Water: Our Future
About Future Directions International

Future Directions International (FDI) has two roles: to ensure that Australians recognise they are part of a two-ocean continent and that West Australians see themselves belonging to a dynamic, national entity in a developing region of the world.

Much of Australia’s external focus has centred on the Pacific, Southeast and Eastern Asia. With its developing wealth, increasing population, evolving trade and shipping capabilities and expanding geographic, political and security significance, however, the Indian Ocean and its littoral states will play an increasingly important role in Australia’s future.

Western Australia is entering an unprecedented period of wealth and development. For this to be sustained, however, West Australians need to understand the challenges and opportunities they face, nationally, regionally and globally.

To achieve these outcomes, leaders and their policy makers and implementers need to be aware of the geo-strategic complexities of their region. With this in mind, FDI has established four areas of research that embrace the following:

- Developments in the Indian Ocean Region, including its littoral states;
- Meeting Australia’s energy requirements by 2030;
- Developments in Northern Australia and their impact on the economy, population, infrastructure, environment, security and foreign relations; and
- Implications for Australia of the developing global food and water crises

FDI will continue to ensure that its product is passed to an increasing number of Associates who will benefit from its future looking research. In so doing, FDI is establishing itself as an Australian centre of excellence in these four areas.

Launched in 2000 as the Centre for International Strategic Analysis (CISA), by the then former Governor of Western Australia, Major General Michael Jeffery AC AO (Mil) CVO MC (Retd), FDI has since grown over the past decade to become a respected Australian research institute.

As a Perth-based independent research institute for the strategic analysis of Australia’s global interests, FDI has proven itself to be a centre of ongoing influence in shaping public discussion and government policy.
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Future Directions International

Foreword

Food security will increasingly become of major global concern, as the world’s population increases, greater access to limited fresh water becomes necessary and the amount and fertility of arable land declines. Some analysts suggest that we may need to double the amount of food produced by 2050.

Access to sustainable fresh water resources is a major issue in providing this additional food.

This Landmark Study, therefore, is a timely and relevant record of a number of papers produced by the Perth-based research institute, Future Directions International.

Specifically, the Study seeks to answer the following questions:

What role does the availability of fresh water play in determining the likelihood of a global food crisis? And what are some of the means by which this crisis could be ameliorated?

The conclusions reached suggest access to freshwater is critical to global security. Without water, several billions of people could be affected by starvation leading to the likelihood of serious civil unrest and mass migrations. Policy makers therefore need to comprehend and accept the challenges we face.

The Study examines some solutions but does not seek to answer comprehensively all issues relating to water security. Instead, it is a broad study requiring constant review. It presents some unique perspectives and collates information in a refreshing way. It also identifies areas for further research. The Study is designed to be read by key decision makers who are not necessarily experts in the terminology and jargon of water security.

FDI is indebted to the Associates and Interns who compiled the document. The results of a roundtable conference, which involved a number of national and international experts who are named at the end of the Study, are included throughout.

I congratulate FDI and recommend that the Study be widely read.

Major General Michael Jeffery (retd) AC, AO(Mil), CVO, MC
Chairman, FDI

Future Directions International
Executive Summary

Sustainable food production depends on an adequate supply of water and its proper interaction with healthy soils.

Analysis indicates, however, that by 2050 a third of the world’s population may experience severe or chronic food shortages. If this situation is to be avoided, a key issue will be on how we secure and better manage the requirement for, and our use of fresh water. This will need improved government, corporate and individual consideration, significantly greater research and better education and training.

This Landmark Study analyses the issue from certain perspectives and results in a number of conclusions that are listed below.

Water Crises - International Areas at Risk

- By 2050 water scarcity could affect three-quarters of the world’s population.
- Regions to watch have high population density (greater than 100/sq.km); low per capita GDP (less than $765/person); overall unfriendly relations; politically active minority groups; proposed large dams or other water development projects; and few, if any, freshwater treaties.
- As the stakes become higher as a result of concerns such as declining water resources and increasing populations, the globe may see a marked change in the way that countries are prepared to defend or acquire rights over freshwater sources.

Water Surplus Countries

- By 2050, predictions indicate that 15 per cent of the world’s countries will be experiencing water deficiency, most of them in the Middle East, North Africa and China.
- The regions of water surplus have geographical characteristics such as: good rainfall, resulting in good run off; aquifers; large freshwater sources (lakes, rivers, etc.); and low evaporation rates (due to humidity or low flow rate of fresh air; cold water evaporates slower).
- Water surplus regions have water usage characteristics such as low population density and effective usage of available water supplies.
- Countries with water surpluses are generally located in South America, North America, Northern Europe (including Russia), South East Asia and Australasia.
- Most countries with water deficits are located in the Middle East and North Africa (MENA) region and Central Asia.
- Currently, 166 countries enjoy a water surplus.
- By 2050, 34 countries, or 15 per cent of the global total, will be experiencing water deficiency - five more water deficit countries than there are presently.

Global Water Availability to 2050

- Increased demand for water will also result from an increase in demand for milk, meat and other high water-usage agricultural products.
The Middle East and North Africa are the regions at the highest overall risk. Other water hotspots, where water stress is likely to be high, are in Mexico, the USA, North Africa, the Middle East and the North China Plain.

Australia, South Africa and parts of India and the United States, also have high water-stress levels.

Urbanisation will create further challenges for water supply, recycling and delivery.

UN reports say clearly that, by 2050, it will not be so much the lack of land, but rather the lack of water that will be the major constraint on food security.

**Walking on Water-Global Aquifers**

- Almost all parts of the global landmass hide a subterranean water body.
- The volume of freshwater on the earth is around 35 million cubic kilometres; 30 per cent is stored underground and potentially available for human consumption.
- Estimates suggest that by 2050 an additional 6,000 cubic kilometres of water will be required annually, to feed an additional 2.5 billion people.
- For the majority of countries, water consumption from aquifers has been over-exploited; that is more is being pumped out than is being collected.
- Access to water, water rights, restoration of the small water cycle and trading in water will become increasingly important in the next century as demand for the resource increases.
- As water becomes more valuable we can expect an increase in underground exploration for new water sources.

**Desalination: A Viable Answer to Deal with Water Crises?**

- There are about 14,500 desalination facilities across the globe but the highest desalination capacity is located in the Middle East. Desalination plants are vital for economic development and social stability in many arid regions. The global demand for desalination units is projected to triple within the next six years.
- Desalination is the only climate independent source of water available. Other alternative sources, such as water recycling and storm water harvesting, still require sufficient amounts of water entering the water cycle to allow them to operate.
- Desalination facilities have specific, expensive infrastructure and relatively high energy use, which challenges its economically sustainable development. Developments in desalination techniques and energy efficient technology, are vital to make the desalination option economically sustainable.
- The two main ways that a desalination plant causes environmental harm are through greenhouse gas emissions, when coupled to a power plant, and degradation of marine environments. Improvements are being undertaken to minimise environmental harm caused by desalination processes.
- When considering the viability of a desalination plant, a comparison of market drivers and restraints is essential. At present, key market drivers are in favour of an expansion in the global desalination market.
The Rundown on Rainmaking

- Estimates indicate that 24 countries are participating in a total of 80 cloud seeding projects.
- Artificial rainmaking has the potential to form a significant component of water resource management.
- The United States invests approximately US$600,000 each year in cloud seeding, which has produced an average annual output of 50 million tonnes of water for drinking and farm water supplies.
- Cloud seeding does not produce changes in long-term weather patterns or climate and is a costly operation.
- Cloud seeding does not work everywhere. Suitable conditions must be available for it to be a cost-effective means of increasing rainfall.
- It could take some years before it provides the reliable and consistent results desired by drought-affected agricultural producers.

Options for Using Urban Water Runoff to Water the Cities

- A growing urban population across the globe is straining water infrastructure.
- Studies have suggested that when urban runoff techniques are implemented, stormwater runoff can be reduced by up to 70 per cent. This reduces pollution entering waterways by up to 90 per cent and also reduces site development costs.
- Capturing urban runoff could be an effective alternative water source, if there is interagency coordination.

Water Security in India: The Coming Challenge

- Booming populations, extreme poverty, rampant industrialisation and urbanisation, inefficient water use and, increasingly, climate change, have all had a negative impact on the overall water situation in Asia.
- By 2030, India will be extremely close to becoming ‘water scarce’.
- The volume of groundwater in India is inadequate to sustain their huge population, especially one that is industrialising and urbanising at such a rapid pace.
- By 2030, the Ganges and Brahmaputra river systems will become unreliable sources of water for those who depend on them.

Several other issues are also worthy of greater consideration and will be the subject of further FDI studies.

One of the studies reflects work presently being done by Outcomes Australia. This study seeks to understand how nature evolved and sustained productive and resilient bio-systems. Chapter 9 makes a number of useful observations with regard to this issue. It states that as climate changes intensify, this is going to become even more serious, resulting in:

- An expected 30 per cent decrease and more variable rainfall patterns in southern Australia.
➢ Up to a 50 per cent decrease in water runoff and stream, wetland and dam recharge.

➢ Serious risks to the water supplies and security of agriculture, industry and cities.

Australia must focus on regenerating its soil structure, the health of which governs the effective filtration of rainfall. Soil structures can be improved, practically, rapidly and even profitably, by simply restoring their natural soil organic matter content, thus aiding:

➢ The infiltration, retention, availability and sustained supply of water from such soils.

➢ The aeration and capacity of roots to proliferate and penetrate deep into soils, and

➢ The capacity for water to recharge and irrigate soils from below to limit excessive evaporation.

There are a number of ways of doing this: rebuilding soil structures, restoring woodlands, recharging wetlands and flood plains and creating ‘counter-gravity’ hydrological processes.

Other water issues that FDI is considering include:

➢ Water pricing and trading.

➢ Water quality.

➢ Food wastage and how better management could reduce the need for water to support the growth of food.
Water Crises - International Areas at Risk

By Gary Kleyn, Manager
Future Directions International Global Food and Water Crises Research Programme

Key points

➢ By 2050 water scarcity could affect three-quarters of the world’s population.

➢ Regions to watch have high population density (greater than 100/sq.km); low per capita GDP (less than $765/person); overall unfriendly relations; politically active minority groups; proposed large dams or other water development projects; and few, if any, freshwater treaties.

➢ As the stakes become higher as a result of concerns such as declining water resources and increasing populations, the globe may see a marked change in the way that countries are prepared to defend or acquire rights over freshwater sources.

Analysis

Today an estimated one billion people do not have access to sufficient safe water. By 2025 the United Nations expects that half the nations will face water shortages or anxiety. By 2050 water scarcity could affect three-quarters of the world’s population. Between 1900 and 1995, global water consumption is said to have risen six-fold – more than double the population growth.

The Food and Agriculture Organization calculated in its 2007 report ‘Coping with Water Scarcity - Challenge of the Twenty-First Century’, that if all the freshwater were divided equally among the global population, there would be 5,000 to 6,000 cubic metres of water available for every person, every year. The definition of scarcity is when people have less than 1,000 cubic metres per person, which includes water used for drinking and the production of food.

These figures suggest that there is an abundance of water and certainly no global shortage. As the FAO report stated, however, it is not a question of total world supply but rather of the distribution of water. Water is distributed unevenly across the globe, as is the world’s population. It then follows that countries with most acute water scarcity issues, have high population densities, in addition to relatively low availability of freshwater. The FAO report says, for instance, that Jordan is already well below the threshold, with less than 200 cubic metres per person.

Some countries, by virtue of their location and topography, have access to sources of freshwater; other countries are dependent on the goodwill of their neighbours to ensure that the waterways, basins and rivers flow unobstructed past their boundaries. Egypt is an obvious example; its water supply depends on the goodwill of countries upstream on the River Nile.

There are 263 international basins that cross the political boundaries of two or more countries. These basins cover approximately half of the earth’s surface, and those areas account for an estimated 60 per cent of the global freshwater flow and accommodate 40 per cent of the world’s population.

Historically, evidence shows that despite the complexity of many water disputes, the majority have been handled diplomatically rather than through military means. In the past 50 years, 37 acute disputes have resulted in violence, while conversely 150 treaties were signed.
According to the Food and Agricultural Organization, more than 3600 treaties related to international water resources have been drawn up since 805 AD. In South East Asia, Cambodia, Laos, Thailand and Vietnam have managed to cooperate since 1957 in the Mekong River Commission, sometimes even in the presence of other political conflicts. Likewise, Israel and Jordan have held regular talks about sharing the Jordan River, while the Indus River Commission continues to handle water issues between India and Pakistan. In 1999, a framework involving ten countries was agreed for the Nile River Basin.

The Institute of Water and Watersheds at Oregon State University in the United States, has published detailed accounts of historical and current international conflicts over water as part of its Basins at Risk study. The university has developed a database of fresh water rivers and basins, which lists a number of places where highly conflictive events have occurred. These include the Amur River and Aral Sea (internal drainage), and the Rivers Ganges-Brahmaputra-Meghna, Jordan, Karnaphuli, Kura-Araks, Nile, Orange, Senegal and the Tigris and Euphrates. The Jordan tops the list with 29 negative events involving conflicts between neighbours. At the other end of the spectrum, the institute’s research shows that the Danube enjoys high cooperation between states, as do some sections of the Ganges.

The same report, which considers water cooperation and conflict from 1948 to 1999, found that there was overwhelming cooperation over water between countries, including issues of water quantity, quality, joint management and hydropower. Conflictive events tended to relate to quantity and infrastructure concerns.

During the period studied, there were 1831 events, affecting 124 countries. Events could be anything from a formal declaration of war, hostile political or military actions, through to strategic alliances or treaties. Out of the 1831 events, 28 per cent were conflictive, 67 per cent cooperative and the remaining five per cent were neutral or non-significant.

Water quality, infrastructure, joint management and hydropower dominated the issues that countries dealt with. The majority of events were associated with basins in North Africa, the Middle East, sub-Saharan Africa and Eastern Europe; followed by Southeast and South Asia, and South America. The Middle East and the North African region show the lowest level of cooperation, while Western Europe had the highest.

What Mechanisms Exist

The United Nations has worked in different regions to bring about cooperation through River Commissions and other frameworks. The 1997 United Nations Convention on Non-Navigational Uses of International Watercourses deals with shared water resources.

The Convention:

- Calls for reasonable and equitable use of shared watercourses;
- Requires that countries do not do appreciable harm to others;
- Establishes environmental protection standards;
- Calls for the sharing of water-related information; and
- Establishes that the linkages between surface water and groundwater need to be considered.

The convention’s ambiguity, however, leaves the interpretation of these issues up to the individual
countries. Perhaps indicating the ineffectiveness of the convention and the difficulties met in ratifying it, only 16 countries, heavily slanted by European representation, have ratified the water sharing international agreement: Finland, Germany, Hungary, Iraq, Jordan, Lebanon, Libya, Namibia, Netherlands, Norway, Portugal, Qatar, South Africa, Sweden, Syria and Uzbekistan.

In addition, in 1992 the United Nations adopted the non-binding Agenda 21, which relates to the protection of the quality and supply of freshwater resources. In 2008, the UN General Assembly adopted the ‘Law of Transboundary Aquifers’ resolution, which encourages nations to make bilateral or regional arrangements for the sustainable management of transboundary aquifers. An aquifer is a layer of rock or soil able to hold or transmit water.

The United Nations, however, believes that there is a need for an institution that provides third-party support, trusted by all factions, and that develops a process of cooperation. The United Nations also believes that there must be workable monitoring provisions, enforcement mechanisms and specific water allocation provisions.

