domestic
Reform Water Education System in Primary, Secondary and Tertiary Sectors and Wider Public	Education	Domestic
Improve ecosystem protection from point and non-point pollution	Water/ environment	Domestic
Clean-up and rehabilitate waterways in highly visible locations to improve aesthetics and ecological functioning	Urban/water	Domestic/regional/global
Irrigation water use efficiency	Agriculture	Domestic
Community (including decision-makers, planners, and politicians) values ecosystem services for Malaysia	Water/ environment	Domestic
Advanced water and wastewater treatment	Water/wastewater	Domestic
Wetland ecosystem repair	Water/ environment	Domestic
Water management planning to improve resilience with uncertain climate future	Water	Domestic

Table 3: Malaysia's domestic competitive advantages by industry sector

Industry sector	Competitive advantages
Agriculture	▪ Large reliable water resource ▪ Government R&D priority in agricultural sector
Energy	▪ Strong manufacturing base ▪ Commercial development pathway ▪ Increasing service sector
Tourism	▪ High quality natural assets ▪ Tourist friendly ▪ Multicultural
Forestry	▪ Tropical forest ▪ Rubber wood as alternative to forest timber ▪ Sustainable forest management ▪ Reforestation program in place

Industry sector	Competitive advantages
Fisheries	▪ Growing ornamental fish industry for domestic and export market
Ecosystem services	▪ Tropical climate with high rainfalls ▪ Rain-forest as major eco-tourism ▪ Diversity in forest plants and herbs of medicinal value ▪ Government support and policy on eco-tourism
Urban	▪ Prowess in urban design
Health	▪ Already met Millennium Development Goals
Education	▪ Strong interest in S&T education ▪ High quality water education institutions
Water management	▪ Abundance of fresh water ▪ Water management expertise

Table 4: Role of water STI in increasing sector economic performance

Industry sector	Water economic stimulus
Agriculture	▪ Increase crop for the drop (productivity) ▪ Improve water use efficiency (WUE) ▪ Reduce pollution downstream ▪ Sustainable extraction limits ▪ Water-less rice production ▪ Multi-disciplinary approach of agriculture water saving for sustainability in economic, social and ecological aspects
Energy	▪ Improve hydro energy provision ▪ Supply water fit-for-purpose ▪ Manage waste stream
Tourism	▪ Identify sites for eco-tourism and general tourism ▪ Protect sites for their natural values ▪ Design appropriate development and access ▪ Ensure best practice in catchments
Forestry	▪ Forest protection and rehabilitation ▪ Growing stock change
Fisheries	▪ Fresh water and marine fish farming
Ecosystem services	▪ Identify and describe ecosystem services ▪ Protect or enhance these services ▪ Educate population ▪ Ecosystem restoration ▪ Aquatic plant management
Urban	▪ Urban water design ▪ Lakes and pond rehabilitation ▪ Channel to soft engineering ▪ Quality of wastewater discharge ▪ Stormwater management ▪ Flood management
Health	▪ Meet MDGs ▪ Reduce water-borne diseases ▪ Meet or exceed water quality health standards ▪ Reduce flood risks
Education	▪ Educating overseas students ▪ Increasing quality/capacity of Malaysian water science and technology ▪ Cultural change in water use

Industry sector	Water economic stimulus
Water management	▪ Ecosystem approach of water resources management ▪ Regular water quality monitoring program ▪ A centralised agency responsible for water resource management ▪ Improve the industrial discharges standards

Table 5: Potential enablers that may be required to achieve STI outcomes

Enabler	Comment
Visioning	A grand statement like 'we'll land man on the moon in 10 years'
Policy	Highest level of government action
Legislation and regulation	Follows setting of clear policies
Standards and guidelines	Specifies minimum requirements or in some cases 'best practice'
Administration	Processes and means for implementing policies or legislation
Governance	Specifies roles, responsibilities and decision-making rules
Institutional arrangements	Specifies roles and responsibilities of agencies which have carriage of task
Programs and/or projects	Provides the framework for specifying outcomes, targets, resources, ongoing monitoring and evaluation, reporting requirements etc
Planning requirements	Meet planning requirements for example of local government
Funding	May be government, private, philanthropic, in-kind etc
Public-private partnerships	PPPs can be designed with different levels/roles of 'partnership'
Private sector	Private sector investment for commercial outcomes
Philanthropy or corporate social responsibility (CSR)	Suitable for some parts of the private sector and may attract tax benefits
Incentives	Range of potential government incentives
Knowledge and capacity building	Specific programs designed to build a suitable workforce in a short timeframe
Expertise, skills	Specialist expertise is required in most major projects
Suitable technologies	Soft engineering, high tech treatment etc
Research and development	Address knowledge gaps or novel situations
Ex-ante cost-benefit evaluation	Important part of establishing the business case and maximising multiple benefits from a single investment

