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DOMESTIC POLICY FRAMEWORKS FOR ADAPTATION TO CLIMATE CHANGE IN THE WATER SECTOR

Part I: Annex I Countries

Ellina Levina and Helen Adams, OECD

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FOREWORD

This document was prepared by the OECD and IEA Secretariats in March-May 2006 in response to the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy-makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document are those listed in Annex I of the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Korea and Mexico, as OECD member countries, also participate in the Annex I Expert Group. Where this document refers to “countries” or “governments”, it is also intended to include “regional economic organisations”, if appropriate.

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OECD and IEA information papers for the Annex I Expert Group on the UNFCCC can be downloaded from: http://www.oecd.org/env/cc/

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Acronyms

AIXG	Annex I Expert Group
C-CAIRN	Canadian Climate Impacts and Adaptation Research Network
Defra	Department for Environment, Food and Rural Affairs
DWR	California Department of Water Resources
EA	England and Wales Environment Agency
EHS	Northern Ireland Environment and Heritage Service
EPA	United States Environmental Protection Agency
EU	European Union
FEMA	United States Federal Emergency Management Agency
GLA	Greater London Authority
HadCM2	Hadley Centre for Climate Prediction and Research coupled atmosphere-ocean general circulation model
IPCC	Intergovernmental Panel on Climate Change
NIMS	National Incident Management Systems
NRCan	Natural Resources Canada
NYCDEP	New York City Department of Environmental Protection
Ofwat	Office of Water Services
PIR, OMPIR	Ontario Ministry of Public Infrastructure Renewal
SEPA	Scottish Environment Protection Agency
SLR	Sea level rise
SWRCB	California State Water Resources Control Board
SWSI	Statewide Water Supply Initiative
UKCIP	UK Climate Impacts Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WFD	Water Framework Directive

Executive Summary

Adaptation to climate change needs to be integrated into policy development. This paper examines domestic policy frameworks in the water sector and analyses how adaptation could be incorporated into these frameworks. Global climate change will have a significant impact on water resources in all countries. Consequently, a key challenge that countries face is how to govern and manage their water resources in the conditions of changing climate. What should be done, when and by whom, is a function of the rate of climate change, but also of the existing water policy frameworks of each country.

This study examines current water policy frameworks in four countries (Canada, Finland, United Kingdom and United States). It reviews the existing legal frameworks, institutional arrangements, key players and water planning mechanisms. One objective was to determine to what extent adaptation to climate change is beginning to be incorporated into water policy frameworks and whether there are some lessons that can be drawn from current experiences.

The study concludes that a certain degree of adjustment to climate variability and extreme weather events is inherent to the water sector. However, adaptation to long-term climate change is generally not a significant factor in the management of water resources in the four countries, although some initiatives are being undertaken in several countries to build climate change into decision making. All four countries have water policy frameworks, which to different extents, can help them adapt to climate change. These water policy frameworks, which differ in each country, can be enhanced to promote adaptation to climate change. They generally include the following elements:

- A system of laws (legal frameworks) that stipulate rights and responsibilities of different levels of government and private entities. These may include, for example, a system of water rights and abstraction permits;
- A variety of national, regional and sub-national institutions that are responsible for developing policies and overseeing their implementation;
- A set of policies that guide the implementation of national, state and provincial laws;
- Clearly defined roles for the key players, including government ministries, departments, water suppliers, regulators and other local authorities;
- Physical water infrastructure, that is dams, levees, reservoirs and sewerage systems that are capable of managing the flow and distribution of water;
- A set of water management plans (long-term strategic plans, drought plans and flood plans) with flexibility to anticipate and respond to climate changes; and
- A system to share current and projected climatic information.

For the most part, national governments will have to determine how current policy frameworks should be modified in order to prepare for climate change. However, there is little doubt that broadening the exchange of information will be a crucial element, if countries are to be prepared to properly manage their water resources.

1. Introduction

At the September 2005 Meeting of the AIXG, the delegates requested the Secretariat to prepare a paper on policy frameworks for adaptation, focusing on one of the most vulnerable sectors (agriculture, water resources, costal zones, energy, human health). The priority sectors identified by the delegates were water resources and coastal zones. This paper focuses on water resources.

The aim of the paper is to analyse existing policy frameworks in various Annex I countries and identify elements that are important for facilitating adaptation to climate change impacts in the water sector. The analysis is based on the approach of integrating (mainstreaming) adaptation into policy development. In this paper the water sector is defined as water resources (surface water and groundwater), their use (e.g. irrigation, public water supply, environmental needs) and their governance and management (legal and institutional issues, abstraction permitting, water infrastructure, water policies). The paper does not specifically examine issues related to water quality.

The analysis is based on information from four countries, namely the United Kingdom, the United States, Canada and Finland. The following four key components (and their elements) of policy frameworks were examined for each country:

1. <u>International and domestic legal frameworks</u>: international and national, state and local legislation and regulations that govern water resources management, including international agreements and committees.

2. <u>Institutional landscape</u>: key players in the water sector and the government and private institutions within which they operate (governmental institutions at all levels; water providers: public and private regulators).

3. <u>Water management policies and instruments</u>: water resource management plans, flood and drought plans, pricing, metering, water-related strategies, public-private partnerships, infrastructure maintenance and renewal.

4. <u>Information</u>: scientific capacity, monitoring systems, mechanisms and tools to translate available information for policy-makers, mechanisms for information dissemination.

The situation in each country is very different in terms of water resources and their availability, current climatic effects and expected climate change impacts. Legal and institutional arrangements, and water management practices and priorities also vary greatly between and within countries. Therefore, the following questions were used to structure the analysis:

- How do the current water policy frameworks deal with water resources and existing stresses?
- Can current policy frameworks handle possible future climatic conditions?
- Which of the current elements of water policy frameworks facilitate adaptation to climate change?
- What elements of the current framework might become an obstacle for adaptation?
- Who in the water sector should participate in adaptation?
- Are there any generic recommendations that we can give for a policy framework in the water sector to make it more prepared for handling adaptation to climate change?

This approach allowed commonalities between the governance and management practices of different countries to be identified. The analysis revealed that the key elements of policy frameworks mentioned above will play a central role in adaptation to climate change in the water sector in all countries. These elements are: a system of rights for water abstraction, water management strategies, flood and drought plans, monitoring and scientific analysis of water resources and meteorological conditions, information sharing between scientific community and policy makers at all levels, and water infrastructure.

Within each country's water sector there are aspects of the policy framework that would facilitate adaptation and aspects that would need to be changed for adaptation to take place. However, the analysis of four countries demonstrated that the basic elements are present. The paper addresses how to reinforce those mechanisms and elements that facilitate adaptation, and alter other elements that potentially can impede successful adaptation to future climate change.

The paper is structured around the selected four components that construct policy frameworks in the water sector. It starts with looking at the current and expected in the future climatic conditions that should play a central role in developing adaptation strategies. Section 2 of the paper illustrates differences among case-study OECD countries in their susceptibility to possible negative effects of climate change and their vulnerabilities to these effects. Section 3 focuses on domestic and international legal issues that govern water sector. Section 4 identifies institutions and key players in the water sector who should also become the key actors in adaptation. Section 5 examines water management approaches and policies and how adaptation could "piggyback" on existing approaches and policies. Section 6 evaluates information needs and existing mechanisms for information sharing and dissemination that would be instrumental for successful adaptation. The paper concludes with a summary of key findings and recommendations for further analysis.

2. Impacts and Vulnerability to Climate Change

A key point to bear in mind when considering approaches to adaptation within the water sector is that climate change will not impact all countries and regions to the same degree and that all countries will not be equally vulnerable. This has implications for the magnitude of actions and changes required and the amount of funding that will need to be allocated for adaptation. Vulnerability within a country varies between regions and sectors. Water resources, because of their reliance on precipitation, are extremely sensitive to climate change and can potentially be one of the most vulnerable sectors.

The vulnerability of the water sector to climate change is determined by the magnitude and nature of changes that are expected, the natural ability of the hydrological system to adapt to these changes, and the capacity of the relevant institutions and infrastructure to respond to the anticipated changes. The ability of a nation to adapt its water sector depends on the institutional set-up, regulations, water management practices and the state of the water system at present in terms of infrastructure age and its ability to cope with present climatic conditions.

The exposure and sensitivity of water resources to climate change impacts should be an indication of the necessity for adaptation. Therefore, the paper includes a brief discussion of expected impacts from climate change in four examined countries. The main aim of this section is to illustrate the differences in the expected impacts from climate change and the varied vulnerabilities among countries and between different regions within countries. Projected climate change impacts and the current physical features of the water sector should be the key determinants in defining the necessary adjustments in the existing policy framework.

The analysis of policy frameworks presented in this paper should be viewed in conjunction with information on the state of available water resources in a particular country and the expected impacts. Uncertainty in precipitation scenarios and the limits of hydrological and management models must also be recognised.

Climate change will affect different regions and countries differently. According to general circulation models, there is a high probability that precipitation will increase in northern Europe (+1% to +2% per decade), but decrease in southern Europe (by -1% per decade) (Parry, 2000). As a result, runoff will increase in the north and decrease in the south. There will also be a change in timing of maximum stream flows with inland areas experiencing peak flows earlier in the year. Both European countries of this analysis, Finland and the UK, are situated in the north of Europe, and potentially can expect similar impacts of the changing climate. However, the effects from these impacts on the water sector are projected to differ. For more temperate regions, the probability of an increase or decrease in rainfall is more difficult to characterize. What follows is information from the literature on likely climate changes.

Table 1 below highlights how climate change may affect the water sector in the countries investigated. Increased risk of flooding is fairly ubiquitous, as is the risk of droughts. However, droughts do not necessarily lead to a shortage of water. For example, in Scotland there is sufficient water and drought conditions should not affect water supply. Also, most countries will see a decrease in snow pack – snow may disappear from the Scottish highlands and southern Finland – but this will not lead to serious water supply problems since these areas do not rely heavily on snow melt for water supply. In California and Colorado however, water supply systems rely on snowmelt during the spring and summer, therefore changes in snowmelt patterns will require changes in water infrastructure and management practices. A summary of climate change impacts is presented below.

Table 1. Expected climate change impacts on water resources in the countries of this analysis

		Climate Impact					
Country	**Country/State /Province/ Basin**	**Snowmelt water supply**	**Flash floods**	**Floods**	**Drought**	**Insufficient water**	**Saltwater intrusion**
USA	California	**X**	**X**	**X**	**X**	**X**	**X**
	Colorado	**X**	**X**		**X**	**X**	
	New York			**X**	**X**		**X**
Canada	British Columbia	**X**		**X**	**X**		
	Ontario	**X**		**X**	**X**		
USA/ Canada	Great Lakes Basin				**X**		
United Kingdom	England and Wales			**X**	**X**	**X**	**X**
	Scotland			**X**	X		
	Northern Ireland			**X**			
Finland	All		X	**X**			

Finland

For Finland the major challenge will be in controlling floods. Three different research programmes have studied expected changes in runoff of three drainage basins. The range of forecasts is between no change to increases in runoff of 8%. According to the HadCM2[1] simulation, the one, five and 14-day design for flood control from precipitation values may go up by 35-65% by the end of this century (Tuomenvirta, 2004). Higher annual temperatures will also lead to a decrease in snow cover (which may disappear completely in southern Finland) and frequent thawing periods during the winter. Therefore, Finland will experience increased frequency and intensity of winter floods from heavy rainfall events and winter thawing episodes. Increased temperatures during summer may cause increased intensity and longer periods of drought. Currently Finland does not experience water shortages but prolonged droughts might cause problems for hydropower, water traffic and water supplies during summer[2].

[1] UK Hadley Center for Climate Prediction and Research coupled atmosphere-ocean general circulation model
[2] General analysis of expected changes in runoff suggests an overall beneficial impact on Finland's hydropower.

United Kingdom

In the UK, winter flood risk will also become much more of a problem. By the 2080 England and Wales could face losses up to £27 billion annually from flooding (EA, 2005). Impacts will also vary regionally; in the north and west of the UK flooding will be more of a problem than in the south and east. This is because the winter climate is already wet and there is little storage capacity to absorb excess flows. However, unlike Finland where major water shortages are not expected, drought in the UK will become a serious problem. This impact will be felt over the whole country, but will be most severe in the south and east. This will exacerbate current pressure on the region which presently is an area with low precipitation, a high population and high population growth. For example, the population of London has increased by 190,000 in the past two years whilst population in other urban areas has fallen (GLA, 2002). The runoff in the southeast of England is predicted to decrease by up 50% during the summer months in 2050 (Arnell, 1998).