**Regions to Watch**

The Basins at Risk report evaluated past conflicts over water to determine what some of the similarities were, so that it would be possible to predict future flashpoints. The aim was to prevent conflicts occurring. It found that basins with a high risk of conflict have the following characteristics:

- High population density (greater than 100/sq.km);
- Low per capita GDP (less than $765/person – 1998 World Bank lowest income country definition);
- Overall unfriendly relations;
- Politically active minority groups that may lead to internationalisation;
- Proposed large dams or other water development projects; and,
- Few, if any, freshwater treaties.

Water Basins experiencing both high population density and average low per capita Gross Domestic Product include:

- **Asia:** the Ca (Laos and Vietnam), Fenney (India, Bangladesh), Ganges-Brahmaputra-Meghna (India, Bangladesh, Bhutan, Nepal, Burma, and China), Han (North and South Korea), Indus (India, Pakistan, China, Afghanistan), Irrawaddy (India, Burma and China), Karnaphuli (Bangladesh, India), Red (China, Laos, Vietnam), Saigon (Cambodia, Vietnam), Song Vam Co Dong (Cambodia, Vietnam), and Yalu (China and North Korea).

- **Africa:** Cross (Cameroon and Nigeria)

- **Balkans:** Drin (Albania, Macedonia, and Serbia & Montenegro)
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Source: The 2008 Chart of Conflict, The International Institute of Strategic Studies
The future

The United Nations has recognised the importance of maintaining cooperation over fresh water sources. In 2005 it launched the International Decade for Action, Water for Life 2005-2015. In a backgrounder to this decade of action, the United Nations said that a total of 145 nations include territory within international basins, and 21 countries lie entirely within international basins. Thus water is a significant issue.

Population growth and poorly managed development is cited as the cause of serious tensions among major water users in many countries. Therefore, with a growing world population it is likely that conflicts may arise over water.

The Oregon Study said possible opportunities exist for technological, economic or management innovations in obtaining water and its delivery, use and overall management; for example trans-global shipments, cheap desalination and water sector privatisation. Challenges include: changes in water-borne vectors; environmental and health impacts from reusing waste water; and urbanisation. In addition, as financial wealth increases, per capita water consumption is also expected to rise. Climate change and nervousness over the impact of global warming, may also lead to more conflicts as countries reassess their water strategies.

Currently, there is no incentive for countries to conserve or protect supplies for users beyond their national boundaries. On the contrary, they have every incentive to capture and use the water before it goes beyond their political control. Pollution of waterways that feed into other countries has already been cited by the International Institute of Strategic Studies as leading to potential conflict.

The sophisticated data collection of water conflicts and cooperation that is being developed at Oregon State University is making it easier to identify potential future flashpoints. History also shows that countries have demonstrated a surprising degree of constraint and cooperation in the sharing of freshwater, even among countries that are at war over other matters of contention. As the stakes become higher as a result of concerns such as climate change and increasing populations, the globe may see a marked change in the way that countries are prepared to defend or acquire rights over freshwater sources.
Key Points

- By 2050, predictions indicate that 15 per cent of the world’s countries will be experiencing water deficiency, most of them in the Middle East and North Africa.

- The regions of water surplus have geographical characteristics such as: good rainfall, resulting in good run off; aquifers; large freshwater sources (lakes, rivers, etc.); and low evaporation rates (due to humidity or low flow rate of fresh air; cold water evaporates slower).

- Water surplus regions have water usage characteristics such as low population density and effective usage of available water supplies.

- Countries with water surpluses are generally located in South America, North America, Northern Europe (including Russia), South East Asia and Australasia.

- Most countries with water deficits are located in the Middle East and North Africa (MENA) region and Central Asia.

- Currently, 166 countries enjoy a water surplus.

- By 2050, 34 countries, or 15 per cent of the global total, will be experiencing water deficiency - five more water deficit countries than there are presently.

Analysis

The information collated by organisations such as the UN Food and Agriculture Organization (FAO) and the projections by the Intergovernmental Panel on Climate Change (IPCC) forecast grave situations for future water supply. By 2050, it is predicted that 15 per cent of the world’s countries will be experiencing water deficiency, most of them in the Middle East and North Africa. There are, however, still many countries with an abundance of water. Water redistribution can occur in various ways, including water shipping, water management, and virtual water trade. Water availability for the future rests upon good management of the water we have now and planning for tomorrow.

A good starting point is to determine what constitutes a water surplus country. When water availability in a country exceeds the water requirements for food production and domestic use, the country can be viewed as being in water surplus. The definition used by international hydrological scientist Dr Malin Falkenmark, which will be used as the basis for this chapter, suggests that a water surplus country has more than 1,300 cubic metres of water available for food production and domestic use (total available renewable water resources) per capita per year.

Total available renewable water resources (TARWR), is an index used to portray the water resources that are available for development, from all sources, in a particular country. This includes surface water runoff, groundwater recharge from precipitation and external flow. It also takes into account the portion of water allotted to a country from water resources shared internationally. The volume is expressed in cubic kilometres per year, unless it is divided by the nation’s population, in which case it is expressed in cubic metres per capita per year.
Although this requirement is helpful in understanding the water volumes available to each country, it does not take into account water quality or water accessibility. Further, it does not take into account the fact that some countries, although technically enjoying water surplus, may be undergoing water stress due to high water usage rates. The definition also does not take into account that there could be significant differences within the one country, where some areas are enjoying water surpluses while other regions are experiencing deficit. Recognising these limitations, the definition nonetheless provides a good benchmark for determining water surplus or deficit countries.

Water surplus countries have certain geographical, management and water usage characteristics that provide useful parameters in determining how countries can remain, or become, water surplus countries.

The regions of water surplus have geographical characteristics such as: good rainfall resulting in good run off, aquifers, large freshwater sources (lakes, rivers, etc.), and low evaporation rates (due to humidity or low flow rate of fresh air, cold water evaporates slower). Water surplus regions also have management characteristics such as: effective water management, ensuring against water pollution; premium water quality; and fair treaties and agreements for shared water resources.

In addition, these water surplus regions have water usage characteristics such as low population and effective usage of available water supplies. These geographical, management and usage characteristics are shared by most, but not all, regions of water surplus.

Water surplus countries at present

Countries with water surpluses are generally located in South America, North America, Northern Europe (including Russia), South East Asia and Australasia. Most countries with water deficits are located in the Middle East and North Africa (MENA) region and Central Asia.

Currently, 166 countries enjoy a water surplus. Of these, 62 countries could be viewed as having an abundance of water, with 10,000 cubic metres per capita per year – more than seven times the basic requirements. Seven countries have in excess of 100,000 cubic metres per capita per year: Republic of the Congo, French Guiana, Greenland, Guyana, Iceland, Papua New Guinea and Suriname.

As the richest in TARWR, Greenland has 10,578,950 cubic metres per capita per year and far exceeds water surplus threshold.

Prediction for 2050: countries experiencing water surplus

A prediction from the Special Report on Emission Scenarios, published in 2001 by the IPCC, says that by 2050, 34 countries, or 15 per cent of the global total, will be experiencing water deficiency - five more water deficit countries than there are presently.

On top of that, an additional five countries could be considered vulnerable or borderline, because they will have 1,300 to 1,700 cubic metres per person per annum (see countries shaded yellow in the map on the previous page). Any increase in population unaccounted for in population projections, coupled with a lack of development in water productivity, would see those countries experiencing water deficiency. These water deficient countries are largely in Africa’s North, Central Asia and Southern Asia.
In 2050, the following countries will have in excess of 10,000 cubic metres per person, per annum.

- Argentina
- Australia
- Bolivia
- Botswana
- Brazil
- Canada
- Central African Republic
- Colombia
- Republic of the Congo
- Costa Rica
- Denmark
- Finland
- French Guiana
- Gabon
- Guyana
- Ivory Coast
- Kazakhstan
- Mongolia
- Burma
- Namibia
- New Zealand
- Norway
- Panama
- Papua New Guinea
- Paraguay
- Russia
- Senegal
- Suriname
- Sweden
- Uruguay
- Venezuela

Water Surplus Countries in 2050

The map illustrates in green the number of countries in 2050 facing water surpluses (>1,300 cubic metres per capita per year) and, in orange/red, countries facing deficits (<1,300 cubic metres per capita per year). Falkenmark et al. 2009

Characteristics of water surplus regions

**South America**

South America could be considered the world’s most water rich region. South America receives 28,584 cubic kilometres in precipitation annually. It holds 28.8 per cent of the world’s freshwater sources. It has 32,165 cubic metres per capita per year of internal renewable freshwater resources (FAO Aquastat).

South America has naturally stable river flows, not prone to flooding. It is relatively free of natural disasters, such as monsoons and hurricanes, due to its latitudinal positioning. South America, however, is affected by ice/snow melts and the El Niño-Southern oscillation (Jones & Scarpati).
**North America**

North America receives 13,726 cubic kilometres of precipitation per year. It has 13,401 cubic metres per capita per year of internal renewable freshwater resources. It holds 14.1 per cent of the world’s freshwater resources (FAO Aquastat).

The far North Eastern area of North America is sparsely populated and rich in water resources, with a large number of small dams (particularly Alaska). Other areas in North America, such as the South and West, are heavily dependent on limited groundwater and surface water resources. According to the US Environmental Protection Agency, the agricultural region (North America's Midwest) is dependent on rain water and irrigation.

**Southern and Eastern Asia**

The Southern and Eastern Asia region receives 24,107 cubic kilometres in precipitation per year. It has an internal renewable water resource of 3,155 cubic metres per capita per year. It holds 27.1 per cent of the world’s freshwater resources (FAO Aquastat).

Indonesia constitutes six per cent of the total world water resources. It experiences a humid tropical climate and therefore receives a high rainfall level; but the country is spread over a wide area and there is considerable variation between islands. (FAO Aquastat).

**Australasia**

Australasia receives 4,598 cubic kilometres in precipitation per year. It has an internal renewable water resource of 32,366 cubic metres per capita per year. Australasia has 1.9 percent of the world’s freshwater resources (FAO Aquastat).

**Northern Europe and Russia**

Northern Europe receives 1,150 cubic kilometres in precipitation per year. It has an internal renewable water resource of 3,999 cubic metres per capita per year. It holds 4.9 per cent of the world’s freshwater resources (FAO Aquastat).

Russia receives 7,865 cubic kilometres in precipitation per year. It has an internal renewable water resource of 30,503 cubic metres per capita per year. It holds ten per cent of the world’s freshwater resources (FAO Aquastat).

**Water surplus and its possible uses**

**Shipping**

Water surplus countries could consider exporting water to water deficit countries as a possible way of utilising the surplus water. This would, of course, depend on the deficit country being able to afford the shipments. It could, however, be a way of assisting deficit countries to trade for water. Water shipping is currently being tried by companies in the United States, such as S2C Global Systems and the Natural Resources Corporation.

Water shipping companies are able to modify crude oil vessels and associated infrastructure (such as loading/unloading offshore systems, moorings, sub-sea pipelines, etc.). Through using existing infrastructure to ship water, the companies drastically cut costs.

Water shipping is dependent on a number of factors. Appropriate ports are necessary and shipping must be economically viable. In 2008, Turkey had plans to ship water to Israel, Tunisia and Libya but it was
Future Directions International postponed because high oil prices rendered it economically unviable. At present, water shipping remains a small-scale enterprise, using large vessels holding 189 million litres of water. The volume of water that can be shipped is usually curtailed by supply constraints. For example, S2C Global is restricted in the volume of water it ships to less than one per cent of California’s yearly allotment.

**Virtual Water Trade**

Countries with insufficient water to support domestic agricultural development, could invest in virtual water imports. Virtual water is a measure of how much water was involved in the production of a particular product or service. For example, 1,000 litres of water is used to produce a kilogram of wheat. Virtual water is also known as embedded water, hidden water or embodied water. The term is used in connection with trade.

Interesting facts come to the fore when comparing the map below with the projected water surpluses and deficits for 2050. Countries such as China, India, and Tunisia are currently major virtual water exporters. However, this may not be possible in 2050, due to projected water deficits. Countries such as Finland, Sweden, Indonesia and the United Kingdom are currently importing virtual water. These countries, however, are projected to have water surpluses in 2050.

A readjustment of the virtual water trade would be beneficial, so that countries facing water deficits imported virtual water, while countries facing water surpluses made use of their surplus by increasing their agricultural production and exporting virtual water. What the virtual trade statistics demonstrate is that virtual imports are lower in countries already experiencing deficits. By increasing food imports, these countries could be turned into water surplus countries. Agriculture uses 70 per cent of available global freshwater. In the developing world, approximately 95 percent of freshwater is used for agriculture (World Water Assessment Programme).

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**Net Global Virtual Water Trade**

![Map of Net Global Virtual Water Trade](image)

Efforts could be applied to further increase water surpluses so that there might be more to share and utilise. This can be done by an increase in water productivity and efficiency through technological advancement. Irrigation of agriculture, for instance, has been made more efficient by minimising water use through technological advancements such as drip irrigation. There are other agricultural advancements that could be made more widespread, such as the vertical gardens currently being used in the Netherlands.

**Water Management**

Water management would be very effective if a water surplus country were located near a water deficit country. Possibilities for water management include: diversion, damming, transfer of water among basins, and pipelines.

**Damming**

The damming of transnational rivers can be used to provide water deficit countries with water resources. The International Rivers lobby group claims that more than 50,000 dams are in use in more than half of the earth’s major rivers.

Major rivers such as the Nile, Mekong, Yangtze, Ganges and Brahmaputra already have extensive dam networks in place that can be used for the benefit of water deficit countries.

The River Nile has ten riparian states including: Egypt, Sudan, Eritrea, Ethiopia, Democratic Republic of Congo, Uganda, Kenya, Tanzania, Burundi and Rwanda. The Nile Basin Initiative is a partnership of these states to monitor the water’s uses and distribution. The Nile is sourced mainly from the two tributaries, White Nile (Lake Victoria) and Blue Nile (Lake Tana in Ethiopia).

Egypt uses 75 per cent of the Nile water (55.5 billion cubic metres of water per annum), compared with 11 per cent for Sudan and one per cent for Ethiopia, and the remaining 13 per cent is shared by Kenya, Tanzania, Rwanda, Burundi, DR Congo, and Uganda.

The Nile has a number of dams. Sudan’s Roseires Dam stores 3.7 billion cubic metres and provides irrigation water for the Gezira Plain. The Sennar Dam, also in Sudan, is 3,025 metres long, with a height of 40 metres. It provides water for crop irrigation in the Al Jazirah region.

**Pipelines and Canals**

Pipelines and canals provide opportunities for water management that can be used to redirect surplus water into areas experiencing water deficit.

In Egypt, the Toshka Project, which is due to be completed in 2020, involves redirecting water from the River Nile to create a second Nile Valley in Egypt’s south through irrigation. It will increase the habitable land of Egypt from five per cent to 25 per cent and create new jobs and a new urban centre.

A vast system of canals and pipelines is being developed to transport water from Lake Nasser into the Western Desert of Egypt. To pump the water through these canals and pipelines, the Mubarak Pumping Station was built. Its innovative design enables it to have a discharge capacity of 1.2 million cubic metres per hour. The Toshka Project uses ten per cent of Egypt’s River Nile water allotment.

**Water Diversion**

Water diversion is also referred to as artificial storage and recovery. It involves diverting surface waters into percolation basins, infiltration lagoons, ditches, or recharge pits to revive aquifers. It makes use of water that would otherwise evaporate as surface water or be drained into the salt oceans.
**Conclusion**

By 2050, according to Dr Falkenmark, 83 per cent of the world’s countries will still be enjoying a surplus of water. There are options available to countries to readjust how they are currently managing and using the water resources available to them. There may, however, be many difficulties in implementing these possibilities. For instance, management of transnational river flows requires the cooperation and fairness of all countries involved. If water sources become scarce it will become increasingly difficult for this cooperation to be achieved.

