018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D2.2.1b Catalogue of Options for the Reuse of Stormwater

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EXECUTIVE SUMMARY

Within the literature the term ‘stormwater reuse’ appears to be used as a generic term, being used to describe both potable and non-potable uses, being applied across a variety of scales from individual household to community scale with similar applications being variously described by a range of terms such as stormwater recycling, secondary stormwater use, stormwater use, rainwater harvesting and stormwater harvesting. Within the SWITCH project, the intention is to keep the definition of the process of collecting, storing and using stormwater as broad as possible, to maximise its inclusivity, applicability and relevance to as many of the Learning Alliances and their members as possible. Hence, within the SWITCH project, the term ‘stormwater reuse’ refers to the use of collected surface runoff within potable or non-potable applications.

Section 1 of this catalogue of options for the reuse of stormwater, considers the meaning of stormwater reuse. The current use of water resources and current trends in relation to both overall, as well as region specific patterns of water use are considered and the potential for stormwater to provide an alternative water resource, as opposed to its traditional incorporation within wastewater management strategies. This section also considers approaches to stormwater reuse at the household level by the collection of runoff from roofs, drives and other impermeable areas and storage in water butts and tanks and at the municipal level by the collection of runoff from municipal buildings, roads and other paved areas and storage in ponds, lakes and wetlands.

The reuse of stormwater for aquifer recharge and reuse (artificial process); groundwater recharge (natural process); stormwater harvesting for drinking water; stormwater harvesting for non-potable use in homes (garden watering, toilet flushing, hot water, car washing), and stormwater harvesting for industrial uses (e.g. cooling towers, cleaning processes, electricity generation and toilet flushing) are addressed. Examples are given of national guidelines, concerns and public perception of water reuse. The relevant objectives of the SWITCH programme to water reuse are listed.

The benefits in more and less economically developed countries including southern/arid or semi-arid countries subject to poor socio-economic conditions are described with examples of water reuse in different countries for various functions presented in Section 2. In Section 3, information sources are listed including details of previous rainwater harvesting projects, rainwater harvesting organisations and commercial companies

1 INTRODUCTION

This catalogue aims to provide an overview of the current state-of-knowledge in relation to the collection and subsequent use of stormwater as an alternative water resource. The aspects discussed relate to what this practice involves, the applications stormwater is currently used in, the benefits and concerns which have been associated with this approach and case studies of the use of stormwater at a variety of scales.

1.1 What is stormwater reuse?

Within the literature the term 'stormwater reuse' appears to be used as a generic term, being used to describe both potable and non-potable uses (Environment Agency, 2006) and being applied across a variety of scales from individual household to community scale. Similar applications of this technique are variously described by a range of terms such as stormwater recycling, secondary stormwater use, stormwater use, rainwater harvesting and stormwater harvesting. Within the SWITCH project, the intention is to keep the definition of the process of collecting, storing and using stormwater as broad as possible, to maximise its inclusivity, applicability and relevance to as many of the Learning Alliances and their members as possible. Hence, within the SWITCH project, the term 'stormwater reuse' refers to the use of collected surface runoff within potable or non-potable applications.

1.2 Current use of water resources

In considering the potential for stormwater to act as an alternative water resource, it is useful to first consider current trends in relation to both overall, as well as region specific, patterns of water use so that the potential for using alternative resource supplies can be jointly evaluated in relation to water demand.

Table 1 provides an overview of the use of withdrawn water on an annual average basis within the agricultural, industrial and domestic sectors both globally and in relation to patterns of water use in Europe and Africa. It is important to note that these values refer to withdrawn water only and do not include, for example, irrigation of land by direct rainfall. Although there are marked differences in the amounts of withdrawn water consumed per sector when considered on an African as opposed to European basis, of particular note is the consistently relatively low percentage of total withdrawn water used for domestic purposes, suggesting that promoting stormwater reuse by industry and agriculture could have a far greater impact on water withdrawal than the more conventional focus of stormwater reuse as a household water conservation method.

Table 1 : Distribution of total water withdrawn for human use between various sectors on an annual average basis (%)[1] (People and Planet 2003)

	Agriculture	Industry	Domestic use
Global	69%	23%	8%
Europe	33%	54%	13%
Africa	88%	5%	7%

[1] = This figure does not include rainfall data

1.3 Stormwater as an alternative water resource

Over the last 100 years the world population has trebled but our water use has increased six-fold (International Water Year, 2003). Over the same time period, half of the world's wetlands have been lost and some major rivers no longer continually reach the sea. 20% of freshwater fish are endangered and in the past 30 years there has been a 50% decline in the population of freshwater species (International Water Year, 2003). Even this brief summary of facts and figures clearly demonstrates that our current approach to managing aquatic ecosystems is not sustainable; finite freshwater resources are being stretched further and further with our current approach to managing water resources as a whole resulting in serious environmental degradation. With the UN predicting that an additional 2.4 billion people are expected to live on the planet by 2050 (UN, 2003), it is clear that not only are changes in our current approach to water resource management required, but that developing and implementing measures to ensure the sustained supply of safe clean water is one of the most urgent challenges facing populations throughout the world. It is within this context that the potential for stormwater to provide an alternative water resource, as opposed to its traditional incorporation within wastewater management strategies, is presented within the following sections.