Therefore, although both the UK and Finland will experience increased winter floods and summer droughts, the impact this has on the water sector depends on this sector's vulnerability in a particular country, dictated by present water resources, water demand and infrastructure.

United States

The US is a large country that is spread across several climatic zones. The impacts of climate change will differ significantly from region to region. The three states that were analysed in the US (California, Colorado and New York) all have different hydrological conditions (although California and Colorado are similar in their dependence on snowmelt in a semi-arid region) and their vulnerabilities to climate change differ. For example, an important concern for New York is the need to maintain a reliable supply of water for New York City. Much of the water infrastructure for New York City is on low lying coastal areas which over a period of centuries could also be affected by increasing sea level rise, and altered storm frequency and intensity.

California's water resources are very dependent on water stored as snow pack in the Sierra Nevada and Cascades mountains. Increase in average annual temperature will lead to the snowline in these mountains increasing in altitude, causing decreases in snow pack volume and runoff. Peak runoff will also occur earlier because of higher temperatures which will lead to greater flooding during the spring, and less water and water shortages during the summer. Population is increasing rapidly in California putting increased pressures on water supplies. Population is also increasing most rapidly in the arid south of the state. Sea level rise will put the Sacramento-San Joaquin delta at increased risk from flooding and salt water intrusion with implications for water supply throughout California; this area supplies two thirds of the state's water.

Colorado water resources are also dependent on snowmelt from the Rocky Mountains and will have similar problems relating to water supply as California. Colorado's population growth was the third fastest in the US during the 1990s. Both Hadley Centre and Canadian Climate Impacts and Scenarios models predict that precipitation will increase in the west. However, whether the increase will be enough to provide a net increase in water availability with increased evaporation is not known. Colorado's vulnerability is increased by the huge range of altitudes it encompasses (from the highest peaks in the Rockies to plains in the east) which makes it difficult to develop reliable regional climate models.

Canada

In Canada, climate change will have a range of impacts on both the hydrological cycle, and water availability and uses (Hofmann et al, 1998). For the nation as a whole, climate change will likely increase precipitation, evaporation, water temperatures and hydrological variability. For many regions of Canada, climate change will likely result in decreased summer flows, warmer summer water temperatures and higher winter flows. Regional projections include declining Great Lakes water levels, decreasing soil moisture in southern Canada, and a reduction of wetlands in the Prairies. Another key concern is increased conflict between water users due to increasing discrepancies between supply and demand. For example, Ontario is commonly perceived to be an especially water-rich province, yet it suffers from frequent water shortages. Similarly, more than 17% of British Columbia's surface-water resources are at or near their supply capacity for extractive uses (Lemmen & Warren, 2004).

The IPCC has identified several general physical features that make a water system particularly vulnerable to climate change (Arnell & Chunzhen, 2001). Some of these features have been identified in various areas of the countries analysed:

- The current hydrological and climatic regime is marginal for agriculture and livestock.

In arid areas, agriculture can use up to 90% of the water abstracted from surface and aquifer sources. In California and Colorado (and much of the western United States) agriculture occurs in semi-arid to arid zones and agricultural cultivation is only possible through irrigation. Also, on the eastern plains of Colorado, 70-80% of precipitation occurs from April to September during the growing season. However, in many years only 50% or less of the long term average precipitation occurs resulting in droughts (Doesken et al, 2003). The southern prairies of Canada (in Alberta, Saskatchewan, Manitoba) and the interior of British Columbia suffer severe droughts during some part of most summers and are prone to long-term drought conditions. Irrigation and water transfers are relied on to provide stability in crop production[3].

- Highly seasonal hydrology that is the result of either seasonal precipitation or a dependence on snowmelt.

Water supplies for much of California originate in the Sierra Nevada as snowmelt. Snow packs act as a natural reservoir of water which is slowly released throughout the summer. Reliance on snow pack makes an area vulnerable to climate change because the hydrological regime to which infrastructure is built and adapted will change. Global warming will reduce the snow pack (and therefore the volume of runoff) and cause the snow pack to melt earlier in the year. Storage capacity will need to be increased so that winter runoff can be captured for use in the summer and so that flood risk in the winter can be accounted for. The problem of how to increase water storage but yet also manage earlier spring high flows (which requires empty space in a reservoir) is one that will need to be resolved in order for California, and other snowmelt-dependent areas, to adapt.

- The sedimentation rates of rivers affect the storage capacity of reservoirs and therefore their ability to mitigate the effects of droughts and floods.

The Glen Canyon dam in Arizona was built upstream of the Hoover dam to be used by the Upper Colorado Basin states during water shortages so that sufficient water continued flowing to the Lower Colorado basin states. The Hoover dam guarantees a constant supply of water to the Lower Colorado Basin states. The Glen Canyon dam has reduced the vulnerability of the Hoover dam by trapping sediment from the river. However, it is vulnerable itself as 100 million tons of sediment is deposited behind the Glen Canyon dam each year[4].

- The topography and land use patterns promote soil erosion and flash flooding conditions.

The eastern plains of Colorado are susceptible to flash flooding because summer precipitation falls as heavy rainfall events and thunderstorms (Doesken et al, 2003). Flash floods have also been a problem in recent years in England. These events are projected to increase with climate change.

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[3] The Atlas of Canada, http://atlas.gc.ca/maptexts/map_texts/english/freshwater_irrigation_e.html

[4] Glen Canyon Institute, http://www.glencanyon.org/library/sediment.php

3. International and Domestic Legal Frameworks

3.1 Water rights

Water rights are the fundamental issue that defines legal relationships in the water sector. The analysis of four countries revealed differences in water right systems (riparian right, riparian right with mandatory abstraction permits, appropriation doctrine and prior appropriation). Although historically these systems were based on different principles, close examination reveals that each has been modified and common aspects are identified.

Table 2. Water and abstraction right systems in the countries analysed

Country	Country/State/ Province/ Basin	Type of system	Comprehensive permitting system?	Conflict resolution during drought	Licences time limited?	Regulation of public water supply?
US	California	Prior appropriation & riparian	Yes	'First come, first served'	No	Yes
	Colorado	Prior appropriation	Yes	'First come, first served'	No	Yes
	New York	Riparian	No	Shortages shared	No	Yes
UK	England and Wales	Riparian	Yes	Shortages shared	Yes	Yes
	Scotland	Riparian	No	Shortages shared	N/A	Yes
	Northern Ireland	Riparian	No	Shortages shared	N/A	Yes
Finland	All	Riparian	Yes	N/A	No	Yes
US/ Canada	Great Lakes basin	Riparian	No	Shortages shared	No	Yes
Canada	Ontario	Riparian	Yes	Shortages shared	Yes	Yes
	British Columbia	Riparian and prior appropriation	Yes	'First come, first served'	No	Yes

In most European countries land ownership or rental is required in order to have rights to abstract water. Currently, in most OECD countries water rights are supplemented with licensing systems that clearly define how much water and for which purposes water can be taken. In case of problems with water quantity or quality, the government has authority to intervene into abstraction even though the legal right for the water might be with the land owner. In the eastern states of the US, the eastern provinces of Canada, and the UK, the allocation of water is governed by the law of *riparian right* borrowed from English common law. Only those who own property adjoining lakes or streams are allowed to abstract water from those bodies of water and are only able to do so in a way that does not interfere with the rights of other riparian users, i.e. "authorisation to use water in a stream or other water body is based on ownership of the adjacent land" (Jacobs et al, 2000). Thirty one eastern US states practice the riparian doctrine. Land owners are allowed to make "reasonable use"[5] of the water on their land, but are not allowed to take it in a way that would affect the reasonable use of other riparian landowners. Water rights under the riparian doctrine belong to the land and cannot be sold without the land.

While not an ownership right, riparian rights include the right of access to, and use of the water. The extent of these rights varies from country to country and is further defined by the water licenses or permits that are required for water use in many countries. According to the original riparian doctrine, a riparian owner is not allowed to extract water for purposes unrelated to the riparian land.

New York State follows the riparian doctrine and does not complement it with a licensing system. Only abstractions for public water supply systems require a permit. Also, abstractions from the Great Lakes Basin of more than 3 million gallons (11 356 235 litres) of surface or ground water during a consecutive 30-day period are required to be registered. This is to adhere to international agreements over the Great Lakes Basin. Anyone surrounding the Great Lakes has the right to take water from the basin as long as it does not harm other abstractors.

The riparian doctrine prevents transfer of water to areas unrelated to the adjacent land, and could have either positive or negative effects on adaptation depending on a specific situation. For example, large water diversion projects that are common in California and Colorado would not be possible in the east of the US for legal reasons. On the other hand, the riparian doctrine makes sure that all the water from the watershed stays where it belongs. This could facilitate adaptation in areas with low runoff and competing demands for water. However, when the riparian doctrine is not supported by a system of abstraction permits and does not envision accountability of abstracted water it contributes to the vulnerability of water resources to climate change. Accurate accounting of all water abstraction and use is necessary for adaptation to take place. It is clear that some additional provisions to the riparian doctrine will be necessary to allow for flexibility and accountability in water resources management and for the adaptation to be successful.

In the western regions of both US and Canada, water laws have evolved differently, primarily because of water scarcity and competing needs. The *prior appropriation* water doctrine in the west gives senior (priority) water rights to those who can demonstrate an earlier use of that water; i.e. 'first in time, first in right'. For example, the doctrine of prior appropriation was introduced in British Columbia in 1859 to resolve conflicts over hydraulic mining. However, this right can be lost if it is not exercised for several years.

Current interpretation of this doctrine in the state of Colorado translates into the following principles:

- Water in a stream is not the property of anyone but every person, municipality or corporation has the right to use the water for beneficial purposes.

[5] "reasonable use" is not defined

- Allocation of the water within a stream works on a 'first in time, first in right' basis.
- An appropriator can take water from its source and put it to beneficial use at any location. Land bordering a watercourse has no right to the use of the water, without an appropriation.
- An appropriator has to gain right of way to access the water course.
- Water rights are decreed in water courts through adjudication proceedings. These courts also deal with other water matter cases and approve changes in the nature or place of use of water rights e.g. diversion, change from agricultural to municipal use, direct flow to storage or part-time (spring and summer) to full time.
- There are two kinds of water rights - direct flow and storage.[6]

This suggests that water users in the western states may be susceptible to changes in the water regime since senior rights holders will receive all the water that is available when water supply becomes short. However, measures have been put into place over the years so that development is not limited by water rights. These measures may provide flexibility to water users as the climate becomes more variable.

Modifications to the prior appropriation doctrine have been applied in each state or province. For example, in California two types of water rights are recognized under the law: riparian rights and appropriative rights (SWRCB, 1990). The people of California own all the water in the state and water rights provide the right to reasonable and beneficial use of the water, not to ownership of the water. Article X, Section 2 of the California Constitution requires that all riparian uses of the state's water be both reasonable and beneficial. It places a significant limitation on water rights by prohibiting the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water (Department of Water Resources, 2005).

Under the prior appropriation doctrine in California, a person may acquire a right to divert, store, and use water regardless of whether the land on which it issued is adjacent to a stream or within its watershed. A senior appropriative water rights holder may not change an established use of the water to the detriment of a junior, including a junior's reliance on a senior's return flow. Acquisition of appropriative water rights is subject to the issuance of a permit by the State Water Resources Control Board (SWRCB) with priority based on the date a permit is issued. Appropriative rights may be sold or transferred.

A common method to obtain the use of water in California is under contract. For example, an individual or a group contracts with someone who has water rights and is allowed to use the water subject to the conditions specified in the contract. These contracts do not create an appropriative or other water right for either the buyer or the seller. Instead, they define the obligations and entitlements between the buyer and the seller to the extent the seller has a valid water right to divert water for beneficial use. This can be as simple as one land owner contracting with his neighbour or as complex as the State Water Project or Central Valley Project contracting with numerous water districts throughout the State who in turn contract with other districts or water companies (SWRCB, 1990).