It is likely that any increase in uncertainty will lead to water hoarding or increased use and wastage by countries wanting to access the water before other countries. There could be a race between nations, or even within nations, to extract water as quickly as possible. This race could also occur between economic sectors, for example between industry, agriculture and households. Not only would this undermine any fairness and cooperation that could exist between nation states but it would also worsen the water situation.

In shipping, there are ethical issues that need to be considered when treating water as a commodity. Given the significant amount of water consumed by the agricultural sector, any readjustments to agricultural trade policy could have a significant impact on domestic situations. Water management techniques such as damming, building canals or pipelines can also pose problems by leading to the displacement of people or animals and the loss of habitat.

Despite these difficulties, it is encouraging to note that the Earth holds an adequate amount of freshwater. Good management of currently available water resources is vital to ensure future global water availability.
Key Points

- Increased demand for water will result from an increase in demand for milk, meat and other high water-usage agricultural products.
- The Middle East and North Africa are the regions at the highest overall risk. The water hotspots, where water stress is likely to be the highest, are in Mexico and the USA, as well as in North Africa, the Middle East and the North China Plain.
- Australia, South Africa and parts of India and the United States, also have high water-stress levels.
- Urbanisation will create further challenges for water supply and delivery to the urban population.
- UN reports say clearly that, by 2050, it will not be the lack of land, but rather the lack of water that will be the major constraint on food security.

Analysis

By 2050 water forecasters are expecting global water shortages or a ‘gap’ between the supply and demand for water, driven, in a macro sense, by the increase in population. However, as David Molden, Deputy Director-General for Research, International Water Management Institute (IWMI), put it at the FDI Roundtable, increased demand for water will also result from an increase in demand for milk, meat and other high water-usage agricultural products. In addition, increasing affluence in many parts of the developing world will further increase demand for these high water use foods.

How large the gap will be, however, is open to debate.

In a global sense, speaking of a water gap is somewhat simplistic. The gap will clearly be larger in some regions than others, while in other parts of the globe water surpluses will continue to exist. Nor does the predicted gap take into consideration the possibility of finding new underground aquifers. Nevertheless, water security is already shaping up as the greatest challenge facing many nations, with Australia being no exception, over the next century.

FDI Associate and water expert, Dr Munir A. Hanjra, made it clear at the Water Roundtable that he believes the gap will be about 3,000 cubic kilometres of water a year. To put this in some perspective, this is the equivalent of the annual flow of three Nile Rivers. Equivalent sources will be needed to cover the shortfall. FDI Associate and author of ‘The Coming Famine’, Julian Cribb, believes that in forty years, the annual shortfall will be more like 6,000 cubic kilometres. While the amount of shortfall is disputed, the view held by many water futurists is that a gap will exist in some parts of the globe.

Where are we going to find that water?

Dr Hanjra believes that humans will have to go through a transformation in the way that they make use of water. To do that, however, the incentives have to be in place.
“We simply don’t know how humans, technology and markets will respond to the kind of challenges that we face around the globe”, he said.

While water supply for human consumption will be challenged in future years, it will really be the agricultural sector that faces the greatest difficulty in expanding its water use – a necessity to feed a growing population with higher demands.

Maplecroft released a global risk assessment in November 2010. It indicates that the Middle East and North Africa are the regions at the highest overall risk. As the global map above indicates, however, Australia, South Africa and parts of India and the United States, also have high water-stress levels. The map makes it clear that there are significant disparities between regions, with some areas not facing a water deficit gap.

Mr Molden says that the water hotspots, where water stress is likely to be the highest, are in Mexico and the USA, as well as in North Africa, the Middle East and the North China Plain. Other critical areas are Australia, West and South India, and Pakistan. They are all major breadbaskets and that creates serious problems. Yet, in other parts of the world, ground water provides major opportunities that have not yet been tapped, such as Sub-Saharan Africa. Clearly, there is an opportunity for better exploitation and management of ground water.

Education

If water is to be the significant concern of the 21st Century, as is being suggested in many quarters, then the energy devoted to education in this area will increasingly need to reflect that importance. Education about water usage can take two forms: one that is linked to water demand and the other to water supply.

On the demand side, education needs to be channelled towards the end users, the consumers; whether industrial, agricultural or domestic household consumers.

On the water supply side of the equation, education could be important for engineers and non-government organisations.
Mr Molden says that there is a need to change practices and to keep the water demand down to an additional 20 per cent above current demand levels by 2050 (20 per cent additional evapotranspiration\(^1\) from agriculture). This will be a hard task, particularly with increasing agricultural production and the need to grow more food with less water.

Part of the education process involves ensuring methods are adopted to reduce the wastage. For example, agricultural practices in Pakistan and other countries lead to a huge amount of wastage. Professor James Trevelyan believes about two-thirds of food produced in India and Pakistan is lost due to wastage, because excess food cannot be stored without reliable electricity supplies for refrigeration. If this wastage could be substantially reduced, there would be more than enough capacity to meet the growing demand for water and food. There are many agricultural practices that also waste water, such as open channel systems or leaking pipes or using inappropriate watering systems.

Productivity differences already exist between food that is grown on agricultural research stations and food grown by normal farmers. So there is potential for improved productivity and an increase in agricultural output, if the technology that we have today is put into the hands of the people that are growing the food. The available technology provides enormous capacity to meet the increasing demand.

**Education is the key.**

Professor Trevelyan believes that the education system is inefficient and does not seem capable of producing people that can join the dots when dealing with water issues. The graduates required need the ability to work across disciplines and not to be confined to specialisations. Technological breakthroughs can then be adopted, but only if technologists have the breadth of understanding to see how social, economic, environmental, safety, health and governance issues shape effective solutions.

However, while much can be done to improve water security, Dr Hanjra believes a water gap will continue to exist, despite increased efficiencies. He has considered a number of scenarios that could be applied in future planning, but found none that would overcome the water gap. Every increase in productivity will be putting more pressure on ground water resources.

While water availability is determined by the climate, there is scope to change people’s behaviour. For example, in Brisbane an education campaign reduced demand for household water use by 30 per cent. Mr Pascoe believes that this indicates that social, behavioural and attitudinal behaviours need to merge with the technical solutions.

**Management**

In dealing with water security, a more unified approach is required, not only in international cooperation but also in the level of understanding between government departments. Professor Hanjra believes that the traditional method of treating water and food security, environment and climate change, as separate issues dealt with by separate ministries, has had its draw backs.

Mr Pascoe believes that the complex nature of water management needs to be understood by government. Getting the right political will is also important, as is having farmers who have the expertise for dealing with water issues.

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\(^1\) Evapotranspiration is a term describing the transport of water into the atmosphere from surfaces, including soil (soil evaporation), and from vegetation (transpiration). These two are often the most important contributors to evapotranspiration. Other contributors to the process may include evaporation from wet canopy surfaces (wet-canopy evaporation) and evaporation from vegetation-covered water surfaces in wetlands. Source: The Encyclopedia of Earth
Water governance remains a major issue that many countries need to overcome. Mr Molden cited an example where, in South East Asia, there has been a trend towards private pump use, to avoid government interference. However, this is having a negative impact on water tables in the region, so that governments need to stay in tune and ahead of such private entrepreneurial initiatives, to ensure long-term sustainability of water usage. As with the private pumps, there are many ways in which people can get access to water or energy without paying, particularly in countries with limited government control.

It is important to think of ways to provide cheap, reliable and fraud-resistant technology for payment collection, which can handle many small payments efficiently, according to Professor Trevelyan. An example could be the use of smart metering technology. This will also encourage private investment in the sector, because the free- loaders can no longer have a presence in the market and undermine the recovery of the costs involved in providing such technology.

By-passing the government, or having the ability to work in regions where the government is ineffective, is also important. Systems need to be able to work also in ‘failed’ states, independent of the need for government support. Actionable goals are required, that are achievable and that can be scaled up once the initial goal has been reached.

If this is done correctly, there is enormous potential for the development of water resources in areas such as Pakistan, India and Africa. Further investment in exploration for water resources could pay handsome dividends, if new sources of water can be found.

People working for non-government organisations need training in dealing with local power structures, when the government does not have a strong presence.

**Urbanisation**

Urbanisation will create further challenges for water supply and delivery to the urban population. In 2010 more than 50 per cent of the global population lived in urban centres. Members of these urban populations are going to demand more lifestyle products, such as swimming pools and better food, which means the per capita water footprint is likely to continue to increase.

The growth of mega-cities, with populations exceeding 10 million people, often in developing countries, will create a considerable challenge. New expertise in water delivery will be needed to supply these cities, for example in Jakarta half the city does not have a water supply. Two options exist for water engineers. Either they learn to adapt their water supply infrastructure to the urban form, or the design of the urban centres will need to change to make greater allowances for sustainable water supply.

Professor Hanjra believes that one of the challenges is that poor people urbanise faster in developing countries. Urban centres and mega-cities are like magnets, because of their access to better services. While there is a pull factor, there is also a push factor. People are being pushed out of rural areas because of a lack of access to land or quality water. Professor Hanjra says that the result is that there are enormous demands on the urban water systems, often because the poor and new comers are not welcomed into the city and they are yet to be connected to the water supply system.

Mr Pascoe feels that it is understandable that some of the fastest growing urban areas are struggling to supply water to their inhabitants. He says that it has taken 150 years for the western world to develop its urban water systems. We do not have 150 years for the developing world to develop theirs, because of the significant health problems that would produce.
Potential for Conflict

Historically, very few serious conflicts between nations have occurred over water. There are indications, however, that water will be the resource that nations and communities will fight for in the 21st Century.

A paper produced by Future Directions International, entitled ‘Water Crises – International areas at risk’ (Gary Kley; 16 March 2010), made it clear that, historically at least, most disputes are handled diplomatically. In the past 50 years there have been 37 disputes involving some level of violence as a result of water conflict, whereas there were 150 treaties relating to water sharing signed during this period.

We have not seen water-inspired conflict in the Middle East, despite the problems that they have there. It has always been managed.

Dr Hanjra says that if water scarcity penetrates downward it will pitch community against community, farmer against farmer and State against State. It could mean that there are many little, or not so little, wars in the making. People will fight because, in many places, the option to migrate to other countries or regions is not available, particularly in poorer regions. He sees this particularly playing out in countries such as Pakistan and India.

Mr Molden said that while water has not been the source of major conflicts to date, there is a lot of local conflict over water. Also, water is often the target during a conflict.

Dr Hanjra believes that the globe is approaching the tipping point, where people are beginning to realise that water is becoming the constraint on wealth creation. It has not yet become a constraint on economic growth but it is moving that way. UN reports say clearly that, by 2050, it will not be the lack of land, but rather the lack of water that will be the major constraint on food security.

Are we ready to guard against such a risk?
Walking on Water - Global Aquifers

By Mendel Khoo, Research Intern & Gary Kleyn, Manager
Future Directions International Global Food and Water Crises Research Programme

Key Points

- Almost all parts of the global landmass hide a subterranean water body.
- The volume of freshwater on the earth is around 35 million cubic kilometres; 30 per cent is stored underground and potentially available for human consumption.
- Estimates suggest that by 2050 an additional 6,000 cubic kilometres of water will be required annually, to feed an additional 2.5 billion people.¹
- For the majority of countries, water consumption from aquifers has been over-exploited; more is being pumped out than is being collected.
- Access to water, water rights, and trading in water will become increasingly important in the next century as demand for the resource increases.
- As water becomes more valuable we can expect an increase in underground exploration for new water sources.

Analysis

Aquifers play a key role in the provision of water for farming and for consumption by both animals and humans. Almost all parts of the global landmass hide a subterranean water body. Aquifers are underground beds or layers of permeable rock, sediment or soil, where water is lodged and can be accessed. This chapter examines some of the major aquifers around the world and determines how countries are coping with increased water usage.

Studying aquifers presents a number of problems, in part because scientists are yet to develop a complete picture of the globe’s aquifer systems; the sub-surface geology still holds mysteries. Further discoveries of aquifers and information on their connectivity with surface water, can be expected in the future. The process should be similar to the way in which new discoveries of energy sources beneath the earth’s surface are still being made.

An additional impediment lies in the different terms used to describe aquifers, some of them arising simply because of language differences. Aquifers do not fit into one neat category, as there are many variations in their form. The terminology for aquifers can include: underground water basins; groundwater mounds; lakes and parts of rivers; as well as artesian basins, which are confined aquifers contained under positive pressure. Hence, aquifers are not only located underground but some, or all, parts may also be found on the surface.

Finally, much of the research on aquifers is focussed on identifying cross-boundary aquifers. The inventory of aquifers falls short, therefore, of providing a complete picture of their true number and extent. What does seem clear is that aquifers, in some shape or form and at varying depths, are found under most of the global landmass. Hence, we literally are walking on water.

Finding data from secondary sources on each particular aquifer is also problematic, when considering criteria such as: maximum capacity, current capacity, annual withdrawal rates and the number of people served by a particular aquifer. In many cases the data is not readily available.

One dictionary describes aquifers as water-saturated rock formations. The word aquifer means “water-bearing formation”, i.e. Latin “aqua” (water) and “ferre” (to bear). One aquifer may refer to a single geologic formation, a group of formations or a part of a formation; in all cases, the formation must carry and yield a “significant” amount of water.

This paper examines some of the major aquifers around the world and determines how countries are coping with increased water usage. In no way is the list comprehensive, as there are hundreds of aquifers, which cover much of the sub-surface. The paper will consider how many people have access to a particular aquifer, its average withdrawal levels and sustainability. Where no current statistics are available, statistics from The Footprint Network provide useful data. It was developed to show how much water each country used per annum between 1997 and 2001. The statistics collected have demonstrated a wide divergence in per capita water usage.

For example, South African per capita water use was 931 cubic metres of water per annum, whereas Australia used 1,393 m³, Greece, 2,389 m³ and the United States 2,483 m³. The world average is 1,243 m³ per year per person; creating a total annual demand of 7,452 cubic kilometres per annum.²

A Global Outlook

Statistics from the United Nations indicate that the total volume of freshwater on the earth is around 35 million cubic kilometres; 30 per cent is stored underground and potentially available for human consumption.

Most of the water taken from aquifers is used for irrigation by the agricultural industry (70 per cent), with only eight per cent used for domestic consumption, such as drinking. Water use, however, has been growing more than twice as fast as the world’s population growth. The United Nations predicts that by 2025 two-thirds of the world’s population could be living in countries with absolute water scarcity.3

Hence, countries need to begin looking at possible solutions. Estimates indicate that by 2050 an additional 6,000 cubic kilometres of water will be required annually to feed an additional 2.5 billion people.4

There are 37 great aquifer systems of the world. These aquifers jointly cover almost 35 million square kilometres – equivalent to just under a quarter of the entire land surface.

Oceania

Australia and New Zealand

There are four main aquifers located in Australia, including one of the largest in the world known as the Great Artesian Basin. The Great Artesian Basin is located beneath the surface of four states (Queensland,
Northern Territory, South Australia and New South Wales). It covers about one quarter of Australia and is estimated to contain 64,900 cubic kilometres of ground water. It is Australia’s largest source of water and is sufficient to fill Sydney Harbour 130,000 times. It could supply the current Australian population for the next 2,500 years, even if replenishing rain stopped – based on Australia’s current water use rate of about 26 cubic kilometres a year. Obviously, with greater water efficiency the water could supply the country for significantly longer.

The Gnangara Groundwater Mound and Jandakot Groundwater Mound are Western Australia’s main water sources. Together they supply about 40 per cent of the State’s drinking water. There is an estimated total of 150 cubic kilometres of water in various basins under Perth. The Gnangara Mound holds about 20 cubic kilometres of fresh water, while the Jandakot Mound holds close to four cubic kilometres. It is estimated that these water sources could keep Perth supplied for over a century. The Yarragadee Aquifer is also located in Western Australia and is situated beneath both the Gnangara and Jandakot Mounds. It is estimated to currently store 1,000 cubic kilometres of water, which is sufficient to supply Western Australia’s current population for the next 370 years.

