THE WATER RESOURCES OF JERSEY:

AN OVERVIEW

Report prepared by the British Geological Survey
for the Public Services Committee,
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Serving the Island

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The views represented in this report reflect those of the principal author and are not necessarily upheld by any Committee within the States of Jersey. The British Geological Survey and WRc maintain impartiality.

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SUMMARY

- The groundwater and surface waters of Jersey together form a single interactive water body which is sourced by rainfall over the Island.
- The water body is currently stressed by a number of factors which constrain the volumes of water available for consumption and the quality of that water.
- All the surface and groundwater on Jersey is vulnerable to pollution from both point source (spills, leaking septic tanks etc.) and diffuse (nitrate fertilizer, pesticides) forms of pollution.
- There have been a number of serious pollution incidents in recent years.
- Careful management of the water body should ensure sufficient volumes of water are available on Jersey to sustain the Island community. The required management machinery is only partly in place and enabling legislation will be required to manage the resource or volume aspects of the water body.
- The new Water Pollution (Jersey) Law 2000 is a welcome component to the toolbox available for managing the water body.
- The Jersey New Waterworks Company maintains the public water supply in a commendable manner. The Queen's Valley Reservoir is a major asset.
- The water undertaking is constrained by raw water quality issues but it has no control over the protection of its sources.
- The States of Jersey should be working collectively towards enhancing the environment of Jersey for the benefit of its people. There may be a need for a single agency for the environment.
- Current interest in chlorthal and nitrate in Jersey waters is stimulating a keen interest in the aqueous environment. Neither compound may be damaging to health at present concentrations, but their presence is, nevertheless, of concern.

INTRODUCTION

Background

Whilst several technical reports have been prepared on the water resources of Jersey there is a need for an easily understood overview document. This report aims to provide that overview.

Domestic demand for potable water on Jersey increases with demographic growth and with increased standard of living. The 1996 Census reported a population of 85 150 compared with 76 000 fifteen years earlier. Much of the population lives along the south coast of the Island, but there is also a widespread distribution of rural dwellings across the Island. Water demand for agriculture and horticulture remains buoyant, although if the market for early potatoes declines, it will reduce water requirements in the early spring. Demand for irrigation water for leisure purposes is, if anything, increasing with time, whereas industrial consumption appears to be remaining steady.

The States has recently enacted legislation to control pollution. In addition, with the Queen's Valley Reservoir in commission, Jersey experienced no difficulty with public water supply shortfall in 1996 (unlike neighbouring Guernsey), although Jersey had previously suffered in the 1989 to 1992 'drought' before the Queen's Valley project came on line.

The water resource is, however, a finite body which is very sensitive and highly responsive to change. The water body is currently responding to number of separate external influences. These are:

- the diffuse loading of nutrients, principally nitrate and phosphorous, coupled with the residues from a variety of pesticide applications and their *metabolites*[1];
- isolated, but significant, point source pollution incidents;
- regular, but generally small pollution incidents;
- changing trends in land use;
- climate change.

As a consequence, Jersey has some of the highest concentrations of nitrate found in natural waters anywhere in the British Isles, and is also facing a dilemma over how to deal with the organic metabolite Chlorthal.

Management

Management of the Island's water resource falls largely at the door of the Public Services Committee. Currently, however, the Harbours and Airports Committee, Health & Social Services Committee and the Agriculture and Fisheries Committee are also involved. The Jersey New Waterworks Company, which is majority States owned, is powerless to take matters such as catchment land-use control into its own hands despite the provisions of the Water (Jersey) Law 1972. Matters which should attract the attention of the States (such as the Nitrates and Pesticides Working Party Report), have not done so in the past. However, the formation of a Water Resources Steering Group in 1999 involving several Committees and the Water Company, will hopefully achieve better direction. At the same time, public interest in environmental issues on the Island is increasing, the local media are beginning to give a higher profile to environmental news than has been the case in the past, and there is growing political will to manage the water resource as a whole.

TOPOGRAPHY AND CLIMATE

The Island

Jersey, the largest of the Channel Island Group has a land area of 117 km^2. The Island comprises a plateau which lies at an elevation of between 60 and 120 m and which is divided by a series of north-south valleys which cut deeply into the land. The valleys drain towards the south from the higher land in the north. They are from west to east: St Peter, St Lawrence (Waterworks Valley), Les Grands Vaux and Queen's.

The northern coast is cliff-lined, whereas the eastern and western coasts include large tracts of low-lying sandy bays. The south coast is dominated by St Aubin's Bay, but there are cliff-lined

[1] Technical terms are shown in italics when first introduced, and are defined in the Glossary at the back of the report.

bays to the west and a low lying rocky foreshore to the east. The spring tides range in height up to 12 m.

The Climate

Prevailing winds are from the west and south-west bringing moisture from the Atlantic. Occasional north-easterly winds blow in from continental Europe and these are generally dry. The average long term annual Island-wide rainfall is 877 mm but there is significantly less rainfall over the west and south-west of the Island than in the east. Actual annual rainfall may vary considerably from the long term mean, as little as 600 mm in 1991/1992 to over 1 100 mm in 1994/1995. Mean annual *potential evapotranspiration* ranges between 648 and 754 mm.