Enabler	Comment
Community participation	Projects that require community consultation, learning or assistance

Table 6: Risk-Return Assessment for Opportunities for Creating New Wealth

Opportunity	Return	Risk	Combined risk-return & rank
Eco-tourism around high ecological value sites	8	2.7	117
Urban water-based tourism	8.4	3.5	113
Market and export high quality water	8.1	3.3	111
Clean water for aquaculture Industry	7.4	2.8	107
Malaysian brand for domestic water purification unit	6.9	2.5	104
World leading tropical aquatic research and education	7.4	3.2	101
Knowledge export	7.4	3.3	100
Tapping urban water	7.7	4.2	93
Rainwater harvesting	7.4	4.3	87
Zero pollutant discharge	6.8	6.2	61

Table 7: Risk-Return Assessment for Opportunities for Sustaining the Resource

Opportunity	Return	Risk	Combined risk-return & rank
Exploit groundwater further as a resource and drought protection	7.7	2.3	119
Improve flood forecasting and mitigation	7.7	2.3	119
Reform Water Education System in Primary, Secondary and Tertiary Sectors and Wider Public	8	3.8	102
Improve ecosystem protection from point and non-point pollution	7.9	4	98
Clean-up and rehabilitate waterways in highly visible locations to improve aesthetics and ecological functioning	7	3.5	91
Irrigation water use efficiency	5.7	3.2	79
Community (including decision-makers, planners, and politicians) values ecosystem services for Malaysia	5.8	3.8	72
Advanced water and wastewater treatment	6.3	4.7	68
Wetland ecosystem repair	6.2	4.8	65
Water management planning to improve resilience with uncertain climate future	6.2	5.2	62

Table 8: Return-risk Analysis for Eco-tourism Around High Ecological Value Sites

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	8	Holistically robust	0.17	3
			Political/institutional barriers	0.17	3
			Ecological damage	0.17	2
			Adoptability	0.17	2
Total return scores		8	Total risk scores		2.7

Table 9: Return-risk Analysis for Urban Water-Based Tourism

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	9	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	9	STI skills and capacity	0.17	3
Competitive advantage	0.3	7	Holistically robust	0.17	4
			Political/institutional barriers	0.17	2
			Ecological damage	0.17	5
			Adoptability	0.17	4
Total return scores		8.4	Total risk scores		3.5

Table 10: Return-risk Analysis for Market and Export of High Quality Water

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	9	Technical barriers	0.17	4
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	4
Competitive advantage	0.3	7	Holistically robust	0.17	5
			Political/institutional barriers	0.17	3
			Ecological damage	0.17	2
			Adoptability	0.17	2
Total return scores		8.1	Total risk scores		3.3

Table 11: Return-risk Analysis for Clean Water for Aquaculture Industry

Return Criteria	**Weight**	**Score**	**Risk Criteria**	**Weight**	**Criteria**
Market potential/ROI	0.4	8	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	6	Holistically robust	0.17	2
			Political/institutional barriers	0.17	4
			Ecological damage	0.17	2
			Adoptability	0.17	3
Total return scores		7.4	Total risk scores		2.8

Table 12: Return-risk Analysis for Malaysian Brand Domestic Water Purification Unit

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	9	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	7	STI skills and capacity	0.17	3
Competitive advantage	0.3	4	Holistically robust	0.17	2
			Political/institutional barriers	0.17	2
			Ecological damage	0.17	2
			Adoptability	0.17	3
Total return scores		6.9	Total risk scores		2.5

Table 13: Return-risk Analysis for World Leading Tropical Aquatic Research & Education