There are around 200 groundwater aquifers in New Zealand. Most of them, however, are shallow, making them vulnerable to pollutants from land use. One of the main aquifers is the Canterbury Plain Aquifer, located in the South Island of New Zealand.

Europe

Europe has an estimated 89 transboundary aquifers and many more that do not cross national boundaries.

The largest aquifer in Western Europe is the Paris Aquifer, which covers about half of France. In addition, Russia has three significant aquifers, known as the Russian Platform Basin, the North Caucasus Basin and the Pechora Basin.

Africa

Northern Africa

It has been said that the greatest untapped potential for water from underground aquifers lies in Africa. One of the main aquifers in Northern Africa is known as the Bas Saharan Basin. This transnational aquifer encompasses Tunisia, Algeria, Libya and Morocco and covers 140,000 square kilometres of land.

Another critical aquifer system in Northern Africa is the Nubian Sandstone Aquifer System. It covers parts of Sudan, Chad, Libya and most of Egypt. It is estimated to contain 150,000 cubic kilometres of high-quality water – sufficient to supply the four countries for the next 920 years, based on current annual water usage and without taking into account replenishing.

There have been political disputes between the countries that use this System, with the latest being over Libya extracting substantial amounts of water to develop its own man-made river project. However, there are international development projects in place that have brought the four countries together to establish rational and equitable use of the System. Withdrawals from it have been increasing over the past 40 years; Libya and Egypt alone have extracted a total volume of 40 cubic kilometres from the Nubian Sandstone Aquifer System.7

Other aquifers in Africa include: the Northern Sahara aquifer system of Algeria, Libya and Tunisia; the Basin of Murzuk-Djado of Libya, Algeria and Niger; the Basin of Taouden-I-Tanezrouft of Algeria, Mauritania, Mali, Burkina Faso and Guinea; the Senegal Mauritanian Basin of Mauritania, Senegal, Gambia and Guinea Bissau; the Iullemeden-Irhazer aquifer of Niger, Algeria, Mali and Nigeria; the Lake Chad Basin that covers parts of Niger, Nigeria, Chad, Cameroon and the Central African Republic; the Sudd-Basin Umm Ruwaba aquifer of Sudan and Ethiopia; the Ogaden-Juba Basin of Ethiopia, Somalia and Kenya; the Congo Basin of the Congo Democratic Republic and the Central African Republic; and the Cuvelai Basin-Upper Zambezi Basin of Angola, Botswana, Zambia and Zimbabwe.

Asia

Middle East

The Yarkon-Taninim Aquifer is shared between Israel and Palestine and is one of their biggest water sources. The Aquifer supplies Israel with about 0.34 cubic kilometres of water a year, while Palestine uses about 0.20 cubic kilometres a year. Other aquifers in this region include the Nablus-Gilboa Aquifer, which is mainly used by Israel for agricultural irrigation and supplies it with about 1.15 cubic kilometres a year. The third significant aquifer in the region is known as the Eastern Aquifer. It supplies 0.40 cubic kilometres annually to Israel and 0.60 cubic kilometres to the Palestinians.8

South Central Asia

Groundwater aquifers are an important source of water for India, providing 90 per cent of its drinking water and 80 per cent of its irrigation water needs.9 The amount of water in aquifers is estimated to be 430 cubic kilometres, or around one-quarter of India’s water supplies. India is the largest user of groundwater in the world, with an estimated usage of 750 cubic kilometres annually.10 The Indo-Ganga-Brahmaputra basin has enormous fresh water resources that have not been utilised, according to a 2010 report by India’s Central Ground Water Board to the Minister of Water Resources.11 The report suggests that tracts of north eastern India have ‘quite productive’ aquifers, while the Upper Gondwanas ‘constitute prolific aquifers’.

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The Strategic Foresight Group believes that India could be facing a water deficit by 2030. Water availability is expected to decline to 1240 cubic metres per person per year, from the current level of 1730 cubic metres per person. The findings were published in the Group’s paper, *The Himalayan Challenge: Water Scarcity in Emerging Asia*. Not taking into consideration the in-situ amount of water, the annual replenishable quantity of underground fresh water is 433 cubic kilometres. There are 12 major river basins, the largest being the Gangetic Plain Aquifer, which has an annual replenishable quantity of ground water of 206 cubic kilometres.

The Occurrence of Transboundary Aquifers in Asia

![Image of transboundary aquifers in Asia]


The Indian Ministry of Water Resources estimates that the in-storage underground water volume is 10,812 cubic kilometres, which it says can be retained for future use and harnessed in periods of crisis. The Indian Government is limiting the exploration of aquifers but believes that more needs to be done to develop and use the underground water resources.

With such large volumes of groundwater being consumed, India’s ground water aquifers are under strain. The World Bank has reported that India’s ground water table will begin to dry up in 15 years if corrective measures are not immediately put in place. In the same report, it stated that 60 per cent of India’s aquifers will be in critical condition if current water usage trends continue. States in India that are experiencing serious water problems include: Rajasthan, Gujarat, Andhra Pradesh and Madhya Pradesh, where water was in sufficient supply 15 years ago. The ground water levels have been depleted to below 300 metres and, with drought becoming a common problem, it is expected that these subterranean water levels will continue to fall. However, the deep water resources, in what is known as fossil aquifers, may still have untapped potential for the sub-continent.

Eastern Asia

China is another country facing issues with its water supply from aquifers. China’s available water supply from all sources (e.g. rivers and aquifers) has been falling over the years, as water consumption has continued to increase. China’s ground water usage volume has caused a depletion of an estimated 10 cubic kilometres per annum. This has resulted in large areas of land suffering serious land subsidence. Large aquifers in China include: the Alluvial Fan Aquifer of Juma River; Karsts Aquifer of Chezhoushan; Karst Aquifer of Easter Erdos Basin; and the Aquifer of the Yangtze River Delta.

The country draws 100 cubic kilometres a year, with 76 per cent of this taken from aquifers in the north. Estimates indicate that the amount of natural charge into underground aquifers is about 884 cubic kilometres per annum, of which 656 cubic kilometres is in mountainous areas.14 There are, however, still 70 million people in China with no clean groundwater to drink. The problem for China is that the rain is not falling where it is needed. The demand is concentrated in certain areas but the recharge is across a wide geographical area that is not necessarily connected to the aquifers that are being used for extraction.

Another problem that China faces is ground subsidence over aquifers or “karst”. More than 1,400 karst collapses have occurred, with the total number of collapse holes exceeding 40,000. Karst collapses occur in areas where limestone has been undermined by water erosion. In addition, seawater has intruded into coastal aquifers in the Liaoning, Hebei, Shandong, Guangxi and Hainan provinces.

Most of China’s water is consumed by the agricultural industry. As a result of the decreasing water supply, China’s agricultural industry has had to cut back production significantly. For example, China’s overall grain production fell by 43 million tonnes from its peak of 392 million tonnes in 1998, to an estimated 358 million tonnes in 2005.15 Still, the agricultural sector utilises an estimated 400 cubic kilometres of water annually.16 This cutback in grain production because of water scarcity, results in loss of income for the Chinese agricultural industry. With China’s population estimated at 1.3 billion people, urban water consumption is estimated to have exceeded 80 cubic kilometres in 2010, a jump of 30 cubic kilometres a year from 2001.17 China’s response to the excessive use of water is to aim for a 60 per cent cutback in water used to produce each dollar of GDP by 2020.18

Other significant aquifers are: the Tarim Basin, located in the Taklimakan Desert in Central Asia; the North China Aquifer system; as well as the Huang-Huai-Hai and Song-Liao Plains in eastern China.

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Latin America
South America

Deemed the largest aquifer in the world, the Guarani Aquifer covers 1,200,000 square kilometres and is located beneath Argentina, Brazil, Paraguay and Uruguay. It has a maximum capacity of 40,000 cubic kilometres of fresh water but is currently estimated to hold 37,000 cubic kilometres. The main use of the aquifer is for drinking purposes but it also has industrial and agricultural uses. It is estimated that 70 million people have access to the Guarani Aquifer, while 24 million people have restricted access because they are located outside the boundaries of the aquifer.19

Central America

Mexico has nine aquifers in the state of Mexico City alone. One of them is the Texcoco Aquifer, which is located in the Basin of the Valley of Mexico. This particular aquifer has experienced high levels of exploitation, with estimates reaching 850 per cent annually.20 This means water is being pumped out of the Texcoco Aquifer at a rate more than eight times the rate at which water is going in. The rest of the aquifers in Mexico are also over-exploited but none as severely as the Texcoco Aquifer.21 One of the consequences of the over-exploitation of aquifers in Mexico City has been the subsidence of the city by nearly 10 metres.

It is estimated that by 2025 Mexico City will have a population of 19 million and this will create an estimated annual demand of 1.08 cubic kilometres of water; seventeen cubic metres more than in 2005.22 Thus, Mexico City faces a water crisis requiring it to pump out more water from its aquifers; already over-exploited to the extent that the city is sinking as a result of its efforts to meet future demand for water. Hence, Mexico needs to either look at other ways of sourcing water or look at ways of reducing population growth in the capital.

Northern America
The United States

The Ogallala Aquifer is one of the largest aquifers in the world and is located across eight states in the United States: South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas. The Ogallala Aquifer system is estimated to provide 80 per cent of drinking water to people living within its boundaries. Like a lot of other aquifer systems throughout the world, the Ogallala Aquifer is experiencing excessive use. The quantity of groundwater held in 2005 was recorded at 3,600 cubic kilometres, but declined by 300 cubic kilometres in the next five years. Julian Cribb in his book The Coming Famine, states that the aquifer could dry up within 25 years.23
Conclusion

This chapter seeks to give a brief insight into the current situation faced by a number of different countries using aquifers as a main source of water. For the majority of countries, water consumption from aquifers has been over-exploited; more is being pumped out than is being collected. This is an increasing problem because, as populations grow, there is a greater demand for water, which is becoming a declining commodity. The consequences of overexploiting aquifers, especially those located underground, are severe. Countries risk serious land subsidence, which can result in landslides and damage to infrastructure. Places like China and parts of India are already dealing with the consequences of over extracting water, with water tables falling in some areas and aquifers being depleted.

However, many countries are now becoming more aware of their high water consumption levels and the possible consequences if changes are not made. These countries have, or are at least talking about, setting policies in place to: limit or minimise water consumption; look to other sources of water; inherit or develop new technologies to source water, perhaps from the oil and gas industry; and to limit irrigation usage by agricultural industries.

The consequences of the depletion of aquifers can be costly. For example:

- Countries will need to look to other forms of water collection, which are expensive to create and are usually less efficient than aquifers;
- A major depletion in the farming of crops (e.g. wheat, corn and rice) that rely heavily on the pumping of water from aquifers;
- Increasing political tensions between countries that rely on the same aquifers (e.g. Israel and Palestine), over the volume of water usage, and natural and potential deliberate contamination, and
- Stricter regulations on water usage, which may include a higher price paid by consumers.

Concern is often expressed about using water from aquifers at a rate that goes beyond the level of replenishment, because it is considered unsustainable. Yet aquifers in some parts of the world are large enough to sustain present consumption rates for centuries or, in some cases, thousands of years. We could ask why we are not using this resource, while still feeling comfortable about exploiting other resources that also have a finite life.

Intuitively it is easy to conclude that aquifers are reliant solely on rainfall for replenishment. Yet there is some evidence that water may have been sitting in situ since the creation of the earth and is part of its make-up. The late Lance Endersbee, who was an authority on global water, made a compelling case in his book, A Voyage of Discovery, that large quantities of water are deep in the ground and have been since the earth's creation. Water vapour coming from volcanoes also suggests the presence of water deep underground. Indeed, it has been argued that the Great Artesian Basin is fed from deep within the earth, in addition to its intake from rainfall. Researchers cannot discount these possibilities. Our deepest mines go to depths of just a few kilometres and are only touching the surface of the earth, with its radius of 6,378 kilometres.

Fossil fuels are also not replenishable, yet they have provided the globe with incredible capacity and the means to lift living standards over the past century. Perhaps it is time for aquifers to be viewed in a similar way. Using the water in the aquifers could lift living standards in many parts of the globe. It could even lead the next economic expansion. If keeping the water beneath the surface is crucial to geological stability, as is likely to be the case in some parts of the globe, this needs to be explained by hydrologists. If the fossil fuel extraction from below ground is anything to go by, water can also be taken and used judiciously, without permanent damage to the earth.
The challenge around the globe, but especially in countries that will have severe water shortages, will be to reduce water consumption and improve efficiency. Access to water, water rights, and trading in water will become increasingly important in the next century, as demand for the resource increases. It is likely that inter- and intra-state conflict will occur over water. Therefore, water security will be a major issue facing governments around the world. The proper management of these aquifers could avert such conflicts. As water becomes more valuable, we can expect an increase in underground exploration for new water sources. In the future we may see exploration companies listed on the stock exchange looking not for energy but water resources.
Desalination: A Viable Answer to Deal with Water Crises?

By Alain Nellen, Research Intern
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Key Points

➢ There are about 14,500 desalination facilities across the globe but the highest desalination capacity is located in the Middle East. Desalination plants are vital for economic development and social stability in many arid regions. The global demand for desalination units is projected to triple within the next six years.

➢ Desalination is the only climate independent source of water available. Other alternative sources, such as water recycling and storm water harvesting, still require sufficient amounts of water entering the water cycle to allow them to operate.

➢ A two-year project, run by the National Centre of Excellence in Desalination Australia (NCED), is testing a new desalination technology designed to supply enough quality drinkable groundwater for remote areas in Australia.

➢ The technologies most often applied to desalinate water are: multi-stage flash (MSF) distillation, which uses steam; and reverse osmosis (RO), which is a membrane technology.

➢ Desalination facilities have specific, expensive infrastructure and relatively high energy use, which challenges its economically sustainable development. Developments in desalination techniques and energy efficient technology, are vital to make the desalination option economically sustainable.

➢ The two main ways that a desalination plant causes environmental harm are through greenhouse gas emissions, when coupled to a power plant, and degradation of marine environments. Improvements are being undertaken to minimise environmental harm caused by desalination processes.

➢ When considering the viability of a desalination plant, a comparison of market drivers and restraints is essential. At present, key market drivers are in favour of an expansion in the global desalination market.

Analysis

To deal with the increasing global water crisis, desalination plants have become the latest vogue, providing alternative fresh water sources. There were about 14,500 facilities in 2010, with approximately another 240 units under construction. The global number of desalination plants is expected to continue to rise for the foreseeable future. This paper will look at the characteristics of desalination plants and outline the main economic and environmental challenges for their sustainable development. It concludes that this development is challenged by issues involving capital costs and energy consumption, gas emissions and the negative impact on the marine environment.

Global occurrence

Most of the global desalination capacity is located in the Middle East, followed by North Africa, the United States and Europe, as Figure 1 indicates. Global Water Intelligence suggests that China has the potential to become the world’s second largest desalination market after Saudi Arabia. This prediction follows
concerns that the recent drought in the Chinese Yangtze Basin challenges the viability of the South-North Water Transfer Project, intended to transport additional water to the North-East coast of the country.

Desalination plants are viewed as a last water supply option to support economic development and social stability in many arid, coastal areas around the world, where fresh water is not easily accessible. These areas are facing a scarcity of supply from traditional water sources, due to issues related to capturing water from them and/or the uneconomical transportation of collected water. Predictions indicate that the demand for desalination will almost triple over the next six years, resulting in a possible global desalination market that will top $30 billion by 2016 (Figure 2).

