APPENDIX III

SHADOW SCRUTINY PANEL

DRAFT WATER RESOURCES (JERSEY) LAW 200-

(EXTRACTS FROM 1991, 1998 & 2000 BGS REPORTS: Section C refers)

2 Hydrogeology

2.1 PHYSICAL

2.1.1 The aquifers

A shallow, fractured bedrock aquifer underlies most of the island. Sustainable well and borehole yields are, for the most part less than 0.5 $l\ s^{-1}$, many less than 0.1 $l\ s^{-1}$. The highest sustainable yield known on the island is just less than 4 $l\ s^{-1}$ from a borehole in the Volcanic Group (collectively the Bouley Rhyolite Formation, the St John's Rhyolite Formation and the St Saviour's Andesite Formation; Figure 2). The performance of boreholes varies geographically but lithological controls in the basement rocks are not a significant control (lithological control over groundwater chemistry is also small — see section 3.1.1.). Short-duration pumping tests tend to reflect local storage rather than the bulk parameters of the aquifer (Table 2), and the mean transmissivity value for the bedrock aquifer is 30 $m^2\ d^{-1}$. This is a high value considering the nature of the aquifer and the performance of boreholes that draw on it. As there are many dry and low yielding boreholes unsuitable for testing, this figure approximates the best conditions available within the aquifer.

Site engineering investigations beneath St Helier and in the Queen's Valley indicate that the hydraulic conductivity of granite, migmatite and of the Jersey Shale Formation lies in the range 10^{-3} to 1 $m\ d^{-1}$ (data supplied by PSD). A MODFLOW finite difference groundwater flow model developed by BGS in 1992 suggested that the range in hydraulic conductivity was 10^{-1} to 10 $m\ d^{-1}$, with the highest values occurring inland of St Aubin's Bay. However, the higher values probably reflect a pessimistic estimate of recharge, and an overall value for the main shallow bedrock aquifer is more likely to lie in the range 10^{-3} to 1 $m\ d^{-1}$.

Depth to the water table is generally only a few metres increasing to 10 to 30 m beneath higher ground. The piezometric surface follows a subdued version of the surface topography. For the most part, groundwater storage and transport is shallow and within the top 25 m of the saturated rock (i.e. from the water table to 25 m below it). This is borne out by the mean depth of penetration of boreholes on Jersey; it reflects reduced dilation of available cracks and fractures with increasing depth and pressure of overburden to the degree that the fractures can no longer conduct water. However, a few boreholes have encountered useable quantities of groundwater at depths up to 84 m below ground surface, and these may penetrate the deeper lines of structural weakness that trend east-north-east to west-south-west across the island. These features encourage deeper flow of groundwater than is normal elsewhere on the island, but the flow is of relatively limited volume with regard to the overall transport of groundwater beneath the island from recharge area to point of discharge[1].

[1] This deeper fracture bound groundwater should not be confused with the mystical underground rivers that water diviners portray flowing from east to west bringing water from the Pyrenees to succour Jersey (and Essex in south-east England) under the driving force of the moon (Langlois, 1992; Baudains, 1992). No evidence to substantiate this vision has ever been presented by the diviners.

It is not uncommon to intersect water under a confining head within a fissure during drilling. This happens when a fracture is penetrated which is interconnected to a higher elevation and which is also saturated, so that the water rises under the pressure difference to the water level of the higher elevation fissure. The classic example of this is the well at Fort Regent. This well was excavated using explosive charges, and was reportedly dry to a depth of 72 m. One final blast at that depth caused water to enter the well and rise up to a static level some 21 m below ground level, a level which reflects the water table beneath that part of Fort Regent. Needless to say, with a column of water some 30 m deep in the well, pumping has to be of short duration as it is almost entirely from storage within the well, with overnight recovery before more water can be withdrawn. A contemporary writer (Jones, 1840) describes the well as follows:

> After sinking through 235 feet of compact rock, and upon firing a blast the spring was laid open . . . when 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] cysterns 800 gallons of water.

This rate of abstraction is equivalent to a short term yield of 0.5 $l\ s^{-1}$.

In addition to the bedrock aquifer there are relatively thin Holocene sands which form shallow superficial aquifers behind St Ouen's Bay and the southern part of the Royal Bay of Grouville. The St Ouen's Bay sands are thickest in the southern part of the bay and become interbedded with peat horizons to the north. The sand aquifer is thin and protected from the sea by a rock lip so that a normal saline wedge is unable to develop and saline intrusion is not a cause for concern. The low-lying sand aquifer behind the southern half of the Royal Bay of Grouville is also interbedded with peat, is shallow, but is susceptible to saline intrusion during periods of intense pumping from boreholes in the coastal area.

2.1.2 Flow-paths

The level of the main water table (there are some local perched water tables particularly at times of prolonged and intensive rain) is shown on the Hydrogeological Map of Jersey (BGS, 1992). The configuration of the piezometric level readily allows flowpaths to be constructed. These indicate a regional or island-wide pattern of groundwater flow which discharges to the sea (Figure 5), and a local or catchment-wide flow pattern which discharges water as baseflow to surface water-courses.

Much of the island-wide flow concentrates on St Aubin's Bay as an outlet; this discharge can be seen on the foreshore across much of the bay at low tide, when a fresh to brackish seepage is maintained from the lower foreshore until it is again submerged by the rising tide. Very little groundwater flows to sea across the north coast where the

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.