Ballyshannon GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority		Associated surface water bodies	Associated terrestrial ecosystems	Area (km^2)
Hydrometric Area 36 Donegal Co. Co.		***Rivers***: None identified. ***Streams:*** 68 unnamed streams. ***Lakes:*** Lough Behy, Lough Carricknahorna, Lough Laheen, Lough Legaltan, Lough Doo, Lough Gorman, Lough Lee, Lough Roshin, Lough Round, Lough Tullaghelvin, Lough Tullyhorky, and 10 unnamed lakes.	Lough Golagh and Breesy Hill (O'Riain, 2004)	33
Topography		This approximately rectangular GWB (Figure 1) is bounded by lower permeability rocks to the east, a topographic divide to the north (Hydrometric Area 37), and coastline to the south and west. The landscape is generally low-lying with E-W orientated drumlins. Elevations range from <10 mAOD at the coast to 120 mAOD on the inland drumlin-crests. The drumlins are generally c.30-60 m in height. Surface water flow is southwest to westwards, towards Donegal Bay.		
Geology and Aquifers	**Aquifer type(s)**	**Rk^d**: Regionally important karst aquifer dominated by diffuse flow, is the dominant aquifer is this GWB (83%). Approximately 4 km^2 is underlain by **Lm**: Locally important aquifer which is generally moderately productive, and there are two smaller intervening areas of **Ll**: Locally important aquifer which is moderately productive only in local zones.		
	Main aquifer lithologies	The GWB comprises three rock groups: Dinantian Pure Bedded Limestones (83.23%), Dinantian Sandstones (11.19%) and Dinantian Shales and Limestones (5.57%). Refer to Table 1 for details.		
	Key structures	There are a small number of faults between the different rock types in this GWB and dips to the southeast are generally <10°.		
	Key properties	The limited data in this GWB are only available for the Pure Bedded Limestones ~ 5 well yields ranging from 120-327 m^3/d (averaging 220 m^3/d) and specific capacities of 4, 11, 32 and 168 $m^3/d/m$ for 4 of those wells, which are all located in the same general area. Four well yields are available in the adjacent GWB (Donegal-Ballintra): 109, 491, 927 and 1090 m^3/d, and one specific capacity value – 103 $m^3/d/m$. The data indicate that higher transmissivity values are achievable. The variable discharge and rapid response to rainfall in the Parkhill Spring (Ballyshannon GWB) indicates the potential for rapid groundwater flow and low storativity in this type of aquifer. High annual variation in groundwater levels (up to 25 m) have been recorded in one borehole (Figure 2), which *may* also suggest low storativity. One data point for the Dinantian Sandstones is located in the adjacent GWB (<1 km away), which has a yield of only 25 m^3/d but a specific capacity of 168 $m^3/d/m$ (Productivity category II (Wright, 2000)). From the minimal karst work undertaken in this part of Donegal, c.30 karst features have been recorded in the limestones in this and the adjacent Donegal-Ballintra GWB, and there are likely to be more unrecorded features e.g. there are a number of isolated and discontinuous lengths of streams that may represent swallow holes, enclosed depressions (dolines) and caves. All but one of the 15 available groundwater levels are 0-10 m below ground level, with 9 <5 mbgl. The data are inadequate to calculate groundwater gradients although overall flow directions are to the southwest and west, with groundwater discharging to the sea. *(Minerex Reports; Donegal GWPS; Pure Bedded Limestones Aquifer Chapter*)		
	Thickness	In the pure limestones, most groundwater flows in an epikarstic layer c.2-3 m thick and in a zone of interconnected solutionally-enlarged fissures and conduits that extends approximately 30 m below this. Most of the groundwater flux in the Lm aquifer is also likely to be in uppermost top 30 m (c.3 m broken, weathered material underlain by interconnected fissuring), although the zones of interconnected fissures may be shallower (c.15 m) in the Ll aquifer. There will also be a zone of isolated, poorly connected fissures – typically less than 150 m bgl – in all of the rock types. Water strikes that are slightly deeper than the interconnected fissure zone (40-43 mbgl) have been recorded in one well.		
Overlying Strata	**Lithologies**	Till is the predominant subsoil in this GWB (c.69%), with a small proportion of peat (8%). Approximately 18% of the GWB is recorded as outcrop/shallow rock.		
	Thickness	The till drumlins each represents a thicker deposit, frequently >10 m thick, with rock near the surface of the inter-drumlin areas.		
	% area aquifer near surface	*[Information will be added at a later date]*		
	Vulnerability	Vulnerability ranges from Extreme where subsoil deposits are absent or thin (mainly to the northeast and northwest), to Moderate and Low over the thick drumlin deposits, in central and southern areas.		