Figure 1 Global Capacity of Seawater Desalination Plants

Figure 2 Value of Regional Desalination Markets

Source: http://www.desertec-australia.org/content-oz/cspdesalination.html

Alternative water source

Water is the most important resource for the existence of human kind. Estimates show that 97.5 per cent of the earth’s water is seawater and 2 per cent is in the form of ice, leaving only 0.5 percent as fresh water. The supply of desalinated water is possibly one of the only water resources that does not depend on climate patterns. Desalination stops dependence on long-distance water sources and even prevents local traditional water sources from being over-exploited. This alternative water source is suitable for dry countries. Australia, for example, depends on rainfall and aquifers to supply reservoirs and dams and most major cities are located on the coastline close to a source of seawater.

From a global perspective, desalination technology is applied for several purposes, such as: providing fresh water for industrial sectors; supplying high quality drinkable water for the domestic and public sectors; and acquiring water for emergency situations, such as army and refugee operations.

Brackish desalination in Australian remote areas

There are a number of reverse osmosis (RO) units, which desalinate brackish water, in remote areas around the globe, including Australia. It seems, however, that new desalination technology can become an important component in securing water supplies across Australia. The National Centre of Excellence in Desalination Australia (NCED), hosted by Murdoch University, is undertaking a two-year research project to develop a sustainable and appropriate desalination system. The aim is to supply good quality drinking water to remote areas, such as the Tjuntjunjarra community, located 800 kilometres North East of Kalgoorlie in Western Australia.

A new desalination technology, developed by Singapore company, Memsys, will be tested to make sure that the Tjuntjunjarra groundwater is drinkable. The Memsys unit is a small capacity thermal-driven membrane distillation (V-MEMD) desalination system, driven by solar-thermal energy and the waste heat produced by small-scale power generators. Project leaders have confidence that this kind of desalination unit will have a unique capability to supply drinkable water to remote areas.

Desalination technology

Desalination of seawater is one of the oldest techniques used to make water drinkable. Due to the improvement of desalination technology, the process can now be undertaken on a huge scale. The most common processes used to remove salt and minerals from seawater are evaporation and condensation, or membrane technology. The desalination process produces low-salinity water. Brine contains a high concentration of salt, which is a waste product of the desalination process.

Desalination processes can be undertaken with several technologies. The most common are units based on multi-stage flash (MSF) distillation, which uses steam, and processes using RO, which is a membrane technology driven by electric pumps. MSF desalination technology is mainly used across the Middle East. In recent years, however, RO seawater desalination plants have become more popular, because of their sustainability, cost effectiveness and simplicity, achieved by technological improvements.

Viability of desalination plants

There are a number of principles that need to be, or should be, considered in determining the viability of desalination.

Worldwide, there are a number of desalination plants that have been described as uneconomical and unproductive. Those plants are generally expensive, incorrectly promoted, badly designed or established in unsuitable terrain. Therefore, to make a desalination plant appropriate for a region, the advantages and disadvantages must be carefully studied. American Senior Research Associate with the Pacific Institute’s Water Program, Mrs. Heather Cooley, states in her article ‘Seawater Desalination: Panacea or Hype?’.
that final decisions are influenced by several multifaceted reflections of “local circumstances and needs, economics, financing, environmental, and social impacts, and available alternatives”.

Economic and environmental factors are the most important issues in considering the sustainability of desalination plants.

**Economic issues**

Desalination plants’ sustainable development is restrained because major plants use a huge quantity of energy and specific, costly infrastructure. The cost of desalinated water depends on each plant’s capacity, location, the water’s salt intensity, its energy source and the application of technology. Therefore, it can often be more expensive than collecting groundwater or water from rivers. For example, desalinated water from the Perth metropolitan desalination plant is estimated to cost around $1.17 per kilolitre, whereas supplies from traditional water sources cost less than $1 per kilolitre. In places away from the sea, like New Delhi and Mexico City, it is often more economical to transfer water from traditional resources than to desalinate it.

Energy is the most expensive component of running a desalination plant; it is often responsible for one-third to more than half of the cost of desalination. Therefore, the cost of desalinated fresh water is more vulnerable to the fluctuation of energy prices than any other water source. This influences the industry, especially in countries reliant on international energy prices. On the other hand, the Middle East, with an intense need for desalinated water and where no other solution exists, has water tariffs among the lowest in the world due to low energy prices.

**Figure 3 Typical Costs for a Reverse-Osmosis Desalination Plant**

![Figure 3 Typical Costs for a Reverse-Osmosis Desalination Plant](http://www.pacinst.org/reports/desalination/20060627.html)

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It is likely that desalination will remain the most expensive method of delivering water supplies unless more energy efficient technologies can be developed. A report by the United Nations Environmental Programme, explains that an alternative method of reducing a plant’s energy consumption is “the development of energy recovery methodologies that will make better use of the energy inputs to the system”. Although the cost of desalinating water has decreased over the last decade, due to improved technology and competition in the market, scientists hold different views on whether the cost to establish and manage desalination plants will keep decreasing or whether it has arrived at its cost reduction limits.

Environmental issues

A desalination plant’s establishment and operation can create different environmental impacts on the atmosphere and its location. The two main ways that a desalination plant causes environmental harm are through its greenhouse gas emissions and the degradation of marine environments.

Greenhouse gas emissions

The majority of desalination plants in operation (and planned future plants) use energy from fossil fuels or nuclear power. For countries in the Middle East, which have a huge quantity of domestic petroleum sources, that seems the obvious choice.

Energy generation from both these sources includes serious interlinked environmental concerns. Therefore, growth in the number of desalination plants could result in a larger reliance on fossil fuels and an increase in the greenhouse gas emissions that contribute to climate change. Globally, the use of renewable energy technology as part of the main power supply is becoming more popular. Solar or wind generated energy can be used as a low temperature heat source. For example, by the end of 2011, Western Australia will derive about 30 per cent of its fresh water from two seawater RO desalination plants operated by renewable energy, such as wind. The construction of another plant of the same type for Esperance and Karratha is under consideration.

Marine environment

Construction and long-term operation of a desalination facility can harm the local marine environment. Globally, there have been a number of very badly designed desalination facilities that have produced a common concern among scientists that the huge amount of water taken from the ocean can have harmful consequences to the marine habitat. Marine organisms such as: “adult fish, invertebrates, birds, and even mammals, are killed on the intake screen (impingement); organisms small enough to pass through the intake screens, such as plankton, eggs, larvae, and some fish, are killed during processing of the salt water (entrainment)”. Issues of impingement and entrainment, however, have been taken under serious consideration, to minimise the effects as much as possible, especially by the Australian and US desalination industries. Desalination plants have been designed to keep the flow rates at a specific level, so that maritime organisms close to the intakes are able to swim away.

A desalination plant’s brine discharge is believed to cause the most significant harm to the marine environment surrounding the plant. Normally, brine contains double the amount of salt found in water collected from the ocean. The release of brine into the sea increases the sea temperature around the outlet. The waste water can also contain the remains of maritime life killed during the desalination process. These issues result in thermal pollution, causing further harm to marine organisms. For example, the Persian Gulf and Red Sea are regions with low water turbidity and a high salt intensity. These areas have already illustrated the potential threat of seawater desalination plants to the local maritime ecosystem. There is a global increase in the number of projects, but strict environmental regulations are being implemented to minimise the impact of brine on the surrounding environment, including minimum dilution rates.
Market forces
Consideration of market forces is essential to determine a desalination plant’s viability. Figure 4 indicates key market forces (drivers and restraints) that influence the desalination plant market in Europe, the Middle East and Africa. The length of the arrows highlights the significance of each influence. The dotted arrows show where the importance of a particular force is decreasing. Figure 4 indicates, however, that the main drivers favour an expansion of the desalination market. Key market forces that have not been mentioned previously, will be discussed below.

Private Finance
Private financing has become a powerful driver in the increasing construction of desalination plants. Large private enterprises arrange the financing of desalination plants by using financial models on a build, own, operate and transfer basis. Market Analyst Ms. Mili Shah states in her short paper ‘An Overview of the Desalination Plant Market in Europe, The Middle East and Africa’, that “private financed desalination offers large-scale projects to companies with a guaranteed long-term fixed income and is a trend that is being encouraged across Europe, the Middle East and Africa”. There are plants in Israel, such as the Ashkelon Desalination Plant, which are run by large private companies.

High Capital investment
The cost to construct and operate desalination facilities is relatively high compared to other water sources. Therefore, it is often only large water supply companies, with a high number of consumers and large industries, which have considered the desalination option. Figure 5 indicates typical capital costs of an RO-seawater desalination plant. If the price to establish and operate desalination plants continues to decrease, however, this key market restraint is predicted to weaken.
Political stability

Political stability is an ideal requirement for the establishment of desalination facilities. Conflicts result in economic insecurity, producing high inflation and currency fluctuation. Therefore, the global desalination market could be affected by a shortage of domestic funding and a lack of international investment into unstable economies. For example, regions in the Middle East suffer from this market restraint. The Middle East has become one of the most unstable political and economic areas, due to major events such as the Iraq war and the conflict over Palestine.

Environmental opposition

Although limited research has been undertaken on the environmental impacts of desalination plants on the maritime ecosystem, developers are encouraged to include environmental considerations in the design of desalination infrastructure and improvements to desalination technologies. To weaken this market restraint and secure desalination plants as a viable option, several principles must be considered.

To be suitable, the location must be in an industrial zone with enough available land. The location should be away from residential zones and schools, due to the enormous noise pollution of desalination facilities. Desalination plants should be close to a power station and the ocean, to minimise the length and cost of pipe lines. Environmental institutions should provide an environmental assessment before a plant is built or expanded. It is also essential that a plan is established to deal with environmental issues caused by brine discharge.

Finally, to minimise, or even prevent, environmental consequences, permanent observation of the plant must be established. Finally, to minimise, or even prevent, environmental consequences, permanent observation of the plant must be established. The need for integration of sustainability principles into all

Figure 5 RO-desalination capital costs

![Figure 5 RO-desalination capital costs](http://www.globalwaterintel.com/archive/10/11/analysis/seawater-reverse-osmosis-desalination-plant-costs-chart.html)
projects is especially being recognised in Australia and the US.

Conclusion

Desalination plants have been established in arid, coastal areas around the world to improve economic and social development. In the future, the number of desalination plants is likely to increase, especially in areas where traditional water sources struggle to meet the demand for fresh water. Desalination of water can potentially be a viable option to deal with the global water crisis. As this report clearly indicates however, the establishment and long-term operation of desalination facilities involves economic and environmental sustainability challenges. The global desalination market’s effectiveness and sustainability can only be secured if economic and environmental challenges and other market restraints are minimised.

High capital cost is a significant challenge for the sustainable development of desalination plants. The costs of desalination are influenced by many factors, such as the plant’s size, location, salt-intensity and the development of applied technologies. Desalinated water prices are vulnerable to energy price fluctuations due to the plants’ high energy consumption during operation. The capital and operational costs of desalination can be reduced by improving desalination and energy efficiency technologies.

Environmental issues, such as a desalination plant’s greenhouse gas emissions when coupled to a power plant, and its negative impact on the marine environment, have to be addressed to meet the precautionary principle of sustainable development, which highlights a ‘better safe than sorry’ approach. To achieve environmental sustainability, requires a suitable location, plans to deal with the negative impact of brine, and the establishment of permanent observation of plants. In recent years, desalination industries, especially in Australia and the US, have made great improvements in addressing environmental concerns.
The Rundown on Rainmaking

By Brooke Jones, Researcher
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Key Points

- Estimates indicate that 24 countries are participating in a total of 80 cloud seeding projects.
- Artificial rainmaking has the potential to form a significant component of water resource management.
- The United States invests approximately US$600,000 each year in cloud seeding, which has produced an average annual output of 50 million tonnes of water for drinking and farm water supplies.
- Cloud seeding does not produce changes in long-term weather patterns or climate and is a costly operation.
- Cloud seeding does not work everywhere. Suitable conditions must be available for it to be a cost-effective means of increasing rainfall.
- It could take some years before it provides the reliable and consistent results desired by drought-affected agricultural producers.

Analysis

An average rain cloud contains eight million tonnes of rainwater, meaning there is a vast quantity of untapped rain in the sky. This is why artificial rainmaking techniques seem to be an obvious solution to water shortages around the world. In 2010, the World Meteorological Organisation reported that 24 countries were participating in a total of 80 cloud seeding projects.

Cloud seeding was discovered in 1946, when scientists realised that dropping particular substances into clouds could trigger rainfall. Typically, cloud seeding is the dispersion of silver iodide aerosols or frozen carbon dioxide (dry ice) throughout the upper part of clouds.

There are three different types of cloud seeding methods: static, dynamic and hygroscopic. The static and dynamic methods fall into the category of cold cloud seeding, which is typically applied to cumulus congestus clouds. These clouds are produced by strong updrafts and are usually taller than they are wide. The hygroscopic method, referred to as warm cloud seeding, is aimed at convective clouds, which are smaller and stretch several kilometres across.

Australia's susceptibility to drought has affected its farming capacity in the past and continues to do so now. This is despite extensive research on weather modification and the development of technology designed to ameliorate water shortages. Artificial rainmaking has the potential to form a significant component of water resource management. Worldwide, scientists have attempted to induce rain artificially, using various techniques, to ease drought conditions. These techniques include laser technology, that triggers the formation of water droplets in the air, and cloud seeding, which involves the introduction of chemicals into clouds in an attempt to stimulate the precipitation process.
Cold Cloud Seeding

Static cloud seeding seeks to increase precipitation by scattering silver iodide into the cloud formation. Silver iodide has a crystalline structure similar to that of ice and hence the moisture in the clouds condenses around its molecules, which become heavy. These water droplets fall from the sky as rain or, in some cases, snow. While silver iodide acts as an ice-forming agent by providing additional nuclei for water vapour condensation, dry ice lowers the temperature as it evaporates. In turn, this works to increase the amount and rapidity of ice formation.

Dynamic cloud seeding involves the injection of a much larger amount of silver iodide crystals than in the static method, so as to cause glaciation of the cloud. The heat released from the freezing process adds buoyancy and enhances the vertical air currents, with the aim of yielding increased precipitation. Although more complex than the static mode, dynamic cloud seeding is capable of producing more rain.

Cloud seeding chemicals are dispersed either by light aircraft or by devices on the ground. Targeting with aircraft is more efficient and accurate, but it is also the more expensive option. When released by ground-based generators that burn the granular form of the chemical, the fine particles are carried downwind and upwards by air currents. Another means of delivery is by rocket launchers, which have been widely used by China.

Warm Cloud Seeding

Hygroscopic seeding affects warm cloud processes. It involves the use of water absorbing particles, usually sodium chloride, that are spread through the lower parts of clouds. They attract water droplets, which induces the process of coalescence and produces rain. The salts are usually delivered by pyrotechnic flare technology. It was recently discovered, however, that the optimal size of hygroscopic particles is too large to be dispersed by current flare technology.
The Limitations of Seeding

There are a number of drawbacks associated with cloud seeding. In most cases, there is no control system in place that can determine whether a cloud would have produced rain even without being seeded. Also, particular conditions are required for cold cloud seeding to be effective. The clouds must contain a significant amount of super cooled water that is below freezing point, but not frozen, at a temperature falling approximately between -10°C and -20°C. The wind must also be below a certain speed so the cloud is not dispersed. Warm clouds need to maintain an updraft of moist air. The depth of clouds is another significant factor; to allow sufficient time for the ice particles to grow before falling. Given that the potential for rainfall is strongly dependent on the dynamics of the clouds that are being seeded, cloud seeding is not a cure for drought.

There is also much scepticism in the field. Researchers in Israel recently analysed data covering fifty years and ultimately proclaimed that cloud seeding is an ineffective method for increasing precipitation. They argued that cloud seeding is only successful when performed on orographic clouds, which are formed over mountains and short-lived.