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	7	STI skills and capacity	0.17	4
Competitive advantage	0.3	7	Holistically robust	0.17	5
			Political/institutional barriers	0.17	3
			Ecological damage	0.17	2
			Adoptability	0.17	2
Total return scores		7.4	Total risk scores		3.2

Table 14: Return-risk Analysis for Knowledge Export

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	5
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	4
Competitive advantage	0.3	8	Holistically robust	0.17	4
			Political/institutional barriers	0.17	3
			Ecological damage	0.17	1
			Adoptability	0.17	3
Total return scores		7.4	Total risk scores		3.3

Table 15: Return-risk Analysis for Tapping Urban Runoff

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	5
Competitive advantage	0.3	7	Holistically robust	0.17	5
			Political/institutional barriers	0.17	6
			Ecological damage	0.17	2
			Adoptability	0.17	4
Total return scores		7.7	Total risk scores		4.2

Table 16: Return-risk Analysis for Rainwater Harvesting

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	4
Potential to protect or restore ecosystems health	0.3	7	STI skills and capacity	0.17	5
Competitive advantage	0.3	7	Holistically robust	0.17	6
			Political/institutional barriers	0.17	5
			Ecological damage	0.17	3
			Adoptability	0.17	3
Total return scores		7.4	Total risk scores		4.3

Table 17: Return-risk Analysis for Zero Pollutant Discharge

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	7
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	7
Competitive advantage	0.3	4	Holistically robust	0.17	6
			Political/institutional barriers	0.17	8
			Ecological damage	0.17	2
			Adoptability	0.17	5
Total return scores		6.8	Total risk scores		6.2

Table 18: Return-risk Analysis for Conjunctive Use

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	2
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	7	Holistically robust	0.17	2
			Political/institutional barriers	0.17	2
			Ecological damage	0.17	2
			Adoptability	0.17	3
Total return scores		7.7	Total risk scores		2.3

Table 19: Return-risk Analysis for Flood Forecasting

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	2
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	7	Holistically robust	0.17	2
			Political/institutional barriers	0.17	2
			Ecological damage	0.17	2
			Adoptability	0.17	3
Total return scores		7.7	Total risk scores		2.3

Table 20: Return-risk Analysis for Education Reform

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8	Technical barriers	0.17	2
Potential to protect or restore ecosystems health	0.3	9	STI skills and capacity	0.17	3
Competitive advantage	0.3	7	Holistically robust	0.17	6
			Political/institutional barriers	0.17	6
			Ecological damage	0.17	1
			Adoptability	0.17	5
Total return scores		8	Total risk scores		3.8

Table 21: Return-risk Analysis for Protection of Ecosystems for Point and Non-Point Pollution

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	8.5	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	9	STI skills and capacity	0.17	3
Competitive advantage	0.3	6	Holistically robust	0.17	6
			Political/institutional barriers	0.17	7
			Ecological damage	0.17	1
			Adoptability	0.17	4
Total return scores		7.9	Total risk scores		4.0

Table 22: Return-risk Analysis for River Rehabilitation

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	7	Technical barriers	0.17	4
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	6	Holistically robust	0.17	3
			Political/institutional barriers	0.17	7
			Ecological damage	0.17	1
			Adoptability	0.17	3
Total return scores		7.0	Total risk scores		3.5

Table 23: Return-risk Analysis for Irrigation Water Use Efficiency

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	3	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	6
Competitive advantage	0.3	7	Holistically robust	0.17	4
			Political/institutional barriers	0.17	2
			Ecological damage	0.17	1
			Adoptability	0.17	3
Total return scores		5.7	Total risk scores		3.2

Table 24: Return-risk Analysis for Community Values Ecosystem Services for Malaysia

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	4	Technical barriers	0.17	3
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	3
Competitive advantage	0.3	6	Holistically robust	0.17	2
			Political/institutional barriers	0.17	8
			Ecological damage	0.17	1
			Adoptability	0.17	6
Total return scores		5.8	Total risk scores		3.8

Table 25: Return-risk Analysis for Advanced Water and Wastewater Treatment

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	7.5	Technical barriers	0.17	5
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	5
Competitive advantage	0.3	3	Holistically robust	0.17	6
			Political/institutional barriers	0.17	5
			Ecological damage	0.17	2
			Adoptability	0.17	5
Total return scores		6.3	Total risk scores		4.7