Water trading is carried out in England and Wales but in a much smaller, watershed-based way. It is defined as "the transfer of licensable water rights from one party to another, for benefit"[7]. Trades are carried out through the Environment Agency (see Section 4.2 on Key Players), but the parties involved agree on the price or "benefit" between themselves. One abstractor applies to the Environment Agency to revoke their license or permanently reduce the volume of water they abstract. The person they have traded

[6] Summary of the Law of Water Rights in Colorado, Holland & Hart, LLP
http://www.westernwaterlaw.com/SummaryCoWaterLaw.pdf
[7] Environment Agency
http://www.environment-agency.gov.uk/subjects/waterres/564321/409360/?version=1&lang=_e

with then can apply to take up those rights. The Environment Agency cannot reserve water prior to the submission of an application therefore measures have to be in place to ensure that the correct person obtains the recently freed-up water rights. The water rights will have a new license that can contain new conditions, such as minimum flows. Also the licenses have to be located within the same catchment or groundwater unit and the Environment Agency ensures that the trade will not result in environmental damage. The Environment Agency can prohibit the trade if it is seen to damage the environment, or if it wants more water available for in-stream uses.

Several other countries also allow various forms of trading of abstraction permits. For example, Spain has had tradable rights to water since the 13th century. Three states in Australia have experimented with trading abstraction permits. Chile and Mexico have introduced laws that allow water markets to develop (Defra, 1998).

The western Canadian states also use a prior appropriation system. However, there are differences in the ways it is administrated. In British Columbia the prior appropriation principle is used along with the riparian doctrine in dealing with licenses for water use or diversion. The water belongs to the Crown, i.e. the provincial government. Water rights can only be acquired by a person who owns the land or has Crown tenure for the land the water is on. Permission (or the right) to use surface water is obtained by license or by an approval under the *Water Act*. Licenses are granted in perpetuity but they remain with the land they are granted for. The BC Water Act gives *all* property owners equal access to water on a first come, first served basis. The license belongs to the land (as in the case of the riparian rights) and can be transferred only with the land, but in case of a dispute the owner with earlier issued license has the priority over other license holders for water from the same stream[8].

In these ways the system in British Columbia is unlike the system in the western United States. All the water in the river is not appropriated, and water cannot be transferred between basins. This prevents the big water diversion projects that are seen in the United States. Licences are not required for small irrigation or household purposes. However, owning rights to the water use gives security during drought periods. In times of drought water is allocated by the date the application was filed (called the priority date). Therefore, the earlier water rights are requested, the more rights the abstractor has to his/her water in times of shortage. Filing an application for water rights therefore acts as a kind of insurance policy[9]. Water in British Columbia is plentiful in general, although droughts can occur on the smaller streams in the interior of the province. Prior appropriation, therefore, allows water disputes to be settled in a straightforward way in times of drought. However, the senior right holder might not be the one who has the most urgent water needs and so it might not be the most practical. Prior appropriation also allows all water abstractions to be monitored. Any new diversions or changes in the point of diversion or place or purpose of use may not cause harm to existing appropriators, (Jacobs et al, 2000).

In the US, the prior appropriation doctrine also distributes water rights between states. For example, Los Angeles has senior water rights to Denver on the Colorado River. Senior rights holders can put a ‘call’ on the river, i.e. they can legally force upstream users to reduce their abstraction if they are unable to abstract their full water right allocation[10].

This system can lead to regional water shortages and to engineering investigations to import from more distant, un-appropriated water resources. These issues have become especially controversial in southern Alberta, Canada, where water shortages are common and competition is increasing. Reforms have begun

8 Water Act, [RSBC 1996] Chapter 483
9 Personal communication, Ernie Shirley, Counter BC, National Resources Opportunity Centre, Kamloops, BC
10 Personal communication, Jim Pokrandt, Colorado River Water Conservation District

and amendments to Alberta water act in effect since 1999 include provisions for voluntary marketing of water licenses within watersheds.

The prior appropriation doctrine might impede adaptation in the water sector if it does not include specific provisions that allow more balanced water distribution in times of water shortages. Examples from the US and Canada mentioned above illustrate that governments are moving in the right direction by modifying the original principles of prior appropriation and adjusting the doctrine to current and expected situations.

To resolve inter-provincial and international disputes over water that is allocated based on the appropriative doctrine, Canada has introduced a principle of *apportionment*, which refers to the negotiated division of transboundary river flows between or among those jurisdictions.

Apportionment agreements bring security to each of the participating governments in terms of share in the water supply upon which to base their long-term development plans. Inter-provincial and international apportionments have the advantage of flexibility in water sharing because they are based primarily on percentages of available flow rather than the absolute flow entitlements.

The England and Wales water rights system contains attributes of both prior appropriation and riparian systems.

- Water can be removed from land and sold (similar contracting under prior appropriation).
- A license belongs to a person, but it is for a particular place. When the person leaves, the license is transferred to new land owner.
- Trading can occur but is limited to within the groundwater unit or catchments and the environment agency can refuse to allow trading if it will be detrimental to the environment.
- Time limited licensing has only just been brought in and is being worked into existing licenses.

The ability to transport water away from the source enabled by the prior appropriation doctrine could both increase and decrease vulnerability; it can move water to where it is most needed but it can also leave the source without water resources for future development.

Rights to groundwater vary in different western states of the US. Some states treat tributary ground water - water that is hydro-logically connected to surface flow - in the same manner as surface water rights. Such ground water is integrated into the surface water rights priority system. Thus, a well withdrawing tributary ground water is treated in the same manner as a surface diversion from a stream for the purposes of administration of water rights in accordance with the priority system.

Many western states also have legislative schemes that allow for the designation of critical ground water areas. These are usually areas in which ground water withdrawals have been a primary source of water supply for municipal or agricultural water uses, and in which aquifer water levels are dropping. The purpose of the designation is to allow special rules to be established for protection of the aquifer resource, yet permitting some continued development, or use of the underground water. Priority systems may be put into place, or modified to require all water users to share the burdens pro rata. New wells may be permitted only if the proposed appropriation will not unreasonably impair existing rights from the same source. [11]

In the EU ground water rights are attached to the land the water is on, and in addition is regulated by a system of permits in many countries. In Finland, for example, all groundwater intake which exceeds 250m^3/d requires a permit.

[11] Water Rights Law -- Prior Appropriation, Anne J. Castle Holland & Hart LLP, http://profs.lp.findlaw.com/water/

3.2 Domestic legislation

All countries examined in this study have sophisticated legal systems with numerous laws and regulations that govern various aspects of water management. Each country has laws in place that address the following aspects of water resources and their management:

- Water abstraction permitting and licensing;
- Environmental water quality;
- Drinking water quality;
- Environmental impact assessment from water resources projects;
- Regulations regarding industry/water supply and sewerage companies;
- Water resources management;
- Flood management;
- Drought management;
- Dam, dyke, levee maintenance and safety.

In addition, countries have several laws that protect ground water, natural wetlands, sensitive coastal territories and other sensitive ecosystems.[12]

European countries that are members of the EU have to comply with EC legislation by transposing the EC directives into domestic legislation. While a number of directives such as The Urban Waste Water Treatment Directive aim to protect the environment from the adverse effects of discharges of urban waste water, the one most applicable to water resources is the ***EU Water Framework Directive (WFD)*** (European Commission, 2000). It requires member states to implement a wide-ranging set of reforms to achieve "good status" of all inland and coastal waters by 2015. These goals are reached through the creation of river basin water management plans, requirements for a systematic licensing of water abstraction (both surface and groundwater) and full cost pricing. The Directive provides a means by which the EU member countries should develop integrated, sustainable and coherent water policies based on the ecosystem approach and include citizens in this process.

The implementation of the ambitious legislative framework, its objectives and targets, is now an important challenge in the water sector. In 2001, the Member States agreed on a Common Implementation Strategy for the WFD to harmonise and facilitate the implementation process. The Directive is to be implemented by the Member States within a specific timeframe, step by step, including completion of guidance documents by 2006. River Basin Districts are identified and River Basin Management Plans for each river basin district should be completed by December 2009. There are eight River Basin Districts in Finland; the total number of river basins is 74. There are nine districts in England and Wales, plus two districts that are shared with Scotland. Scotland has one River Basin District solely in Scotland; Northern Ireland has three River Basin Districts, two of which are shared with Ireland.

The WFD is potentially a powerful implementation tool for climate change adaptation policy. Its integrated river basin approach encourages strategic planning and water resources management that incorporates sustainable supply-side and demand-side management, drought measures, flood protection, water quality issues and environmental health of the basin. While the WFD does not explicitly mention that climate

[12] For example, Finland has laws that protect some rapids–specific rivers- from hydropower development.

change impacts need to be recognised, the approach of the WFD will serve as an important adaptation tool. The approach of the WFD encompasses the following steps and actions: comprehensive stocktaking and monitoring; defining a target level of environmental status, identifying the necessary measures in a comprehensive multi-annual plan, taking into account and integrating all environmental stresses, taking an ecosystem approach, planning long term, and repeating this planning cycle in 5-6 years in order to reflect current developments. It is unlikely that the first River Basin Management Plans (2009-2015) will address adaptation to climate change. However, the on-going discussions in the EU, including the preparation of the German Presidency conference in February 2007, give a clear signal that specific adaptation measures will be included in the second River Basin Management Plan cycle (2015-2021).

The EU member countries are also currently negotiating the new Flood Directive which will complement the Water Framework Directive.

In addition to EU laws, each EU country also has a set of national and regional laws. Due to the administrative structure of the UK, England and Wales, Scotland and Northern Ireland, each have their own environmental laws. Finland has one main legal document, The Water Act of 1961, which governs water resources management.

The US and Canada have decentralized water management legislation systems. The legal framework is composed of common law principles, constitutional provisions, state (US), provincial (Canada) and federal statutes, court decisions and contracts or agreements. The US and Canada have a few federal laws that focus on water quality issues. In Canada, in addition to federal laws on water quality, there are some other laws that can govern management of the limited water resources under federal control and that also have provisions for agreements with provinces on water management issues. However it is state and provincial laws and regulations that govern water use in these countries. Each state/province has its own set or laws and regulations under which water resources are managed. Under the Canadian Constitution Act of 1867, the provinces are "owners" of the water resources and are responsible in their day-to-day management.

Domestic legislation defines basic relationships among the stakeholders and sets out the main principles of water resources management. Existing legal frameworks will also be determinant for adaptation in the same way as they define the rules for water management. There are some laws in the current policy frameworks that will facilitate adaptation by promoting efficient water use, setting economic values for water and market mechanisms, and others. For example, efficient water use is a legal requirement of California. The Water Recycling Act of 1991[13] sets goals for the volume of water recycled in California: 700,000 acre-feet of water per year by the year 2000 and 1,000,000 acre-feet of water per year by the year 2010.

An analysis of existing laws in terms of their roles in adaptation might be necessary to identify tools and procedures that can be adopted and expanded in adaptation strategies, and legal obstacles for certain adaptation measures.

3.3 International water issues

Many countries have international boundary agreements on water bodies which will have to be flexible in the face of climate change. The European Commission requires the member states to address transboundary issues in River Basin Management Plans and make special provisions when river basins are shared with third (non-EU) countries.

[13] California Water Code, Section 13575-13583

For example, Finland shares rivers with Sweden, Norway and Russia. The most significant river basins where international co-operation is needed are those of the rivers Tornio, Teno, Paatsjoki and Vuoksi. Decisions on issues related to these river basins are handled by transboundary river basin commissions set up through bilateral government agreements. The regulation of water levels in Lake Inari, one of the largest lakes in the world and located entirely north of the Arctic Circle, is covered by a special agreement between Finland, Russia and Norway.

Canada has several laws that are specifically designed to handle international issues of river basins shared with the US. The International River Improvements Act provides for licensing of activities that may alter the flow of rivers entering the United States. The Governor in Council may make regulations regarding the construction, operation and maintenance of international river improvements on international rivers[14].

The Great Lakes are shared by eight US states and two Canadian provinces. The region has a long history of international and inter-state and inter-provincial agreements. In 1983, the Council of Great Lakes Governors created a task force to develop an institutional framework for dealing with water diversions from the Great Lakes. This framework led to the 1985 Great Lakes Charter. The Charter builds upon the initial interest in preserving lake levels and inflows mentioned in the Boundary waters Treaty of 1909. The Boundary Waters Treaty of 1909 determines the priority of interests in the Great Lakes (domestic and sanitary purposes are of highest priority followed by navigation, power generation and irrigation) and provides the principles and mechanisms to help resolve disputes and to prevent future ones; primarily those concerning water quantity and water quality along the boundary between Canada and the United States.

While the Charter is “soft law” and not legally binding, it does help guide the behaviour of the eight Great lakes states and two provinces. Most importantly, any major new or increased diversion or consumptive use of Great lakes basin water requires prior notification, consultation and concurrence of all affected parties.

