THE WATER RESOURCES OF JERSEY:

AN OVERVIEW

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

PSd
PUBLIC SERVICES DEPT.
Serving the Island

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Report prepared by the British Geological Survey for the Public Services Committee, States of Jersey

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CONTENTS

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.

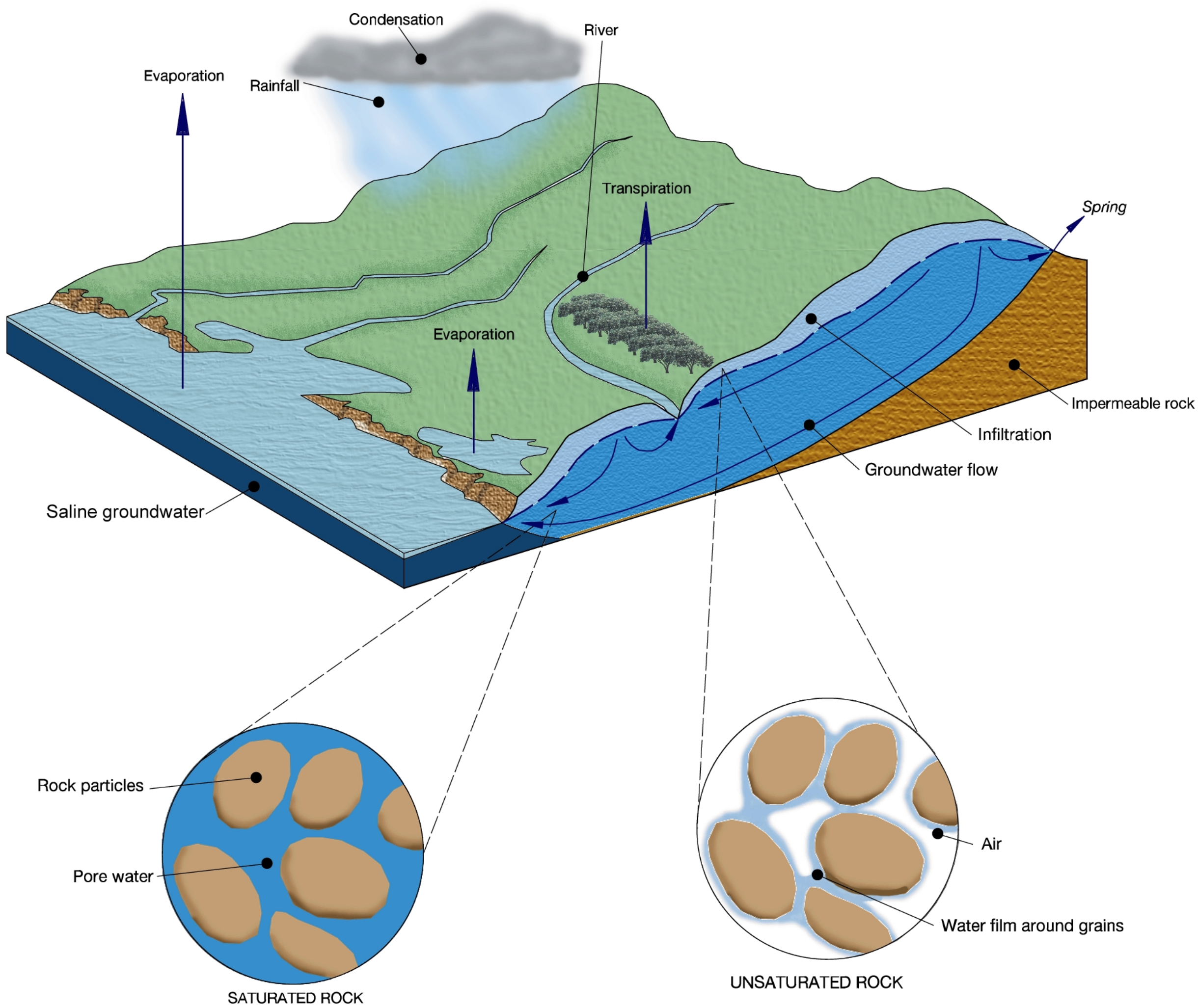

FIGURE 1 *Groundwater in the hydrological cycle*

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.