GEOLOGY

Bedrock

Most of the bedrock beneath Jersey consists of ancient metamorphosed rocks of Precambrian age including shales and volcanic rocks, which have been intruded by granites and other igneous material. The extreme north-east corner of the Island has younger, although still very old, rocks of Cambro-Ordovician age which form the distinct conglomerate seen in the cliffs around Rozel Bay and Fliquet Bay. There is a distinctly oriented structural trend in the rocks which follows an east-north-east direction, and this creates lines of relative weakness in the rock.

Superficial Deposits

The bedrock is partly covered by young unconsolidated deposits of Quaternary age. These include raised beach material, head, or valley side rubbley material, and loess which was blown onto the Island during the Ice Age when the muddy floor of the English Channel was exposed to the elements. Post-glacial deposits of peat, alluvium and blown sand are also present in valleys and low-lying coastal areas.

THE WATER RESOURCE

Surface and Groundwater

The fresh water reserves available on Jersey are replenished by direct rainfall on the Island. Part of the rain that falls on the ground returns to the atmosphere directly through the loss of water through the transpiration of plants, and evaporation from the soil (*evapotranspiration*). The remainder is termed the *effective rainfall*, and this is divided between a component which runs off the land into the streams, called *run-off*, and a component which infiltrates through the soil to the *water table* to become *groundwater* (Figure 1). The effective rainfall replenishes the water resource so that run-off goes to the surface waters and infiltration to groundwater. Together, surface water and groundwater create the water resource, a single dynamic body of water in which surface water interacts with groundwater and groundwater with surface water.

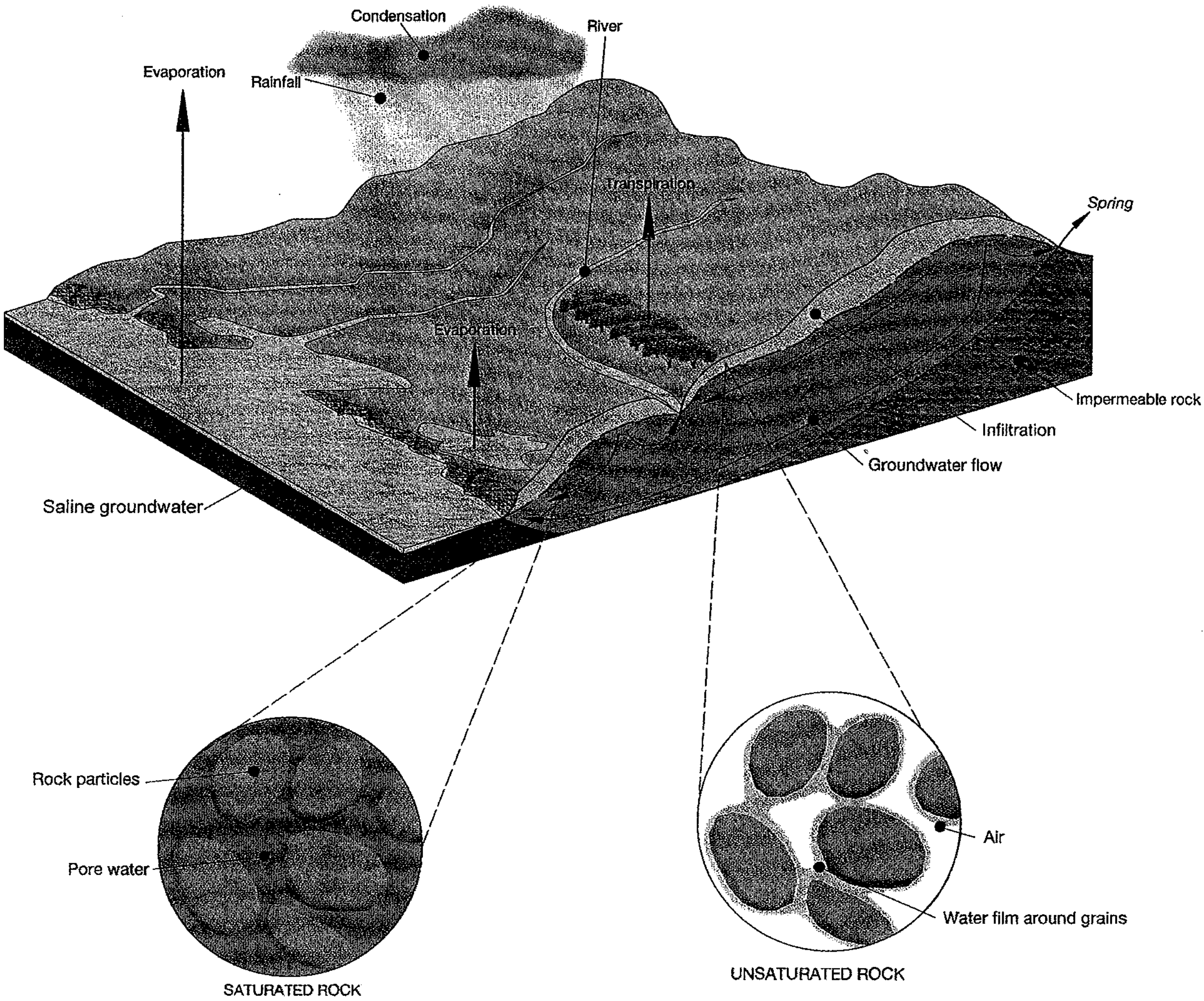

FIGURE 1 *Groundwater in the hydrological cycle*

Part of the rainfall returns to the atmosphere through evaporation and transpiration by plants, and part flows over the ground. The remainder infiltrates aquifers and replenishes groundwater storage. Groundwater flows through aquifers to outlets in rivers, at springs and in the sea. Springs occur where the water table intersects the ground surface, as in valleys and along coastlines, and where water overflows from an aquifer where it overlies a less permeable rock.