Table 26: Return-risk Analysis for Repair of Wetland Ecosystem Services for Malaysia

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	5	Technical barriers	0.17	4
Potential to protect or restore ecosystems health	0.3	7	STI skills and capacity	0.17	4
Competitive advantage	0.3	7	Holistically robust	0.17	4
			Political/institutional barriers	0.17	7
			Ecological damage	0.17	2
			Adoptability	0.17	8
Total return scores		6.2	Total risk scores		4.8

Table 27: Return-risk Analysis for Water Planning in an Uncertain Climate

Return Criteria	Weight	Score	Risk Criteria	Weight	Criteria
Market potential/ROI	0.4	5	Technical barriers	0.17	6
Potential to protect or restore ecosystems health	0.3	8	STI skills and capacity	0.17	6
Competitive advantage	0.3	6	Holistically robust	0.17	6
			Political/institutional barriers	0.17	4
			Ecological damage	0.17	3
			Adoptability	0.17	6
Total return scores		6.2	Total risk scores		5.2

APPENDIX 4: Investment Roadmap

Develop Eco-Tourism around High Ecological Value Sites

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	National mapping of potential high value ecotourism sites. Assessment and research. Identification of unique values and attractions of Malaysian ecosystems potential. Assessment of direct and indirect benefits of the identified sites in a triple bottom line format, blending local/indigenous interests with commercial interests for mutual benefit, research on climate change impacts on eco-tourism in Malaysia tourism market	Research into Biodiversity Inventory of the identified and assessed eco-tourism sites. Ecosystem management science and technology education	Green technology (energy source, transportation, buildings, etc.), research and education	Demonstration of ecological and biodiversity conservation Chemical free water treatment and processing	Green technology application Malaysia as the hub for biodiversity, high-tech ecotourism management
Enablers	Commitment of various government agencies. Coordination between various government agencies. Financial and institutional support. High-tech marketing and promotion of eco-tourism including packages.	Creation of "Sustainable Trail Initiatives (STI)" voluntary groups e.g. friends of an ecosystem	Extensive ecosystem science for the development of detailed code of practice for tourism operators to minimise damage	60% of population in urban - education and promotion, higher temperatures encourage people to take refuge in cooler places including eco-tourism areas	People appreciate green technology, research funding, ecological laws in full force.
Outcomes	National maps of high value ecotourism potential sites. Complete full ecological assessments of the identified ecological sites. High values and appreciation of	Highly valuable biodiversity inventory of Malaysian eco-tourism sites Local community and national economic benefits of the eco-tourism	Demonstration of fully green technology in action in and around the eco-tourism sites, critical mass professional eco-tourism guides and managers.	Highly valued biodiversity and ecological attractions for high valued customers/tourists	Tropical forest and wetland base and marine base eco-tourism as the main attraction

	ecosystems for and ecosystems		Specialized eco-tourism sites (birds watching/water sports/mountain climbing/marine recreational fishing, etc)		

Urban Water-Based Tourism

	2010-15	**2015-20**	**2020-30**	**2030-40**	**2040-50**
STI	Assessment of restoration potential on water quality and ecosystem functions	Adaptation and development techniques applicable to tropical urban system	Application of science and technology to developing restoration plans	Application of science and technology to implement restoration plans	Specialised training facilities
Enablers	Vision and commitment	Research and development funding	Critical mass of restoration skill	Funding and competent implementer	Service industries with specialised Malaysian consultant
Outcomes	Identify potential urban based tourism plan and location.	Restoration techniques applicable to Malaysia's urban rivers	plans for restoration project with target benchmark	5 flagship urban water based tourism projects completed	Export services to other tropical countries

Market and Export High Quality Water

	2010-15	2015-20	2020-30	2030-40	2040-50
STI Investment	Mapping potential source of high quality virgin spring water from the untouched tropical forest Ecofriendly packaging	Develop quality standard and regulation	Ensuring sustainable extraction of bulk waters	Advanced bulk water transport technology	Major player in water export technology
Enablers	Ecofriendly marketing advantage	SME to develop niche water market	Private sector investment- 2 billion people facing water scarcity	Private sector investment - 3.5 billion people facing water scarcity	Private sector investment - 9 billion people facing water scarcity
Outcomes	Niche market water sources known	Export water industry developed	Malaysia enters the bulk water export market	Malaysia is an established world player	Malaysia is a prominent water exporter