1.4 Approaches to stormwater reuse

- Household level
  - Collection of runoff from roofs, drives and other impermeable areas
  - Storage in water butts and tanks
- Municipal level
  - Collection of runoff from municipal buildings, roads and other paved areas
  - Storage in ponds, lakes and wetlands

1.5 Stormwater reuse: how is it used?

- Aquifer recharge and reuse (artificial process)
- Groundwater recharge (natural process)
- Stormwater harvesting for drinking water
- Stormwater harvesting for non-potable use in homes e.g.
  - garden watering
  - toilet flushing
  - hot water
  - car washing
- Stormwater harvesting for commercial/industrial uses e.g.
  - cooling towers
  - cleaning processes
  - electricity generation
  - toilet flushing

1.6 Stormwater reuse: benefits in more economically developed countries

(See also Sections 2.2, 2.5, 2.6, 2.8, 2.11, 2.12)

The identified benefits can be categorised as shown below:

- Local municipalities, developers and planners
  - Capacity to reduce size and cost of traditional stormwater infrastructure

  - Freeing-up of capacity within sewerage systems facilitating further development
  -
- Water companies
  - Reduced flows to centralised wastewater treatment plants extending design life
  - Reduced amounts of energy and chemicals used in treating and pumping water

- Environmental regulators
  - Reduced volumes of treated effluent flows to receiving waters
  - Reduction of non-point source pollutant loads entering receiving waters

- Community benefits
  - Alleviation of flood risk and potential for downstream flooding
  - Saving money on water bills
  - Provision of wildlife habitat, recreational and amenity areas
  - Reducing the possibility of water shortages and summer water rationing

1.7 Stormwater reuse: benefits in less economically developed countries (see also Sections 2.1, 2.3, 2.4, 2.7, 2.9, 2.10): southern/arid or semi-arid countries subject to poor socio-economic conditions

- reduction of burdens of the poor e.g. less time spent in collecting water
- reduction in water-related diseases as quality is usually better than water from traditional sources (less sick days and savings on medical costs)
- improved health status as excess rainwater used for vegetable and crop growing leads to improved diet;
- less back problems and growth reduction particularly among children and women as transportation of heavy loads over long distances is reduced;
- improved economic and health status from the income from vegetable and other crops, and other economic activities using excess rainwater;
- more time for education and personal development as time saved is now used for school attendance or homework (Smet , 2003).

1.8 Stormwater reuse: National Guidelines and Concerns

Examples of the concerns and management advice on stormwater reuse currently relevant in the UK are given in Table 2. In Australia, the phased development of national guidelines for water recycling (www.ephc.gov.au/ephc/water_recycling.html) consist of two separate components:

Phase 1 guidelines, completed in November 2006 and subtitled 'managing health and environmental risks', focus on large-scale treated sewage and greywater for:

- Residential garden watering, car washing, toilet flushing and clothes washing
- Irrigation for urban recreational and open space, and agriculture and horticulture
- Fire protection and fire fighting systems
- Industrial uses, including cooling water

Greywater treated on-site (including high-rise apartments and office blocks) can be used for garden watering, car washing, toilet flushing and clothes washing.

Phase 2 guidelines, expected mid-2007, will address:

- Use of recycled water for direct or indirect augmentation of drinking water supplies
- Managed aquifer recharge for end uses including drinking water supply, non-drinking purposes and ecosystem protection
- Urban stormwater re-use

Table 2: Stormwater reuse: concerns and management advice; UK

Concerns	Current management advice
Public health and safety	• Potable use of rainwater not currently recommended [1] • Correctly collected and stored stormwater can be used in washing machines and toilets without further treatment [1]
Size of tank	• Typical tank size for a 4 person home is $2m^3$ [1]
Mosquitoes/ contamination	• Cover tanks to exclude mosquitoes, birds, animals and sunlight [2] • Check roof is clean and not made of toxic metals or asbestos [3]
Legal requirements	• No regulations relating to the water quality for WC and washing machine use [1] • Mains water backup must be in accordance with the Water Supply (Water Fittings) Regulations (1999) [1]
Costs	• Businesses qualify for Enhanced Capital Allowance Scheme [4] • Installation more cost attractive in new developments[1]

Sources: [1] Environment Agency for England and Wales (2006); [2] Your Home: Technical Manual (2005); [3] Centre for Alternative Technology (2006); [4] UKRHA (2006)

1.9 Public perception of water reuse

Even if recycled water is provided for non-potable uses, contact with humans can result in perceived health issues although a 'near zero risk' approach has been adopted by the authorities in Australia and Singapore. In rural Australia, up to 90% of properties have rainwater tanks of a required minimum capacity of 2000 litres, and the water is often used for drinking. Toowoomba in Queensland, Australia, experienced a sharp change in public opinion on the issue of planned Indirect Potable Reuse (IPR) and a referendum rejected planned IPR despite the chronic water shortage. Subsequently, the Queensland Premier cancelled a plebiscite planned for March 2007 on whether the public were prepared to have recycled water in their drinking supply. However, the Premiers of South Australia and New South Wales have rejected the Queensland plan.