(after Groundwater Forum, 1998)

Transport of surface water and of groundwater is affected by gravity. Streams flow down valleys. They may be impounded by a dam to form a water store or *reservoir*. Ultimately, residual flow will reach the sea and discharge into it. Each stream drains a discrete *catchment* which is bounded by a watershed or a boundary between it and an adjacent catchment. The volume of stream flow is a function of recent effective rainfall and the catchment area as well as the degree to which water can infiltrate to groundwater. Infiltration moves vertically downwards through the soil zone and the *unsaturated zone* of the *aquifer* until it reaches the water table. The direction and speed of groundwater flow depends on the prevailing slope of the water table (the *hydraulic gradient*) and the ability of the rock to allow water to pass through it (*the hydraulic conductivity*).

The Island-Wide Water Body

The overall Island-wide water body is replenished by rainfall so that a continual flow of water takes place towards the coast both above and below ground. Rainfall distribution varies across Jersey in response to the prevailing moisture laden westerly winds (Figure 2). Rainfall is essentially seasonal in the Channel Islands, with the bulk of the rain falling between October and March (Figure 3). Run-off takes place directly in response to rainfall, and as the soil dries out in the spring, further runoff is likely to take place throughout the summer until the onset of the autumn rains.

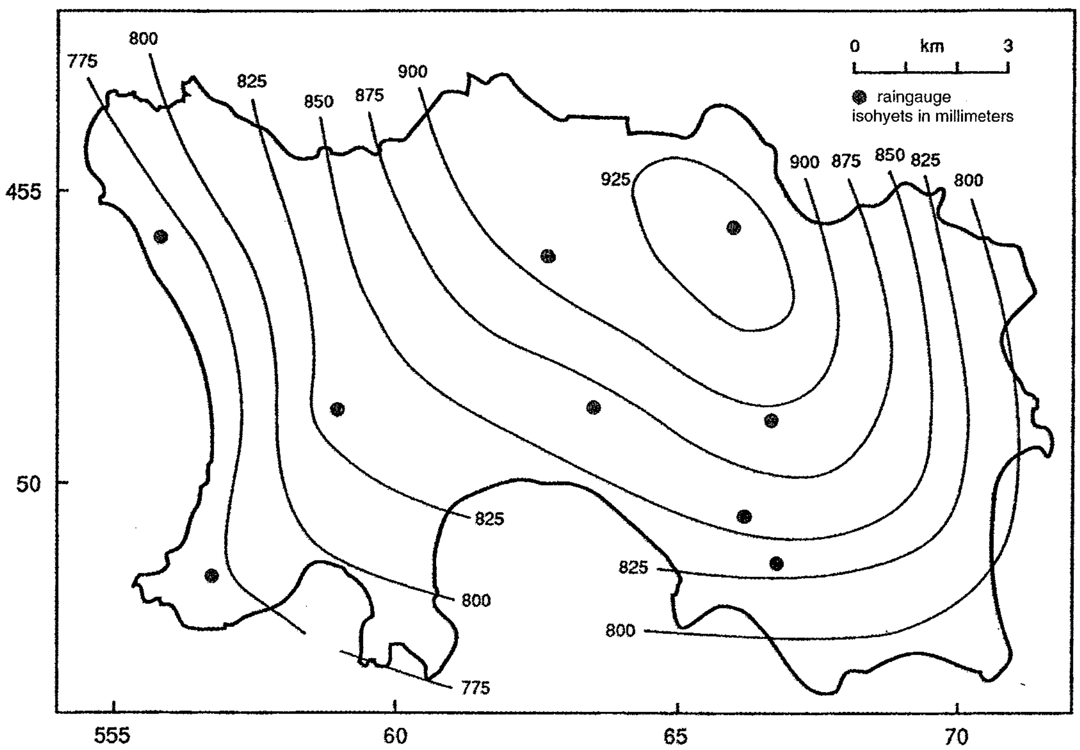

FIGURE 2 *Average annual rainfall (1961-1990)*

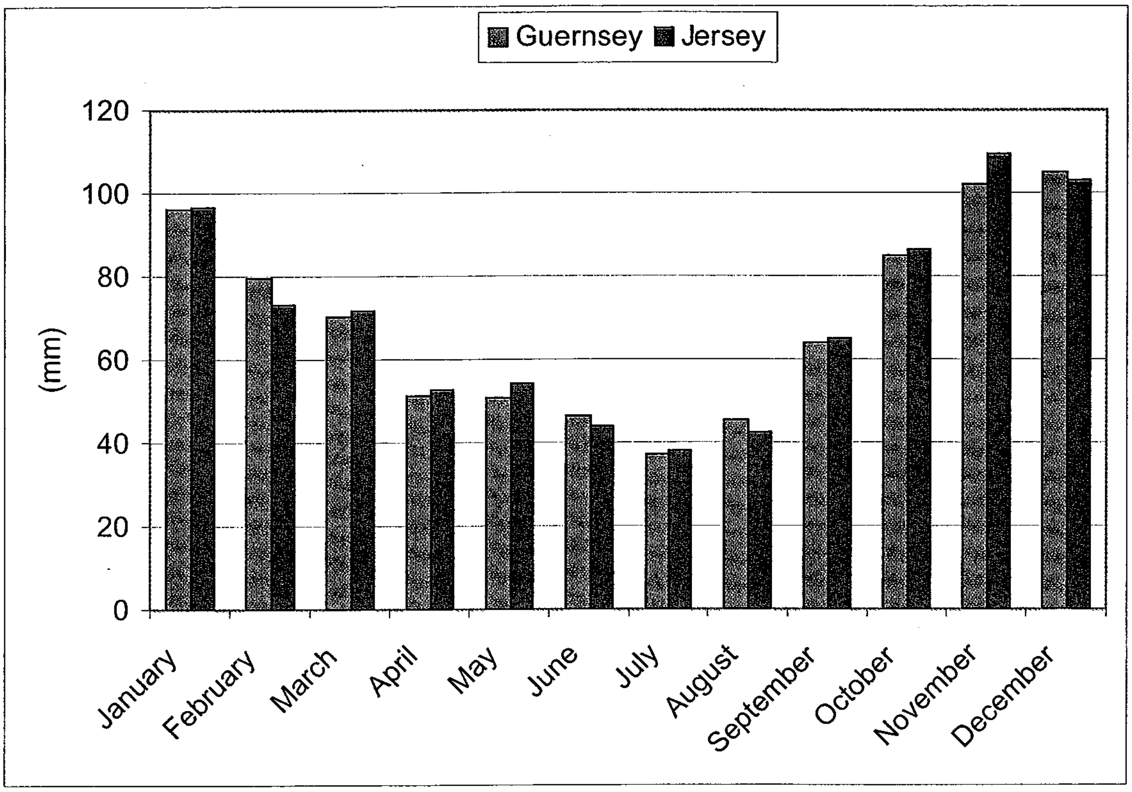

FIGURE 3 *Channel Islands mean monthly rainfall distribution*

In the meantime the groundwater store discharges through springs and as seepages directly to valley bottoms to maintain the *low-flow* in the streams. This flow is called groundwater *baseflow*, and it normally occurs throughout the year. It is greatest when the water table is highest, and it declines slowly as the water table falls in response to baseflow discharge and direct abstraction from the groundwater store. If the winter rains should largely fail (e.g. during the period 1989 to 1992) then groundwater baseflow may cease to occur in some catchments and streams dry up. As the water table falls further, shallow boreholes and boreholes in elevated coastal areas in the north of the Island begin to dry up. Under normal conditions, stream flow amounts to run-off plus baseflow.

Groundwater not only discharges to the streams as baseflow but it also discharges directly to the sea along the coast. Much of the water flowing out onto St Aubin's beach at low tide is brackish and this represents a mixture of groundwater and residual sea water contained in the sands. A positive hydraulic gradient towards the coast (the water table slopes seawards) is essential in order to stop sea water flowing inland into the aquifer. The water table beneath the central part of the Island may decline during prolonged dry weather to such an extent that *sea water intrusion* may occur on a local basis. This has happened in the low-lying coastal parts of Grouville and adjacent to the central area of St Aubin's Bay whenever local boreholes are pumped heavily in summer.

The Renewable Water Resource