In 2001, a supplementary agreement to the Great Lakes Charter was signed. It reiterates the commitment, but also entrusts states and provinces to prepare a basin-wide binding agreement to establish a decision-making standard for review of proposals. The Charter provides that no state or province will approve or permit any major new or increased diversion or consumptive use of the water resources of the Great Lakes Basin without notifying and consulting with and seeking the consent and concurrence of all affected Great Lakes states and provinces. The trigger point for notification and seeking consent of other Great Lakes states and provinces is an average use of 5 million gallons (19 million litres) per day in any 30-day period.

The Great Lakes Charter also records a commitment by the signatory states and provinces to pursue the development and maintenance of a common database of information regarding the use and management of Basin water resources; the establishment of systematic arrangements for the exchange of water data and information; the creation of a Water Resources Management Committee; the development of a Great Lakes Basin Water Resources Management Program; and additional coordinated research efforts to provide improved information for future water planning and management decisions. Although not fully implemented, these commitments move toward the kind of cooperation and coordination that is required and will become more necessary in the future.

The Charter may be ineffective in facilitating adaptation and preserving the Great Lakes resources unless triggers for consideration of new diversions and consumption are greatly lowered. Also, the consent of all Great Lakes states/provinces is not required for the new diversions or uses to take place and there are no standards for when consent should be given or withheld and there is no provision for public involvement in the process.

[14] International River Improvements Act (R.S., 1985, c. I-20)

In the US, there are other inter-state issues that are addressed by specific legal acts. For example, the Law of the River, which includes the Colorado River Compact, signed in 1922 by the seven states of the Colorado River basin. The Compact divided water between the Upper Basin states (Colorado, Wyoming, Utah and New Mexico) and the Lower Basin States (California, Nevada and Arizona). Water is also allocated for Mexico. Future long term droughts combined with rapid population growth in many of the western states will make it increasingly hard for all states involved in the Compact to meet their requirements as part of the agreement.

4. Institutional Landscape

The four countries examined here represent three different administrative systems. The US and Canada are federal countries that are governed by a federal government and numerous regional (state and provincial) governments with independent institutional and legal systems. Finland is a Unitarian country and has one central government that is divided into regional and municipal jurisdictions. The UK is represented by the devolved governments of England and Wales, Scotland and Northern Ireland. When devolution occurred in the UK, only certain powers were granted to the devolved administrations; powers over environmental matters (including water resources) were included based on the recognition that environmental matters are better managed on regional scale.

These different administrative systems are translated into different institutional and legal structures. Some legal particularities are examined in Section 3 of the paper. This section focuses on the institutional set-up and key players/stakeholders in the water sector framework.

4.1 Institutional set-up

The institutional set up of a country influences its ability to mainstream adaptation in the water sector and the approach it takes. Each examined country incorporates features of centralised and decentralised institutional structures and stakeholder relationships. However, due to fundamental differences in types of administrative systems, in each country either a centralised or decentralised structure and way of governance dominates.

4.1.1 Centralised structure

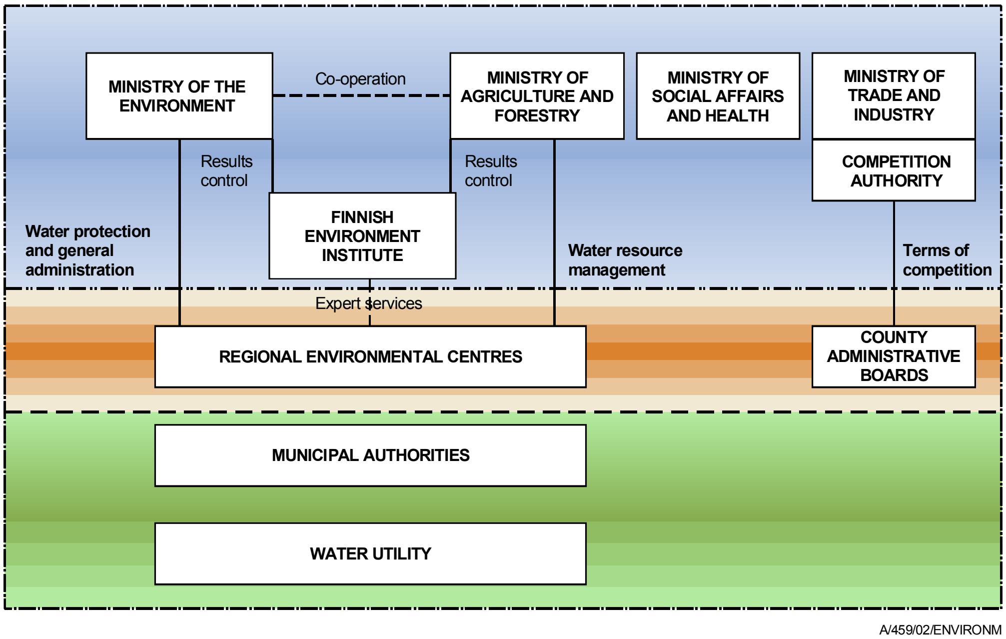
A centralised structure implies a top-down approach to policy development when central and devolved governments form policies and delegate their implementation to regional offices. Municipal authorities promote and supervise implementation of policies at a local level. Finland and the UK have a centralised institutional structure. In England and Wales, the Environment Agency deals with all water management issues, implements policy formulated by the Department of Environment, Food and Rural Affairs (Defra) and formulates its own policies and strategies on water. The devolved Scottish parliament has powers over the Environment in Scotland, and it follows the same pattern using the Scottish Environment Protection Agency (SEPA) to implement its policy across Scotland. In Northern Ireland, water policy is administered by the Environment and Heritage Service, part of the Department of the Environment. The environment agencies have regional and local offices ensuring that policy is implemented ‘on the ground’.

In Finland, the Ministry of Agriculture and Forestry is responsible for water resources and, along with the Department of the Environment, manages thirteen Regional Environmental Centres which implement water protection and water management measures at a regional level. Municipal environmental authorities implement water legislation at a local level. Figure 1 shows the water resources hierarchy in Finland (taken from Kuusisto, 2006).

In addition, there are water supply companies. In England and Wales drinking water is supplied by privately-owned companies with regional monopolies that are regulated by the Environment Agency and the Office of Water Services (Ofwat) which was established by, but is independent of, the government. In Scotland and Northern Ireland water is supplied by single publicly-owned bodies: Scottish Water and the

Northern Ireland Water Service. Drinking water in Finland is supplied by public waterworks and is regulated by the Ministry of Agriculture and Forestry through regional offices.

Figure 1. Water resources hierarchy in Finland



The following features may either facilitate or impede adaptation under a centralised institutional structure and need to be taken into account in developing adaptation strategies.

Consistency: A centralised structure can facilitate a consistent policy approach to the sector across the country. Adaptation to climate change can be integrated into water sector long-term policy for the whole country by developing an appropriate guiding document. This approach is an efficient way of reaching a broad and diverse group of stakeholders who are involved in water resources management. A centralised approach allows a coherent regulation of water related activities which could ensure that adaptation is included in planning processes.

Long-term strategic thinking: A centralised structure may allow for a top-down strategic thinking that is based on a broad overview of the situation and looks into the long term future. This approach can encourage regional and local decision-makers to take actions with long term benefits rather than focusing on short-term, reactive changes. For example, it was only after the 1987-92 drought in California that laws were passed to ensure that every water supplier with more than 3000 customers produced an Urban Water Management Plan.

If long term regional or local plans are made, they rarely consider that climate change may bring climatic conditions never before experienced. However, a top-down approach to adaptation can make sure that the country is prepared for future changes in climate by enforcing adaptation actions at different levels. For example, Defra's initiative to develop a country-wide Adaptation Policy Framework will facilitate adaptation across sectors and regions through stakeholders at different levels.

Limited number of players: The centralised intuitional framework may limit the number of players in the water resources sector. This simplifies matters when it comes to co-ordinating adaptation activities.

Bureaucracy: The top-down nature of the centralised institutional system implies that all the policy initiatives come from the top. Local-level stakeholders are not expected to develop policy approaches even though they are more intimately involved in the water resources management and at times might have better understanding of the situation and better management and/or adaptation ideas. This could be a significant limitation to adaptation if undertaking stakeholder consultation is not a common practice and is not taken seriously by the central government.

Link between national priorities and budget allocations: A centralised structure can theoretically facilitate a budget allocation for adaptation actions – increasing dam capacity, new infrastructure, water conservation publicity, improving levees etc. However, very often national budgets are spread thinly across many priority issues, and sufficient funding is not always available. Recently, OECD governments started exploring possibilities of public-private partnerships in the water sector to facilitate flow of capital from the private sector. A centralised structure can facilitate a priority setting system so that the available resources are first allocated to the most vulnerable regions.

Link between national and local priorities: One challenge of a centralised structure is incorporating local and regional interests into a national agenda. There might be competing priorities and interests among regions, and careful consideration should be given to each particular situation. Stakeholder consultations play an important role in policy development and should take a prominent place in the area of adaptation to climate change.

Flow of Information: A centralised approach can ensure that the right information is reaching the right players. National Governments have an access to interagency and international consultations and potentially posses a unique bank of information and resources that can generate information. For example, national government representatives participate in the UNFCCC negotiations, AIXG and other informal meetings that facilitate exchange of information, ideas and experiences of different countries.

The national government is also able to assess the overall situation in the country (whereas local players cannot) and evaluate what type of information would be instrumental for adaptation in the water sector and who the key players are who need it. The government can then promote research in these areas and put the results of the research into relevant formats for water managers. For example, the hierarchical structure of the UK Environment Agency is well designed to disseminate climate change-related information. Information could flow from the central offices which are in direct contact with research institutions and central government through to regional offices, local offices and the people who are actually making decisions regarding water management.

However, in practice the process of information dissemination is not so smooth. If formal links and channels for information dissemination are not established, information does not reach all the key stakeholders at the right time and in a consistent format and context. Another barrier in the process of information sharing is the status and form of the disseminated information. When regional and local authorities receive information from central offices they also need to know how it is meant to be used and applied. A centralised system implies direct guidance from high level government to subordinate levels on any significant action. When information from the central authorities is passed down the hierarchical scale it needs to be accompanied by clear guidance on what to do with it.

4.1.2 Decentralised structure

The United States and Canada have a decentralised system of water management. Generally, only limited guidance is issued from federal government regarding water management – this responsibility is given to state and provincial governments. In the US, the federal government is involved in some activities such as flood and drought disaster management (Federal Emergency Management Agency), dam and water project ownership and operation (Bureau of Reclamation of the US Department of the Interior), dam and levee construction (US Army Corps of Engineers) and hydrological monitoring (US Geological Survey).

Within a state and provincial government, there are usually several different agencies and departments that deal with water resources. In addition, there are municipal water authorities that have responsibility to supply water to the public. There are also water conservation districts and water districts. Water conservation districts such as the Colorado River Water Conservation District are subdivisions of the state government formed under state law with the purpose of acquiring water rights and developing water storage availability for the greater benefit of the area. They have the authority to form taxing districts.

Water districts such as the Metropolitan Water District of Southern California or the Southeastern Colorado Water Conservancy District, are local government agencies that are established to contract with United States on the construction, operation and financing of big water diversion projects. They can act as water wholesalers and may sell water to municipalities and agriculture entities.

There are certain features of decentralised structures that would either facilitate or impede adaptations.

Inconsistency across the country: Since rivers and lakes do not observe political boundaries, varied approaches to water management and adaptation in the water sector between states/provinces might have a negative effect on the overall adaptation of the country. Inter-state agreements will become instrumental in resolving conflicts over water resources if drought conditions become more severe and prolonged with climate change. This will put an additional burden on institutions and legal infrastructure. The Great Lakes region is a good example of how inter-state, inter-provincial and international (US-Canada) agreements play a role in the management of water resources of Great lakes. The history of these agreements dates back to 1909 and discussions and negotiations on shared rights and responsibilities regarding water quantity and quality are on-going.

Flexibility: Regional and local level stakeholders have more power to implement policies that have the biggest relevance to their particular situations. It means that real adaptation actions can take place faster and more efficiently since there is no provision for the formulation of broad strategies that can have little practical application. Secondly, it may actually lead to more adaptation taking place, since institutions aren't waiting for instructions, direction and guidelines from their central government. It also allows adaptation to be tailored to a specific region. For example, in Canada, a provincial-level drought plan is produced by Ontario, but not by British Columbia. This is because the population density is much higher in Ontario (three times the population for the same land surface area), so water resources are more stretched and more people are put at risk in a drought situation.