Singapore's NEWater project has involved 60% of the population of 4.2 million in visits to a water recycling plant and visitor centre. 3% of potable water in this country will be supplied by recycled water by 2011 (DTI, 2006). The successful acceptance of planned IPR in

Singapore indicates the need for a very strong public engagement to ensure the acceptance of water reuse**.**

1.10 Stormwater reuse and SWITCH

This catalogue contributes to meeting the following objectives of the SWITCH project;

Theme 2: Stormwater management
Objective 2.2**:** To develop concepts of sustainable stormwater resource use which cities can utilise for their own stormwater management strategies.

Theme 3: Efficient water supply and water use for all
Objective 3.2: To develop and demonstrate sustainable treatment (and storage) technologies for the promotion of safe water reuse.

Stormwater reuse processes are compatible with existing water supply and drainage technologies and can operate on a variety of scales e.g. from individual plot to catchment and from household to industrial to agricultural locations. The introduction of reuse strategies encourages the generation of a local supply to serve local needs. The introduction of stormwater reuse contributes to integrated management within the urban water cycle through:

- Directly reducing the impact on the volume and quality of generated stormwater runoff
- Indirectly impacting on sanitation (through reduction in flows to wastewater treatment plants)
- Conserving drinking quality water supplies (by using the lowest quality of water for lowest quality needs)
- Generating water supplies for urban agriculture/other uses

2. EXAMPLES OF WATER REUSE

A range of examples of water reuse for various functions in different countries and continents is presented in the following sections and in Table 3. These examples are only a selection of those available but illustrate a range of environments and technologies used to collect and reuse stormwater. Table 3 shows that rainwater harvesting for non-potable use in homes is ubiquitous, whereas its use for drinking water is limited. Similarly, examples of industrial use are given for four of the eleven countries and continents and a maximum of four for irrigation, the creation of artificial water bodies and recharge of natural wetlands.

Table 3: Stormwater reuse in examples from different countries and continents

Stormwater reuse	Africa	Australia	Brazil	China	Germany	India	Singapore	Sri Lanka	Thailand	UK	USA
Aquifer recharge and reuse (artificial process)											
Groundwater recharge (natural process)	x			x							
Rainwater harvesting for drinking water			x			x	x	x	X		
Rainwater harvesting for non-potable use in homes e.g.											
* garden watering	x	x	x	x	x					x	x
* toilet flushing	x	x	x	x	x	x	x	x	X	x	x
* hot water	x	x	x		x	x	x	x	X	x	
* car washing	x	x			x						
Rainwater harvesting for industrial uses e.g.				x							
* cooling towers		x		x	x		x				
* cleaning processes					x		x				
* electricity generation		x		x	x			`			
* toilet flushing					x		x				
Irrigation e.g.											
* grazing lands	x	x									
* crops		x									
* golf course		x		x							
* parks										x	x
Creation of artificial water bodies e.g.				x							
* lakes		x		x						x	x
* wetlands		x		x						x	x
* ponds		x		x						x	x
Recharge of natural wetlands	x	x									
Commercial vehicle washing				x	x						
Fire fighting											

2.1 AFRICA

Accra, Ghana

Rainfall is the main source of groundwater recharge in Accra and as such all aquifers in the city are recharged through natural processes such as infiltration, percolation etc. The city therefore is a clear example when it comes to the reuse of stormwater for the recharge of groundwater (natural process). In Ghana, rainwater has historically made significant contributions to the water supply requirement of all urban and rural communities. The supplies of the Ghana Water Company Ltd (GWCL) do not meet the demands of the city. The people in the city harvest rain as much as they can whenever it rains for domestic uses such as drinking, washing, cooking, flushing of toilets etc. Some residential areas in Accra such as East Legon, Adenta, Airport Residential Area, East Ridge, Cantonments etc have included in their buildings roof gutters connected to underground tanks or poly tanks to harvest rain. The collected water has been used to wash cars, irrigate lawns, flowers and backyard gardens.