The surface water/groundwater body is a dynamic system which responds to input from rainfall and which discharges ultimately to the sea. It is also a vital resource for the Island, being the sole source of potable water. Exploitation of the surface water resource is by means of impounding reservoirs and a complex system of pumping via a network of raw water mains which ensure that any fresh water stream discharge to the sea may be collected and sent to the reservoirs for storage. Exploitation of the groundwater store is by pumping from boreholes and water gathered from spring sources. The only additional fresh water available on Jersey is collected from roof-tops (particularly glass house roofs) and small scale rainwater harvesting schemes (also used by the horticultural industry). In addition, weakly mineralised water is produced by the Jersey New Waterworks Company from the new desalination plant. However, these volumes are relatively small compared to the overall resource.

A great deal of effort has been made in recent years to quantify the *renewable water resource.* This is done both as a long term annual water budget and by consideration of relatively dry winters and groups of dry winters (e.g. late 1980s, early 1990s). This is particularly pertinent in the light of climate change and the unpredictability of weather systems. Indeed, Guernsey has observed a 10 % reduction in rainfall since the 1940s (Robins et al, 2000).

The Water Budget – Instrumented Catchment Study

Early work on the water budget was carried out within off-Island consultancy projects reviewing surface water availability (Hawksley, 1976; Watson Hawksley, 1986). These studies significantly underestimated groundwater recharge and overestimated run-off. It was only during the 1990s that funding became available to actually measure the water balance in an *instrumented catchment* that a better picture of the long-term resource potential was forthcoming. This work was carried out for the Public Services Department by the Institute of Hydrology (Blackie et al, 1996) as part of a longer term study of the groundwater resources undertaken by the British Geological Survey (Robins and Smedley, 1999).

The instrumented catchment was situated above the Grands Vaux Reservoir in Trinity. The catchment area represented just over 5% of the total land area of Jersey. During the three years of study the annual rainfall was 1205 mm, 1361 mm and 776 mm against the long-term average for Howard Davis Farm at the centre of the instrumented catchment of 849 mm. Statistical baseflow separation of the stream flow coming out of the catchment indicated that nearly two thirds of the stream flow derived from groundwater baseflow. This ratio is called the baseflow index, i.e. the upper Trinity catchment has a baseflow index of 0.66. Further detailed analysis of data from weather stations, steam flow and groundwater level and soil moisture profile data in the instrumented catchment, provided the calibration for a predictive model. The model was used to determine the *water balance* for any given year for the 25 year period prior to the start of the study. These were extrapolated to create an Island-wide estimate of rainfall and groundwater infiltration according to the rainfall and land-use distribution (Table 1).