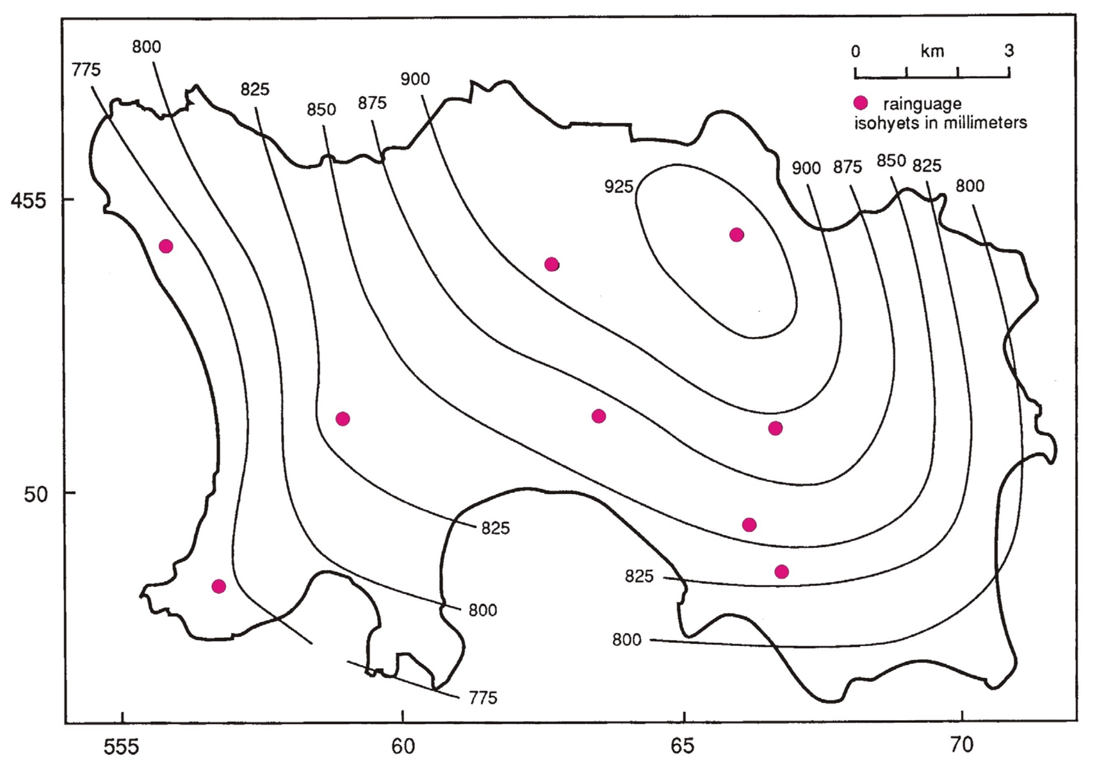

FIGURE 2 *Average annual rainfall (1961-1990)*

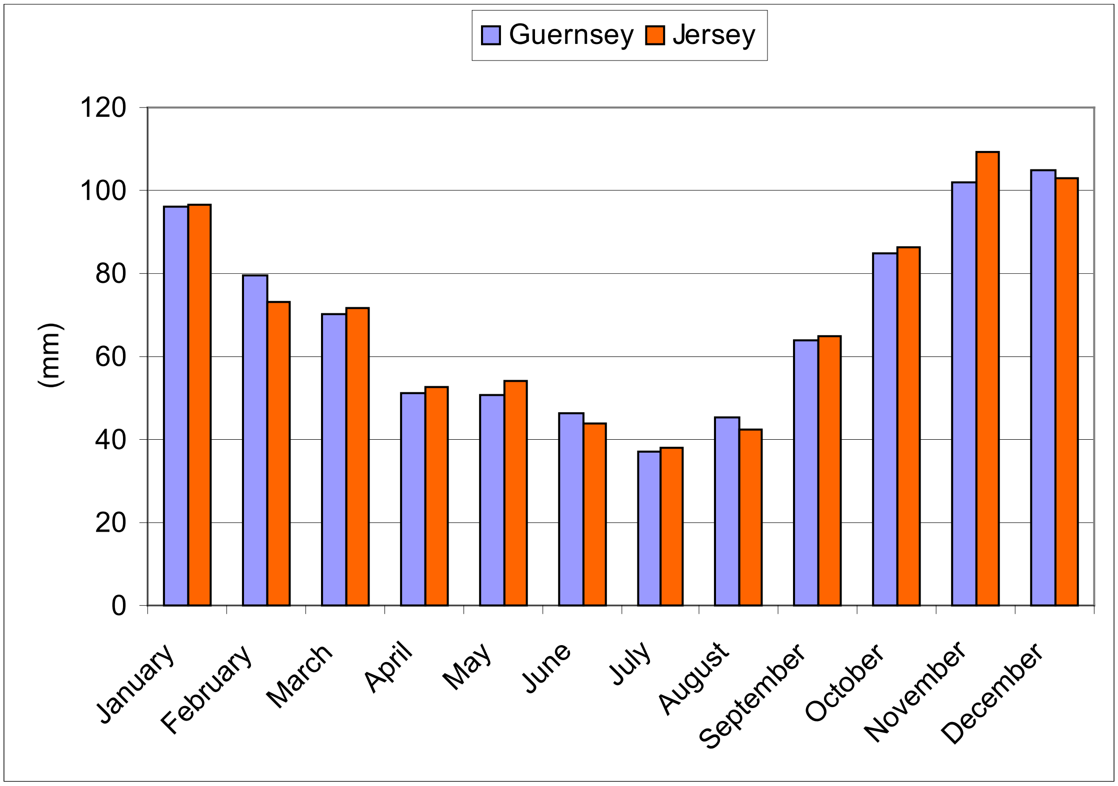

FIGURE 3 *Channel Islands mean monthly rainfall distribution*

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.

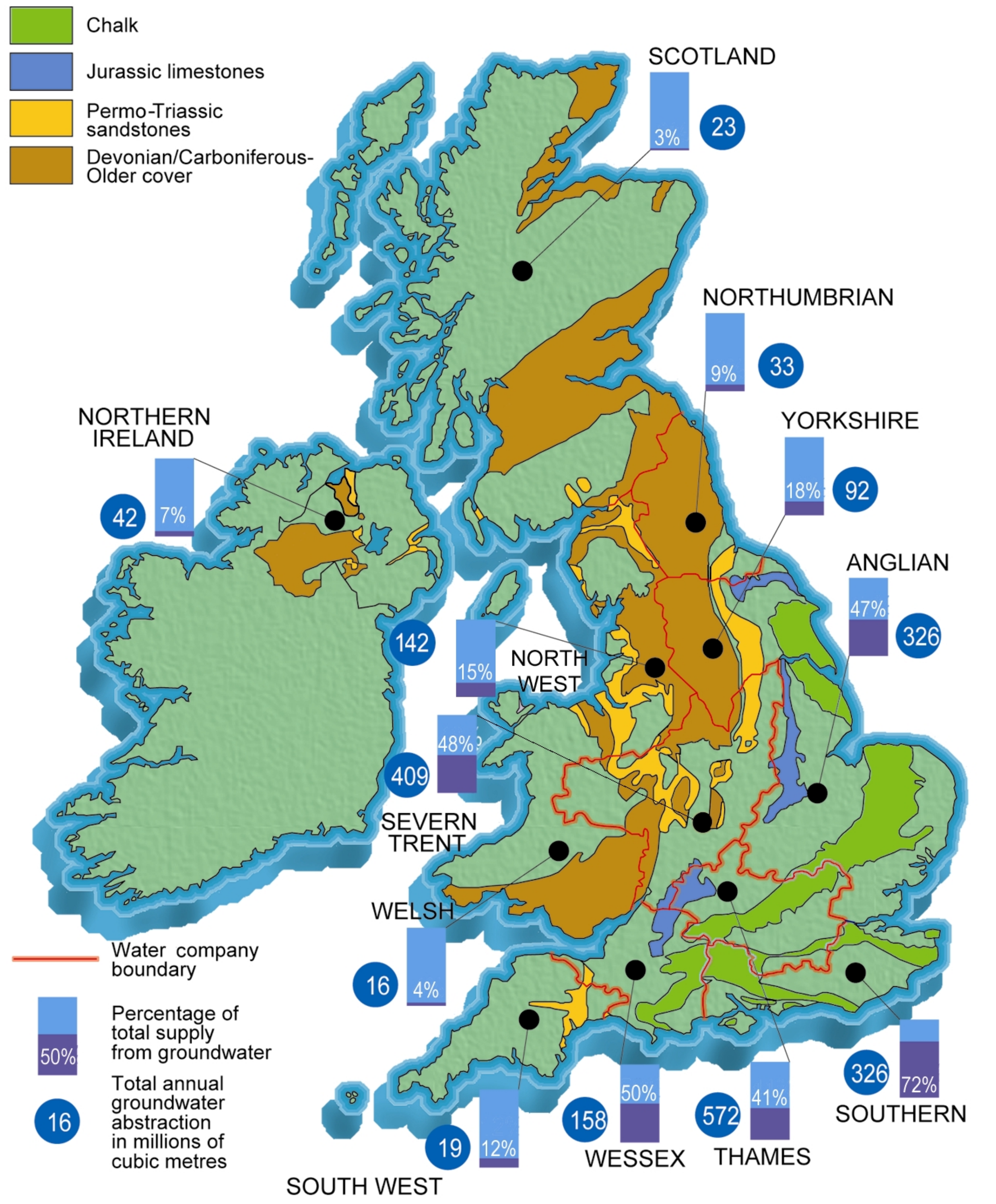

FIGURE 4 *Groundwater use in the public supply in the UK, none is currently used in Jersey although 4 million cubic metres is abstracted for private use (after Groundwater Forum, 1998)*

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 Electonic 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.