Clean Water for the Aquaculture Industry

	2010-15	2015-20	2020-30	2030-40	2040-50
STI Investment	Recycling water to a standard for a guaranteed high quality product	Application of smart sensors	Synthetic marine water for optimization of location and design of aquaculture facilities	Fully automation using robotics system	Design of sustainable large scale aquaculture enterprises
Enablers	Importation and adaptation of existing technology	Nanotechnology research	Land/ water use capability assessment	Application of robotics technologies	Collapse of global fisheries and increasing global water scarcity
Outcomes	Disease prevention	Real time monitoring water quality for quality control	Aquaculture optimally located for optimal human, economic and environmental benefits	Sustainable, reliable, efficient and high quality water supply for eco label aquatic product	Exploiting Malaysia's abundant water resources to upscale aquaculture for high value exports

Malaysian Brand for Domestic Water Purifier

	2010-15	2015-30	2030-40	2040-50
STI **Investment**	• Identification of existing local products in the market • Development of operating procedures for halal and tayibah certification	• Development of local and innovated produts of filter medium and other auxiliaries • Promotion and export of local products at the global market	Green technology on domestic water purifier and its components	
Enablers	Government and private initiative	Government and private initiative	Government and private initiative	
Outcomes	Certification procedures	New and improved products	Eco-friendly products	

World Leading Tropical Aquatic Research and Education

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Design of world leading tropical aquatic research and education centre recognising Malaysia's abundant aquatic/ecosystem resources	Real-time testing of facilities as they come online. Course development completed with fully enabled virtual learning.	Course and research programs rolled out across Malaysia	Understand science, research and education needs across many tropical countries	Monitoring and evaluation plan for centre's impact on sustainability designed and implemented
Enablers	Business model presented and agreed with government and partners	Funding, virtualisation technologies	Highly skilled professional staff attracted	International marketing; international reputation	Funding for impact assessment
Outcomes	Business model and development plan in place that is futuristic to match foreseen technology advances over 50 year lifespan and incorporates appropriate level of commercial features (e.g. Australian CRC model)	Facility built in physical and cyberspace	Recognised leading research and education centre in Malaysia	Recognised as a leading institution across all tropical regions with real and virtual nodes established in many countries and cornerstone of capacity development	Impact of centre on sustainability of tropical regions recognised and results fed back to continuously improve effectiveness of centre. Export earnings amongst best for special centres in Malaysia.

Knowledge Export

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Focus on human resource development specializing in water sector Improvement of experts and expertise directory	National research alliance on water STI	Demonstration of successful R&D and commercialization of Water STI	Government and private partnership in water STI	Malaysian companies on water STI operating overseas
Enablers	Strong policy directive towards water STI	Strong legal and policy support to potential products/ technology and expertise	International partnerships and collaborations	International satellite offices	International trade promotion and legal supports
Outcomes	Enhanced interest in the water sector STI Increase number of human resource trained in water STI	Enhanced R&D and commercialization Increase in international partnerships and collaborations	Intensified R&D and commercialization of water STI including overseas markets	Increasing trend of national income generated overseas from the water based products/ technology and expertise.	Significant contribution from water based technology/ products and expertise to national income generated overseas

Downstream Water Tapping

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of demonstration unit of RBF system along major rivers Mapping off urban runoff potential for water supply Public awareness campaign on total protection of water resources	RBF is widely accepted for large scale implementation Design of smart barrage that can automatically regulate flow Flood risk modelling for potential site which incorporate climate change impact	Show case of urban water collection system for water supply Public awareness campaign on total protection of water resources	Tapping urban runoff technology is implemented in high water demand areas Realization of integrated river basin management	Enhancement of urban water facilities for eco-tourism and conservation
Enablers	Policy statement, Hydraulic modeller	Availability of fund and technical resources	Private investment, Incentive from the government, enforcement	Private investment, Flexible water supply policy	Private sector, greater public ownership/ participation
Outcomes	Public acceptance of RBF system Documented urban runoff potential	Acceptance by potential investor and the public RBF provides cleaner water	Cleaner river, wider acceptance by the public	New source of freshwater in urban area Reduced cost for water transfer Cleaner urban runoff through public participation Improved river habitat	Healthier river ecosystem Increase property values Increase tourism revenue