The Ministry of Water Resources, Works and Housing together with the Ghana Science Association and some NGO's have started creating awareness of the benefits of rainwater harvesting. The government is in the process of passing legislation requiring all houses to incorporate rainwater harvesting schemes. The University of Ghana, in association with the Agricultural Research Centre (ARC) Kpong and the Graduate School of Agricultural Science, Kyoto University, Japan, constructed a self-reliant irrigation tank (micro-dam) in 2001 that directly catches and stores rainwater from a prepared catchment to grow maize. Car washing bays in Accra have traditionally used either treated water or deep wells to supply their needs. However, those depending solely on treated water from the GWCL are unable to operate every time there is a problem at the treatment plant. Because of this, some washing bays have constructed underground tanks to collect rainwater as an alternative source of supply. Harvested rainwater has also reduced their operating costs as it is free and lathers easily with soap (IWMI, 2006).

Katsukunye , Zimbabwe

Katsukunye, which is located approximately 170 km from Harare, Zimbabwe was well known for perennial water shortages. As the functioning of the local school and clinic was becoming adversely affected, the Ministry of Health and Child Welfare was on the verge of closing them down. However, the community's endeavour to harness rainwater and evolve rules for its sustainable management has prevented these closures. As a consequence, about 120 people in the clinic and 700 students in the school are benefiting from the supplied water.

The absence of a rainwater harvesting (RWH) system and the presence of adverse hydrogeological features, such as a rocky terrain and saline groundwater have contributed to intensifying the water shortage crisis. Pregnant women were the most affected, as the nearest potable drinking water source was ~3 km away. Following an approach from the local leaders, the Rainwater Harvesting Association of Zimbabwe (RHAZ), through the Mvuramanzi Trust, carried out a feasibility study which suggested the use of granite rocks for the construction of a 192 m^2 catchment area feeding into a 15 m^3 storage tank.

The necessary construction work was accomplished with community participation involving 300 households and 460 students. Katsukunye's local leaders supervised and mobilised resources, while providing construction materials. The project concluded in 2001 with significant economic and environmental gains. These included a marked improvement in the children's school performances and considerable reductions in cases of diarrhoea and unhygienic child delivery. The women now have more time to invest in productive ventures. Adequate gully control measures have helped to control environmental degradation around the granite rocks.

In order to avoid future conflicts over the limited amount of water, a water users committee has been formed including members from the village, school and clinic. A demand management protocol was also formulated to allocate water as per user needs. In this situation, RWH has proved to be a reliable option in an area with serious water shortages.
www.rainwaterharvesting.org/catchwater/april-may2003/partnership_news.htm

Rakai, Uganda
Rakai is in the southern hills of Uganda and has a tropical bimodal climate. Small (700 litre) jars (Figure 2.1) have been made by a women's group to collect water from roofs and supplement their potable and non-potable water needs. The jars cost less than $70 each to produce.
www.ircsa.org/factsheets/lowincome.htm

Figure 2.1 Water storage jar, Rakai, Uganda

2.2 AUSTRALIA

Hamilton, Newcastle, New South Wales
Twenty seven residential dwellings with a density of 45 units/ha have been constructed at Figtree Place, a 0.6 ha site. 4-8 dwellings are linked to each rainwater collector of 8-10 kl capacity. The target for stormwater reuse is 50% of toilet flushing and hot water storage and 100% of irrigation usage and bus and vehicle washing. There is an effective 'no runoff' target for up to a 1:50 year storm event. Overall potable water use has been reduced by 60% with a reduction in water bills. There is also a 20% capital cost savings on conventional infrastructure (Ellis, 2007).

K2, Victoria

K2 will be the first medium-density, multi-level sustainable public housing project in Victoria state (Figure 2.2). The 96 unit social housing block, a major project for the Department of Human Services (DHS)/Office of Housing (OoH), will be a model of energy conservation and sustainable building design. The key objectives of the building design by Arup, in conjunction with architects, Design Inc, were to: minimise greenhouse gas emissions; make use of reusable and recycled construction materials; minimise habitat degradation through efficient water use and pollution control. These key objectives have evolved into the design of four connected buildings ranging from four to eight storeys in height. The buildings are orientated east-west to give each unit's living room northern solar access. Rainwater collected from unit roofs will provide approximately 20% of the domestic water for non-potable use for the development each year. Grey water will be collected from sinks and basins, treated and then used for toilet flushing, (Ove Arup, 2007).

Figure 2.2 Public housing, K2, Victoria, Australia

Melbourne Cricket Ground

Melbourne Cricket Ground (MCG) has been upgraded into a 100,000 seat modern day stadium (Figure 2.3). The system includes drainage system diversions, storage tanks, pumps and disinfection. Reuse options include, pitch irrigation, toilet flushing and adjacent parkland irrigation. These measures enhance the image of the MCG as an environmentally responsible and sustainable venue as well as going a considerable way to meeting the Victoria State Government's Ecologically Sustainable Development (ESD) Guidelines for venues that were utilised for the Melbourne 2006 Commonwealth Games. (Ove Arup, 2007).