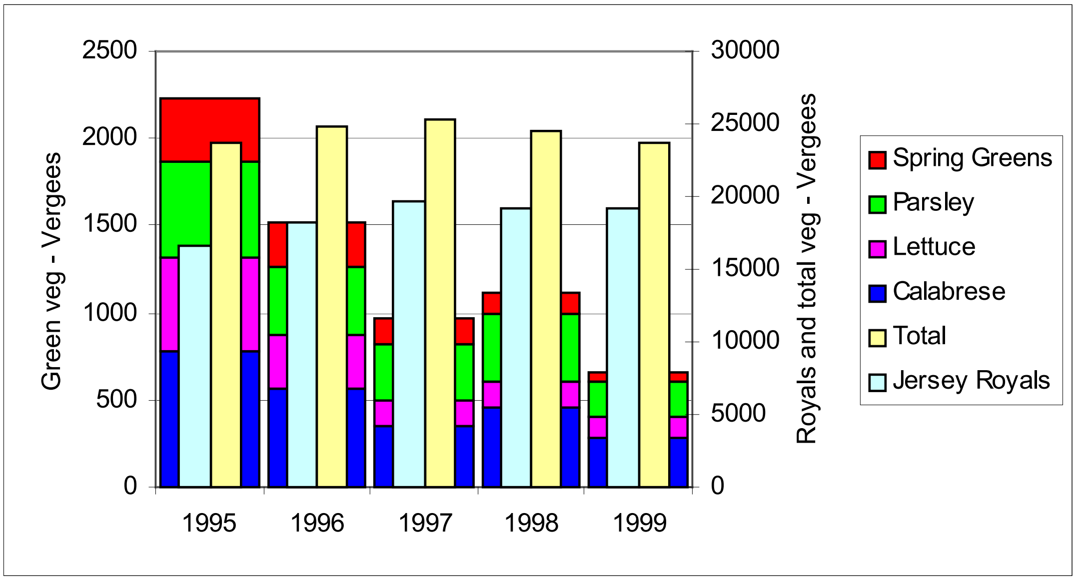

FIGURE 5 *Recent trends in vegetable production*

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.

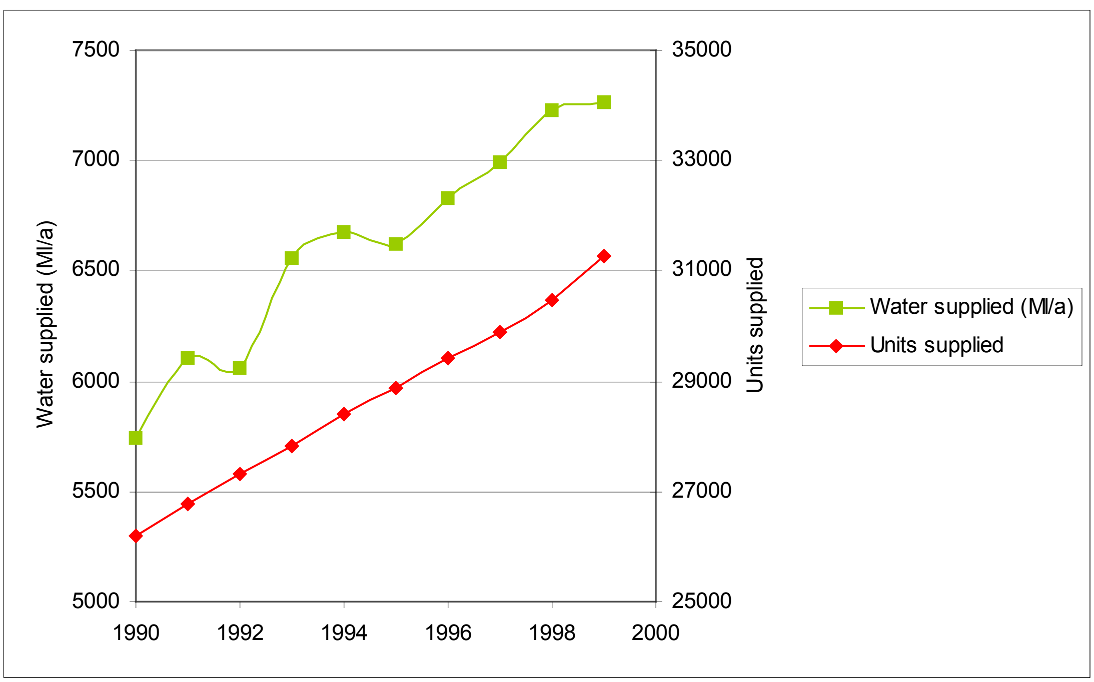

FIGURE 6 *Mains water coverage throughout the 1990s*

Other Supplies

Additional water consumption in the private sector derives from a number of sources. These include direct abstraction from flowing surface water courses, rooftop collection, interception of spring water discharges and groundwater abstraction from wells and boreholes. Of these, only rooftop collection gathers water from a source other than the Island's main water body; the others all draw on either surface or groundwater. Direct abstraction from surface waters is not currently regulated and is difficult to quantify. Groundwater abstraction and spring flow interception are also unregulated but estimates of annual use were made when borehole meters were installed following the State of Emergency Powers granted in the drought of 1989 (Table 2). The 4 000 domestic sources service about 5 200 domestic properties.

TABLE 2 *Estimated groundwater use in the period 1989 to 1991*

Water use	Sample population	Mean consumption (m^3 d^{-1})	Estimated number of sources	Annual abstraction (Mm^3)
Agriculture	24	7.7	500	1.4
Domestic	6	0.6	4000	0.9
Leisure	9	42.4	50	0.8
Hotels and hospitals	20	4.5	60	0.1
Industry	10	10.9	20	0.1
Total (including uncategorised)	76		5000	3.6

Consumption of groundwater during the 1990s showed no discernable trends and it is likely that the average annual volume abstracted remains at about 3.6 M m^3a^{-1} to this day. However, demand is variable from year to year, with demand greatest in dry warm summers such as those of 1991, 1992 and 1994. Some of the groundwater used for irrigating parks and golf courses and some of the irrigation and hydroponic fluids used in agriculture and horticulture will return to the water table, although volumes are difficult to estimate.