Links between national and regional priorities: While a decentralized structure allows for local and regional interests to be fully incorporated into a particular region's policies and strategies, it may or may not facilitate integration of national interests or other regions' interests in all the relevant regional policies. Special provisions have to be made for flood and drought management when water bodies are shared among several regions. Adaptation strategies will have to facilitate and incorporate inter-state agreements and provisions on shared water bodies and their management.

Numerous players: Due to the nature of the water sector, it is rather decentralized under any administrative system. A decentralized administrative system contributes to the further decentralization of the water sector management and multiplies the number of national, regional and local institutions and stakeholders involved. For successful adaptation in the water sector to take place, all of these stakeholders need to be aware of climate change impacts and incorporate adaptation into their decision-making. Reaching out to all the numerous stakeholders and their coordination might be a challenge for adaptation in the water sector in general and even more so in a decentralised government.

Flow of information: State and provincial governments may not have the same access to information that the national government has. Some states and provinces have very sophisticated scientific institutions and broad monitoring networks; others rely on out of state research and information. Even those states and provinces that have a strong scientific basis might still lack some global data that can be crucial in climate change science. This highlights the importance of inter-state and inter-provincial cooperation and exchange of data and information.

Canada provides a good example on how information sharing is currently being addressed in a decentralized system. In October 2000, at the Joint Meeting of Energy and Environment Ministries, the federal, provincial and territorial ministers (except Ontario) approved Canada's National Implementation Strategy on Climate Change. The strategy provides a framework to address the issue of climate change in Canada. To understand impacts of climate change and develop appropriate methods to deal with, or adapt, to these impacts, Natural Resources Canada (NRCan) established the Canadian Climate Impacts and Adaptation Research Network (C-CIARN), as part of the Government of Canada's Climate Change Impact and Adaptation Program. C-CIARN is comprised of six regions and involves seven national sectors connecting researchers and stakeholders across the country.

4.2 Key players

The water sector is complex because many different players are involved at different levels of government. Water supply planning and management varies from country to country. It can also vary within a country if water management issues are delegated and not handled by central government. This makes generalisations and comparisons difficult. Compounding the issue is the range of historical settings, cultural values and hydrological situations. All play a part in deciding who the key players are in water resources management and who will be key to future adaptation decisions.

Introducing adaptation measures can be challenging, simply due to the fact that many different levels of government administer water management activities. Even within one level of government, several separate agencies are often involved in water legislation. Identification of the important players and their roles is an important first step in building adaptive capacity. The enhancement of mechanisms to foster interagency collaboration and exchange of information is another step in adaptation development.

When looking at decision-making in the water resources sector one has to bear in mind the decentralised nature of the water resources sector, and the range of different activities that it encompasses.

The decentralised nature of water supply and management means that there are people making important decisions at all levels of government. At the highest level, Prime Ministers, Governors and Presidents are able to put climate change and adaptation on the agenda and in the public eye. Not only do they increase awareness but they also increase funding for adaptation activities to take place. An example of this is Governor Schwarzenegger's drive to become the 'Green Governor' by establishing the Climate Change Team under an Executive Order. In this Executive Order Governor Schwarzenegger orders the Secretary to 'report to the Governor and the State Legislature by January 2006 and biannually thereafter on the impacts to California of global warming, including impacts to water supply, public health, agriculture, the coastline, and forestry, and shall prepare and report on mitigation and adaptation plans to combat these impacts'. Another example is Prime Minister Tony Blair using the UK's European Union and Group of Eight leaderships to promote the climate change agenda.

In many cases, responsibilities within the water resources sector tend to fall under the umbrella of an environmental department. These are present at the national, regional, state/province level (e.g. US Environmental Protection Agency, California Environmental Protection Agency; Environment Canada and the Ontario Ministry of the Environment, UK Department for Environment, Food and Rural Affairs and

Environment Agency in England and Wales) and local levels. The national departments are important because they advise senior ministers on important environmental issues, form policies and develop strategies on water management. In some cases, climate change and its impact on water resources is acknowledged at the national level of government and is incorporated into some strategies and plans, e.g. *Directing the flow - Priorities for future water policy* which was released in November 2002 by Defra which recognizes that climate change will be one factor stressing water resources in the future.

<u>Other line ministries and 'departments' within the environment ministries</u> (directly and indirectly connected with water resources) are another important group of stakeholders who may need to play a role in adaptation to climate change in the water sector. Ministries of agriculture and spatial planning make important decisions that affect and can be affected by water resources. Departments of fisheries develop strategies and plans that can be affected by water resources. Decisions by departments of agriculture and fisheries can have implications for the ministries of trade and economic relations. Departments of waste management need to be integrated into the water sector adaptation network as waste sites might be affected by floods, and water quality might be affected by floods and droughts. Also, energy departments often have responsibilities for dams and other electric generating facilities that are dependent on water resources.

Within the <u>environment departments at the state level</u> there may be an agency that is responsible for water quantity and quality management. Sometimes the structural (dams) and rights administration aspects are handled by a different agency from the flood defence and drought management. This is the case in Colorado: the Division of Water Resources deals with dams and water rights, and the Colorado Water Conservation Board is responsible for flood and drought management. In Finland and the UK both these activities are carried out by one agency.

Many water ministries and departments have <u>regional offices which are responsible for implementing and administering projects and activities</u>. In England and Wales the Environment Agency has eight regional offices and 26 area offices. In Colorado, the Department of Water Resources has seven Division Engineers Offices, one in each of the main watersheds. In Finland, the Ministry of Agriculture and Forestry and the Ministry of the Environment manage thirteen Regional Environmental Centres and three Environmental Permit Authorities. The staff at these regional and local offices decide whether to issue water abstraction permits, how and when to enforce water management regulations, monitor river levels, and in some cases manages floods and issue flood warnings.

<u>Water suppliers</u> are responsible for ensuring that the population within their area receives sufficient high quality water. Water managers have to construct long term water supply plans, decide how demand will be met in the coming years, balance reasonable prices for customers with system requirements, and in the case of the England and Wales, with shareholder needs.

In most countries water is supplied by municipal authorities. These can range in size from one system that serves 9 million people such as the City of New York and its surrounds, to a system supplying a series of rural villages. Water suppliers can also be private companies such as in England and Wales where public water authorities were privatized in 1989[15]. Water suppliers may decide the degree to which water conservation is promoted; they can also decide whether or not to promote water metering. Water providers make projections regarding future demand and identify where future supplies will come from. They also own and operate a great deal of infrastructure which might be sensitive to impacts from climate change. Decisions as to whether water supply and sewerage infrastructure is replaced, and whether it is upgraded to higher design standards are often made by water utility companies and municipal water suppliers, although their decisions usually require approval from state, regional or national authorities.

[15] There are ten regional water and sewerage operators in England and Wales based on the areas that used to be served by ten public water authorities. There are also fifteen supply-only water companies (no sewerage services).

Regulators play a role in monitoring performance and setting charges and prices. They need to ensure that water prices are set high enough to ensure that water quality and reliability is sustained, but not so high that they will disadvantage consumers. They also review water supply plans to ensure that there will be no gaps between demand and supply and that plans are in place to mitigate water supply disruptions. In the future, they may be able increasingly able to require that adaptation measures are considered in long-term water supply plans and infrastructure improvements.

For example, the UK Office of Water Services (Ofwat) is a non-ministerial government department (which reports to the parliament) that regulates the private water companies in England and Wales. Its role has tended to be one of encouraging water companies to consider adaptations by making them include climate change in water resource plans and drought plans. In fact, Ofwat explicitly requires water supply companies to consider climate change in their projections of future requirements. Currently this translates into building adaptive capacity rather than delivering adaptation actions.

In Ontario, Canada, Conservation Authorities review municipal planning applications for municipalities within their watershed, ensuring that septic system capability, water quality and quantity issues are all dealt with before developments go ahead[16]. This increases the possibility that a watershed will be managed in an integrated manner, and be able to support development, particularly as the need for adaptation increases.

Local authorities can also play a role in flood defence. In general, they have the jurisdiction to grant or deny planning permission on floodplains. In England and Wales, the Environment Agency advises, but cannot prevent construction on a floodplain. In the US, state and local governments work with the Corps of Engineers and Federal Emergency Management Agency (FEMA) on flood plain management issues. Once designated a floodplain certain building standards may need to be adhered to. In Ontario, Canada, Conservation Authorities can prohibit construction on floodplains.

[16] North Bay-Mattawa Conservation Authority, http://www.nbmca.on.ca/planning.htm

5. Water Management

Water management in this chapter implies water abstraction, supply and use, including all the related infrastructure and policies. Proper water management is needed to ensure that water supplies are sustainable and remain reliable as hydrological conditions change, in the short and long-term. This means not only water for human consumption, but water for agriculture, power generation, industry and commercial enterprises. Water management can be distilled down to three key tasks:

- Development of long-term water resources management strategies.
- Regulation of water abstraction, supply and demand.
- Minimising the risk from floods and droughts.

The first task is important as it requires setting long-term water resources management strategies that should provide general guidance on the key aspects of water management, including the two other tasks mentioned above. Central to the second task is ensuring that sufficient water is available when and where it is required. It involves balancing the needs of competing users and mitigating drought through licensing, water restriction policies and demand side management. The third task – flood/drought minimisation involves continuous monitoring, timely warnings and correct infrastructure operations.

Each country, state and region within a country must manage their resources under a different set of climatic and social pressures. Historically, each country has found its own way of doing so. This section will examine how different approaches to water management lend themselves to adaptation.

5.1 Long-term water resources management strategies

To address increasing problems of water shortages, floods and droughts OECD governments are introducing policies and developing strategies that are focused on facilitating sustainable water management. However, most of these strategies and policies are developed to address current problems in the water sector. They often look 10-20 years in the future, but long-term climate change rarely plays a role. Nevertheless, strategies and policies directed at efficient water use, protection from floods and preparedness for droughts, and sustainable land-use planning improve countries' adaptive capacity and facilitate adaptation to future climate change.

There are several examples from the countries examined of mid- and long-term strategies that indirectly facilitate adaptation by promoting measures that improve the water sector's capacity to handle expected changes. For example, EPA Strategic Plan 2004-2008 among other things calls to achieve a net increase of 400,000 acres of wetlands that would be important for flood protection. Water 2025: Preventing Crises and Conflict in the West (a document prepared by the US Bureau of Reclamation) sets forth a framework to focus on meeting water supply challenges in the future and to reduce conflict over water resources. This framework includes principles to guide the Department of Interior in addressing water problems and tools to help proactively manage scarce water resources. The tools that this framework proposes are: conservation, efficiency and markets; collaboration; technology, removal of institutional barriers and increased interagency cooperation.

There are other strategies adopted in the US, Canada, UK and Finland that suggest measures to improve water use efficiency, identify innovative methods of increasing water storage and storage techniques such as groundwater storage reservoirs, promote integrated approach to water resources management.

These examples point out that even progressive long-term strategies that indirectly facilitate a certain degree of adaptation, are not sufficient to provide for a full protection from expected climate change.

There are many reasons why climate change is not explicitly mentioned in water management strategies. When climate change is not high on a political agenda, water management practitioners and policy makers simply overlook available information on climate change when developing short and long term water management strategies. Another reason is hesitance to rely on highly uncertain projections. The reactive, rather than proactive, nature of water management may also play a role. Another important factor could be the lack of standards for incorporating climate change into management and design decisions.

There are, however, exceptions to these general trends. For example, California Water Plan, Update 2005 (Bulletin 160-05) looks at potential impacts of climate change on water resources in California and potential strategies for adapting to these changes. The UK project on the Thames Estuary 2100 examines various approaches to developing a Thames Estuary Flood Risk Management strategy for the next 100 years; these approaches are based on different scenarios of climate change. '*Directing the flow - Priorities for future water policy',* a policy document developed by Defra in 2002, sets out priorities for water policy over the next 20 years and beyond. Climate change is mentioned as one factor that will challenge the water sector by placing additional stress on water resources and quality, and presenting challenges for flood management. It recognizes that water resources are under pressure from climate change even now. The document states that government will ensure that climate change is adequately planned for by water companies in their resource planning (one way sited by the report is through the climate change levy), and in the implementation of the Water Framework Directive (Defra, 2002).

Other sectors' long-term strategies will also play a role in the adaptation of water sector to climate change. For example, sustainable land-use planning, including protection of wetlands can have a significant effect on flood prevention and management. Sustainable agricultural strategies can adopt practices that better retain soil moisture and reduce water demands during dry periods. Projections on increased runoff might be incorporated into strategies for hydro power development (as it is done in Finland).