Figure 2.3 Melbourne cricket ground, Australia

Melbourne Olympic Park

Melbourne Olympic Park Stadium will be a 20,000 seat world class stadium for soccer, rugby and concert events when its construction is completed in 2008. The stadium will add to Melbourne's reputation as one of the world's greatest sporting cities, by complementing the impressive arenas already situated within the Melbourne sporting precinct and inner city areas (MCG, Rod Laver Arena, Vodafone Arena, Glasshouse, Colonial Stadium, Melbourne Sports & Aquatic Centre, etc). Arup assessed the potential for collection and reuse of roof water from the new bio-frame roof. The proposed system includes drainage system diversions, storage tanks, pumps and disinfection. Reuse options put forward include, pitch irrigation, toilet flushing and adjacent parkland irrigation. These measures will enhance the image of the stadium as an environmentally responsible and sustainable venue (Ove Arup, 2007).

Salisbury, Adelaide, South Australia

In this residential development, stormwater wetland harvesting and aquifer storage recharge (ASR) (Figures 2.4(a) and (b)) captures 70% of runoff. 300 Ml/year or 2% of demand is captured, of which 40% is passed to water supply and 60% injected to aquifer storage and recharge (ASR). The household RWH system (gravity and pressure systems) has a 150 m^2 design roof area for a two person dwelling. Water demand is estimated at 500 l/day and the rain tank capacity is 4500 l (Figure 2.5) (Ellis, 2007).

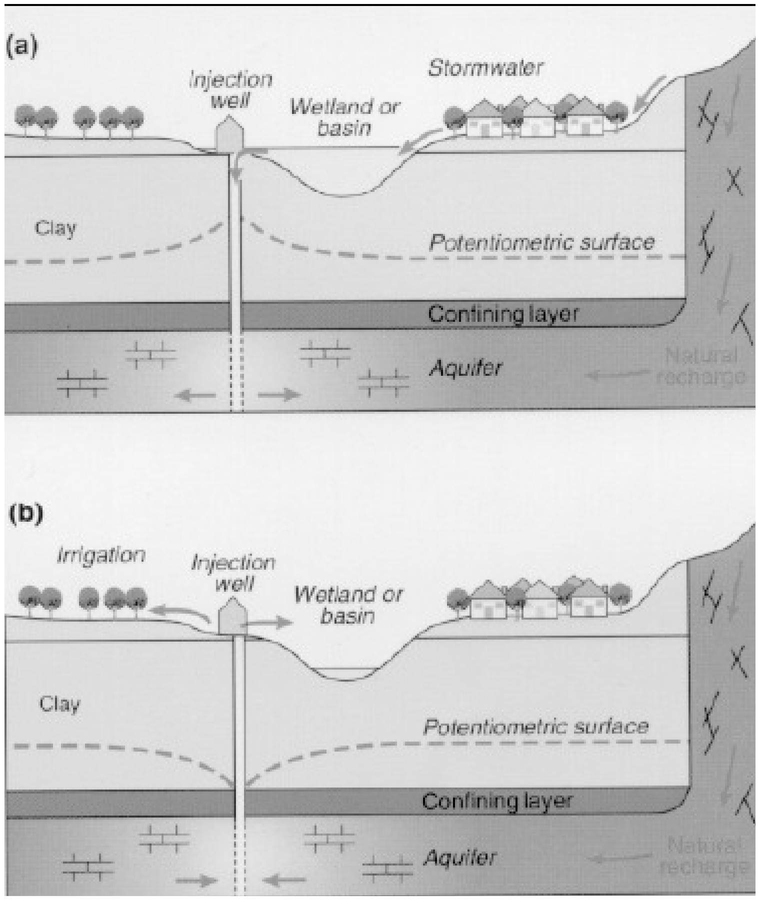

Figure 2.4 (a)(b) Aquifer storage and recharge (ASR)

Figure 2.5 Water storage tanks, Australia

Sydney Olympic Park (SOP)
Water Reclamation and Management Scheme (WRAMS). The design of SOP is based on the concept of an integrated urban water cycle and includes land rehabilitation, flood alleviation, aquatic habitat restoration, stormwater storage and reuse, pollution control and recreational provision. Thirty different constructed wetlands have been created onsite, a water storage basin has been developed in a disused brick pit and the main stadium has 3Ml/d storage for rainwater. Mixed residential and commercial buildings are located in sub-districts. There are eleven end uses of water such as swimmimg pool filter backwash and ornamental fountains. The source of reclaimed water is a 'sewer mine' supplemented by surface runoff from the brick pit. Water use at SOP is 48% recycled, 46% direct stormwater reuse and 6% potable. Of the recycled water, 40% is used for toilet flushing and the remainder is used for irrigation and washdown. www.sydneyolympicpark.com.au