POLLUTION RISK

Pollution in Jersey

A number of recent studies on Jersey have highlighted the vulnerability of both surface and groundwater resources to pollution. These studies reflect the high concentrations of nitrate in Jersey mains tap water - currently at and around the EC *maximum admissible concentration* (MAC) - and they also reflect concern over the occurrence of pesticide compounds in drinking water. In addition there have been a number of contamination incidents in recent years, including the airport fire-ground at St Ouen's and the Beauport potato clamp. There have also been numerous potential contamination incidents such as a recent acid spill at the power station, and many minor spillages of substances damaging to the aqueous environment such as fuel and heating oils, or swimming pool and dry cleaning chemicals. The various forms of pollutant and their potential pathways are shown diagrammatically in Figure 7.

FIGURE 7 *Pollutants and their potential pathways (after Groundwater Forum, 1998)*

Nitrate, phosphorous and the EC

Nitrate (NO_3) and phosphorous (P) contamination of waters has been a concern in Europe for quite some time. The EC MAC for nitrate was set in 1984, and only two years later the EC was threatening to take eight member states to court for non-compliance. Recognizing that agricultural fertiliser was a major cause of the problem, the Nitrate Directive (91/676/EEC) set out in 1991 to control agricultural practice. Consequently by 1993 member states had to declare Nitrate Vulnerable Zones in which the nitrate loading was limited to 210 kg N/ha by 1998 and 170 kg N/ha by 2002. In the mean time legislation on phosphorous is anticipated shortly.

Table 3 shows how the inorganic constituents, pH and mineral content (expressed as ionic concentrations) of water in the public mains supply compare with the EC MAC.

TABLE 3 *Mains water quality (source: The Jersey New Waterworks Company Limited, 1999)*

	MAC	Minimum	Maximum	Mean	Samples taken	% of samples exceeding MAC
pH	>6.5, <9.5	7.3	8.3	7.4	219	0
Nitrate	50 mg/l	24.4	75.1	55	149	62%
Nitrite	0.1 mg/l	<0.001	0.277	0.06	152	11%
Iron	200 µg/l	<7	126	14	26	0
Aluminium	200 µg/l	<20	106	<20	264	0
Manganese	50 µg/l	<20	49.4	<20	149	0
Copper	3000 µg/l	<4	1380	62	72	0
Lead	50 µg/l	<1	32	3	71	0
Zinc	5000 µg/l	<6	1030	50	72	0
Chloride*	400 mg/l	57	97	75	148	0

*Chloride in the raw water as opposed to residual chloride in treated and chlorinated supply water.

Vulnerability to Diffuse Pollution

The water resource of Jersey is particularly vulnerable to both *diffuse pollutants* such as nitrate and pesticides, and to point source pollutants such as leaking fuel tanks. Surface runoff carries with it excess nitrogen fertilizer in solution and scours any soluble pollutants from the ground surface to transport them to the water courses. The groundwater is shallow, protected only by thin and permeable loessial soil. Once at the water table it is contained in a fracture dominated flow system that promotes rapid transport of water and pollutants. Water percolating through the soil zone also leaches out surplus nutrients and pesticide residues and washes leakages from tight tanks and septic tanks rapidly towards the groundwater body. Consequently, any known spillage or pollution incident is dealt with on a priority basis by the Water Resources Section of the Public Services Department based at Bellozanne. Their aim is to identify, contain and control pollution hazards in order to safeguard surface and groundwater bodies.

In 1996 the Nitrate and Pesticide Joint Working Party Report was published and this highlighted concern over nitrate loading in Jersey and the occurrence of pesticide residues in Jersey water. Contamination of the water by nitrate is now a significant concern in Jersey. The EC MAC for nitrate is 50 mg l^{-1} (sometimes reported as 50 mg-NO_3/l which is equivalent to 11.3 mg-N/l). Jersey tap water attains, and even exceeds, this recommended limited for much of the year, and the mean annual concentration significantly exceeds the MAC. This reflects the poor status of the surface waters throughout the year (Table 4 and Figure 8) and shows that the cleanest waters occur in the late summer and autumn and that the highest nitrogen loadings occur in the surface waters in the late winter and spring.

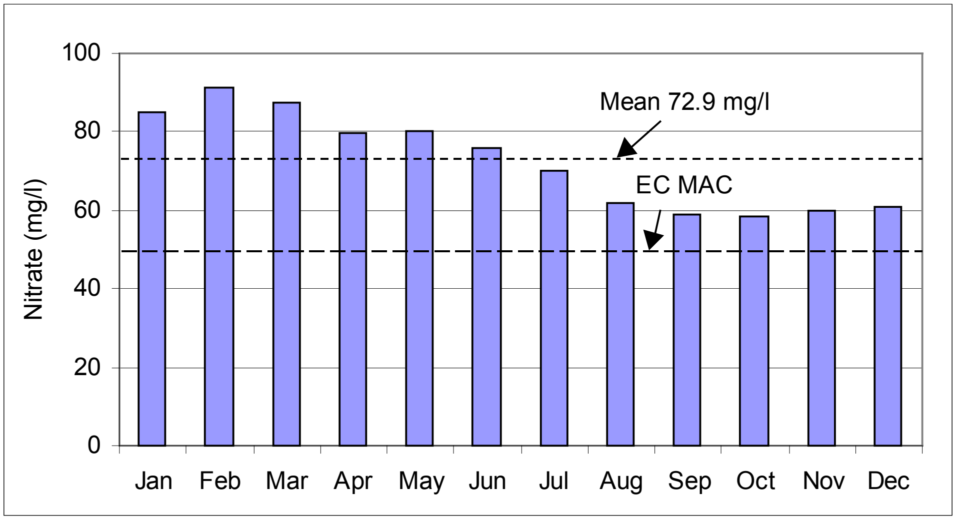

FIGURE 8 *Monthly distribution of the mean NO_3 concentrations for Jersey surface waters*

Recognition of this form of contamination has been around in Jersey for some years although it has only recently been acknowledged locally as a significant issue. It was even highlighted in a UK geography 'A' Level school's text book in the early 1990s when Jersey and its nitrate problem was cited alongside the radiation fallout from Chernobyl as topical examples of pollution of national importance (Foster, 1991).

The presence of nitrate in groundwater can be inferred as a tracer or indicator of a pathway for pollution transport. Its presence suggests that it is likely that other products, including pesticides, could also access the water body by this same pathway. Otherwise the medical implications of high nitrate water are limited to the extremely rare 'blue baby' syndrome, which has resulted in some infant fatalities overseas, and in the past also there has been a tenuous link with stomach cancer. However, there is currently no firm medical evidence that stomach cancer is directly related to prolonged exposure to high nitrate concentrations in drinking water.