Above and beyond Rainmaking

There are other uses for cloud seeding besides rainfall enhancement. It has been used as a way of suppressing hail, to reduce the damage to crops, and also fog, to clear the air around airports. It has even been used to reduce the intensity of hurricanes and, as demonstrated by China prior to the 2008 Beijing Olympics, to clear away air pollution and smog. Also worth noting are reports of the Russian Government’s use of the technology to seed clouds containing radioactive particles over Belarus.

Cloud Seeding in Australia

The general characteristics of many areas in Australia, coupled with inconclusive results from several experiments, led the CSIRO to abandon cloud seeding as a field for scientific exploration in 1984. It is, however, still being tried and tested by other bodies, as a means of increasing rainfall and mitigating the impacts of drought. There are currently three major cloud seeding trials underway in Australia, two of which have concentrated on providing additional capacity to hydro-power systems.

In 1964, the Hydro-Electricity Commission of Tasmania began trialling cloud seeding as a means of increasing the runoff rates into the mountainous hydro-electric catchment area. From initial experiments conducted, the Bureau of Meteorology estimated a 30 per cent increase in rainfall over approximately 2,500 square kilometres in the autumn months. Due to these positive results, cloud seeding operations have regularly been commissioned in the region ever since.

The New South Wales Government has been operating a cloud seeding project in the Snowy Mountains for the Hydro-Electric Scheme. This particular trial uses land-based aerosol generators that shoot miniscule particles of silver iodide, initiating the formation of ice crystals, which in this case fall as snow, not rain. Late last year, the Natural Resources Campaign concluded that the cloud seeding technology had increased snowfall by 14 per cent. The operation has succeeded in adding a tracing element (indium sesquioxide), which can determine how much snow has accumulated due to the seeding. The trial commenced in 2004 and, although there is ample evidence to suggest a significant increase in snowfall, it is not yet known whether this has resulted in commensurate run-off into the dams. The trial has been extended until 2014.
Economic Benefits

Cloud seeding is a costly technology. The first experiments conducted showed that cloud seeding would need to be conducted over a wide area, for an extended period of time, for it to have any worthwhile economic impact. However, if an area contains clouds suitable for seeding, then investment in the augmentation of rainfall can provide great economic benefits, and, potentially, greater food and energy security.

The United States invests approximately US$600,000 each year in cloud seeding, which has produced an average annual output of 50 million tonnes of water for drinking and farm water supplies. This equates to a cost of 1.3 cents per tonne of water. The North Dakota Cloud Modification Project has supposedly increased summer rainfall by five to 10 per cent, which yields increased crop production worth $US8.4 million to $US16 million annually. The hydro-electric project in Tasmania is estimated to be worth about three times the cost of the cloud seeding programme.

Laser Technology

Seeding clouds with lasers has also been investigated as a way of stimulating precipitation on demand. Short pulses of infrared laser rays sent through humid air into clouds can trigger artificial lightning. The discharge of lightning increases the temperature of the atmosphere to such an extent that the molecular bonds between nitrogen and oxygen are broken. This endothermic (heat-absorbing) reaction creates a plasma, which contains charged particles that act as condensation nuclei and allow raindrops to grow, not unlike the effect of silver iodide crystals in cloud seeding. This scientific occurrence is evidenced by the high incidence of lightning flashes during hail storms.

The lasers can be generated from the ground, at cloud level and also in space. In space, solar energy is used to produce high power intensity laser beams on a solar power satellite or a space station. These laser beams are transferred to a particular ground station and released into the surrounding atmosphere, where they act as an agent for artificial lightning.

Some scientists are sceptical of the feasibility of using lasers to trigger rain, stating that typical atmospheric conditions do not have sufficient humidity for it to work. The research team has reported that it will take several more years to fully develop laser rainmaking technology.

Other Rainmaking Technologies

Rain can also be made to fall by applying science that imitates the way rain is naturally created. Collecting solar energy on the ground and using it to heat the surrounding atmosphere, will produce an ascending air current. This air current takes moisture vapour from seawater up into the sky, causing condensation to form cloud particles, and water is accordingly precipitated.

A process to stimulate the artificial growth of clouds and cause their water vapour to condense has also been proposed.

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Conclusion

As population and urbanisation rapidly increase and the impacts of climate change become more severe, water resource management is an ever-increasing concern. Artificial rainmaking technologies have come a long way since the technologies used before the middle of the twentieth century. The objective of current rainmaking methods, particularly cloud seeding, is to make clouds more effective in releasing the rain that they hold.

Although drought has often been the impetus for the implementation of cloud seeding technology, cloud seeding cannot be relied upon as a short-term response. It does not produce changes in long-term weather patterns or climate, and it is a costly operation. Also, cloud seeding does not work everywhere. Suitable conditions must be available for it to be a cost-effective means of increasing rainfall.

Artificial rainmaking is an area in need of continual research and operations that have produced positive results are a sign of hope for many. On the other hand, it could take some years before it provides the reliable and consistent results desired by drought-affected agricultural producers. Meanwhile, the evidence to date shows that the technology should not be abandoned. Cloud seeding projects in both Tasmania and the NSW Snowy Mountains indicate successes, which, if sustained, have the potential to provide some certainty in rainfall patterns.
Using Urban Water Runoff: To Water the Cities

By Catherine Anderson, Research Intern
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Key Points

- A growing urban population across the globe is straining water infrastructure.
- Studies have suggested that when urban runoff techniques are implemented, stormwater runoff can be reduced by up to 70 per cent. This reduces pollution entering waterways by up to 90 per cent and also reduces site development costs.
- Capturing urban runoff could be an effective alternative water source, if there is interagency coordination.

Analysis

There is growing pressure around the world to expand and create cities. Consequently, there is a huge potential for utilising urban water runoff. It would allow for a reduction in the cost of urban water infrastructure, reduce the risk of flooding and the amount of pollution entering the waterways, and, most importantly, relieve the growing pressure on water sources. The need to divert water from other uses would therefore be reduced. To achieve these aims, it is important to understand the urban water cycle and the characteristics of urban developments, and to create a better integrated management strategy. This requires identifying how an urban area can be utilised to become a part of the solution, rather than the problem. The effectiveness of utilising urban runoff as a sustainable option varies from region to region.

Urban and economic expansion has its obvious benefits, but development also places additional pressure on demand for resources; one of the important areas being the supply of water. Some argue that the limits of sustainability are being reached in many cities around the world, and it is no different for Australia. Apart from Antarctica, Australia, as a continent, has the lowest rainfall levels in the world. Paradoxically, Australians are some of the highest per capita consumers of water. New water sources must be developed. These include utilising recycled water, desalinated water and urban runoff. Without water management and investment in new water sources, there will be significant stress on major urban and regional areas around Australia.

There is a possibility that in 50 years time there could be an additional 21.5 million people in Australia. A growing population is of concern due to the distribution of resources. By 2026 Australia can expect to require an additional 600 billion litres of water. By 2056, more than 1,000 billion litres of additional water will be required. Ross Young, from the Water Services Association of Australia, states that recent developments in water efficiency technology, such as recycled water and desalination plants, mean that demand can, in theory, be met, as long as the amount of rainfall remains the same. The problem is that climate change is unpredictable and strategies must be developed that encompass all the potential factors and include the environmental and social impacts.
Rapid growth is occurring in many cities around the globe and, although it can be argued that there are social and economic benefits from that growth, it also increases the demand on resources. Further development results in changes to the landscape that can affect the natural water cycle and lead to habitat fragmentation and degradation.

When many current cities were first developed, water was not valued as it is today; little thought was given to the impact that urban design would have. Rather, the main goal for developers was to remove stormwater from urban areas to prevent flood damage. Water sensitivity is increasingly becoming a feature of contemporary urban development; integrating elements of the natural water cycle into urban designs. Best Management Practices can be used to mitigate the effects of urban runoff and are defined as a: “device, practice, or method for removing, reducing, retarding, or preventing targeted stormwater runoff constituents, pollutants, and contaminants from reaching receiving waters” (United States Environmental Protection Agency 2002, ‘Urban Stormwater BMP Performance Monitoring, a guidance for meeting the National Stormwater BMP Database Requirements’).

Impervious and pervious surfaces alike affect the hydrology of an area and contribute to the amount of urban runoff. Pervious surfaces, such as parks and gardens, allow water to infiltrate into subsurface aquifers, whereas impervious surfaces, such as roads and paths, do not. As a result, runoff builds up quickly. In areas of natural ground cover, with an absence of impervious surfaces, between zero and 20 per cent runoff is created. This is compared to urban residential areas, where between 30 and 50 per cent of surfaces are impervious, resulting in 40 to 70 per cent runoff. Commercial and industrial areas have the greatest potential to catch urban runoff, as 75 to 100 per cent of the area is made up of impervious surfaces.

As impervious surfaces are often interconnected, there are usually high levels of runoff and pollutants. The pollutants, which include oil, rubbish, grease, pesticides and nutrients, are directly carried into waterways, which increases their sediment loads. The runoff that comes from heated roads may cause nearby streams to heat up rapidly, which could cause thermal shock, killing flora and fauna. The speed at which water runs through streams and channels is also an issue, as it can damage the shape of the stream and the surrounding vegetation. To combat this issue, concrete waterways have been built; however, this also leads to changes in the natural processes of the stream, as well as reducing the area of habitat.

**Stormwater Discharges from Various Land Covers**

![Stormwater Discharges from Various Land Covers](Source: The Water Column, 2009.)
Urban Runoff designs

Urban runoff is a viable option as an alternative source of water. Instead of urban areas being designed to remove runoff, there is potential for designs that can retain and reuse it. In Australia, urban runoff is not specifically regulated. There are, however, obligations under health, environmental and agricultural legislation for wastewater reuse. Roof rainwater harvesting is currently the most popular method, but there are many other options that can be used within a community.

This paper will consider each stage of the water cycle and ways in which designs can assist in utilising water runoff, focusing on the processes of collection, treatment, storage and distribution.

Developments in the area of sustainable water management have led to an increased number of trials and experiments, which use different control systems and designs to collect and store urban runoff. It is challenging to utilise runoff in established cities but it can be done.

Collection

The collection of urban runoff can be done through man-made constructions, yet the more that can be filtered naturally into the groundwater the better, as it takes pressure off storage systems and reduces management costs. There are a number of urban runoff designs that can be implemented by urban developers. Water Sensitive Urban Designs (WUSD) allow for high levels of infiltration into the groundwater system. This decreases the scale of floods which, in turn, reduces the need for flood prevention infrastructure. WSUD usually have a combination of retention, infiltration and reuse systems. Examples of WUSD that are widely encouraged in urban areas include infiltration basins, swales and soak wells.

Recommended site design alternatives can be as simple as using native flora to reduce runoff, putting permeable paving in areas with little traffic, and the use of vegetated filter strips and swales, rather than storm sewers and lined channels, to reduce runoff and remove pollutants. Another alternative is to create a “Green Roof”, which is a roof that is completely or partially covered by vegetation, reducing the volume of water and delaying peak flows. The precipitation would enter the soil and could be retained and evaporated back into the atmosphere, or drawn up by the vegetation and released through transpiration, or it may simply pass through the soil to become runoff.

In circumstances where this natural infiltration cannot occur, systems have been developed to remove runoff as quickly as possible from flood prone urban areas, without increasing the stress on natural drainage structures. There are a number of ways to collect the urban runoff that would not otherwise enter the drainage system. They include gutters, pipes, channels, swales, buffers and infiltration systems. There is also the managed extraction of water by pumping water out of drains. To reduce the amount of urban runoff that is lost during periods of heavy rainfall, drains could be modified, without affecting their capacity to minimise flooding.

Around Australia, there have been observable signs of a decline in the quality and quantity of surface and groundwater. This is evident in the decline in water quality and the environmental degradation that has occurred in the Murray Darling Basin and the Hawkesbury-Nepean Basin, due to pollution that is discharged with the urban runoff, as well as the increased demand for water. Australia has also been using swales, bio-filters and stormwater ponds. Increasingly, Water Sensitive Urban Designs are being utilised in new areas of development, which will lead to both environmental and economic benefits.

Even so, stormwater in Australia is not significantly reclaimed. Only eight per cent is utilised for non-potable uses, even though the average amount of stormwater in urban areas is almost equivalent to urban usage. The mean urban runoff volume for each capital city in Australia ranges between 85 to 100
per cent of usage. Not all of the water can be caught, but it is a method capable of providing a significant source of water. In Melbourne, approximately 650 gigalitres of water fall on the city each year – double the amount that is consumed by the city in the same timeframe.

A number of cities around the world could utilise their rainfall to supply most, or a considerable amount, of the water required by their residents and industry. For example, the Los Angeles and San Gabriel Watershed Council estimates that if water were captured in one-quarter of the urban area, 80 per cent of the water caught could supply 800,000 people for a year. It would also reduce runoff by 30 per cent, thus removing some of the stress on drainage systems.

**Treatment**

After the initial collection phase, the runoff must go through a treatment phase. This is vital due to the high quantity of sediments and pollutants associated with urban runoff. Examples of treatment systems include wetlands, infiltration systems and sediment traps. Urban runoff can be a source of potable or non-potable water; depending on its final use, the treatment process will therefore vary. Water that does not go through a vigorous treatment phase cannot be used where humans may come into direct contact with it.

One example of a treatment design is the rain garden bio-filters in Melbourne. As storm water is a significant threat to Port Phillip Bay, the bio-filters have been designed to remove the pollutants from urban runoff before it enters the sea.

**Storage**

The issue of storage is a problem that many cities are facing. It is one of the greatest issues related to the utilisation of urban runoff. The problem with urban areas is that there is little room for storage and treatment plants. Areas must therefore be analysed individually, to find sites that can be utilised; for example, an old dam or factory. In areas where there are aquifers, urban runoff has been effectively used for non-potable reuse; for example, 50 per cent of Perth's urban runoff and six per cent of Adelaide's.

There are a number of site design alternatives that allow urban runoff to be stored. They include Managed Aquifer Recharge, drainage channel modification, and groundwater storage through both underground and surface storage. Each option has its benefits and downfalls. For example, wetlands, which are a groundwater surface storage system, work as a natural filter to remove pollutants from urban runoff because they are heavily vegetated. They encourage a slow flow, improve the quality of the water, create a new habitat that increases the diversity of flora and fauna, have aesthetic benefits and provide flood retention. The downside to a constructed wetland, however, is that unless it is utilised in a new development, it can become costly because land availability is minimal and expensive when the costs of construction are added.

Singapore has an annual rainfall of around 2,400mm and is one of the countries to harvest urban storm water on large scale. The Marina Barrage is Singapore's largest catchment. Located over the mouth of the Marina Channel, it is Singapore's most urbanised catchment covering 10,000 hectares, one-sixth the size of Singapore itself. Water caught in this catchment provides ten per cent of Singapore's current water use and is part of a long-term strategy to secure the country's water supply. Along with the two other reservoirs (Punggol and Serangoon) that will be built, it will increase Singapore's catchment by between one-half to two-thirds. The catchment also helps to avoid floods in low lying areas, such as Geyland and Boat Quay.
Distribution

Urban runoff can be distributed through dual reticulation or by pumping and irrigation systems. The distribution method used depends on environmental factors, such as climate and vegetation, as well as the quantity required. In Australia, irrigation systems make up 50 per cent of stormwater distribution. Irrigation systems are used primarily in small-scale schemes, while larger catchment areas use dual reticulation.