TABLE 1 *Estimated island-wide water balance (mm equivalent depth of water) from 1968 to 1996 (after Blackie et al, 1996)*

Year	Rainfall	Actual Evapotranspiration	Stream-flow	Base Flow Index	Infiltration
1968/69	818	644	154	0.45	89
1969/70	874	662	200	0.51	104
1970/71	748	633	143	0.50	60
1971/72	708	595	122	0.38	33
1972/73	723	602	150	0.48	50
1973/74	763	626	103	0.28	60
1974/75	995	664	272	0.62	184
1975/76	617	624	105	0.46	0
1976/77	827	459	270	0.61	235
1977/78	1026	669	315	0.63	197
1978/79	838	605	258	0.60	157
1979/80	1007	670	307	0.63	191
1980/81	929	641	305	0.64	196
1981/82	996	586	447	0.73	328
1982/83	1034	668	369	0.67	246
1983/84	886	640	237	0.59	136
1984/85	833	595	225	0.56	127
1985/86	783	653	147	0.47	69
1986/87	877	621	275	0.64	179
1987/88	964	658	259	0.59	149
1988/89	704	628	143	0.46	54
1989/90	641	553	117	0.39	18
1990/91	645	569	79	0.19	11
1991/92	607	587	60	0.08	0
1992/93	944	639	233	0.55	181
1993/94	1015	596	385	0.67	300
1994/95	1166	615	539	0.72	389
1995/96	668	597	133	0.44	25
Mean	*884*	*618*	*227*	*0.58*	*130*

The Island-Wide Water Budget

For this period the Island-wide mean annual rainfall was 884 mm of which 227 mm was stream-flow (run-off plus baseflow) and 130 mm was infiltration to groundwater. The groundwater baseflow component of the stream flow or run-off is given by run-off multiplied by BFI or 0.58 x 227 which amounts to 132 mm, and accounts for the groundwater infiltration. There is a notable variation in run-off and infiltration from year to year. Poor winter rains had a marked effect on values for the notorious dry years 1975/76, and the periods 1989 to 1992 and 1995/96. These dry years are significant as it is these years of water stress that the Island needs to be able to cope with in terms of surface water storage capacity and conjunctive abstraction of groundwater.