Source of the Nitrate

Recent work on Jersey has concentrated on the occurrence of nutrients in surface waters (Lott et al, 1999). Nitrate concentrations peak in Jersey streams in spring and are lowest in late summer (Figure 8). Analysis of the Val de la Mare catchment using a simple model based on *nitrogen export coefficients* showed the sources of N in the catchment to derive as follows:

Domestic	1.3 tonne per year
Woodland and scrub	0.5 tonne per year
Grassland	0.3 tonne per year
Arable	9.8 tonne per year
Livestock	1.3 tonne per year

TABLE 4 *Nitrate stream survey for 1999 (mg-NO_3/l) (from The Jersey New Waterworks Company Limited, 1999b)*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	%over MAC
Le Mourier East	109.7	119.6	117.3	118.3	118.7	117.0	114.9	111.0	109.5	107.0	105.9	99.1	112.3	100
Le Mourier West	108.2	118.3	115.9	119.3	119.1	115.8	112.5	108.7	105.2	99.7	93.1	83.4	108.3	100
Le Mourier combined	111.9	121.4	118.1	119.0	120.9	116.8	116.4	113.5	109.0	102.5	97.2	91.3	111.5	100
Val de la Mare East	101.9	107.0	101.9	81.2	76.3	94.3	91.1	83.9	81.4	79.1	76.8	77.3	87.7	100
Val de la Mare West	117.9	118.6	114.7	99.8	103.3	100.3	93.8	83.8	81.7	79.0	76.1	87.2	96.4	100
Pont Marquet	**41.9**	64.6	63.6	59.2	59.6	**48.7**	**49.4**	**40.7**	**32.4**	**38.0**	**33.9**	**45.4**	**48.1**	33
Greve de L'Ecq	106.0	113.3	109.9	101.5	105.4	104.1	103.9	86.7	85.7	85.4	84.8	76.0	96.9	100
La Saline	140.8	161.6	153.7	145.9	137.7	137.0	126.2	115.9	106.0	96.1	92.8		128.5	100
La Hague	80.3	86.7	76.6	74.9	79.2	74.1	68.0	59.5	59.3	60.6	61.3	63.0	70.3	100
La hague dip	65.0	83.0	68.8	71.4	71.5	67.1	66.6	58.6	52.8	52.5	54.7	52.4	63.7	100
Tesson	78.6	88.5	77.8	72.3	76.2	78.1	75.3	64.2	61.2	59.9	67.5	59.5	71.6	100
Little Tesson	83.2	85.4	76.8	67.9	69.2	60.1	51.7	**45.9**	**42.2**	**43.9**	**42.3**	56.9	60.5	67
Handois East	78.3	79.0	81.6	75.3	81.3	76.2	72.5	63.1	66.9	59.7	68.1	60.4	71.9	100
Handois West	61.7	72.3	68.5	52.3	62.0	53.9	**49.5**	**36.2**	**40.1**	**36.7**	**46.5**	54.7	52.9	58
Handois combined	68.7	66.5	74.6	63.9	70.4	61.2	50.7	**42.6**	**46.5**	**47.6**	54.0	53.3	58.3	75
Dannemarche	69.6	68.9	66.0	72.4	65.5	62.4	62.5	52.9	**49.7**	**37.9**	**37.5**	**48.5**	57.8	67
Millbrook	65.9	68.0	67.3	62.6	53.9	**44.6**	**38.8**	**37.6**	**32.9**	**32.4**	**31.9**	**45.9**	**48.5**	42
Bellozanne	86.2	89.3	90.4	72.5	81.9	75.9	74.4	60.5	65.7	64.1	64.5	72.4	74.8	100
Grands Vaux	67.1	70.5	61.7	57.9	60.3	**48.4**	**42.4**	**36.7**	**36.4**	**31.8**	**37.5**	**47.1**	**49.8**	42
Vallee de Vaux	77.2	83.7	77.2	68.7	70.4	61.4	50.7	**46.2**	**33.7**	**41.8**	**43.2**	55.6	59.2	67
Fernlands	70.3	76.1	67.1	60.6	61.1	**46.1**	**31.6**	**23.0**	**21.4**	**29.3**	**29.1**	53.6	**47.4**	50
St Catherine	73.3	75.6	68.6	57.2	60.6	54.0	**49.4**	**43.3**	**39.1**	**39.6**	**44.7**	55.6	55.1	58
Queen's Valley	67.7	88.4	84.8	70.9	51.5	71.9	**48.4**	**49.2**	**35.2**	52.8	59.7	67.7	62.4	75
Frencheville	75.8	72.6	74.0	66.7	73.1	67.4	67.6	59.9	56.4	61.4	60.7	69.6	67.1	100
Rozel	112.0	109.2	102.2	83.3	79.0	60.6	**44.8**	**26.5**	**16.4**	**20.1**	**31.6**		62.3	55

Concentrations in bold type are those which lie within the EC MAC.

The model shows that the main source is clearly arable and of this 70% of the total loading comes from the cultivation of early potatoes, whereas only 10% is produced by domestic (soakaways, septic tanks) and livestock. Lott et al (1999) also state that if the application of fertiliser was reduced to the UK MAFF/ADAS recommended level, then the nitrogen levels in Jersey waters would subsequently fall by some 34%.

Investigation of the source of the nitrogen was also carried out by Green et al (1998). They found that the ratios of nitrogen isotopes correlated with nitrate from mineralised soil organic nitrogen rather than from animal or domestic waste. This again indicated that fertiliser application is a main source of the nitrate. In addition they looked at underground waters along the south and south-east coast of Jersey which are depleted in nitrate. They concluded that the residual signature of nitrogen isotopes suggested that the nitrate had been removed in this area by natural *denitrification* caused by a reducing environment (depleted in oxygen) coupled with denitrifying bacteria.

Point Sources of Pollution

The other main source of pollution is from point sources. Although every care is taken to protect the aqueous environment on Jersey, accidents and incidents do occur. In addition there are a number of sources that lay dormant in the ground until such time as they are disturbed when they may become a major pollution risk. These are the many abandoned *landfill* sites and the former industrial sites such as the gas works in St Helier.

Until the 1950s each farm or dwelling tended to burn its own waste arisings and dispose of the cinders locally. As the volume of waste arising increased there became a need for formal landfill of waste and ashes under control of the parishes, and later centralised under Government. More recently landfill has been replaced by incineration and off-shore land reclamation. Some of the former and abandoned landfill sites generated small quantiites of *leachate* which became a nuisance from time to time. Former landfill sites along the Five Mile Road still discharge through the sea wall to this day, but only in small volume and at low concentration. The main risk remains from the Mont Mado site. This is a former deep quarry and much of the waste was tipped beneath the water table, all though in theory, only quarry waste and inert material should have been placed in the sub-water table area. A formal inventory of the contents was not maintained but the site is known to contain vehicles, their fuel and oil, as well as paint. A number of private domestic wells within a 500 m range to the north and east of the site have had to be abandoned and premises connected to the pubic water supply (Robins, 1997). Other sites that have posed problems are a former fly tipping site at Ville de Quennevais which posed a risk to groundwater in the Mont a la Brune area of St Ouen's and an infilled valley in St Helier on which housing redevelopment is being undertaken.