Rainwater Harvesting

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Rainwater harvesting for new public & commercial buildings and heavy water use industries	Rainwater harvesting system is implemented in 30% of new residential areas and compulsory for heavy water use industries	Show case of large scale rainwater harvesting system In all new housing areas	Treated rainwater for domestic and industrial used	Widely accepted technology for using rainwater in water supply system
Enablers	Enforcement of the existing policy, incentive	Enforcement of existing policy, higher industrial and domestic water tariff	Private investment, right government policy and incentive	Private investment, higher water tariff for domestic and industrial use	Private investment, strong policy and enforcement
Outcomes	Reduced water bill	Reduced dependency on tap water and minimise flash flood	Additional source of raw water Reduced flood risk	Cost saving from delayed construction of major water resources infrastructure	Rainwater as major source in water supply system Significant reduction in flash flood and urban runoff pollution

Zero Discharge

	2010-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of effective tertiary treatment for water recovery at wastewater treatment facilities, either domestic or industry Emphasized in water stress areas such as Kelang Valley and Melaka Also implemented in areas where high natural water body quality is to be maintained, such as upstream of tourism site, where discharge of effluent is to be minimized	Local development and installation of state-of-the-art technologies for manufacturing processes and end-of-pipe tertiary wastewater treatment expansion of zero discharge application to other areas	Export knowledge of wastewater treatment Recovery of materials other than water, e.g. energy	Low carbon footprint technologies
Enablers	Incentives, policy, Stringent regulation & enforcement	Incentive and policy Private & institutional initiatives	Private & institutional initiatives	Political commitment and concern for global warming
Outcomes	Water saving. Hence reduce water stress Improvement of water quality and human and ecosystem health at sensitive areas	Wealth creation Water saving. Hence reduce water stress More improvement of water quality and human and ecosystem health in the country	Wealth creation Eco-friendly industry	Support national low carbon policy

Opportunities for Sustaining the Resource

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Intensive assessment of current and future water resources and demand in all states	Complete mapping of Malaysia's aquifer systems and its capacity Study of Ground water physico-chemical characteristics and propose treatment	Design and installation of large scale groundwater plant to supplement water in 3 major areas (KL, Penang, Johor Bahru)	More groundwater plant to be installed to supplement water in major areas	Technology is fully developed for large and small scale groundwater plant
Enablers	KeTTHA, NAHRIM, JMG	KeTTHA, NAHRIM, JMG	KeTTHA, NAHRIM, JMG, State Gov	KeTTHA, NAHRIM, JMG, State Gov and private investment	Private investment
Outcomes	Updated reliable water supply and demand data for Malaysia known	Updated, reliable Malaysia's aquifer system and its physi-chemical quality known	Increase groundwater usage to 10%. Reduce surface water usage thus cut down treatment cost and river water quality downstream	Increase groundwater usage to 20%. Reduce surface water usage thus cut down treatment cost and river water quality downstream	Groundwater can be a main source for areas far away from water supply

Improve Flood Forecasting and Mitigation

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Application and adaptation of flood forecasting and mitigation models	Perfection of flood early warning system Technique for predicting future rainfall and flood	Adaptation measures to flood associated with climate change	Development of local brand hydraulic and hydrological software specializing in tropical environment	Technology is fully developed and ready for market
Enablers	Sufficient numbers of professionals	Investment on state of the art technology	Private investment	Critical mass of professionals	Private investment
Outcomes	Capable of using models and up to date software	Minimization of flood damage	Reduced risk of extreme flood associated with climate change	Malaysian global player	Market services

Reform Water Education Approach

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Development of local based water module/curricular	Establishing water care groups	Online water education	Integration of education and awareness system	
Enablers	Education Ministry together with all agencies related to water sector	Community based national program	Web 3.0 - intelligent web	Convergence of all good quality education material with information access and strong community involvement	
Outcomes	Incorporate water education in primary, secondary and tertiary education	Experiential learning	Universal access to water information	Whole population values water	