2.3 BRAZIL

Petrolina
Petrolina is in the semi-arid belt of north east Brazil. Rainfall is low and varies from year to year. Tanks with 1-2 kl capacity are used to store water for each household (Figure 2.6). They are usually provided by NGOs as the cost, starting from $200 per tank, is unaffordable by the local population.www.ircsa.org/factsheets/lowincome.htm

Figure 2.6 Water storage tank, Petrolina, Brazil

2.4 CHINA

Beijing National Stadium
This new build stadium has a capacity of 100,000 and will be used initially for the 2008 Olympic Games (Figure 2.7). A rainwater system designed for water saving is proposed for the national stadium. Rainwater will be collected from the field of the main stadium, roof of the stadium, warm-up field and the surface around the stadium before being transported to reservoirs. After being processed to meet the Regenerated Water Quality Standard for the 2008 Olympic Games National Stadium, recovered rainwater will be reused for toilet cleaning, parking lot cleaning, outdoor road cleaning, and as a water supplement for cooling towers, fire fighting, green areas and grass sprinkler irrigation. The total recovered rainfall will be about 61,000 m^3/year, representing 24% of the annual reused water volume for the

stadium. This system will significantly lessen the burden on decreasing water resources in Beijing City, while it will embody the Spirit of the Beijing Olympics, thus combining social and economic benefits (Ove Arup, 2007).

Figure 2.7 Beijing National Stadium, China

Dongtan City, near Shanghai

This will be a new ecocity for 500,000 people, which will be built on the 120 km long Chiongming Island in the estuary of the Yangtze river, 15 km north of Shanghai. The city will be developed on 630 ha of mostly agricultural land. The first phase will be completed by 2010 but the whole city will take 40 to 50 years to build. Rainwater will be captured and stored in canals and water features around the city as well as in reservoirs. There will be processes to capture and purify rainwater. The city is designed to be attractive to residents and to avoid the need to travel to distant locations to work (Ove Arup, 2007).

Gansu Province

Gansu Research Institute for Water and Conservation (GRIWAC) installed 23,000 updated traditional underground water cellars (shuijao) by the end of 1994. Each cellar (15-20 m^3) was associated with 100 m^2 of new catchment and a domestic water supply was secured for a total of 140,000 people. By 2006, 2 million shuijao built or upgraded in the previous 15 years, were helping to solve the water supply problems of 15 million people and supporting the irrigation of 2.6 million hectares (McCann, 2007).

2.5 GERMANY

The household use of rainwater is very common in Germany for garage watering, toilet flushing, washing machines and car washing but rainwater is not permitted for drinking water use. Industrial uses are for cooling towers, cleaning processes (e.g. trains and cars), toilet flushing and electricity generation. Municipal uses are being assessed in a research and development project in Berlin managed by UFA-Fabrik in which stormwater runoff from roofs and roads is being collected and treated by sedimentation, filtration and UV light and reused for non-potable water supply.

The Drinking Water Ordinance explicitly allows stormwater harvesting for garden watering, toilet flushing and washing, with the exception of hospitals. However, water companies are opposed to water reuse and the German Water Association has neglected stormwater harvesting although an association for stormwater reuse has been established (www.fbr.de).

Stormwater infiltration is obligatory for new developments by law in most Federal states (Figure 2.8). 60% of the drinking water in Germany is taken from groundwater and 100% in Berlin. Aquifers are a cheap cistern and it is more efficient to renew groundwater resources than to collect rainwater in man-made tanks. Property owners can save the stormwater fee by infiltrating rainwater.

Figure 2.8 Stormwater infiltration systems, Germany

2.6 INDIA

Raincentres are being established throughout India by the Centre for Science and the Environment to provide people with information on how to harvest rain. Local Non Government Organisations (NGOs) and citizens' groups are identified as partners to disseminate water literacy. Groundwater level monitoring in 11 model projects has shown the impact of rainwater harvesting on improved quality and quantity of groundwater. www.rainwaterharvesting.org/raincentre.htm

A Water Harvesting Manual for Urban Areas provides information on how to decide whether to store or recharge water in relation to the rainfall patterns in a particular region and the design of appropriate systems. In Delhi, Rajasthan and Gujarat, where the total annual rainfall occurs during 3 to 4 months, recharge is usually practiced. In Kerala, Bangalore and Tamil Nadu, where the rain falls throughout the year, a small sized tank is appropriate for each household.www.rainwaterharvesting.org/Urban/Howtoharvest.htm

2.7 SINGAPORE

Bedok NEWater plant and Visitor Centre

The NEWater project Bedok plant has been visited by 60% of the 4.2 million population of Singapore. The Public Utilities Board (PUB) promotes the 'Four National Taps' approach to water provision; local catchment, imported water, NEWater, desalinated water and the 3P approach for the public to contribute; conserve water, value our water and enjoy our waters.

