Ballingarry GWB (Area 24): Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
24 - Maigue Limerick Co. Co.	Rivers: Maigue, Morningstar, Clonshire.	-	94

Topography	The groundwater body is elongated in an ENE-WSW direction along two slightly elevated ridges. The highest elevation on the northern ridge is at Knockfeerina, where the elevation of 288 mAOD is reached by ground underlain by a small area of volcanic rock. The highest peak on the southern ridge is 272 mAOD at Corronoher. The ground decreases elevation towards the margins of the GWB, away from the ridges that are formed by the ORS. Ground elevation also decreases eastwards to heights of around 50-70 mAOD. The River Maigue flows roughly N-S across the eastern part of the GWB, where the elevation is approximately 40 mAOD. The Morningstar River crosses an outlier (that is connected underground) of the GWB at Athlacca. Streams generally flow off the lower elevations of the GWB where they ultimately drain into the River Maigue, Morningstar or Deel. The higher areas are generally well drained; drainage ditches are present in the flatter parts of the area.	
Geology and Aquifers	Aquifer categories	The majority of the GWB comprises **Rf**: Regionally important fissured bedrock aquifer. The volcanic rock is an **Lm**: Locally important bedrock aquifer which is generally moderately productive. In the area between the ridges, there are small areas of the GWB underlain by Dinantian Lower Impure Limestones that are **Ll**: Locally important bedrock aquifer which is moderately productive only in local zones. There are small areas along the ridges where the Old Red Sandstone also has the **Ll** aquifer classification.
	Main aquifer lithologies	Devonian Kiltorcan-type Sandstones underlie the centre of the GWB; Dinantian (early) Sandstones, Limestones and Shales underlie the outer margins of most of the GWB. Volcaniclastic rocks (V) occur as small areas in the centre of each ridge. There are two small areas of Dinantian Lower Impure Limestones in the low ground between the ridges. The ORS in small areas along the ridges is harder and less fractured than in the bulk of the GWB.
	Key structures	The two ridges are the cores of two anticlinal folds that are oriented ENE-WSW. The younger rocks of the Dinantian (early) Sandstones, Limestones and Shales occupy the lower ground between the ridges and at the edges of the GWB. Major faults trending N-S, NE-SW and NW-SE cross-cut and displace the fold axes and disrupt the continuity of the rock units. There are also faults parallel to the fold axes. Compression during the folding caused fracturing and jointing of the rocks, especially in the sandstone layers. In some locations, for example at Ballingarry, erosion along the fault zones has created valleys. The beds dip outwards around the entire GWB at angles of 10-30^o, and inwards to the central valley.
	Key properties	The transmissivity in this rock unit group generally ranges from 40 to 100 m^2/d. At Kilcolman WS in the adjacent Knockaderry GWB, a pumping test on the borehole provided transmissivities in the range 111–197 m^2/d with 154 m^2/d being the best estimate. At Clouncagh WS, also in Knockaderry GWB, analysis of the pumping test data gave a range of transmissivity values from 42–150 m^2/d, with a best estimate of 68 m^2/d. Analyses of a pumping test at the Ballyagran WS in the nearby Bruree GWB provided transmissivities ranging from 94 to 196 m^2/d with 105 m^2/d appearing to be the best estimate. At Bruree WS, analysis of a 10-hour pumping test gave a transmissivity of 132 m^2/d (range 54–151 m^2/d). However, water levels and water temperature measurements taken during the test indicated that a significant proportion of the supply is being contributed by the river. In these rocks, the specific yield is normally about 2%, but near the surface it can be as high as 5%. Groundwater gradients from the higher areas to the river valley are estimated to be approximately 0.04. *(data sources: Rock Unit Group Aquifer Chapters, Limerick GWPS and Source Reports, see references; estimation from maps)*
	Thickness	The effective thickness of this aquifer is up to 200 m (i.e. the entire thickness of the rock unit groups forming the GWB). The upper 10 m may be more weathered and transmissive than the bulk of the aquifer. It becomes confined where it passes underneath the Ballysteen Formation (Dinantian Lower Impure Limestones).