Improve Ecosystem Protection from Point and Non-point Pollution

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Developing a national scale ecosystem services assessment protocol	Application of online sensors and satellite technology	Advanced wastewater treatment, zero discharge, best management practice, precision farming for efficient use of agriculture chemical. Organic farming is widely practised	Design of sustainable ecosystem management	Scientific demonstration/ establishment ecosystem benefit compared to unsustainable practices
Enablers	Political will and funding, overcoming institutional barrier	funding and adaptation of existing technology	Polluters pay scheme strategy is fully enforced	Best practise policy, guidelines and implementation	Massive loss of biodiversity elsewhere in the world. Malaysia is less impacted by climate change
Outcomes	Nationwide prioritisation of ecosystem services and risk protection requirement	Fully established national scale assessment and monitoring	Improvement in overall water quality	Potential of ecotourism is fully realised	Malaysia recognised as a global resource of biodiversity and genetic resources

Clean-up and Rehabilitate Waterways in Highly Visible Locations to Improve Aesthetics and Ecological Functioning

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Design of a national river rehabilitation program based on best available science and proven green and soft engineering techniques. Green jobs initiative supported by river restoration short courses.	Careful mapping and prioritisation of sites based on transparent TBL criteria and public consultation. World best practice river rehabilitation manual for tropical river systems developed. Imaginative new sustainable public access and enjoyment facilities tested in virtual landscapes. Flood mitigation, navigation and real estate developments optimised.	Project initiation and implementation technical supervision and guidance, with before and after evaluation sites established. Restoration sites used effectively in primary, secondary and tertiary and third age education.	Tropical river rehabilitation knowledge packaged for export to other tropical countries, supported by regular 'science tours' of icon projects.	Malaysia submits most successful river rehabilitation project to the International River Prize following best example of pre/post evaluation.
Enablers	Program business plan presented to government	Public support. Business joint ventures. Government financial support.	University staff and/or consultants to supervise projects. Community, local government and local industry tangible support.	Knowledge packaging. Overseas marketing. Growth of Malaysian-based consulting companies.	River prize application.
Outcomes	National river rehabilitation program initiated including 'green jobs' initiative	Priority sites identified. Techniques established. Guidelines for tropical systems finalised. Riverine landscaping concepts and planning for new business opportunities	Six major projects completed for R1billion. Ecosystem functioning restored and iconic species restocked. Local pollution sources controlled. Urban and rural dwellers flock to new tourism sites which emphasised encouraging human sharing of river environments in novel	Tropical river rehabilitation knowledge and skills exported to tropical countries earning Malaysia export income.	Malaysia wins international riverprize ($500,000) that provides impetus to overseas 'twinning ' projects.

		completed.	but sustainable ways. Learning outcomes achieved across all sectors of the community.		

Irrigation Water Use Efficiency

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Intensive assessment of current and future irrigation water use and water auditing in all states	Application of smart sensors to control water supply	Adaptation measures of Irrigation water supply with climate change	Full development of local brand hydraulic and hydrological software specializing in tropical environment	Technology is fully developed and ready for market
Enablers	ministry of agriculture	Sufficient number of professionals to focus on artificial Intelligence research	Integration of data on optimise water use and climate change	Application of fully automation in irrigation sector	Private investment
Outcomes	Irrigation of current and future water needs known	Real time monitoring optimisation of water use	Minimization of water loss	Malaysian global player in Irrigation system	Market services

Community Values Ecosystem Services

	2010-15	2015-20	2020-30	2030-40	2040 -50
STI	Developing a national scale ecosystem services valuation protocol	Application of latest technology (e.g. online sensors and IT) for immediate dissemination of ecosystem conditions	Best practise policy, guidelines and implementation	Application of latest management technology based on ecosystem wealth to drive national economy and development	
Enablers	• Human resource capacity. • Research, education and awareness programs targeted towards general public, politicians and decision makers. • Institutional and financial support.	• Strengthening the aspects of ecosystem services in school and university curriculum. • Extensive awareness programs. • Legislation enforcement on protection of identified ecosystem services	Community involvement in ecosystem services conservation (e.g. Friends of Ecosystem Sustainable Trail Initiatives). Financial and legislation	Government and private institutional commitments and involvement, including universities and research centres, NGOs, etc.	
Outcomes	• Fully established national scale ecosystem services valuation protocol. • Extensive data on the values of Malaysian ecosystem services	Changes of attitudes towards ecosystem services values among the general public, politicians and decision makers	Malaysians are highly knowledgeable and appreciative of the values of ecosystem services evidenced by better ecosystem conservations.	Significant ecosystem services contribution to the economy and development	Ecosystem services as one of the main economic and development drivers