Bedok is one of four NEWater plants which produce 45 Million Gallons per Day (MGD). Secondary effluent from wastewater treatment plants, now renamed water reclamation plants, passes through Microfiltration (MF) and then two-stage Reverse Osmosis (RO) membranes followed by ultra violet light irradiation (UV). The high quality, ultra pure reclaimed water is used either directly by industry for a premium tariff or is returned to the raw water reservoirs to augment drinking water resources i.e. Indirect Planned Reuse. The aim is for 10MGD to be used for planned Indirect Potable Reuse (IPR) by 2011,(DTI , 2006). www.pub.gov.sg

2.8 SRI LANKA

Badulla

The town of Badulla is located in a hilly area of Sri Lanka and experiences a tropical, bimodal climate. Rainwater is used as a main water source and groundwater sources are few and tend to be at the bottom of the hills. To reduce the burden of carrying water, the local authority provided 5,000 l ferrocement tanks at a cost of about $150 per tank, which are used to collect water from roofs for most household water supply (Figures 2.9). The tanks are now being adopted nationwide for use in areas where access to other protected water sources is difficult.
www.ircsa.org/factsheets/lowincome.htm

Figure 2.9 Water storage tank, Badulla, Sri Lanka

2.9 THAILAND

Khon Kaen

Khon Kaen is located in north east Thailand and experiences a tropical monsoon climate. The "Thai jar", with a capacity of 1-2 kl, was selected for one of the world's largest roofwater harvesting projects (Figure 2.10). The jars were produced commercially on a large scale and for less than $30 per jar, thus enabling the purchase of the jars throughout the population. www.ircsa.org/factsheets/lowincome.htm

Figure 2.10 Water storage jar, Khon Kaen, Thailand

2.10 UNITED KINGDOM

Beddington Zed, Surrey

Beddington Zed (Bedzed) is a sustainable mixed use development on a brown field site located in a south London suburb, including 100 dwellings plus workspaces, shops, sports facilities and a sustainability centre. The development incorporates a renewable energy supply, a total water strategy and integrated transport system. Bedzed's water system will operate as a private supply by Albion Water. The plant treats water from residential and office areas, turning it into non-potable "greenwater" which is then recycled to be used in lavatory cisterns. The main treatment plant is housed in an elevated greenhouse, incorporating hydroponics where plants on the roof of the tanks reduce the nitrogen and phosphorus content of the water. Around 33% of the treated flow is reused (Ove Arup, 2007).

Great Bow Yard, Langport

A residential rainwater harvesting system project with a designed reuse of water in 2 toilets and a garden tap for each dwelling. The estimated usage is 104 l per dwelling per day. The average annual rainfall is 800 mm and roof area per dwelling is 66 m^2. The expected annual rainwater collection is 27,900 l although the theoretical value based on rainfall and collection area is 52,800 l and the estimated reduction in CO_2 emissions will be 75%. www.rainharvesting.co.uk

'The Hub' Community Centre, East London

A development of a community resource centre, intended as a community focal point, which includes a nursery, pharmacy, health promotion team, café, business starter units, multi-purpose community hall and consulting rooms. Apart from being sustainable, one of the primary design decisions was to create an environmentally responsive carbon-optimised building, which Arup achieved by making beneficial use of daylight and solar gain for heating. Harvested rainwater is used for toilet flushing and plant irrigation, with an expected saving of 50% in mains water per year (Ove Arup, 2007).

Kingsmead School

A new model primary school for Cheshire County Council, north west England (Figure 2.11). Both photovoltaic panels to provide electricity and solar heating panels to provide hot water are provided at roof level. Rainwater is collected by an underground water tank and used for toilet flushing. Renewable energy sources and conservation measures are integrated into the educational curriculum (Ove Arup, 2007).

Figure 2.11 Kingsmead School, Cheshire, England

Snowdon Summit Building, Wales

This project is a redevelopment of the cafe/visitors centre at the summit of Mount Snowdon in north Wales (Figure 2.12). The building is the highest in England and Wales and its remote location provides a unique challenge to the design team as there are no mains services to the site. Electricity will be generated on site via a combined heat and power unit from which waste heat will provide heating and hot water to the building. Rainwater will be stored and reused for non-potable use to limit the amount of water which has to be carried up on the already over-stretched mountain railway (Ove Arup, 2007).

Figure 2.12 Snowdon Summit Building, Wales

Wetlands and Wildfowl Trust (wwt), Welney

A new visitor centre for the Wildfowl and Wetlands Trust bird sanctuary was designed around environmental and sustainable elements in keeping with the location and provides an area for visitors including a café, shop, educational facilities, exhibition and community space (Figure 2.13). Rainwater is collected from the building roof, combined with SUDS drainage in the car park allowing surface water run off from the site to be used to create ponds and a wetland habitat. Wastewater from the building is treated in a reed bed system to allow outfall into an adjacent water course (Ove Arup, 2007).