5.2 Water abstraction, demand and supply

According to the OECD report "Environmental Performance Reviews: Water" (2003) overall water use in the OECD countries is increasing, although trends in water use vary among member countries and, within countries, among sectors. At the same time, many OECD countries face at least seasonal or local water quantity problems. With projected climate change, most of the areas that face occasional water shortages today will experience more severe water stresses in the future. Table 3 below presents data on water use and per capita consumption in the countries examined.

Each element of the water consumption chain from abstraction to actual use is important in preparing for expected water shortages. The degree and diligence of regulation of water abstraction determines the level of available information on how much water is removed and for what purposes, and also defines flexibility in addressing situations of water shortages or competing needs for limited water resources. The state and regulation of water supply infrastructure contributes to the vulnerability of water sector and also defines technological opportunities for adaptation. Water demand patterns determine the quantity and timing of needed water supply.

Table 3. Water Use and Per Capita Consumption

Country	Country/State /Province/ Basin	Water Use	Per Capita Water Use (litres/day)
USA	California	Environmental (48%), Agriculture (41%) Urban (11%)	380 [17]
	Colorado	Agriculture (91.6%), municipal (4.4%), industrial and other uses (4%)	
	New York	Hydropower generation (57%), public water supply (36%), industrial purposes (4%), irrigation (1%), self-supplied domestic (2%).	
Canada	British Columbia	Thermal power generation (64%), manufacturing (14%), municipal use (12%), agriculture (9%), and mining (1%)	335 [18]
	Ontario		
USA/ Canada	Great Lakes Basin	Irrigation (29%), public water supply (28%), industrial use (24%), thermoelectric power generation (6%), nuclear power (6%), self-supplied domestic (4%), livestock watering (3%)	314 [19]
United Kingdom	England and Wales	Public water supply (40.8%), thermoelectric power generation (38.9%), other industry (11%), fish farming, watercress farming and amenity ponds (7.5%), irrigation & private water supply (1.4%)	154 [20]
	Scotland	Fish farming (60%), water supply (34%), distilleries (3%) and other industries (3%). Doesn't include hydropower generation, thermal and nuclear cooling, navigation, agriculture and golf irrigation	143 [21]
	Northern Ireland	No data	144 [22]
Finland	All	No data	242 [23]

[17] Geotimes, American Geological Institute, www.geotimes.org/may05/feature_worldwater.html#
[18] Environment Canada: http://www.ec.gc.ca/WATER/en/info/facts/e_domestic.htm
[19] USGS 1995 data http://water.usgs.gov/watuse/pdf1995/pdf/domestic.pdf
[20] Ofwat Figures, www.defra.gov.uk/news/2005/050901b.htm
[21] Scottish Executive, 2004
[22] SNIFFER, 2004
[23] Kuusisto, 2006

5.2.1 Abstraction permits

The right of water abstraction is based on the legal foundation of water rights. Such provisions as riparian right, appropriation, prior appropriation and apportionment (discussed in Section 3) define the basis and major conditions of abstraction rights. The abstraction (taking) of water from a river or stream tends to depend on the availability of water within that area. The rarer the water, the more regulation and permitting surrounds its abstraction. In most OECD countries, abstraction of water requires a permit from government agencies. However, there are some states in the US where certain types of abstraction are not regulated at all. It has also been observed that surface water is generally much more regulated than groundwater. Clear regulations on ground water abstraction are found in areas where the problems of unsustainable abstraction of groundwater are visible such as in Antelope Valley in California where the ground has subsided approximately two metres due to water being taken at a higher rate than it is replenished.

The European Union Water Framework Directive requires every member state to have an abstraction licensing system. All ground and surface water use (abstraction and discharge) requires a permit usually delivered by regional environmental departments. This permit specifies the water rights of the user, and determines the volume of raw water that can be used and also the amount of pollutants that can be discharged.

In England and Wales, a license is required from the Environment Agency (an agency of the Department of Environment, Food and Rural Affairs) for surface water or groundwater abstraction for all uses, e.g. public water supply, agricultural, industrial over 20 000 litres/day. The Environment Agency ensures that it is abstracted in a way that does not harm the environment. Abstraction licenses are granted by staff at Environment Agency area offices who have experience in their area's climate and hydrological regime.

The majority of existing licenses in the UK granted prior to 1990 were done so in perpetuity. However, the Water Act 2003 brought it new legislation that allows the Environment Agency to grant time-limited licences with a renewal period of 12 years. The Environment Agency hopes to convert all its existing licenses from permanent to time limited over the next several years. New licences are granted with time limits and in some areas with low precipitation such as the Anglian Region in the southeast of England licences are no longer granted for summer. The Water Act 2003 also gave the Environment Agency powers to take away a license if the owner is causing serious damage to the environment. Public water supply companies were granted licenses automatically allowing them to abstract water in a way that is no longer be sustainable. Therefore, they work with the Environment Agency to find compromises between public water supply and environmental inflow needs.

Abstraction licensing might allow building in flexibility with options for relief when water levels are low. Licenses can also have low flow values incorporated, below which abstraction must stop. They are also tied to a location and water use. In areas where the aquifers are under stress, there can be embargoes on abstraction for a couple of years until water levels recover, e.g. the chalk aquifer in Kent, southern England.

Without a system of licensing the regulatory agency cannot recognise trends in supply/demand changes and has no way of remedying water shortage situations through permits.

Ontario, Canada which borders four of the Great Lakes uses the riparian doctrine – permits are attached to the land and cannot be transferred without the land (see Section 3) - and requires anyone taking more than a total of 50,000 litres of water a day from a lake, stream, river or groundwater source to obtain a water permit from the Department of the Environment. In this way it is similar to England and Wales. It is also similar in the degree of emphasis placed on environmental protection: licences are time limited for ten years, applications are rated by the environmental harm they would cause and in some vulnerable watersheds abstraction is prohibited.

Water abstraction permits in the Western US are based on the doctrine of appropriation; they are not attached to the land and can be sold without the land. However, there are examples when trading of water rights is allowed even under the riparian doctrine. In the UK, the Water Act 2003 formalised water rights trading (although it had been defined since 1991) to be used in areas where no new abstraction licences were being granted. Environment Agency still has to approve the transfer, and may not do so if it is an area where it is trying to increase in stream flow. The same provision is allowed in California. In both areas, water can be contracted meaning that the license owner sells a portion of his/her water that they are not using.

To provide for effective water management and adaptation to climate change all abstractions need to be monitored through registration, even if permits are not required. Abstraction licenses and registration allow governments to really understand how much water and for what purposes is used in their country.

Time limiting of licenses and built in 'hands off flow' agreements and other conditions are important so that catchment management strategies can evolve with the changing climate. In areas where water availability decreases, licenses must be altered with respect to quantity. In areas where the timing of peak flows changes, licenses may have to be altered temporally. For example, in the southeast of England licenses are no longer granted for summer abstraction; only winter abstraction is allowed and water must be stored for use in the summer. Also, in areas dependent on snowmelt, summer abstraction may have to be prohibited as peak flows start to occur in the winter and early spring. Many licenses are still granted in perpetuity (e.g. in British Columbia, Canada) and for many authorities, e.g. the Environment Agency in England and Wales even if the right to remove permits is there it cannot be practiced. This is because in the UK permits cannot be retracted without compensation and the Environment Agency does not have the funds to do so.

Among the countries studied there is a common theme of a hierarchical structure within the permitting agency with a main central office and regional and local offices 'on the ground' that actually give out the permits. This enables people with local knowledge of the climate and hydrological systems to grant licenses with as much information on the surrounding area as possible. However, this structure has its disadvantages because staff at local offices cannot step back and see the bigger picture. Local administrators need to receive comprehensive information on possible water stresses including climate change impacts and any changes on the demand side with clear guidance from the national authorities on how to incorporate this information into the decision-making process. Availability of this information and guidance to the local staff will facilitate adaptation.

5.2.2 Drought plans and water management plans

Drought plans are an integral part of water management. They ensure that when a potential drought situation arises, measures are in place to mitigate its effects. They also ensure that those responsible have defined roles and that actions can be initiated swiftly when water levels begin to fall. They are usually initiated when there is a potential drought situation and deactivated when conditions have returned to normal for some time. Droughts in countries examined can only build up over years. They are never a surprise if water conditions within an area are monitored and are generally caused by lower than average precipitation levels. Their effects can be reduced by water conservation, having sufficient infrastructure in place to store water and through good management practices. Eventually, however, they are only ended by the onset of sufficient precipitation.

In the case of the UK, drought plans are usually updated yearly by the Environment Agency. This allows them to facilitate adaptation because they can be modified as the climate changes. For example, if droughts become longer then drought plans can be modified and extra measures included to accommodate this. On the other hand, this incremental adaptation may prevent proactive measures being taken to adapt to the water shortage conditions that will occur in the future. For example, new reservoirs might need to be built, laws changed to facilitate the easier transport of water between areas or to curb rapid development and population growth in areas where water supply is already short. In this way, drought plans may not be particularly effective as a mechanism for adaptation in the water sector in the long-term.

Water suppliers also produce water management plans which are reviewed by government water departments. For example, water utility companies in the UK have to produce Water Resource Plans which are reviewed annually by the Environment Agency and the results are submitted to central government. In California, municipalities serving over 3000 people have to submit Urban Water Management Plans to the Department of Water Resources every five years. This process of producing plans which are then reviewed by the relevant water management departments can promote adaptation. Recommendations can be made to increase the capacity of the water suppliers. They can be encouraged to take the effects of climate change into account within their plans and major deficiencies (e.g. in California, insufficient storage facilities to capture earlier melt water from the Sierra Nevada) can be addressed.

There has been a drought situation in Colorado which started in 1999, peaked in 2001-03 and has eased in recent years. Inflow into some of the reservoirs was 25% of the long term average in 2002. As a state that is very sensitive to water issues, Colorado has launched a number of initiatives to address potential droughts.

Colorado has a Drought Mitigation and Response Plan which was first created in 1981 (when it was one of only three drought plans in the US), and last revised in 2002. The Department of Local Affairs, the Division of Local Government, the Office of Emergency Management and the Department for Natural Resources were all involved. It was partially funded by the Federal Emergency Management Agency (FEMA). It involves four stages monitoring, assessment, mitigation and response and has been activated fully or partially several times over the last 25 years.

To address long term water shortages, the State wide Water Supply Initiative (SWSI) was carried out in Colorado, the conclusions of which were published in 2005. This was a long-term drought plan that aimed to explore, at a basin level, existing water supplies, projected demands up to the year 2030 and the ways in which supplies could be met. For each basin the ways in which water supplies could be met were researched and listed. This kind of long term water supply plans will be more helpful in adapting to climate change and reducing vulnerability in the long-term. However, climate change was not included as a variable which will affect water supply.

Also in 2005, as a result of the State wide Water Supply Initiative, the "Colorado Water for the 21st Century Act" (House Bill 1177) was passed into law. The act seeks to initiate a state wide discussion on how water may be managed and shared among river basins to meet future water demands (Formisano, 2005). This House Bill also guarantees that the current system of allocating water rights will not be 'superseded, abrogated, or otherwise impaired'.

5.2.3 Water supply infrastructure

Physical infrastructure, such as dams, reservoirs and drainage canals, has traditionally served as one of the most important adaptation technologies to manage water resources. There are conflicting opinions, however, on the potential of building new structures for climate change adaptation. Given the considerable environmental, economic and social costs associated with these structures, many experts support avoiding or postponing the construction of large-scale infrastructure until there is greater certainty regarding the magnitude of expected hydrological changes. Others suggest that water infrastructure improves the flexibility of management operations, and increases a system's capacity to buffer the effects of hydrological variability. For example, communities in the southern Prairies in Canada can use small-scale water infrastructure to increase water storage through snow management, and reduce regional vulnerability to drought.

"Water banks" which are storage facilities are another means to respond to temporary and longer term water shortages in the US. California presently uses them as a short term measure to respond to drought. Arizona tries to ease long-term supply reliability issues by storing excess Colorado River water underground through recharge projects.

In the western US, the water supply infrastructure has become an elaborate system in order to facilitate rapid population growth in areas where there is a limited availability of water. For example, there are 44 trans-mountain or trans-basin diversions that make use of pipes and tunnels in the state of Colorado. Some of the larger projects are owned and operated by the US Bureau of Reclamation and Denver Water. Twenty-seven of the diversions transport water from the western slope of the Rockies to the eastern slope[24]. Snow melt is collected and transported through a tunnel to the eastern side of the Continental Divide to storage reservoirs. Here it is used to supplement irrigation supplies and for municipal and industrial uses.

