Ballyshannon South 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. NI		***Rivers:*** Erne. ***Streams:*** 26 unnamed streams. ***Lakes:*** Lough Bracken, Assaroe Lake and 7 unnamed lakes.	Dunmuckrum Turloughs (O'Riain, 2004)	29
Topography		This is a narrow, E-W orientated GWB (Figure 1), located between Lower Lough Erne (eastern boundary) and Donegal Bay (western boundary). Lower permeability rocks comprise the northern and southern boundaries. The landscape is generally low-lying with elevations ranging from <10 mAOD at the coast to c.90 mAOD along the south-eastern boundary. The main surface water flow direction is towards Assaroe Lake and the River Erne (northwards over the western half and southwards over the eastern half). However, at the western periphery, flow is westwards towards the sea and at the eastern periphery, eastwards towards Lower Lough Erne.		
Geology and Aquifers	**Aquifer type(s)**	**Rk[d]**: Regionally important karst aquifer dominated by diffuse flow, is the dominant aquifer is this GWB (90%). At the coast, approximately 2 km^2 is underlain by **Lm**: Locally important aquifer which is generally moderately productive, and there is a small area of **Ll**: Locally important aquifer which is moderately productive only in local zones.		
	Main aquifer lithologies	The GWB mainly comprises three rock groups: Dinantian Pure Bedded Limestones (91.31%), Dinantian Sandstones (6.2%) and Dinantian Shales and Limestones (1.69%). Refer to Table 1 for details.		
	Key structures	The rocks in this GWB are dipping to the south by 5-16°.		
	Key properties	There are limited data within this GWB – only 1 high yielding spring (4550 m^3/d) in the Finner Camp Military Base. Such high yields frequently occur in karst aquifers however, without additional discharge data, no further conclusions can be drawn about the degree of karstification. Data are available for this rock type in the adjacent GWBs (Ballyshannon and Donegal-Ballintra) – 9 well yields 109-1090 m^3/d and 5 specific capacities of between 4-168 m^3/d/m. The data show the variability of yields and transmissivites, and indicate that higher 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. No data are available for the other rock groups. From the minimal karst work undertaken in this part of Donegal, c.30 karst features have been recorded in the limestones although there are likely to be significantly more unrecorded features. Additionally, Dunmuckrum Turloughs are present in this particular GWB (O'Riain, 2004). The available groundwater levels (8), 6 are 0-5 m below ground level. The data are inadequate to calculate groundwater gradients although overall flow directions are generally towards Assaroe Lake and the River Erne i.e. to the north across the majority of the GWB. *(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.		
Overlying Strata	**Lithologies**	Of the portion of the GWB that has subsoil information (i.e. within the RoI), till is the predominant subsoil (c.60%), with a small proportion of sand/gravel (10%). Just under a quarter of the area is recorded as rock outcrop/shallow soil/subsoil.		
	Thickness	From the Donegal GWPS, subsoil is absent or thin over much of the GWB, especially in the central areas. Thicker deposits (>3 m) are found in the along the southern boundary and the coast, with the thickest (>10 m) in the northwest corner, which are likely to be sand and gravel deposits. A similar pattern would be expected in the eastern part of the GWB (i.e. within NI)		
	% area aquifer near surface	*[Information will be added at a later date]*		
	Vulnerability	Vulnerability ranges from Extreme where subsoil deposits are thin over much of the central area, to High over the peripheral 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 very 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: None identified Springs: Finner Camp Military Base (4550 m^3/d). *The discharge may be influenced by the overlying sand & gravel deposit*. Wells: None identified
	Main discharge mechanisms	The main groundwater discharges are to Assaroe Lake and Lough Erne, which are located along the northern and eastern boundaries respectively, and to the sea, which forms the western boundary. Discharges will also occur to the limited number of lakes (or turloughs), rivers and any springs found within the body. Given the permeable nature associated with Rk^d aquifers, the baseflow proportion of the total streamflow would be to be high, especially where the subsoil is thinner i.e. in the central/northern 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 available groundwater levels are mainly 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 to be the case for the sandstones (Lm aquifers), although shorter flow paths are associated with the Ll aquifers (100-300 m). Overall, groundwater flow is expected to be towards Assaroe Lake and the River Erne (i.e. generally northwards over the majority of the body), 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 within this GWB. Swallow holes, dolines, caves, turloughs (e.g. Dunmuckrum 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	• Northern and southern boundaries represent changes in the aquifer type. The eastern boundary is the Lower Lough Erne and the western boundary comprises coastline. The topography is generally low-lying and gently sloping.
	• 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 less than 2% of the GWB is categorised as have a lower productivity (**Ll** aquifer).
	• Most of the 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 can 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 accordingly, 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, 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 Assaroe Lake and the River Erne, as well as to any rivers and springs within the GWB. Overall, the flow direction is mainly to the north, as determined by the topography.
	• There is a high degree of interaction between surface water and groundwater in the karstified portion of this GWB.

Attachments	Figure 1. Figure 2. Table 1.
Instrumentation	**Stream gauges:** None identified. **EPA Water Level Monitoring boreholes:** None identified. **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.
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.

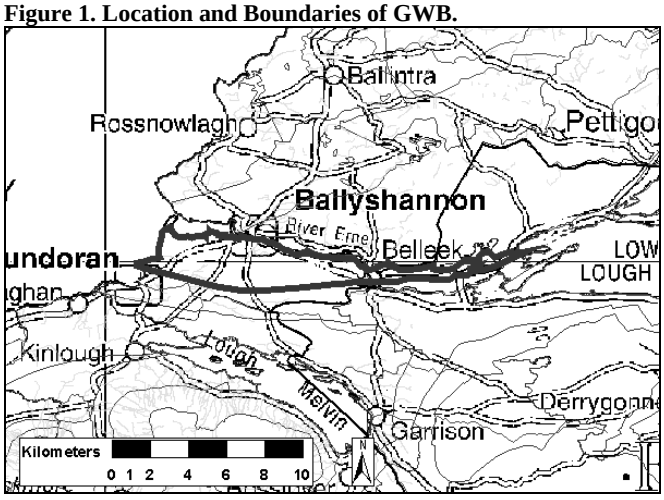

Table 1. List of Rock units in Ballyshannon South GWB

Rock unit name and code	Description	Rock unit group	Aquifer Classification	% Area
Ballyshannon Limestone Formation (BS)	Pale grey calcarenite limestone	Dinantian Pure Bedded Limestones	Rk	91.31%
Mullaghmore Sandstone Formation (MU)	Sandstone, siltstone & shale	Dinantian Sandstones	Lm	6.2%
Bundoran Shale Formation (BN)	Dark shale, minor fine-grained limestone	Dinantian Shales and Limestones	Ll	1.67%
Mudbank limestone (mk)		Dinantian Pure Unbedded Limestones	Ll	0.25%
Basal sandstones (BSbc)		Dinantian (early) Sandstones, Shales and Limestones	Ll	0.02%

Figure 2: Groundwater hydrographs (EPA Groundwater Level Monitoring)