RECENT POLLUTION INCIDENTS

Beauport

Early in July 1992 some 4000 tonnes of potatoes were buried in a shallow pit in a field adjacent to the car park overlooking Beauport Bay. Within two weeks a small spring, which forms the source of a stream leading to Beauport beach, had became severely polluted. The spring is about

100 m from the potato disposal site and the pollution was apparent in two ways. Firstly, by a foul odour which resulted from the presence of up to 30 000 mg/l (milligrams per litre or ppm, parts per million) of *Chemical Oxygen Demand* (COD) in the issuing water, a significant proportion of which was made up of volatile fatty acids, characteristic of the anaerobic digestion of organic materials. Secondly, by an increase in the flow of the spring, from about 0.2 l/s to between 0.6 and 0.8 l/s. The polluted stream water entered the beach at the base of the cliff and induced anaerobic conditions in the sand, with sulphide levels of up to 690 mg/l being recorded. At the same time, bacterial counts in the seawater immediately adjacent to the beach were found to have risen to above 20 000 total coliforms per millilitre.

Site investigations showed shallow groundwater present in the upper, weathered zone of the granite bedrock, with the natural discharge point being the spring feeding the stream to Beauport beach. A proportion of the potatoes had been deposited below the perched water table and had suffered anaerobic decay. In contrast, six months after their disposal, potatoes buried in areas above the water table were found to be desiccated, with yellow, waxy flesh and few signs of anaerobic decay.

It was concluded that remediation by excavation of the potatoes was not the best option, because it would involve the subsequent disposal of large volumes of contaminated material elsewhere on the Island, with the possibility that contaminated water would continue to issue via the spring for some time after removal of the wastes. Control was achieved by the installation of a catchpit to intercept the contaminated flow to the spring, with the contaminated liquid being pumped to sealed holding tanks buried beneath the car park. Contaminated liquid accumulated in the tanks is removed by tanker to the Bellozanne wastewater treatment works.

The process of anaerobic degradation produces both dissolved and gaseous by-products, so that the concentration of dissolved materials may decrease more rapidly than would be predicted by assuming that all the contamination is removed in solution. An initial estimate of the time to flush the degradable material from the 4000 tonnes of potatoes suggested several tens of years, but monitoring of the strength of liquid trapped by the catchpit showed a more rapid decline, from mean values of between 8000 and 10 000 mg/l COD in late 1992, to less than 400 mg/l COD in mid 1996.

Bellozanne

During September 1998 a fracture in an underground supply pipe allowed the escape of up to 5600 litres of diesel fuel into an area of made-ground beneath hard-standing at the Public Services Department's Bellozanne depot. In February 1999 oil was found to be discharging with water from a French drain some 75 m down-valley from the spill site. At the time of the discharge natural groundwater flows were supplemented by the effects of a mains water leakage into the ground at a point higher up the valley.

Site investigations indicated that oil from the leak had reached the shallow groundwater. The oil formed only a thin film on the watertable over a limited area. It was concluded that the oil would be attenuated by *in situ* degradation and that only in exceptional groundwater flow conditions, comparable to those which occurred during the mains break, could significant oil be flushed from the system. The distribution of oil at the watertable was such that oil recovery techniques were not applicable and no invasive remedial action was taken. However, the status and effectiveness of oil interceptors on drains has been checked and routine measurements of groundwater and oil beneath the area now monitor the progress of the attenuation of the spilled oil.

Crabbe

Waste disposal of agricultural waste and beached seaweed at the Crabbe site in Jersey, exacerbated by natural rainfall in 1996, resulted in the production of large volumes of highly polluting leachates. A nearby water supply borehole suffered a deterioration in quality, so a site investigation was carried out by WRc to establish the extent and origins of any groundwater pollution in the area.

Information from the boreholes drilled and the groundwater samples collected and analysed during the subsequent site investigation showed that:

- the groundwater had been polluted at depths in excess of 50 m, and a narrow pollution plume had developed;

- the polluted groundwater was typically of an orange colour, sometimes odorous, with a high pH and bacterial count, and high concentrations of COD, ammonia, chloride and potassium;

- from comparisons between the leachate chemistry and the observed groundwater quality, the origin of pollution was concluded as the leachate produced by the decaying waste on the disposal site, which had percolated into the subsurface, polluting the groundwater;

- the possibility of the groundwater pollution being caused by either surface run-off into boreholes or pollution sources other than the disposal site, such as the septic tanks and soakaways nearby, were discounted;

- the pollution appeared to be migrating towards the stream.

Recommendations for actions included modifications to the disposal area to prevent the leachate generated entering the subsurface and thereby stopping the source of pollution. Further monitoring of the boreholes was recommended to establish if natural remediation of the groundwater would be sufficient or whether additional remediation methods were required. Monitoring was continued between 1996 and 1999, and the results produced in a review report (January 2000).

The concentrations of groundwater pollution had reduced markedly. However, the pollution in certain observation boreholes was still high, with COD levels exceeding 200 mg/l. The surface water of the stream had not been impacted by the groundwater pollution. Natural attenuation of the groundwater pollution was being successful and active remediation measures were not needed. The groundwater pollution depletion rate shown over the two years suggested that it would take about ten years for the COD concentrations in the groundwater to drop close to background.

The monitoring of groundwater quality has shown its value in demonstrating the decrease in pollution and should be continued for the foreseeable future. It was recommended also that the monitoring of rainfall and groundwater rest water levels should continue on a monthly basis. Groundwater and surface water quality should continue to be monitored on a quarterly basis. The day-to day management of the site cleanliness and the leachate control system must be continued to a high standard to prevent waste or leachate escaping from the hard standing or plastic-sealed areas and percolating into the ground. The management system and the integrity of the sealed areas should be re-evaluated annually.

Airport Fire-Ground

Complaints of foaming water in wells in the Mont à la Brune area of St Ouen's since 1985 were linked to the airport fire-fighting ground during a study carried out in 1993 (Consultants in Environmental Sciences Limited, 1994). Uncontrolled discharge of spent Aqueous Film Forming Foam (AFFF), unburned fuel and hydrocarbon combustion products were shown to have seeped away from the training facility via a soakaway to an area of made ground into the St Ouen's sand aquifer. A number of private well sources and the public supply well-field at Blanches Banques have subsequently been shut down.

Considerable effort has been made to try to establish the transport and degradation process now taking place in the aquifer. However, these are inconclusive with regard to hydrocarbon and combusted fuel products. Preferred flow paths and compartments of discrete groundwater flow within the sand aquifer and underlying shale formation have now been demonstrated. The cost of remedial action is, nevertheless, likely to be expensive. Once the pollution source is isolated, self-cleansing of the sand aquifer (naturally over the next few decades) may be an appropriate course of action bearing in mind the relatively rapid throughput of groundwater in this small aquifer. This incident remains a cautionary tale that everyone in Jersey should now learn from.