California has numerous water projects, the largest are the State Water Project, the Central Valley Project, the All-American Canal System and the Los Angeles aqueduct. The California State Water Project captures water from Feather River catchement in Northern California to provide 20 million Californians, through 39 public water agencies with all or part of the water they need. Water flows from Orville reservoir down Feather River where it meets the Sacramento River. The Sacramento River flows into the Sacramento – San Joaquin delta, and from here water is extracted and flows down the 444 mile-long California Aqueduct to central and Southern California, (work began in 1959 and facilities were completed between 1965 and 1975).

The Central Valley Project is operated and maintained by the Bureau of Reclamation to provide water for the fertile but semi-arid agricultural areas in the Central Valley. The system contains 22 reservoirs which can store 11 million acre feel, irrigating more than 3 million acres of farmland and providing drinking water to nearly 2 million consumers. The project started in 1937, completed in 1945. The Los Angeles aqueduct was built in 1913 to divert water from Owens River in the eastern Sierra Nevada down to Los Angeles.

Some of these projects are aging, and require a lot of investment to bring them up to standards that can cope with present day climate variability. In order to climate proof them further investment would be required.

Water infrastructure might also be affected by climate change impacts. For example, all of the New York City Department of Environmental Protection's wastewater treatment plants are located on rivers or coasts. This means that they are susceptible to damage from extreme weather events and sea level rise and flooding which in turn leads to impaired water quality.

[24] Personal Communication, Mark Haynes, Chief of Safety of Dams Program, Colorado Division of Water Resources

5.2.4 Demand-side management

Many government departments and water suppliers are taking a twin-track approach to mitigating the worsening water situation by combining hard, structural, supply-side measures with water conservation and efficiency. Demand side management can involve the installation of water meters, pricing water at its true cost and reducing water subsidies, water recycling, reducing leakage from pipes, encouraging less wasteful water use in home (e.g. fixing dripping taps, using efficient washing machines and dishwashers) and imposing water restrictions such as hosepipe bans.

Water metering is one tool that encourages efficient water use. A study using 1996 data found that in southern Ontario, residential water use in metered municipalities was 27% lower than in those that did not have meters; in northern Ontario, the difference was 37%. However, some controversy even over water metering can be expected. While in opposition the Labour Party in the UK called it a ‘tax on family life’[25]. Meters allow water companies to monitor water use and their own wastage during water supply thereby increasing water efficiency not only by the consumer but also by the supplier as well.

Water use charges are another mechanism that promotes efficient water use. It is especially effective when it is tied to the amount of consumed water. Consumers can be charged at a uniform rate where the price per cubic meter remains the same no matter how much water is used, or the rate can increase step-wise with the amount of water consumed.

There is reluctance in some areas of consumers to pay the true price for water. Many people see it as an infinite resource. Others feel it is a public good and so should not be treated like any other commodity. Without applying the true value of water to its pricing, efficient water use will be hard to encourage. Also, collected funds will be essential for much needed infrastructure improvements and capital investments. For example, in Ontario, Canada the Ministry for Public Infrastructure Renewal predicts that $34 billion will need to be invested in water-related assets over the next 15 years. $25 billion of this will be for capital renewal including $11 billion for deferred maintenance; $9 billion for growth (OMPIR, 2005).

Pricing might be a tricky issue for water providers though, even in countries where consumers pay the real price for water. If prices are set too low then infrastructure renewals and improvement can’t take place. If water prices are set too high, the consumer becomes highly critical of the water provider and questions every investment it makes.

Water efficiency alone won’t be able to solve growing discrepancy in some areas between increasing population and scarce water resources, other measures like control of housing development and city boundaries expansion will need to be introduced. For example, the town of Orangeville in Ontario, Canada, employs a Holding Bylaw to freeze approvals of new residential developments until additional water supplies are developed.

5.3 Flood management

While droughts build up over years and can be identified and mitigated as they start to develop, floods occur within days or hours. Usually only days go by between the initial detection of high river flows (caused by, for example, high rainfall, snowmelt, ice blockage), flooding and conditions returning to normal. Sometimes floods can pass within hours. Flood management is composed of two different activities: long term flood mitigation and flood response. In most areas studied these two activities are carried out by different agencies. For example in England and Wales, flood mitigation schemes (flood plain management; ‘hard’ flood defence options such as flood walls; monitoring and warning systems) are

[25] BBC News article, Wednesday, 1 March 2006, http://news.bbc.co.uk/2/hi/uk_news/england/4759960.stm

carried out by the Environment Agency but flood response is co-ordinated by the Police force and implemented by a number of different agencies.

In the UK, once a flood warning has been issued by the Environment Agency the police step in and co-ordinate the flood response. This seems to work well as long as there is constant communication between the police and the Environment Agency. This communication is facilitated by EA area offices' Incident Rooms which are activated when flood warnings are issued. With climate change in the UK, floods may become more likely especially during winter. Warnings will have to be issued more frequently, and become more effective at reaching people as flood frequency and magnitude increases. Since Flood Incident rooms already exist (these are basically operational head quarters where calls are answered, and warnings issued) there is the possibility of these becoming a more permanent feature as flood risk increases, at least throughout the winter months when rainfall is expected to increase the most.

In the USA and Canada local authorities are responsible for the first flood response, i.e. municipalities, levee maintaining authorities. When flooding overwhelms local authority resources, state departments step in to provide technical assistance. In the US, the Army Corps of Engineers can be requested for emergency assistance. Monitoring is usually provided by the United States Geological Survey and state governments. In Ontario, Canada, Conservation Authorities (agencies representing a group of municipalities on a watershed basis) are also responsible for flood warning.

In the US flood response is carried out under an Incident Command System required by the Federal Emergency Management Agency (FEMA) which is used for all types of disasters. In order for states to receive assistance from FEMA in disaster management they have to comply with National Incident Management System (NIMS) regulations. This involves having a standardized emergency response that is followed during a flood. The creation of these plans is usually carried out by the state/city's Office of Emergency Management or Office of Emergency Services.

Many long term flood mitigation actions in the US are federally funded through the National Flood Insurance Program and Flood Hazard Mapping Programme and carried out in co-operation with state agencies. The National Flood Insurance Program encourages people to take out flood insurance, and the Flood Hazard Mapping Programme supplies funding to keep floodplain maps up-to-date and accessible. Once floodplains are designated, developments within them have to be built to the 1-in-100 year flood standards and in certain areas directly adjacent to the river new builds are prohibited.

In California, local levee maintaining agencies are responsible for ensuring the levees are kept to the required standard to prevent flooding. This makes adaptation difficult since adaptation will require increasing the height of the levees to withstand sea-level rise, which will in turn cost money. Many of the levees are already under maintained, and local residents who are taxed to provide financial resources for levee maintenance are not interested in investing more money into this infrastructure. Convincing and powerful information on future climate change impacts on local level will be important to facilitate positive responses from local authorities and residents.

Those with the responsibility of protecting the population from floods need to have comprehensive powers to do so. For example, the Department of Water Resources in California needs to be able to force levee maintaining authorities to improve their levees; the Environment Agency needs the ability to prohibit further building on flood plains.

6. Information and Tools

Water management policy makers and practitioners need a whole range of information in order to make decisions on how to best use the infrastructure and alter management patterns to ensure reliable water supplies throughout the year. Decisions are based on patterns in precipitation, groundwater level, river flows, river levels and reservoir levels collected through an extensive monitoring network. Present values are compared to the historical average for the time of year to determine the state of water resources. Different areas have different hydrological regimes and available infrastructure so the parameters will not be equally significant in predicting future water conditions everywhere. Precipitation pattern is the most important indicator of potential drought. Flood detection requires the monitoring network to provide real-time flow data at least in key locations. Reservoirs are very important for both, alleviating droughts and mitigating floods.

Historically, decisions on capacity of new infrastructure and long term planning are made using past climate extremes. For example, drought plans are usually based on the worst drought conditions observed in the last 50-100 years. Floods tend to be prepared for on a probability basis. Generally, infrastructure such as flood walls, levees, sewers are built to withstand a particular intensity of floods. For example, most infrastructure in England is designed to endure the 1-in-100 year flood which means the flood that has a 1% chance of occurring in any year.

Recently, however, the magnitude-frequency relationship of flooding has been changing, at least in the UK, and the 1% chance flood is occurring more often than expected. This requires flood probability to be reassessed in the face of climate change. The infrastructure investment decisions have a very long lifespan. For example, most of the UK still relies on the sewer systems that were constructed in Victorian times. Water managers within municipalities, private water utility companies, irrigation districts and government departments need reliable information on future climate conditions and societal needs in order to make right choices for their investment.

This raises several issues. What kind of information on future climate and society is needed to help decision-makers make the right decisions for the future? And what kinds of risk management tools can be used to improve the confidence in these decisions given inherit uncertainty in any long-term predictions?

Another issue is how to deliver the right information to the right people. As discussed in Section 3, there are numerous key players from levee managers and licenses administrators to high level decision-makers who make daily decisions that affect water resources management. These big and small decisions collectively contribute to the resilience or vulnerability of water resources to climate change. The flow of the right information to the right people at the right time is the key to successful adaptation in the water sector.

6.1 Scientific capacity

The OECD countries in general have a high capacity to generate current weather information and scientific climate change information. For example, the UK Hadley Centre for Climate Prediction and Research produces world class climate models and is directly funded by the central government. This centre provides ‘a focus in the United Kingdom for the scientific issues associated with climate change’. It generates climate change projections using coupled atmosphere-ocean general circulation model (HadCM2 and HadCM3). These projections have been used worldwide to assess the impacts of climate change on a global level. The Hadley Centre has also developed a regional scale model-PRECIS (Providing regional Climates for Impacts Studies) that can be applied regionally and generate detailed climate change projections on a regional scale.

In addition to national level scientific institutions, there are international resources that are available to the OECD countries. For example, World Meteorological Organization produces a wide range of scientific tools to address various scientific needs of climate research from global data to high accuracy short-term weather forecasts to global climate models. The World Bank, the IEA and others produce models that project population growth, economic growth, and energy demand.

The main challenge is to adjust global models to regional and local conditions that are the most relevant for policy and management decisions. It is generally recognized that there is a need for models at the country, region, and provincial level. There is often a gap between available scientific information and tools and their actual use by policy-makers and water managers. Very often scientific information rests within scientific circles and does not reach potential users. There is a need for a continuous dialogue between scientific and policy communities so that policy-makers can communicate their needs to scientists, and scientists can explain their findings to the policy-makers.

6.2 Monitoring systems

Monitoring systems are powerful tools for water managers in water rights administration, drought prediction, flood detection, prevention of environmental damage and ensuring that water resources are used sustainably. River flow, river level, reservoir level, groundwater level can all be monitored and either automatically through telemetry, which allows the automatic measurement and transmission of data, usually using the telephone system, or by staff going out and taking measurements in the field.

Surface water monitoring systems are usually more extensive than groundwater systems but there is a shift towards more careful management of groundwater resources. For example, Ontario has recently invested $6 million over three years in a Provincial Groundwater Monitoring Program to increase the quality and extent of groundwater monitoring in the province.

Monitoring comes under the responsibility of a variety of different government and quasi-government agencies. Many systems are operated and funded by partnerships, for example, in Ontario Conservation Authorities and the Ministry of Natural Resources. In the US the USGS operates 7 300 stream gauges with funding from USGS, other federal agencies and 800 State and local funding partners. In the UK water monitoring is the responsibility of the Environment Agency.

An advanced water monitoring system is essential for early detection of changing meteorological and hydrological conditions and instrumental for the development of short-term response measures. Monitoring also generates important entry data for modelling that adaptation strategies rely on. Monitoring of water consumption is less developed compared to the monitoring of natural systems. It should be recognised as another important component for the development of more accurate regional models and adaptation strategies. For example, due to severe drought conditions in the southeast of England in early 2006, drought measures such as bans on hosepipes have been introduced in several municipalities. Water utility companies that provide water for these areas have applied and been granted permission from the government to mandate the installation of 65 000 water meters in the homes of their customers. This will encourage efficient water use and will cut future demand. This measure can also allow for more accurate planning for future summer demand. Precipitation and reservoir level monitoring allows water suppliers to assess the water availability. When water becomes scarce, accurate monitoring data will allow for accurate balancing of water supply and demand.