Recharge	**Main recharge mechanisms**	Both point and diffuse recharge occur in this GWB. Diffuse recharge occurs via rainfall percolating through thin subsoil and outcrops. In the pure limestones, point recharge to the underlying aquifer occurs via swallow holes, dolines and caves. Although recharge along 'losing' sections of streams is also associated with this particular type of karst aquifer, to date none have been recorded in this GWB. The presence of low permeability, thick till drumlins will promote surface runoff. The runoff may either discharge to the streams in the GWB or be diverted to the inter-drumlin areas, where recharge is more likely to occur. The relatively low stream density over the pure limestones, as compared to the surrounding GWBs, suggests a high proportion of aquifer recharge, which is often associated with karstified rocks.
	Est. recharge rates	*[Information will be added at a later date]*
Discharge	**Important springs and high yielding wells**	Sources: Ballyshannon PWS (Parkhill Spring - *250-c.2000 m^3/d*) Springs: See Sources above. Excellent wells: Ballyshannon (500 m^3/d). Good wells: Crockacapple (327 m^3/d), Ballyshannon (260 m^3/d x 2, 120 m^3/d).
	Main discharge mechanisms	The main groundwater discharges are to the streams, rivers, lakes and any springs (e.g. Parkhill Spring) found within the body. Given the permeable nature associated with Rk^d aquifers, the baseflow proportion of the total streamflow is expected to be higher in this GWB than for the adjacent Pl/Pu GWB, especially where the subsoil is thinner i.e. in the inter-drumlin areas.
	Hydrochemical Signature	***National classification:*** Dinantian Pure and Impure Limestones Calcareous. Generally Ca-HCO_3 signature. Alkalinity (mg/l as $CaCO_3$): range of 10-990; mean of 283 (2454 data points) Total Hardness (mg/l): range of 10-1940; mean of 339 (2146 data points) Conductivity (μS/cm): range of 76-2999; mean of 691 (2663 data points) ***National classification:*** Dinantian Sandstones Calcareous. Generally Ca-HCO_3 signature. Alkalinity (mg/l as $CaCO_3$): range of 5-524; mean of 153 (65 'non limestone subsoils' data points) Total Hardness (mg/l): range of 5-502; mean of 162 (67 'non limestone subsoils' data points) Conductivity (μS/cm): range of 39-1184; mean of 408 (69 'non limestone subsoils' data points) *(Calcareous/Non calcareous classification of bedrock in the Republic of Ireland report)*
Groundwater Flow Paths		As these rocks are generally devoid of inter-granular permeability, groundwater flows through fissures, faults, joints and bedding planes. In pure bedded limestones, these openings are frequently enlarged by karstification resulting in significantly enhanced rock permeability. Karstification can be also accentuated along structural features such as fold axes and faults. An epikarst layer in the upper few metres of the rock is likely to be present on top of the diffusely karstified aquifer. The majority of the available groundwater levels are 0-5 mbgl suggesting that shallow groundwater flow is dominant, although a component of deep groundwater flow would be expected. Continuous water tables that reflect topography are considered to exist in diffusely karstified aquifer as the flow regimes are likely to be hydraulically connected. However the degree of interconnect depends on the frequency of fissures, faults, and joints. Groundwater flow is thought to be mainly unconfined. In the karstified aquifers, groundwater flow is regional scale – flow path lengths of several kilometres are not unusual although are likely to be shorter in discharge areas (c.100-300 m). This is also likely be the case for the sandstones (Lm aquifers), although shorter flow paths (<300 m) are associated with Ll aquifers. Overall, groundwater flow will be south-westwards, towards the coastline, but the karstified nature of the pure limestone means that locally groundwater flow directions can be highly variable.
Groundwater & surface water interactions		There is a high degree of interconnection between groundwater and surface water in karstified limestone areas such as in this GWB. Swallow holes, dolines, caves, turloughs, springs, and 'losing' and 'gaining' streams all provide a direct route between surface water and groundwater systems. This rapid interchange between surface water and groundwater is often reflected in their similar water quality as contamination is also rapidly transported between the two systems.