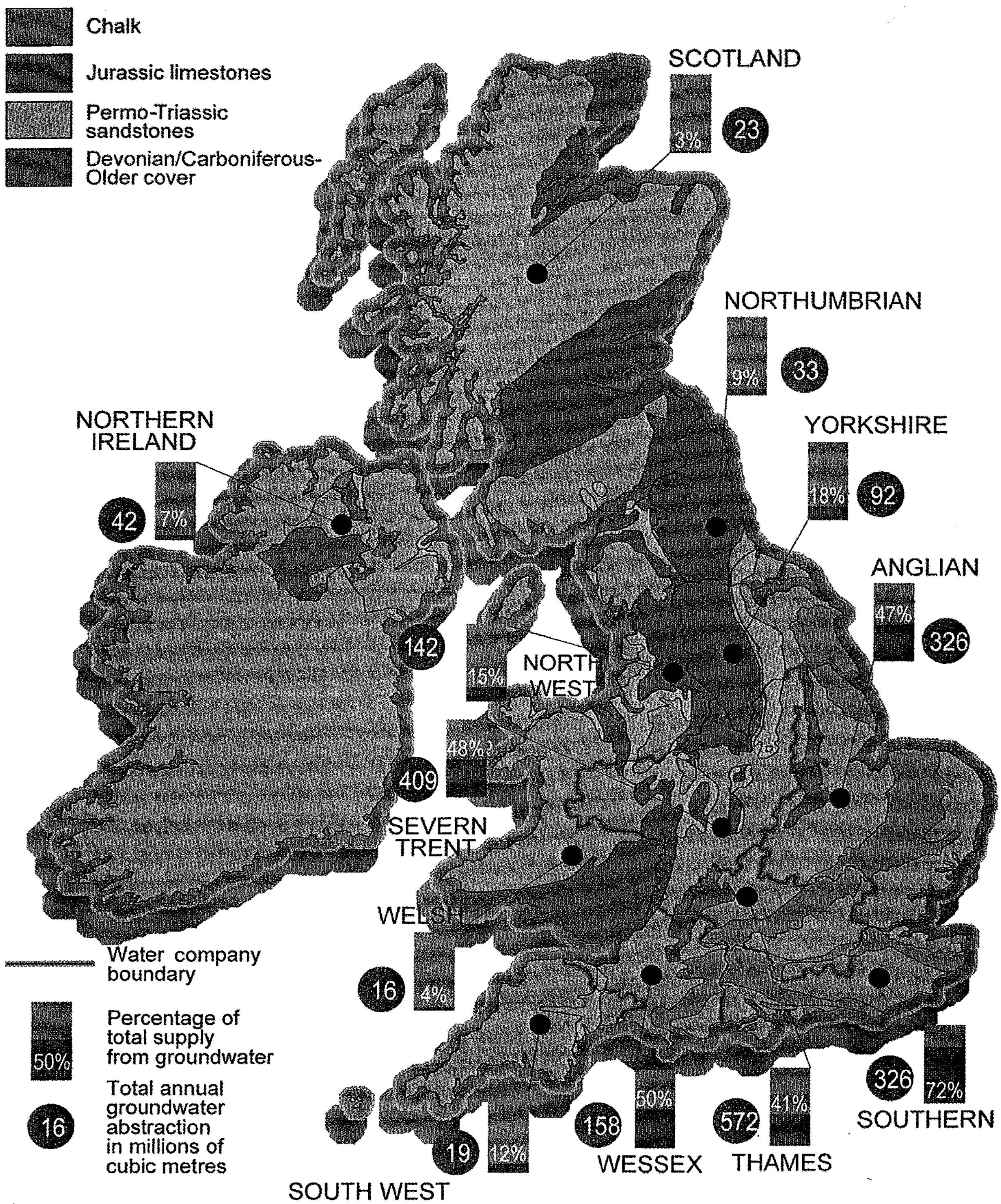

FIGURE 4 *Groundwater use in the public supply in the UK, none is currently used in Jersey although 4 million cubic metres is abstracted for private use (after Groundwater Forum, 1998)*

Given that Jersey has a land area of 117 km^2, the long term average annual surface water stream flow amounts to some 27 Mm^3/a of which some 15 Mm^3/a derives from groundwater baseflow. The actual values ranged from only 7.0 Mm^3/a stream flow and zero groundwater recharge in 1991/1992 to as much as 63.0 Mm^3/a stream flow including 45.5 Mm^3/a groundwater groundwater baseflow only three years later in 1994/95. Poorly resourced years are largely concentrated in the period 1989 to 1996, i.e. these poor years may be more common now than they were in the 1970s. Estimated abstraction of groundwater is about 3.6 Mm^3/a, and public supply amounts to a further 7.3 Mm^3/a. Thus, although Jersey has no groundwater directly abstracted for public supply, about half of the supply derives from groundwater baseflow. Figure 4 shows comparative groundwater consumption figures for public supply in the UK; Jersey being 0%. However, groundwater abstraction reduces baseflow potential by up to 25% in an average rainfall year.

GROUNDWATER FROM FRANCE

A Belief Held By Some

There is a belief, held by some, that groundwater also derives from rainfall over France which flows under the sea to emerge from fractures beneath the Island. This source is claimed to be capable of supplying up to "10 000 gallons per hour from individual boreholes, and to be more reliable than many of the shallow groundwater sources around the Island" (The Water Diviners and Engineers Association, 1999). The belief is supported by two facts: that the geological structure in the region of the Bay of St Malo and Jersey itself trends broadly east to west, and that there may be a *fracture* set running in that direction which could facilitate groundwater transport. The second fact is that the Bay of St Malo is shallow and that Jersey was once part of the French landmass.

However, there is no driving force that could transport groundwater in this manner. Groundwater flow depends on gravity and the head difference created by the hydraulic gradient or elevation change of the water table (or *piezometric level*) between any two points. For a more detailed explanation of groundwater transport the reader is directed towards any one of a number of hydrogeology textbooks, although that by Price[2] is probably one of the more approachable books for the lay-reader. Price also offers a brief discussion on divining and acknowledges that many people, including some scientists, can locate flowing water in field drains and buried pipes, possibly as a muscular reaction accentuated by a twig or bent welding rod. Although he does not dismiss divining, he makes the point that there is a lot more to hydrogeology than just locating flowing water, and that the similarity between shallow flowing water in a crack or pipe and deep-seated but very slow movement of groundwater in fractures is tenuous.

Technical Analysis

For groundwater to flow across the Bay of St Malo there must be a suitable head difference and the rocks must have sufficient *transmissivity* to overcome the friction which resists movement. The transmissivity of the shallow weathered rocks beneath Jersey ranges from 25 to 40 m^2 per day (Robins and Smedley, 1998). Isolated fractures at depth offer considerably less potential as

[2] Price M 1996 *Introducing Groundwater*, 2nd Edition. Chapman & Hall, London.

the depth of overburden reduces their dilation and so inhibits the flow potential. A generous order for transmissivity in the uppermost 100 m of saturated rock could, therefore, be 10 m^2 per day, equivalent to a hydraulic conductivity (transmissivity per unit of saturated thickness of aquifer) of 10^2/day/100m which is equivalent to 1/10 m/day. The distance from the nearest French shoreline towards the east is 25 km, and the elevation difference from high ground on the Cotentin Peninsular to low ground on Jersey is some 300 m (i.e. the hydraulic gradient is 300/25 000, i.e. 3/250). Assuming that flow through a series of weakly dilated fractures equates to flow in a porous media over this large scale (25 km and more), then Darcy's Law applies as follows (see Price, *Introducing Groundwater*):

Groundwater velocity = permeability x hydraulic gradient
= 1/10 x 3/250 = 3/2500
= 0.001 m/day (approximately)

This velocity suggests that it would take a particle of water about 57 000 years to travel across the Bay of St Malo to Jersey. On arrival at Jersey, such ancient water would have taken salts into solution on its journey to emerge as a brine with a distinct *radiometric* signature identifying its age. No such waters have been found on Jersey. The same argument applies to water supposedly deriving from rainfall over the Pyrenees.

The scientific evidence against sub-marine transport of groundwater to Jersey is considerable. There are few deeper boreholes which draw on older water. Groundwater chemistry indicates chemically immature waters which could not have been underground for more than a few tens of years. *Environmental tritium* assays also indicate that the groundwater is generally only a few tens of years old and, therefore, it must derive locally.