6.3 Mechanisms or tools in place to translate available information for policy-makers

Information needs to be delivered in the right form and at the right time for it to be useful. Raw river level data is no use to a water management decision maker – he or she needs trends and comparisons with averages and information on climate extremes. Climate predictions, if not explained correctly, can seem to contradict each other and conclusions can be hard to draw from a mass of probabilities and percentages. Therefore, for adaptation to take place there needs to be mechanisms in place for scientific information to be translated into a form relevant to water managers and policy makers. In the Annex I countries examined for this study, these mechanisms seem to be present. Many universities and research institutions present their findings in special summary reports that are tailored to policy-makers. Also, government agencies include specific requirements on how the research results should be presented in their funding criteria for various research programmes. Sometimes special programmes are set up to act as a bridge between scientists and stakeholders.

For example, the New York City Department of Environmental Protection (NYCDEP) in collaboration with Columbia University and the Goddard Institute for Space Sciences formed a Climate Change Task Force to 'ensure that NYCDEP's strategic and capital planning efficiently takes into account the potential risks posed by climate change-sea level rise, higher temperature, increase in extreme events, and changing precipitation patterns - on the City's water supply and wastewater treatment systems'[26]. Collaborations such as this can be very effective because not only is the research institute conveying its findings in a way that is comprehensible to the government but it can tailor its research needs to specific tasks/needs of policy makers.

Some research institutes have begun to tailor their research towards decision support for water managers. For example, Colorado Water Resources Research Institute (which is a federally funded National Institute for Water Resources based at Colorado State University) participates in an ongoing dialogue with water managers, legislators and state government agencies with interests in water to allow information on current topics of interest to be transmitted and received. In fact, due to the unique water resources situation in Colorado (limited water resources, rapidly increasing population, mismatches between population and water resources, interstate compacts on major rivers) there is a large amount of literature especially aimed at the non-scientific community and water managers.

California Climate Change Center – especially Researchers at University of California at Berkeley are studying how climate change could affect the state's economy through impacts on natural and engineered water systems. Planned work includes: constructing a California water supply database; assessing water available to various users (especially agriculture) and characterizing the water rights and claims of these groups; developing water supply reliability indices; analyzing the relationship between water price, availability, and agricultural production and developing marginal benefit functions for water reliability.

The UK Climate Impacts Programme (UKCIP) translates Hadley Centre climate predictions into a digestible form and uses a similar stakeholder-lead approach to disseminate information regarding adaptation across all sectors in the UK. Stakeholders or partners commission the research or set out the research agenda. It is based at the University of Oxford. UKCIP provides a link between researchers and decision makers in government and business. All the major water providers in the UK are stakeholders in this organisation and so have a general awareness of the need to incorporate climate change into strategic planning.

[26] Personal communication Kate Demong, NYC Department of Environmental Protection

Small regional governments and municipalities might not be able to afford this type of collaboration and may not have resources to fund specific research programs. In such cases, national and regional governments, as well as large municipalities, may need to develop mechanisms to share results and disseminate information.

7. Conclusions

Adaptation to climate variability and extreme weather events is constantly occurring in the water sector. Necessary adjustments to changing conditions are being made in the water infrastructure, water management practices, institutional arrangements, in the legislation and international agreements on shared water bodies. However, long-term climate change is generally not yet a significant factor in the management of water resources in the four countries (Canada, Finland, the United Kingdom and the United States) considered in this study. There are some examples of initiatives that are being introduced by national and sub-national governments to build adaptation to climate change into decision making. A number of factors, including aversion to risk, uncertainty of climate projections, lack of information and inadequate guidance, affect the degree to which adaptation is currently being factored into water management decisions. Nevertheless, countries can learn a great deal from each other about what currently works and what may be needed to manage water resources as the climate changes.

All four countries have water policy frameworks, which to different extents, can help them in adapting to climate change. These water policy frameworks, which can be enhanced for adaptation to climate change, differ from country to country, but include the following common elements:

- A system of laws (legal frameworks) that stipulate rights and responsibilities of different levels of government and private entities. These may include, for example, a system of water rights and abstraction permits;
- A variety of national, regional and sub-national institutions that are responsible for developing policies and overseeing their implementation;
- A set of policies that guide the implementation of national, state and provincial laws;
- Clearly defined roles for the key players, including government ministries, departments, water suppliers, regulators and other local authorities;
- Physical water infrastructure, that is dams, levees, reservoirs and sewerage systems that are capable of managing the flow and distribution of water;
- A set of water management plans (long-term strategic plans, drought plans and flood plans) with flexibility to anticipate and respond to climate changes;
- Scientific data, monitoring systems, information and forecasts on social and natural systems, and mechanisms for information exchange and dissemination.

The way these elements are set up and function may facilitate or complicate adaptation to climate change in the water sector.

The study identified two distinct systems of ***water rights***. A riparian system, by which the right for the water is attached to the adjacent land, and a system of prior appropriation, where anyone can appropriate water without having an access to the land, based on a “first come, first served” basis, as in the western states of the US. Neither system is ideal for adaptation and will have to incorporate flexibility when water resources become scarce. Riparian water rights protect the water from being removed from its watershed and might be an important tool in case of drought. However, if drought occurs elsewhere, it may not be possible to transfer/transport water under this system. Prior appropriation systems also have drawbacks for adaptation. In case of water conflicts, users with an earlier appropriated water right have priority, which means that there will be users who will be left without water during a severe shortage. In some places where there is a risk of water conflicts, some innovative measure have been put in place to build some flexibility into these rigid systems (e.g., water rights trading is allowed in the UK and other countries, and in the western US, ‘water banks’ in the US).

The current trend among OECD countries to introduce ***licensing system for surface and ground water abstraction*** is favourable for adaptation. Water permits can include information on the amount, timing, purposes and period of water abstractions or withdrawals. Such permits allow the government to have control and oversight over water resources. Permits provisions can anticipate how water shortages will be addressed should they occur. In some countries, however, water abstraction permits are not universally required in order to take water (e.g., in the US State of New York, Scotland and Northern Ireland[27]). In general, abstraction permits are not required in areas where water is plentiful and water conflicts are unlikely. Groundwater in general is less regulated than surface water. In many US states and OECD countries groundwater permits are not yet required. However, when problems with groundwater are detected or anticipated there are often initiatives by the governments to control ground water. For example, in California, where land is subsiding due to over-abstraction of groundwater, permits are required for groundwater abstraction.

There are ***numerous stakeholders*** who are involved in water sector management and who should be key players in adaptation planning:

- National, regional and local level policy-makers and managers;
- Water companies;
- Irrigation practitioners;
- Water infrastructure engineers, owners and operators;
- Land planners;
- Scientists; and
- Officials in related sectors like agriculture, electric power production, and fisheries.

A stakeholder processes should be seen as an integral component of adaptation policy development.

The ***institutional frameworks*** of each country will influence the adaptation process in the water sector. In countries with a more centralised way of governance, more responsibility will lie with the central government for long-term strategic planning, creation of formal channels for information flow, providing an adequate level of budget funding, and for making sure that regional and local priorities are incorporated into national plans. Decentralised governance allows for more flexibility and encourages innovative solutions tailored to the local needs and situations but might lack consistency in approaches across the country. Differences in approaches at the sub-national level might become an obstacle to adaptation when a water body is shared among several regions. To counter this risk, national governments may need to encourage or create processes to anticipate and settle disputes. Both types of institutional arrangements will need to be adjusted to cope better with climate change. However, access to climate change information seems to be an essential, if either arrangement is to function properly.

Water infrastructure plays a critical role in water resources management. Dams, levees, reservoirs and drainage systems are the key flood prevention techniques. If this infrastructure is at a high standard and its inherent resistance matches expected intensity of floods and droughts, it can perform well and will be better prepared to cope with future climate risks. Since infrastructure decisions have long-term implications, it is important that these decisions are made with all the relevant information at hand, including the most accurate regional projections of temperature and precipitation. In a few instances, for example, analyses of options for the updates of the Thames river defences, climate change information is being factored into infrastructure decisions.

[27] To comply with the EC Water Framework Directive Scotland and Northern Ireland will introduce water abstraction licenses in 2006.

There are several types of ***water management plans*** that play an important role in guiding the process of water supply and management. There are long-term strategic plans, drought plans and flood plans. Long-term strategic plans usually look 10-20 years into the future. Generally, these plans do not consider climate change. For example, the EC Water Framework Directive requires that river based water management plans be developed for all major river basins in the EU. These plans are currently under development and will guide water management in the EU for the next 15 years, yet climate change is not a factor that needs to be incorporated.

Drought plans are important in some areas since they provide mechanisms to address near-term water shortages. Drought plans, as well as water management plans, can also identify the long-term demand for water and water sources. Further advancing this tool could be important for adaptation. For example, current drought plans could be extended into adaptation plans by incorporating measures for extended droughts outside historical norms. This would allow steps to be taken now to mitigate problems through infrastructure or policy changes over the next few decades. Similarly, long term ***flood mitigation plans*** can play an important role in adaptation through the designation of floodplains, ensuring that flood defences such as levees are up to standard and making sure that flood prevention occurs in an integrated manner.

Adaptation to climate change in the water sector also needs to rely on robust ***water policies*** that promote efficient water use, encourage technological development in the water sector and provide for flexibility in dealing with water rights and abstraction permits. Water needs to be recognised as an economic good that has a cost. Many OECD countries are incorporating fiscal policies into water abstraction. Some countries utilize a unified rate that covers the administrative cost of issuing permits, while others have more sophisticated systems that depend on the amount of abstracted water, water quality and time of abstraction. These innovations facilitate adaptation by sending the right signals to water suppliers and consumers. Water metering is another significant tool that can facilitate adaptation. It helps to detect leakages and enhances efficient water use. In countries, where water shortages occur frequently due to mismatch between locations of abundant water and dense population, governments allow for various forms of water rights trading. This policy tool offers flexibility and will also be important for adaptation. Finally, policies relating to other sectors like land use planning and agriculture are important for the adaptation in water sector. Leaving floodplains free of development facilitates adaptation to floods. Land-use policies that discourage development on flood plains will facilitate adaptation. International agreements on shared water bodies will be an important component of adaptation.

The availability of relevant ***information***, and the ***tools*** to interpret, disseminate and use this information, are imperative for successful adaptation. Adaptation to climate change in the water sector will rely on scientific data on current and expected hydrological and meteorological conditions; current and predicted status of water bodies; and social factors that will influence water demand in the future. These can only be developed through extensive and consistent monitoring, and modelling. For these data to be useful for policy makers, they need to be presented in the right format and at the right time. Collaborations between water suppliers/managers and decision makers and research institutions will be key in guaranteeing that the required information is obtained. Risk assessment and management tools can be further enhanced to assist policy makers in making decisions for the future with some confidence given the uncertainty inherent in any modelling and long-term forecasts. Uncertainty and probability need to be clearly explained for policy makers. Water resources management depends on numerous decisions that are made at different administrative levels, it is important that relevant information reaches all levels of government and stakeholders. Development of formal channels and clear mechanisms for information dissemination, including guidance on how this information should be used, will be vital for adaptation to climate change.

8. Glossary

1-in-100 year flood	A flood which has a 1 percent chance of being equalled or exceeded in any year.
Abstraction	The removal of water from any source, either permanently or temporarily[28].
Abstraction license	Authorisation granted by the relevant government agency to allow the removal of water from a source[28].
Acre-foot	One acre-foot is the volume of water sufficient to cover an acre of land to a depth of one foot (1 233.48184 m^3).
Aquifer	A geological formation, group of formations or part of a formation that can store and transmit water in significant quantities[28].
Borehole	Well sunk into a water-bearing rock from which water will be pumped[28].
Catchment	The area from which precipitation and groundwater will collect and contribute to the flow of a specific river[28].
Groundwater	Water beneath the earth's surface in underground rock layers; can be within large cracks and openings in the rock layers or in inter-connected spaces between individual rock grains. Water within the saturated zone of an aquifer[28].
Irrigation district	A district formed by landowners to pay for the diversion and delivery of water to their land.
Levee	A barrier constructed to contain the flow of water or to keep out the sea. Usually earthen embankments that give flood protection from seasonal high water for a few days or weeks of a year.
Policy framework	International and domestic legislation, institutional landscape, water management policies and instruments and information that together provide a basis for water management decisions and practices.
Appropriative right	The right to divert, store and use water regardless of whether the land on which it is used is adjacent to a stream or within its watershed. The rule of priority between appropriators is “first in time is first in right”.
Riparian right	The right to divert, but not store, a portion of the natural flow for use based on the ownership of property adjacent to a natural watercourse.
Water project	Large infrastructure developments that transport water from the source to where it is required.
Water resources	A country’s usable surface water and groundwater.
Water supplier	A public or private body that supplies clean water to households, industry, agriculture etc.

[28] UK Environment Agency, 2001

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