POLLUTION ISSUES

Pollution and Toxicology

There is considerable interest in the occurrence of the metabolite Chlorthal and in the persistently high nitrate concentrations in Jersey public water supply and selected private supplies. These two contaminants need to be addressed specifically because there is considerable misunderstanding about the health risks that their presence in drinking water poses. The issue is clouded by the States of Jersey policy to maintain limits set by the European Community for use in Europe. It is, however, instructive to review those limits in the Jersey context and in the light of current toxicological evidence.

Chlorthal

The active pesticide Chlorthal Dimethyl was banned in Jersey in 1998. It is an active ingredient in the pesticides Decimate and DCPA which were then applied at high rates to brassicas and soft fruits. Typical application was 4 500 gm/ha. However, Chlorthal Dimethyl has a solubility in water of only 0.5 mg l^{-1} and is readily degradable with a median half life of only 100 days depending on the soil type, its temperature and moisture content. It is believed that it has a relatively low toxicity, but manufacturing impurities in the pesticide include small quantities of hexachlorobenzine and dioxin which are probable human carcinogens and in any case have documented toxicological effects (Fewtrell and Kay, 1999).

A principal degradation product, but which is inactive and currently believed not to be toxic at levels recorded in Jersey, is the metabolite known confusingly as Chlorthal. Chlorthal, unlike its parent, is persistent and is found throughout the Island at concentrations generally greater than the analytical *detection limit* and in places as high as 0.12 μgm/l. Fewtrell and Kay (1999) suggest that Chlorthal offers little toxicological risk to drinking water in Jersey, although evidence for this derives from the data relating largely to the parent compound. The main issue is that it has been found in Jersey waters at concentrations above the EC MAC of 0.1 μgm/l even though it has not been declared a 'relevant metabolite' under the proposed UK Water Quality Regulations.

Modelling work predicting the recession of chlorthal concentrations has been carried out by ADAS on behalf of the Department of Agriculture and Fisheries (Matthews and Carter, 1999). This concluded that all water draining from the soil profile will, by the year 2002, have concentrations less than the critical level of 0.1 μgm/l. Although this will, if the modelling is proved correct, take away the fear that the metabolite is present at a concentration greater than the EC MAC, the metabolite will still remain in Jersey drinking water for some time yet to come.

Nitrate

The nitrate issue is equally convoluted. The EC MAC provides the European standard, and this limit is regularly exceeded in Jersey drinking water. However, the health implications of high nitrate concentrations in drinking water remain uncertain (Buson, 1999; Avery, 1999). But, be that as it may, the very fact that nitrate concentrations in Jersey drinking water exceed the MAC is of concern and effort needs to be made to reduce the occurrence of nitrate in run-off and in water infiltrating the ground and passing down towards the water table. Reduced application levels of nitrogen by the agricultural community would help to achieve this. Besides, the presence of nutrients (nitrogen and phosphorus) in open water reservoirs will promote blue-green algae which may produce toxic scums. In addition, nitrate in water is a useful tracer that indicates that other compounds applied to the land such as pesticides could equally access the drinking water supply.

Status of Surface Waters

A valuable means of evaluating the quality status of surface waters is to analyse the relationship between freshwater macroinvertebrate populations and water quality. Once established this provides a valuable means of measuring change in water quality from the present day 'baseline'. Investigation in Jersey revealed a diverse range of stream qualities ranging from 'excellent water quality' to 'very poor water quality' but badly skewed towards the poor end of the range (Langley et al, 1997). The study concluded that Jersey stream waters are far from pristine with only 20% of all samples having nitrate concentrations below the MAC of 50 mg/l (as nitrate), whereas some samples had concentrations greater than 1 000 mg/l. The worst water quality was in discharges from small streams draining from the south-east of the Island which were characterised by high faecal indicator concentrations and high nutrient concentrations. Earlier studies (Wyer et al, 1996) had shown that faecal indicators rise rapidly in streams at periods of high flow, with between 42% and 97% of all microbial delivery occurring during high flow events.

WATER RESOURCE MANAGEMENT

A Degraded Resource

Aspects of groundwater degradation were addressed in a review carried out by Gass et al (1996). This study highlighted a number of problems that contributed to generally poor water quality status. These included the obvious physical problems of shallow and vulnerable water table and thin soils, and a number of institutional contributors, some of which have now been addressed, but not all. These included:

- the absence of groundwater management including abstraction control;
- the (then) absence of legal and institutional provision for groundwater protection;
- the exceptional strength of customary private claims to water rights;
- the peculiar position of Jersey with respect to EC regulations; and
- the (then) disproportionate strength of the agricultural lobby allowed by the political structure.

The Water Pollution (Jersey) Law 2000

Water resource management in Jersey will receive a considerable boost when the new Water Pollution (Jersey) Law 2000 becomes active on 2 December 2000. This new legislative machinery is designed to protect controlled waters (including all surface and groundwaters) from pollution. The Law embodies current thinking on pollution protection towards maintaining and improving the quality of natural waters, involving best available techniques, invoking where necessary a precautionary stance and invoking the important 'polluter pays' principle. All this requires detailed water quality monitoring and data assimilation to be maintained, and these duties are the responsibility of the Water Resources Section of the Public Services Department.

From time to time, Water Quality Objectives may be set by the Public Services Committee. It will be the responsibility of the Water Resources Section to attain those objectives. By the same token, the States may also, by Regulation, designate Water Catchment Management Areas with specific conditions attached to control pollution by controlling activities that take place on the land. The Law is described in plain English in the booklet *Guidance notes on the provisions of the Water Pollution (Jersey) Law 2000* (Public Services Department, 2000). The Law is framed with point source pollution as its first target, and it remains to be seen whether diffuse pollution from say agricultural fertilizer will also be captured within the Law (see Article 18).

Earlier law includes The Water (Jersey) Law 1972. This lays a statutory duty on the Jersey New Waterworks Company to provide wholesome water for public consumption but neglects to define wholesomeness. There is, however, currently a Memorandum of Understanding between the water undertaking and the Public Services Department to the effect that all the EC Directives regarding drinking water quality should be applied.

Water Resource Management

There is still no useful legislative instrument for the management of water resources. A law for the management of water resources is high on the law drafting priority list for 2001 and the Public Services Committee has the necessary law drafting instructions well in hand.

The underlying principles to Jersey resources management at present relate to Norman Law whereby whatever flows through or under a person's land belongs to him or her. This archaic understanding of environmental resources must be replaced with some ruling to promote sharing of the resource and community responsibility for water resources. This may ultimately require some form of licensing of both groundwater sources and surface water off-takes over and above a set threshold abstraction limit.