Deep-Seated Waters

There has been little tangible evidence presented by the water diviners over the years to support the claim for deep-seated groundwater sourced off the Island. A borehole drilled recently above Rozel Bay is a useful example of the so called 'deep water body'. This newly completed borehole which is situated at a high elevation in the Island, has a small *artesian* flow of 0.2 l/s. It has allegedly been pumped at '6 000 gallons per hour' for 24 hours, although the means of measuring this discharge, which is exceptionally high for a Jersey borehole, are unclear. The borehole was reportedly dry until a fracture at a depth of about 60 m was intersected at which point water rose up the borehole to overflow.

However, this is not an altogether uncommon phenomenon on Jersey, the more widely quoted case being that of the digging of the Fort Regent Well (Jones, 1840):

> 'After sinking through 235 feet of compact rock, and upon firing a blast the spring was laid open . . . whereupon water poured in like a torrent, to the great astonishment of the miners, who were still suspended in the bucket, waiting the effects of the explosion. Twenty four men working for two hours can with ease pump into the surface cisterns 800 gallons per hour'.

This confined fracture flow is caused when a shaft or borehole intersects a fracture containing water under pressure. The confining pressure is caused when the source recharge area is at an elevation greater than the head on the water in the fissure.

The explanation at Rozel is that the borehole is situated along a spring line between the very weakly permeable Rozel Conglomerate and the higher permeability volcanic rocks to the south and west. The new borehole diverts shallow spring flow to the borehole to discharge as artesian overflow. The main supply to the borehole occurs at the point the borehole penetrates the bottom of the Rozel Conglomerate and enters water bearing fractures in the volcanic rocks. Chemical evidence from the discharge indicates a young and fresh source of water which contains dissolved oxygen in solution indicating that it has always been in reasonable contact with the atmosphere (i.e. not under the sea bed for prolonged periods). The salinity of the discharge is low, with a total *Specific Electronic Conductivity* (SEC) of only 432 $\mu S/cm^3$. The area of ground receiving recharge to sustain the source must, therefore, be local and situated at some marginally higher elevation than the borehole well-head.

LAND USE TRENDS

Urban

Land use has a significant effect on the water resource. Man's activities and modification to the landscape influence both the volume of the resource that is available and the quality of the water. Urbanisation, particularly along the densely populated southern belt of the Island, is important. Urbanisation intercepts runoff and diverts it to storm sewers away from the natural water cycle. Leaking sewers and spilled chemicals along with hydrocarbon residues from highways all contribute to the quality of the water that does manage to get into the water body. Housing development is continuing in Jersey and there is a small but significant increase in rainwater interception as a consequence.

Agriculture

The agricultural industry is seeing some important changes at the moment. Although overall production of vegetables and particularly of the Jersey Royal potato has not changed in the five years up to 2000 (Figure 5), there has been a significant decline in the cultivation of most green vegetables. However, the area of potatoes under polythene has reduced slightly. Importantly the value of the early potato crop fell from £824 per tonne in 1998 to only £632 in 1999, and has fallen again in 2000 with the wet spring despite intensive television advertising in the UK (Department of Agriculture & Fisheries, 1999). As a consequence the area under Royals in 2000/2001 is likely to be reduced. What crop will replace the potato remains to be seen, but some land may be left fallow. This decline in production implies that less fertiliser will be imported and that the use of pesticides will decline on an overall Island-wide basis.

The production of narcissi and other flowers remains steady, as does the total area cultivated under glass.

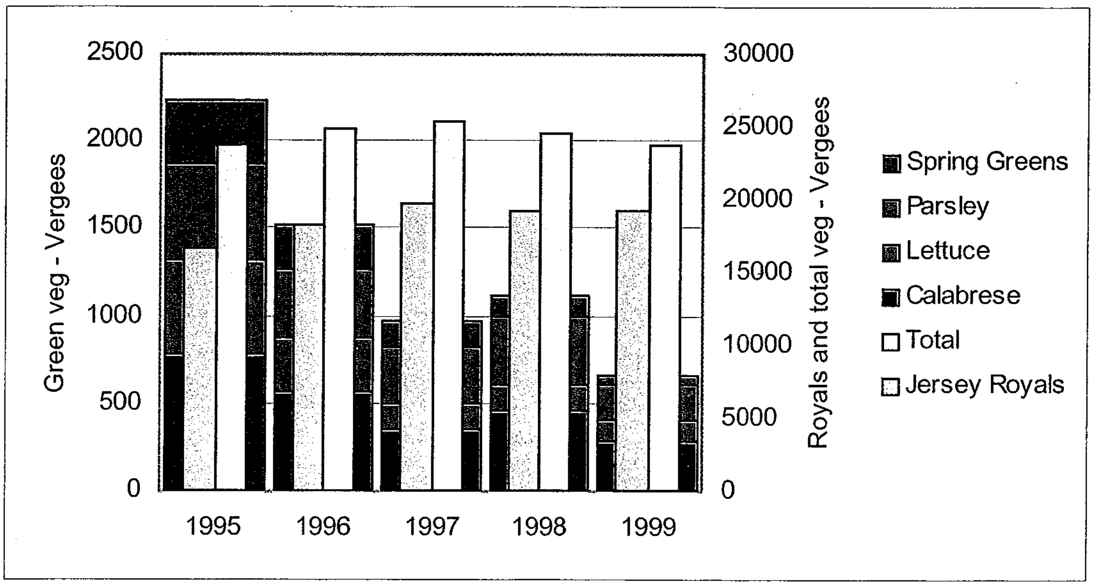

FIGURE 5 *Recent trends in vegetable production*

Milk production continues to rise, overall, by some 8% in the last five years. As a consequence the area to grassland has increased along with the risk of nitrate concentration from cattle standing in fields and the application of slurry to land. Mercury has been detected in the vicinity of a number of cattle byres – the source of this potentially toxic metal is as yet unknown.