Conceptual model	• The GWB is bound to the south and west by coast. The eastern boundary is a change in aquifer type and the northern boundary is a topographic divide (Hydrometric Area 37). The topography is generally low-lying and is dominated by E-W orientated drumlins.
	• The main rock type in this GWB is a karstified limestone that is dominated by diffuse groundwater flow (aquifer category **Rk^{d}**). A smaller proportion of the area is underlain by sandstones, which are also considered to be characterised by a productive fracture flow system (**Lm**), and approximately 5% of the GWB is categorised as have a lower productivity (**Ll** aquifer).
	• Most of the generally unconfined groundwater flux is in the uppermost 30 m of the aquifers. This occurs through a few metres (c.3 m) of broken, weathered bedrock and an underlying zones of interconnected joints, fissures, fractures and faults. In the pure limestones, the upper weathered zone is likely to equate to an epikarst layer and the underling joints, fissures, fractures and faults will be karstified (solutionally enlarged). Deeper groundwater flow may occur along permeable fault or fracture zones.
	• Transmissivity values and well yields are variable, reflecting zones of higher and lower permeability. In the pure limestones, rapid response of springs to rainfall events indicates that there is the potential for high groundwater flow velocities through this rock, and for low storativity.
	• In general, the degree of interconnection in karstic systems is high and they support regional scale flow systems. Long flow paths (kilometres in length) can be expected although are likely to be shorter in discharge areas (100-300 m). Similar flow path lengths would be expected in the sandstones.
	• Recharge occurs by:
	  • diffuse means in all rock types – via outcrops and through thin subsoil, although may be limited by thicker, low permeability subsoil, and
	  • additional point mechanisms in the karstified limestones; swallow holes, dolines, caves and along lengths of losing streams – mainly occurring where subsoils are thin i.e. areas of extreme vulnerability.
	• Due to the combination of point recharge and rapid flow through solutionally enlarged joint/fissure/fracture zones, there is minimal potential for contaminant attenuation in the limestone aquifer.
	• The main discharges are to the rivers and springs within the GWB. Overall, the flow direction is to the southwest, as determined by the topography.
	• There is a high degree of interaction between surface water and groundwater in the karstified portion of this GWB.
	• The Ballyshannon PWS (Parkhill Spring) is within this GWB.

Attachments	Figure 1. Figure 2. Table 1.
Instrumentation	**Stream gauges:** 36032, 36033, 36035 **EPA Water Level Monitoring boreholes:** DON040 **EPA Representative Monitoring points:** None identified.
Information Sources	Lee M. and Fitzsimons V. (2004). *County Donegal Groundwater Protection Scheme.* Main Report. Draft Report to Donegal County Council. Geological Survey of Ireland 58pp. Long, C.B. and McConnell (1999) *Geology of South Donegal: A geological description, to accompany bedrock geology 1:100,000 scale map, Sheet 3, South Donegal*. With contributions by G.I. Alsop, P. O'Connor, K. Carlingford and C. Cronin. Geological Survey of Ireland, 116pp. Minerex Environmental Ltd. (2003). *Ballyshannon and Rossnowlagh Water Supply Scheme – Groundwater Supply. BH1, BH2, BH3, BH4 and Spring 2 pumping test supervision, monitoring, interpretation an reporting.* MEL Doc.Ref.:1492-103 (First draft). O' Riain, 2004. *Water Dependent Ecosystems and Subtypes (Draft)*. Compass Informatics in association with National Parks and Wildlife (DEHLG). WFD support projects. Wright G.R. (2000). QSC Graphs: *An aid to classification of data-poor aquifers in Ireland*. From: Robons, N.S. and Misstear, B.D.R. (eds) Groundwater in the Celtic Regions: Studies in Hard Rock and Quaternary Hydrogeology. Geological Society, London, Special Publications, 182.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae.

Figure 1. Location and Boundaries of GWB.

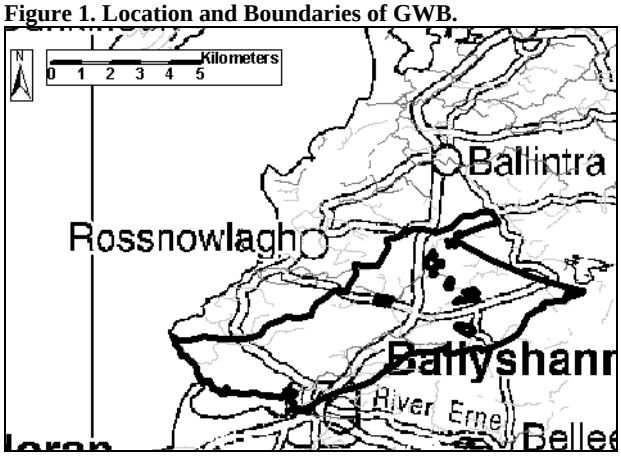

Table 1. List of rock units in Ballyshannon GWB

Rock Unit Name	Code	Description	Rock Unit Group	**Aquifer Class.**	% Area
Ballyshannon Limestone Formation	BS	Pale grey calcarenite limestone	Dinantian Pure Bedded Limestones	Rk	77.04%
Mullaghmore Sandstone Formation	MU	Sandstone, siltstone & shale	Dinantian Sandstones	Lm	17.71%
Bundoran Shale Formation	BN	Dark shale, minor fine-grained limestone	Dinantian Shales and Limestones	Ll	5.25%

Figure 2: Groundwater hydrographs (EPA Groundwater Level Monitoring)