Advanced Water and Wastewater Treatment

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Installation of advanced water treatment at polluted water sources (WTP) Installation of nutrient removal system at STP Installation of effective tertiary treatment for industries (sensitive areas)	Expansion of the advanced technology application to major cities in Malaysia	Expansion of the advanced technology application throughout Malaysia	Export knowledge of wastewater treatment	Low carbon footprint technologies
Enablers	Incentives, policy, Stringent regulation & enforcement	Incentives, policy, Stringent regulation & enforcement	Incentives, policy, Stringent regulation & enforcement	Private & institutional initiatives	Political commitment and concern for global warming
Outcomes	Improvement of water quality and human and ecosystem health at sensitive areas	Improvement of water quality and human and ecosystem health at major cities	Improvement of water quality and human and ecosystem health throughout Malaysia	Wealth creation	Support national low carbon policy

Wetland Ecosystem Repair

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	• Mapping of degraded water ecosystem • Assessment of site specific potential. • Prioritization of wetland for restoration	• Appropriate design and technique for wetland restoration. • Implementation of restoration program for priority wetlands		Evaluation techniques of restoration success	Managed as protection of the ecosystem and development of ecotourism properties.
Enablers	• Expert and government support 2. Rationalization of wetland management	Strong government and local community involvement	Continues program on ecosystem restoration, education and awareness	Budget to support evaluation of restoration success	Committed NGOs
Outcomes	Comprehensive report on degraded wetland	Restoration of degraded wetlands		Enhanced ecosystem services	Managed as protection of the ecosystem and development of ecotourism properties

Water Management Planning to Improve Resilience with Uncertain Climate Future

	2010-15	2015-20	2020-30	2030-40	2040-50
STI **Investment**	Invest in acquiring leading international climate science and modelling to provide up-to-date projections for Malaysia, whilst training up local scientists for ongoing applications.	Apply climate change projections to the coastal assets at risk around the whole coastline of Malaysia, completing a risk assessment that takes into account sea-level rise, storm surges, changing ocean temperatures and acidity, and tropical storms and cyclones.	Couple climate forecasts to hydrological and hydraulic models with better computing power to provide integrated catchment by catchment risk assessments.	Science-based adaption strategies that cater for slow moving climate change and extreme events such as heat wave impacts on sensitive thermal tolerances of aquatic tropical species, sea defences against rising sea levels, dam splillway design for new flood risks, and refined logging practices to minimise risk of landslides.	Re-assess climate projections with latest quantum computing models and better knowledge of global response to reducing greenhouse gas emissions and incorporate across integrated e-planning systems.
Enablers	Access to world class climate science and modelling expertise. Recent Malaysian climate science graduates/PhDs and modellers.	Robust climate change projections combined with the best local knowledge of coastal processes and competent risk assessment.	Use rapidly increasing computer power (e.g. Optical computing) to apply next generation of climate models that couple with land surface processes and feed into hydrological and hydraulic models.	Well developed emergency plans and well considered adaptations at regional and local levels. Strong support from provinces and local utilities.	Quantum computing, e-planning

Outcomes	Improved climate projections for Malaysia covering temperature, precipitation and evaporation, with best estimates of extreme events risks to water resources and dependent communities, industries and environments	Coastal vulnerability assessment completed for all coastal regions of Malaysia including local communities, coast-based industries and coastal ecosystems such as mangroves and estuaries.	Detailed assessments of climate change risks arising from increasing temperature and evapotranspiration, changing rainfall patterns, changing soil moisture, altering flow regimes and extreme events such as heat waves, forest fires, storms, cyclones, and droughts.	Improved triple bottom line resilience through carefully planned adaptations and emergency response guidelines.	Planning systems support reduced long term impacts of Climate Change

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