WATER STORAGE AND SUPPLY

The Store

The key to utilising the available water resource is storage of water from wet periods for later use in dry periods. The groundwater store achieves the storage objectives naturally, but surface water storage has to be engineered. There are six impounding reservoirs:

Queen's Valley	1.135 M m^3 capacity
Val de la Mare	0.908 M m^3 capacity
Grands Vaux	0.227 M m^3 capacity
Handois	0.204 M m^3 capacity
Dannemarche	0.109 M m^3 capacity
Millbrook	0.036 M m^3 capacity

The reservoirs supply the water treatment works at Handois and Augrès. The four main reservoirs are linked by a raw water main to a covered balancing reservoir with a capacity of 0.454 Ml which is situated above the Handois treatment works. In addition to direct stream flow, borehole abstraction and stream flow from other catchments is pumped directly into the reservoirs. The reservoirs are protected by filtration ponds and the streams also pass through a fish stock pond to give warning of polluted stream water which, when detected, can be diverted to by-pass the reservoir (James, 1991).

Production from the low-nitrate Blanches Banques sand aquifer boreholes has been temporally discontinued due to contamination of the resource (ostensibly with *AFFF*, see section on Recent Pollution Incidents, below). This source has recently been replaced by water from the new desalination plant. The Blanches Banques water, although relatively small in volume, is low in nitrate and remains very attractive for blending purposes. Consequently, the new desalination plant was switched on early in 2000 during the month of April to make up for this lost source of low nitrate water suitable for blending. The desalination plant had also been in use during the previous autumn but on that occasion it was to safeguard limited resources in the reservoirs given the poor rains of October and November 1999. In the spring of 2000 it had been necessary in order to provide low mineralised water for blending to reduce raw water nitrate concentrations. As a consequence reservoir levels were holding well given also the wet spring experienced during this same period.

The Mains Supply

Mains water coverage is currently about 85% and mains sewerage covers approximately 83% of all dwellings. Figure 6 shows the development of mains supplies in recent years and how water in supply now exceeds 7 000 Ml per annum. This water derives mainly from surface water storage and comprises elements of surface water run-off (about 32%), groundwater baseflow in surface waters (about 65%), and the remainder from desalination plant output. Pumping from Water Company boreholes has ceased for the time being, with the Blanches Banques sand aquifer boreholes at risk of pollution and the deeper boreholes in Grandes Vaux being expensive to operate for small return. All the boreholes are maintained at operational status.

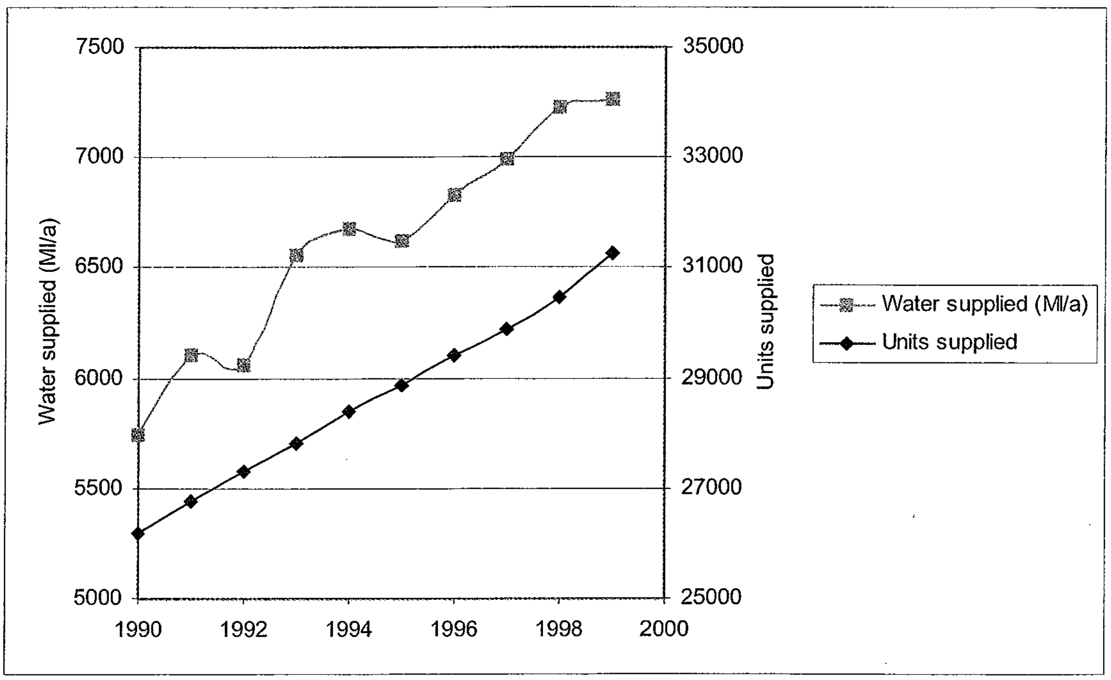

FIGURE 6 *Mains water coverage throughout the 1990s*