The States and the Environment

The responsibility for the environmental impact of current activities and planning proposals does not sit comfortably within any one department of Government. Apart from the potential problem of poacher-gamekeeper in individual departments, there are problems of compliance and appropriate action within others. For example, the continued zealous use of nitrate fertilizer and application of farm slurry remains largely above recommended levels for the UK (cf Lott et al, 1999).

All government departments must pull together towards a common environmental vision. That vision must be based on the long-term sustainability of the environment and the satisfaction of both the current and future needs of the Island. A single environment agency may be desitable.

CONCLUSIONS

The Status of the Water Body

Not all the water body of Jersey is stressed by demand or by pollution. In the early 1990s an attempt was made by a local businessman to develop a groundwater source at the St Brelade's Bay Hotel for bottling as a table water. The product was L'Eau des Iles and it was first marketed in Jersey as a trial for export to a wider market. The product itself was of extremely high quality and comparable with market leaders such as Perrier and Highland Spring. However, L'Eau des Iles was apparently not acceptable in Jersey restaurants as an alternative to these brands apparently because of the perception that all Jersey waters are of poor quality and the knowledge that they are vulnerable to all forms of surface pollution.

The perception that all Jersey waters are of poor status derives from the knowledge that much of the water in supply exceeds the EC MAC values for both nitrate and Chlorthal. Although current knowledge suggests that the health risk implications are minimal, the fact that these compounds are widely present indicates that Jersey waters are by no means pristine. The new Water Pollution (Jersey) Law 2000 will greatly assist the management of the Island's environment and the quality of its water body. However, the States committees need to work together in order to safeguard the resource for future generations.

The Resource and the Future

The volume of water available to Jersey is controlled by rainfall and by available storage between rainfall events. The Queen's Valley Reservoir has enabled Jersey to cope better with drought periods. The current understanding of the groundwater store and the role of baseflow helps towards optimising resource management. Great care, however, is needed at this time of possible climate change when any significant decline in rainfall, as seen for example on neighbouring Guernsey, or corresponding increase in evapotranspiration, may have important ramifications on water usage in Jersey. Enabling legislation to facilitate the equitable apportionment of the resource is required.

Small islands face immense problems with the effective capture and exploitation of their renewable resources: water, crops or energy, and for the secure disposal of wastes. Demographic forces are intense, although Jersey is by no means extreme (the island of Malé, for example, has a population density of 30 000 people per km^2). Key issues in Jersey will always include groundwater quantity and quality, the complexity of the Island aquifer and its drainage system, finite and potentially declining effective rainfall, sea water intrusion and pollution caused by improper waste disposal. The key to addressing these issues lies in the formulation and adoption of an appropriate policy towards husbanding the water body, adequate regulation supported by suitable legislation, and resource monitoring and analysis coupled with sensible application of the findings.

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CONSULTEES

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GLOSSARY

AFFF or Aqueous Film Forming Foam is used as a 3% concentrate for fire-fighting and practice fire-fighting at Jersey Airport.

Artesian flow occurs when the piezometric level in a confined system is at a higher elevation than the ground surface.

Aquifer permeable strata that can transmit and store water in economically recoverable quantities. It may be *confined* by weakly permeable overburden (as in a fracture) or *unconfined* beneath the standing water table.

Baseflow natural discharge of groundwater from an aquifer, via springs and seepages to rivers and streams.

Blending is the mixing of raw waters of different quality to produce water of acceptable quality for supply.

Catchment is that part of a river basin which is bounded by a discrete surface water divide from its adjacent catchments.

Chemical Oxygen Demand (COD) is a measure of the organic content of a waste according to the oxygen required to convert it chemically to stable products such as CO_2, H_2O or NO_3.

Denitrification is the process which occurs either under natural or induced conditions whereby nitrate is progressively reduced to nitrite then to ammonium and then to gaseous nitrogen.

Detection limit the lowest limit of concentration at which a laboratory analytical method can measure concentration for a given determinand.

Diffuse pollutants derive from a diffuse or dispersed source, e.g. nitrogen fertilizer which may be spread widely across agricultural land.

Effective rainfall is rainfall over a period of time (usually one year) minus evapotranspiration.

Environmental tritium the presence of tritium in the atmosphere as a tracer subsequent to the detonation of sub-aerial atomic bombs in the 1950s.

Evapotranspiration loss of water from the land surface through the transpiration of plants and evaporation from the soil.

Fractures/fissures natural cracks in rocks which enhance relatively rapid water movement.

Groundwater is all water under the soil zone be it in the unconfined or vadose zone, or beneath the water table in the saturated zone of an aquifer.

Hydraulic conductivity the rate of flow of groundwater through a cross-sectional area of an aquifer under unit hydraulic gradient.

Hydraulic gradient the prevailing inclination of the water table; this provides the driving force to transmit groundwater laterally and vertically through an aquifer.

Instrumented catchment is a catchment in which the components of a given catchment water balance can be measured individually, either directly (e.g. run-off, or rainfall) or indirectly (e.g. evapotranspiration or groundwater infiltration).

Landfill is a repository usually contained in a convenient hole in the ground for solid and sometimes also liquid wastes in which containment may be engineered to some degree.

Leachate is an anaerobic liquid, which with the gas methane, is a product of biodegradation of putresceble material in a landfill site. It may contain metals in solution and is generally harmful to aquatic and human life.

Low-flow is the state of stream flow that is sustained only by groundwater baseflow, there being no longer any contribution from run-off.

Maximum Admissible Concentration is the prescribed guideline limit for specific determinands in drinking waters in the EC.

Metabolite is a decay product of an organic parent chemical.

Nitrate export coefficient a modelling approach for the prediction of Nitrate (N) and Phosphorous (P) loads delivered annually to surface water drainage

Piezometric level/head the water pressure within a confined groundwater system. The level is the level to which water will rise in a borehole which penetrates water under a confining head.

Radiometric age dating a means of dating the age of waters (time since they fell as meteoric precipitation to the ground) by investigation of the ratios of the isotopic concentrations of selected elements.

Renewable resource the amount of water that can be taken from a water body without damaging it over the longer term.

Reservoir is an engineered surface water body which provides storage between wet and dry seasons in order to facilitate continuity of supply.

Run-off is that portion of rainfall which runs overland or via the soil to form surface water flow in streams.

Sea water intrusion is the entry of sea water into a coastal aquifer.

Specific electrical conductance is the electrical conductivity of a cubic centimetre of water measured in $\mu S/cm^3$. The value holds a broadly linear relationship with salinity.

Transmissivity the product of the hydraulic conductivity of an aquifer and its thickness.

Unsaturated zone that part of an aquifer above the water table through which percolating recharging water falls vertically under gravity. It is sometimes refered to as the *vadose zone*.
Water balance in it simplest form is the balance of the rainfall (input) to a catchment with run-off, evapotranspiration and groundwater recharge or change in the groundwater store (output).

Water table the level beneath which the aquifer is saturated.