Use

There are a growing number of areas in Australia where urban runoff is being utilised effectively. For example, Canberra uses urban lakes and Adelaide urban wetlands, to clean the water before it is released into the groundwater. In Adelaide's Parafield Stormwater Harvesting Facility, stormwater is diverted from the main drain to holding basins and wetlands and then used by a local wool processing plant. The Royal Park Wetlands in Melbourne treat collected stormwater, which is then used to irrigate the Royal Park Golf Course. Although South Australia has tried to utilise stormwater, it does not make up a considerable amount of the state's total water supply. In Sydney, there are a number of projects around the city that utilise urban runoff for non-potable uses. In Manly, runoff is caught and then treated using porous pavement, soils and litter traps, before it is used to irrigate the gardens and Norfolk pines that line the beach. In Kogarah Town Square, runoff from roofs and pavements is used for water features and washing cars. Swales and wetlands have been utilised in Homebush Bay to treat urban runoff for irrigating outdoor areas and sporting fields.

The US state of California has been successfully harvesting rainwater for a number of years. Orange County began replenishing the groundwater as early as the 1970s, with no long-term health issues being recognised. The Sycamore Villages community in Malibu, California is another example. The community has reduced its demand for water by 63 per cent through utilising urban runoff and treated wastewater. Santa Monica aims to utilise all urban rainfall to relieve pressure on water demand. The intention is to use this water for non-potable uses. When it is necessary to discharge the runoff, it is only done after it is treated, thereby improving the health of the area and the water quality.

Pressure on water supply is a problem that will increasingly have an impact on Perth. Surface runoff is an important source of water for Australian capital cities, the only exception being Perth, where the main supply of drinking water is sourced from the Gnangara Mound aquifer. It provides an estimated 60 per cent of Perth's water supply. What is concerning some in the water industry is that, over the last 25 years or so, the water table and the amount of recharge into the aquifer has reduced by around 25 per cent.

Until the 1970s, most of Perth's water was sourced from dams. Since then, however, the amount of rainfall runoff has decreased by 70 per cent, forcing Perth to rely on groundwater from aquifers that lie beneath the Swan Coastal Plain. This reduction has led the Water Corporation of Western Australia to suggest that attempts to utilise the surface water supply could be futile. Urban runoff could be utilised and stored so that, in periods of low rainfall, Perth could rely on the groundwater, which would have been replenished by recycled water and filtered storm water.

If Perth continues to dry out, different solutions must be explored. The Water Corporation is looking at a number of options. It has invested in researching the benefits of groundwater replenishments, looking at the impact it would have on water quality and the environment. These tests are being undertaken in Perth; to examine the effect recharging groundwater will have on the local environment. It is, of course, important to develop the most water efficient options specific to the region in question, by assessing the variations in aquifer characteristics, urban land availability, soil type and existing infrastructure.
Conclusion

There are many benefits to utilising urban runoff, as it can reduce construction, maintenance, replacement and stormwater impact costs. It also reduces environmental costs through flood control, protecting sensitive areas and habitat creation, as well as having aesthetic benefits. Although stormwater can be an inconsistent supply due to changes in weather patterns, it is more accepted by the public than recycled water as a solution to water supply pressures.

To reduce reliance on traditional water sources in an attempt to adapt to a changing climate, both social and environmental, it is imperative to have interagency coordination. Therefore, there is a need for cooperation between local and state governments to make urban runoff an effective method of water supply. The water industry must work with all stakeholders, including governments, planners, local agencies, developers and individuals in the community. Utilising urban run-off allows cities to access a significant amount of water, but unless water sensitive urban design is incorporated into the planning process, it is difficult to achieve.
Case Study

Water Security in India: The Coming Challenge

By Ms Anumita Raj, FDI Associate
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Key Points

➢ Booming populations, extreme poverty, rampant industrialisation and urbanisation, inefficient water use and, increasingly, climate change, have all had a negative impact on the overall water situation in Asia.

➢ By 2030, India will be extremely close to becoming ‘water scarce’.

➢ The volume of groundwater in India is inadequate to sustain a huge population, especially one that is industrialising and urbanising at such a rapid pace.

➢ By 2030, the Ganges and Brahmaputra system will become an unreliable source of water for those that depend on it.

Analysis

In the latter part of the 20th century, oil was directly and indirectly responsible for most of the conflicts in the world. That trend continued into the beginning of the 21st century. One thing is certain, however, where oil was ‘casus belli’ for the last 60 years, in the coming decades water will very quickly take its place. In Asia, booming populations, extreme poverty, rampant industrialisation and urbanisation, inefficient water use and, increasingly, climate change, have all had a negative impact on the overall water situation. India and China, with their enormous populations, are already facing several water-related problems, and these problems are set to worsen considerably in the next 15-20 years.

In June of 2010, the Strategic Foresight Group published its paper ‘The Himalayan Challenge: Water Security in Emerging Asia’. In the paper, India’s impending water scarcity is highlighted in stark detail. In the decades since its independence, India has been mostly cavalier with its precious water resources. Marked by inefficient use, and lack of storage facilities, India’s relationship with its water resources has always been unsteady. As a result, in 2010, India found itself in a precarious position, water-wise. And this situation has already impacted several other facets of Indian life, from agriculture and food security, to the economy and livelihood. India’s per capita water availability was 1,730 cubic metres per person per year in 2006, dangerously close to the 1,700 mark declared by the World Bank to be ‘water stressed’. By 2030, the per capita water availability is expected to decline to 1,240 cubic metres per person per year. This means that by 2030, India will be extremely close to becoming ‘water scarce’, a condition that is defined by the World Bank to be when a country’s per capita water availability reaches 1,000 cubic metres. India’s water utilisation rate is 59 per cent, already far ahead of the 40 per cent mark that is set as the standard. Any utilisation rate above 40 per cent means that the natural mechanisms in place do not have the capacity to recharge water sources adequately. Basically, water is being used at a rate that is unsustainable.

India’s water resources are a combination of groundwater and surface water resources. While rivers form the lifeblood of most of the cities, towns and villages across the country, groundwater is also vital to India’s people. As a majority of the rivers in the country are not perennial, groundwater actually sustains much of the population during lean months. The volume of available surface water resources, however, is much greater than groundwater resources.
India’s Rivers

Of the different types of surface water resources, rivers constitute the most valuable and voluminous part. In India, rivers are classified as large, medium and minor. There are 15 large rivers, 45 medium ones and more than 120 minor rivers. India’s rivers are usually described according to their origin – either as Himalayan and Peninsular or East and West flowing. The majority of India’s rivers are rain-fed, with the exception of those originating in the Himalayas. The Himalayan Rivers are perennial rivers, owing to the glacier melt that feeds them throughout the year. This makes them vital to India’s fortunes year round. While other rivers in the country are seasonal in nature, due to their dependence on rainfall, the Himalayan Rivers flow all year round. Of these glacier-fed rivers, the Ganges and the Brahmaputra are the largest and most important. Between the two, their basins are home to roughly 400 million Indians, thus linking the rivers to the futures of more than a third of the country’s population.

Moreover, given that the total of India’s water resources is 1,900 Billion Cubic Metres (BCM), the fact that the Ganges (525 BCM) and the Brahmaputra (585 BCM) contribute 1,110 BCM, or 58.5 per cent of the total, makes them all the more valuable to the country. When viewed purely from the prism of utility and value, the Ganges and the Brahmaputra are the most important rivers in the country.

Groundwater in India

While rivers, particularly the Himalayan ones, are vital to the survival of India’s population, its groundwater resources too are vital but for a different reason. Since most rivers in India are not perennial, in several parts of the country groundwater is the only constant source of supply. Since a majority of the population is engaged in agriculture as a profession, groundwater is often the primary source of irrigation. The volume of groundwater in India is inadequate to sustain a huge population, especially one that is industrialising and urbanising at such a rapid pace. The groundwater resources in the entire country total roughly 433 BCM.

Excessive groundwater abstraction in India has become unsustainable. There are approximately 20 million tubewells in India, and over 50 per cent of agricultural land in the country is sustained by groundwater. The Ministry of Water Resources in India estimates that nearly 60 per cent of the groundwater has been developed. In urban areas, groundwater is the principal source of water, and tubewells are often dug several feet into the ground to keep up the high level of use. Increasingly, rainfall does not penetrate into the groundwater tables due to factors such as urbanisation and climate change. In a country so heavily dependent on groundwater, relying on underground aquifers that are not replenished on an annual basis could be disastrous.

Climate Change and Water

The effects of climate change are now apparent all over the world. Impacts are being witnessed in every aspect of human security. In India, climate change is expected to impact the Himalayan Rivers in two distinct ways. One, the rising temperatures will likely affect the glaciers at the head of rivers like the Ganges and the Brahmaputra, accelerating the rate at which they melt. Two, global warming will impact monsoon patterns in such a way that rainfall is more intense and heavy, but concentrated on fewer rainy days. A combination of these two factors has already started to seriously impact the two rivers that sustain themselves on rainfall and glacial melt.

The rate at which the glaciers in the Himalayas are melting has become a controversial topic over the last year. Due to differences in opinion between scientists, there has been an intense debate raging between all parties as to exactly what the effects of the glacial melting will be, as well as the exact speed at which they are melting. Most scientists agree that the glaciers are melting at a rate much higher than before, due to the ill effects of global warming. The lack of meteorological data and comprehensive mapping of the glaciers has hampered most efforts to gather information. As to the rivers they feed, the effect of
the glacial melt is hard to pin down with accuracy. It is expected that as the rate of melting increases, the flow of the rivers will correspondingly increase. However, this is not likely to be a long-term impact. As the glaciers melt quicker and they start to shrink at a rapid pace, in the long-term, the volume of water contributed by them to the rivers will reduce. If this continues unabated, rivers like the Brahmaputra and the Ganges could become seasonal rivers.

At the same time, the changing rainfall patterns will compound the effect of climate change on the rivers. Any minor change in the monsoon pattern has an immediate and discernible effect on rivers. While glaciers allow the rivers to flow throughout the year, rainfall is the major contributor to the annual runoff or volume of the rivers. During the months from June to September, the high season for the Ganges and the Brahmaputra, the rivers experience over 80 per cent of their total annual runoff. Due to climate change, monsoon patterns are expected to become increasingly erratic, arriving unpredictably and withdrawing in a similar manner. Rainfall is also expected to become more intense and concentrated on fewer days, which will lead to adverse situations, such as flash floods. At the same time, due to the fewer days of rain, adequate amounts of water will not percolate down to the groundwater tables, further jeopardising the precarious water situation. Increased temperatures will also increase the rate of evapotranspiration, the simultaneous movement of water from the soil and vegetation into the atmosphere through evaporation and transpiration. This will actually reduce the amount of water that is available for human use.

Cumulative Long Term Impact

By 2030, the Ganges and Brahmaputra system will become an unreliable source of water for those that depend on it. This status quo is already somewhat evident, but will become increasingly apparent in the next two decades. While on paper, the two rivers' water quantity is not expected to decline significantly, the effects on the ground are more serious. Even as climate change factors jeopardise the long term future of the rivers, human neglect and inefficiency contribute to their decline. The Ganges is often counted amongst the most polluted rivers in the world. Due to industrial effluents, untreated sewage and other types of human waste being deposited directly into the river, in its present state the Ganges’ water is not only unfit for drinking and bathing purposes, but also for agriculture, along several parts of its banks. While the Brahmaputra is not considered to be too polluted, due to the relatively low level of industrialisation along its basin, it is expected that unchecked development in the region could change that.

Ripple Effect: Food Security and Agriculture

As in any agrarian society, a change in water security has a direct and immediate impact on agriculture. A majority of India’s population, almost 58 per cent, is employed either directly or indirectly by the agricultural sector. About one-third of India’s GDP is contributed by this sector. India’s primary crops, rice, wheat and maize, are all water intensive crops, especially rice. Already, across India, weak and delayed monsoons have caused havoc to India’s farming prospects, reducing yield significantly each year. Farmers in India are hit with a twofold problem. Most crops are directly dependent on the monsoon. A delay in the monsoon or a truncated monsoon disrupts the natural cycle of the crops. To reduce this dependency and create more food security, farmers turn to irrigation, which is, in turn, dependent on both the river and the underground aquifers, which are also fed by the monsoon. Moreover, irrigation places a major strain on the water resources of India, depleting them at a rate faster than they can be replenished. This means that farmers are stuck in a ‘damned if you do, damned if you don’t’ scenario, without any realistic way out. Farmers in drought-ridden states have been committing suicide at an increasing rate for the last decade or so, with no relief in sight. The government and the scientific community have spent several crores \(^1\) on finding new varieties of the main cash crops that can resist drought.

\(^1\) Traditionally, Indian financial nomenclature has not used thousands, millions and billions, referring instead to rupees in groupings of 10: lakh (100,000 rupees) and crore (100 lakhs or 10 million rupees).
Apart from the immediate impact of lack of water on crops, there is also the problem of growing desertification due to depleting water resources. Lack of adequate water resources in lands that were once water rich, will inevitably lead to desertification. While this trend has not yet reached a critical point in India, it is not inconceivable that this could happen in the near future. Both Nepal and China, who also have prominent Himalayan Rivers within their boundaries, have serious issues with desertification caused by rapidly diminishing water resources. This phenomenon has lead to the loss of arable land, further exacerbating an existing threat to food security. If left uncontained, the water shortage in India could lead to the creation of arid lands through desertification, and the loss of agricultural land. This could be catastrophic to the economy.

**Ripple Effect: Economy and Livelihood**

Undoubtedly, the threat to food security will directly manifest itself in India’s economy, especially considering the size of the contribution that the agricultural sector makes to the country’s GDP. The rate of farmer suicides is likely to increase, not only placing an additional burden on the families of those farmers, but also on the community and state. Moreover, any new ventures or industries that wish to set up in India, will strongly consider the availability of water for the functioning of their plants before they decide to invest in India.

Apart from agriculture, there will also be an impact on India’s fisheries and aquaculture sector. In total, the lack of future food security will have an immediate and irreversible impact on the economy of the nation, as well as on the livelihood of hundreds of millions of Indian workers and their families, who depend wholly on the agricultural and fisheries sectors for their livelihood.

**Ripple Effect: Health security**

Water-borne diseases contribute to as many as 80 per cent of all disease cases in South Asia, and are caused largely by a lack of access to clean water and sanitation. They take a heavy toll, particularly on the health of young children, who often do not fully recover from their effects. With significant sections of the Himalayan river basins lying in the tropical or subtropical regions, the population of the area is easy prey to water-borne diseases due to the warm climate and annual monsoons. Hundreds of cases of water-borne diseases, like cholera, are reported every year. Vector-borne diseases like malaria will thrive when temperatures increase as a result of global warming. As temperatures increase and rainfall becomes more erratic and intense and falling over fewer days, India is fast becoming a breeding ground for the disease-causing vector, the mosquito. The mosquito is also a vector in the case of dengue, one of the fastest spreading vector-borne diseases. Apart from the risks caused by increased temperatures, there are also the risks caused by a more intense rainfall, which could result in floods and water-logging in several places. Water-logged areas are potential breeding grounds for mosquitoes.

In India, polluted water sources are also a leading cause of water-related diseases. Especially in the Ganges basin, the poorest among the population often have no choice but to drink and cook with seriously polluted water, causing numerous diseases and stomach infections like diarrhoea and dysentery. As these trends become more entrenched into the national cycle, they could cause epidemic-like situations in the future. Water shortages have an enormously devastating impact on human health, including: malnutrition, pathogen or chemical loading, infectious diseases from water contamination, and uncontrolled water reuse. With the water supply slowly becoming inadequate to meet the growing demand for water, the availability of safe drinking water will decrease. Lack of safe drinking water could result in people using whatever water is available to them, including water tainted with sewage and agricultural runoff, or even contaminated water. People living in rural areas and urban slums will be more vulnerable to disease and infections since they do not have access to piped water and cannot afford to buy clean water. In the future, this cycle of diseases will place an enormous burden on the government, which will have to scramble to provide health care for all those affected, as well as prevent the situation from worsening.
Ripple Effect: Migration and Conflict

With several parts of the country becoming increasingly water scarce, especially in North India, millions of people will be forced to move away from their homes in search of work and water supply. In the next two decades, more and more rural residents will be forced to abandon their hometowns due to the lack of water resources, and the increase in extreme weather events such as floods. Lack of job security in the agriculture sector due to water shortages will also force many farmers to leave their villages and move towards urban areas. This phenomenon, known as environmental migration, will not be restricted to the Indian territories. Migrants from countries like Nepal and Bangladesh will likely move into India due to a serious shortage of water within their own countries, creating a serious human security problem.