Figure 2.13 Wetlands and Wildfowl Trust (wwt), Welney, England

2.11 USA

Texas State

The Texas Manual on Rainwater Harvesting, a revised third edition, was published in 2005 and provides information on the design of rainwater harvesting systems, best management practice (BMP) guidelines and financial incentives for their adoption.
www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Seattle.

Rainwater storage barrels with a capacity of 1800 l, are provided free to selected citizens. Newer municipal buildings are provided voluntarily with rainwater storage. New development sites are required to have a minimum 30% of the site area taken up by measures such as rainwater harvesting (McCann, 2007).

Rainwater/humidity harvester

Federal disaster (FEMA) officials recently unveiled a machine that uses salt to draw as much as 1,200 gallons of water a day from the air and does it at a fraction of what it costs to truck water into remote areas. FEMA officials worked with North Miami Beach-based Aqua Sciences to design a unit capable of drawing water from the air, while at the same time purifying water from other sources such as ponds or wells. A requirement for the treatment units was that they had to be easily transported to wherever they were needed, so the FEMA units were built in 13 m containers, which are able to be shipped by truck, train or boat. The water-generating machines cost about $500,000 each and in the event of an approaching hurricane, can be moved to a staging area near where the storm is expected to impact.

Because the machines are capable of dispensing either cold or hot water, they could prove to be a valuable asset if it becomes necessary to set up a portable hospital. Just as a salt shaker attracts water, so does the salt in the machine, which is a much higher grade than table salt. The water is drawn from the air and then ejected from the salt, which serves to purify it. It is then filtered, but since the water is so pure when it leaves the salt, the filters last a long time. While the normally high humidity in Florida may increase the rate at which water is produced, the machine will work anywhere, even in the desert. The FEMA units are unique in several ways, beginning with the steel containers that house them. There are nine of the water-harvesting machines in the unit and, if one fails, the unit would continue to work. It also has two generators and can store enough fuel to run 24 hours a day for five to seven days. If an electrical source is available, it can be used in place of the generators. It costs about 30 cents a gallon to remove the water from the air It can easily cost $15 to $30 a gallon to supply water when it must be trucked to remote disaster areas.www.timesleader.com/mld/timesleader/living/16146989.htm .www.aquasciences.com

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UN (2003). World population prospects: 2002 revision. Available: http://www.un.org/esa/population/publications/wpp2002/WPP2002-HIGHLIGHTSrev1.PDF. Verified 2 January 2007.

Your home: Technical Manual (2005) Water use: rainwater. Available: http://www.greenhouse.gov.au/yourhome/technical/fs22.htm. Verified 2 January 2007.

3.1 Information Sources

3.1.1 Previous rainwater harvesting projects

Development Technology Unit of the University of Warwick
www.eng.warwick.ac.uk/dtu/rwh/index.html
Rainwater Harvesting in the Humid Tropics (funded by the EC)
Roofwater Harvesting for poorer households in the Tropics (funded by UK Dept for International Development DFID)

Project pages, reports and recommendations for designing rainwater harvesting system tanks can be downloaded.

3.1.2 Rainwater Harvesting Organisations

www.ircsa.org/ International Rainwater Catchment Systems Association.
Fact sheets; prepared by the Development Technology Unit of the University of Warwick

Rainwater catchment in mainland China. Prepared by Prof. Qiang Zhu, Vice-President of IRCSA

Guidance on the use of Rainwater Tanks (Australia). Prepared by David A Cunliffe for the National Environmental Health Forum

UNEP Sourcebook of Alternative Technologies for Freshwater Augmentation, Africa, Asia, Latin America, Small Islands

Conferences. Rainwater and Urban Design 21-24 August 2007, Sydney, Australia.

www.ukrha.org
UK Rainwater Harvesting Association

www.rainwaterharvesting.org/Urban/Howtoharvest.htm
RWH systems in India

www.rainwaterharvesting.org/raincentre.htm
Raincentre exhibitions in India

www.lankarainwater.org
Sri Lanka Rainwater Harvesting forum

www.forgottenrain.com/int_links.htm
Website designed to provide information and links to RWH projects

www.wateraid.org/documents/technology_notes_low_res.pdf
RWH . Design of systems for RWH from roof catchments, and storage tanks. pp 32-34.

www.savetherain.info
The Save the Rain campaign aims for all new homes in the UK to have a RWH system within the next three years

3.1.3 Commercial companies

www.aquasciences.com
System for harvesting water from the atmosphere.

www.graf-online.de
GRAF Rainwater solution tanks

www.eurogauge.co.uk
Afriso RWH system

www.freewater.co.uk
RWH systems . Rainman & Aquacycle 900

www.rainharvesting.co.uk
Rain Harvesting Co

www.wpl.co.uk
GARANTIA Rainwater system tanks, water butts etc.