This trend will worsen the tensions that are already prevalent in parts of the country over migrant workers. In urban areas, especially, where most rural migrants are likely to go, these tensions will exacerbate existing ethnic and social divides and increase crime rates. With an increased number of people competing for scarce resources and jobs, an anti-outsider mentality will start to take over, and create a backlash against migrant workers. This tension could manifest itself violently, given the appropriate circumstances and external pushes. While this ‘locals versus outsiders’ conflict is already prevalent in certain parts of the country, and to a large extent in most urban centres, future water shortages will push these conflicts to the forefront of national dialogue.

The Future

The Strategic Foresight Group’s paper ‘The Himalayan Challenge: Water Security in Emerging Asia’ focuses on all these issues, from the primary problem of water security, to all its secondary impacts on food, health and human security. The need of the hour is not only to recognise these problems as already being apparent, instead of a potential threat in the future, but also to act upon that recognition. Unless solutions are found at the micro and macro levels simultaneously, in a country the size of India it is unlikely that this serious and looming threat will be resolved.

Apart from the crisis in the Himalayan River basins in India, there is a parallel threat in the countries of China, Nepal, Bangladesh and even Pakistan. Lack of water will mean food shortages in these countries, which India will have to contend with on a regional level. Workers who have lost their farmland in Bangladesh or Nepal will likely migrate to India, causing a serious security threat to the country. Any instability in these countries will lead to further instability in the region, of which India is the most prominent entity.

Most importantly, since all the Indian Himalayan Rivers are transboundary in nature, the problem will not be truly solved unless the solution is also transboundary. Long-term solutions will be found only through joint action and collaboration. Even if the water crisis is somehow staved off in India, unless it is resolved in Nepal or Bangladesh as well, it is not likely to matter. When discussing water problems in India, policy makers often speak in nebulous terms, implying that the problem is neither immediate, nor already in our midst. This mindset will first and foremost have to change, as the problems are already here, and their consequences have already started to affect Indians across the country.
Summary

In 2010, Outcomes Australia held a forum in Canberra involving senior government officials, scientists, policy makers and peak bodies representing the agricultural and natural resource management sectors. The aim was to outline the case for a strategic change in how water is managed in Australia. This chapter outlines the points that were raised at the forum and proposes a broad concept for realising that change.

Analysis

The Strategic Situation – An Imperative for Change

Water not only distinguishes the blue planet by covering 71 per cent of its surface but has been the medium for the basis of life. We humans are some 70 per cent water and our bio-chemistry is mediated by water. Our industrial ecology relies on water and most of what we consume, be it our energy, steel or food, often involves large volumes of embodied water in its manufacture and footprint. It is therefore clear that we must think of our water as a key natural and national strategic asset.

Securing an adequate supply of safe, reliable water may become a key limiting factor and strategic determinant for communities, regions and nations in the coming years. Unless we understand the limits of our fresh water resources and manage them wisely and fairly, its decreasing availability, and our absolute dependence on water for life, pose the risk of escalating social and regional conflict.

Australia is by far the driest inhabited continent, with variable, unreliable and ineffective rainfalls. How we conserve and use each drop is critical. This is particularly so as climate changes intensify, not just in marginal temperature increases, but the further serious systemic aridification of regions and bio-systems, as is already happening in southern Australia. In Australia, we should consider water as our primary strategic asset and manage and value it accordingly.

The realities now confronting our water needs

Associated challenges in meeting Australia's water needs are far from simple and include:

- **The systemic aridification of southern Australia.** This aridification can be attributed to the change in behaviour of atmospheric latitudinal circulation features, through the southward extension of the Hadley cells and the displacement of the cool moist winter Ferrel cells, as a result of climate change. Although first apparent in WA from 1975, these declines in winter rainfall and stream recharge are anticipated to spread and intensify throughout southern Australia over the next few decades, resulting in a projected significant decline in rainfall and, consequently, water resources.\(^1\) This represents a systemic climate shift and, despite recent monsoonal rain from the Indian Ocean, threatens the viability of the Murray Darling Basin (MDB) and other important food and fibre producing regions.

- **The aridification of eastern Australia, with vegetation reducing over the past 120 years.** In addition to this impact from climate change, Bureau of Meteorology data indicates that the rainfall over much of eastern Australia has been declining over the past 120 years. It often has

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\(^1\) CSIRO, Bureau of Meteorology State of the Climate report, 15 March 2010, p.6
not recovered to its former levels, particularly following periodic droughts. This decline may be associated with changes to vegetation, due to land management practices, droughts and possibly haze and rainfall nucleation processes.

- **The declining affordability but increased dependency on oil-based agricultural inputs.** As oil prices increase as a result of scarcity and increased demand, the viability of maintaining many oil-based agricultural inputs will decline. However, many agricultural systems have become increasingly dependent on oil-based inputs to sustain productivity. Unless alternative sustainable and lower-input systems can be designed in their place, we risk serious declines in both agricultural outputs and food availability.

- **The decreased capacity of degraded, less resilient landscapes and bio-systems to adapt to a combination of climate fluctuations and input stresses.** In contrast to past priorities that were placed on maximising the growth potential of agricultural systems through high off-farm inputs, future productivities may depend more on the capacity of plants to sustain adequate growth despite stress conditions and with limited inputs. Priorities may need to shift to restore the resilience of agricultural soils and systems to allow them to operate under such limiting conditions.

**Change is needed**

In 2010, we are experiencing new weather conditions and a new water-stressed reality that must be faced urgently. Business as usual and policies on rainfalls, water supplies, availability, reliabilities, expectations and particularly ‘entitlements’ that are based on past assumptions, cannot be sustained. The physical reality is that key storage facilities have often only been 30 per cent full for decades. Low inflows into these facilities may become normal in the future and while it is possible to trade virtual water entitlements, these cannot be supplied from dry dams. Water must not be managed simply as a commodity but also in terms of its physical availability, as a biological essential and necessity for life.

To meet future demand, Australia may need to secure up to ten times the actual water that is projected to be available under ‘business-as-usual’ scenarios. We need to be prepared to look at all new innovative options to achieve this target. While some options, such as desalination may be able to offset critical urban shortages, its high energy, capital and depreciation costs indicate that it will not be viable in securing our wider water and food needs.

Effectively, Australia needs to be prepared to go back to basics and look closely at the natural hydrology of the landscape and how nature evolved and sustained immensely productive and resilient bio-systems, despite this being the driest inhabited continent. Policy makers, researchers, land managers and engineers need to understand these hydrological processes and use them to refocus and redesign resilient water systems.

**New perspectives on Australia’s water dynamics and availability**

To achieve the objective of securing and better managing Australia’s water needs in a changing climate, it is important to first analyse and understand the ‘battleground’. What, for example, happens to our typical 100 units of rain that currently fall in different regions – where do these units of rain go, what governs these dynamics, how effectively are they used or lost? What changes must we anticipate and design for with the further aridification of southern Australia? What water conservation and efficiency measures can we use to secure our future water needs?

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2 A target should be based on demand increases due to projected population increases, increased urbanisation, as well as the embodied water needs to produce food and energy. This needs to be done against the backdrop of an expected 30 per cent reduction in annual rainfall in southern Australia and higher temperatures leading to greater evaporation rates. In addition, Australia’s obligations to meet the Ramsar Convention need to be considered.
As presented to the Australian Academy of Science:3

- 98 per cent of Australia’s rainfall falls on soils (the so-called ‘front of pipe’), just 12 per cent of this reaches streams and only 2 per cent is currently stored in dams (‘end of pipe’).
- Over 50 per cent of Australia’s rainfall is lost from the landscape due to evaporation.
- We substantially rely on the 2 per cent that can be stored in dams that are seldom full.

As climate changes intensify, this is going to become even more serious, resulting in:

- An expected 30 per cent decrease and more variable rainfall patterns in southern Australia.
- Up to a 50 per cent decrease in water runoff and stream, wetland and dam recharge.
- Serious risks to the water supplies and security of agriculture, industry and cities.

Australia will not be able to secure its future water needs from dry dams at the ‘end-of-pipe’. Instead, Australia needs to better conserve and use the water in the landscape at the ‘front of pipe’; over 50 per cent of which is commonly lost via evaporation. Public spending on buying back entitlements to virtual water or on infrastructure for dry dams at the ‘end of pipe’, appear problematic in addressing our actual physical water needs.

Realising this potential will require greater focus on ‘front of pipe’ initiatives to ensure that:

- More of the 98 per cent of the rainfall that falls on soil, infiltrates, and is retained within, the soil. It will then be available to slowly recharge floodplains, wetlands, streams and dams and less would be lost to evaporation.
- The bio-systems develop root systems that enable them to access water ‘in soil reservoirs’ over extended periods. This will reinforce the productivity and resilience of Australia’s bio-systems despite the intensifying climate stresses.
- Managers of irrigation systems optimise their water use efficiencies by focusing on developing subsoil water supply processes that have over 95 per cent efficiency, rather than spray or surface applications, which often operate with less than 10 per cent efficiency.

To achieve these outcomes Australia must focus on regenerating its soil structure; the key property that governs the effective use of rainfall. Soil structures can be improved, practically, rapidly and even profitably, by simply restoring their natural soil organic matter content, thus aiding:

- The infiltration, retention, availability and sustained supply of water from such soils.
- The aeration and capacity of roots to proliferate and penetrate deep into soils, and
- The capacity for water to recharge and irrigate soils from below to limit evaporation.

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3 Presentation to the Fenner Conference on the Environment 2007: Who uses all the water? held at the Australian Academy of Science; Barney Foran, Fenner School, Australian National University; March 2007
While there is always more to understand, we do know that the following complementary practical methods can realise the sort of change needed:

- Rebuilding the soil structures, their sponginess and water holding capacity effectively recreates in-soil reservoirs. Sequestering carbon is the safest, practical and relatively quick way of restoring the natural organic matter status of the soils, to increase their water holding capacity.

- The restoration of woodlands, tall perennial grasses and scrub lands, together with extensive, slowly bio-degrading litters, will reduce water losses. Effectively, they reduce surface wind speeds and extreme temperatures that would otherwise encourage significant evaporation losses.

- By returning to natural processes, the riparian areas can be restored and flood plains recharged. Slowing the water rushing through the landscape with simple structures like leaky weirs in streams that allow their reconnection with the flood plain. Importantly, the restoration of soil reservoirs in the non-floodplain landscape will reduce the dangerous erosive inflows to the incised water courses and the riparian areas.

- Australia’s natural bio-systems evolved hydrological storage and irrigation processes that supplied plants with their optimal water needs from below ground at minimal energy cost and evaporation losses. These ‘counter- gravity’ hydrological processes need to be restored and include:
  - The natural raising of stream beds and stream alignments through litter weirs and sedimentation, to levels above surrounding flood plains so as to disperse flood flows onto them.
  - The natural generation of hydrostatic pressures from the raised billabongs and chain of ponds that continuously recharge and irrigate surrounding floodplain vegetation from below.
ground, from the water stored in the flood plain and ponds.

- The development of highly efficient processes for capillary uplift or ‘hydrolation’ of water from subsoil reservoirs, to irrigate root zones as a result of the very high soil levels of linked organic matter.

- Greater understanding and use of root and microbial ecologies in the hydrology of the Australian landscape, so as to enable plants to better access water, often from deep soil strata, is pivotal. By effectively colonising soils so that the available water can be accessed by plants and encourage plant survival, especially during droughts, the resilience of our natural and agricultural bio-systems is enhanced.

Given Australia’s challenge of securing a ten-fold increase in available water from these bio-systems, the adoption of such practical technologies to give the MDB and other key food and fibre producing regions, their best chance to remain viable, must be fostered. Considering that much of our current water use relies on the 2 per cent that is stored in dams, and given the much higher volumes that could be conserved in the landscape with the appropriate management, even modest water savings in the latter will help Australia reach that target of a ten-fold increase in available water.

**A Strategic Plan for Change**

To realise the widespread change required, the people who manage land need to be willing to help implement nation-wide change. Fortunately to assist in meeting this challenge, a highly committed network already exists that includes:

- Leading innovative scientists, experienced in restoration ecology and management;

- More than 5,000 innovative farmers and land managers committed to strategic change; along with

- A range of leading practical demonstrators and case studies of what can be achieved.

Consequently, much of Australia’s challenge may need to focus on how best to lead, coordinate, catalyse and extend the awareness and adoption of essential change within communities and regions. Initially, this can be carried out in selected catchments and then more widely across Australia. This process needs to focus on:

- How best to strategically focus and coordinate the many disparate interests to achieve the critical mass needed to breakout from current assumptions and ‘business-as-usual’ approaches; and

- How best to identify and overcome the various blockages in policy and practice that hinder the adoption of innovation and change leading to the regeneration of the landscape and the restoration of natural hydrological systems.

In concert with the federal and state government departments and agencies planning to address reduced water availability in catchments across Australia, it appears opportune to establish a ‘front of pipe’, strategic change initiative. This would assist water users to adjust to the much lower amounts of water likely to be available at the ‘end of pipe’ under current management approaches. The establishment of a small, multi-disciplined, group to oversee a three-phase plan to initially demonstrate, promote, then expand best practice ‘front of pipe’ approaches in water management and use, could help in achieving this critical change and in securing the water future.
Conclusion

This chapter has argued that there is an urgent imperative to change the way we manage water in Australia. While we have long realised how essential water is in the bio-productivity of the landscape, what Outcomes Australia’s research has reinforced is how extensively Australia has degraded the nation’s hydrology and why and how regenerating the landscape to secure future water needs is urgently required. There is the potential to do this but only by increasing the conservation and efficient use of water – front of pipe – primarily through the regeneration and wise management of Australia’s landscape.

While there is always more to know, we have an adequate understanding of key scientific processes that should be able to help us realise a 10-fold target increase in available ‘front-of-pipe’ water, relative to the limited availability of using an ‘end-of-pipe’ philosophy. To realise this potential Australia needs selected demonstration sites and documentation of the key processes essential to restoring natural landscape functions, so as to enable a wider audience to be aware of the technical feasibility of such approaches, their economic viability and sustainability. These demonstration sites and documented evaluations can then inform leaders and policy makers on how best to multiply and extend their adoption throughout each region across Australia.

About Outcomes Australia: Outcomes Australia (OA), a Sydney-based not-for-profit organisation, one of whose tasks is to examine ways to regenerate the Australian landscape.
Much of Australia's external focus has centred on the Pacific, Southeast and Eastern Asia. With its developing wealth, increasing population, evolving trade and shipping capabilities and expanding geographic, political and security significance, however, the Indian Ocean and its littoral states will play an increasingly important role in Australia's future.

Western Australia is entering an unprecedented period of wealth and development. For this to be sustained, however, West Australians need to understand the challenges and opportunities they face, nationally, regionally and globally.

To achieve these outcomes, leaders and their policy makers and implementers need to be aware of the geo-strategic complexities of their region. With this in mind, FDI has established four areas of research that embrace the following:

• Developments in the Indian Ocean Region, including its littoral states;
• Meeting Australia’s energy requirements by 2030;
• Developments in Northern Australia and their impact on the economy, population, infrastructure, environment, security and foreign relations; and
• Implications for Australia of the developing global food and water crises

FDI will continue to ensure that its product is passed to an increasing number of Associates who will benefit from its future looking research. In so doing, FDI is establishing itself as an Australian centre of excellence in these four areas.