Overlying Strata	Lithologies	Limestone till, sand and gravel deposits, till-with-gravel; clayey till with silt. *[More information to be added at a later date]*
	Thickness	The subsoil varies in thickness from about 4 m to more than 30 m. The thinner subsoils are found in the higher areas, where there are also small scattered outcrops. Deeper subsoils occur around the edges of the GWB, in the lower-lying areas.
	% area aquifer near surface	*[Information to be added at a later date]*
	Vulnerability	*[Information to be added at a later date]*
Recharge	Main recharge mechanisms	Diffuse recharge will occur over the entire groundwater body via rainfall soaking through the subsoil and directly into outcropping rock. It will occur most readily where rock is close to surface. A percentage of rainfall will not recharge the aquifer, but will runoff. Gravel lenses in the subsoils may contribute flow and storage to the aquifer.
	Est. recharge rates	*[Information to be added at a later date]*

Discharge	Springs and large known abstractions (m^3/d)	Ballingarry (~450 m^3/d) (partial contribution from bedrock, main contribution from gravelly tills that are not a gravel GWB at Ballingarry), Athlacca South WS (109 m^3/d), Granagh GWS (85 m^3/d), Banoge WS (196 m^3/d). According to GSI records, Pullagh GWS is not operational. *[More information to be added at a later date]*
	Main discharge mechanisms	The streams crossing the GWB are gaining, as are the Rivers Maigue, Morningstar and Clonshire. The streams start as springs which mainly emanate mid-way down the ridge slope. Deakin (1995) considers that the small springs, rises and isolated ponds within the GWB are perched.
	Hydrochemical Signature	The only data for this GWB are from a source that is mainly fed by groundwater flowing in till-with-gravel (Ballingarry WS), although the underlying bedrock may be contributing. There are two sources in the adjacent Knockaderry GWB, Clouncagh WS and Kilcolman WS. Groundwater from the borehole at Clouncagh is indicative of a hard water (279–293 mg/l $CaCO_3$), with moderately high alkalinity (270 mg/l $CaCO_3$). At the Kilcolman source, which comprises two springs and a summer backup borehole, the hydrochemical analyses of groundwater at the sources are indicative of a moderately hard to hard water (244–292 mg/l; $CaCO_3$), with moderate alkalinity (224–261 mg/l; $CaCO_3$). The conductivities are variable although generally range from 500–700 µS/cm. It is probable that there are some localised flows to the springs in gravelly lenses/layers in the till. At Ballyagran WS in the nearby Bruree GWB, the mean conductivity is 650 µS/cm, and the hardness is in the region of 335 mg/l (as $CaCO_3$) while the alkalinity is approximately 310 mg/l (as $CaCO_3$). pHs are neutral. Background chloride concentrations will be higher than in the Midlands, due to proximity to the sea. Iron can be a problem in the sandstone aquifers. All analyses are indicative of a calcium-bicarbonate type water which is more typical of a limestone aquifer in which carbonate dissolution is the dominant chemical process. This is may be due to the carbonate cement or limestone bands within the formation, or may be a reflection of the presence of limestone-dominated subsoils through which recharge is infiltrating. (Where the aquifer is significantly confined, ion exchange may have taken place, altering the hydrochemical signature towards sodium-bicarbonate.) Where there is mixing with surface water, these parameters have lower values. The bedrock strata of the Old Red Sandstone aquifer are **siliceous**, although they may have some carbonate cementing the sand grains. The Lower Limestone Shale rock unit (part of the Dinantian (early) Sandstones, Limestones and Shales rock unit group) is **calcareous**.
Groundwater Flow Paths		The rocks are devoid of intergranular permeability; groundwater flow occurs in fractures and faults. The fissuring associated with faults results in higher transmissivities, specific capacities and yields for some wells. The sandier units (at the top of the ORS and the base of the Lower Limestone Shales) are more prone to fracturing. In certain areas the rock cement has been dissolved and so the rock is crumbly and easily weathered. Here it may have intergranular permeability - a feature that is very unusual in Irish bedrock. The folding of the rock units renders the aquifer both confined and unconfined; groundwater flow is initially unconfined but, as it travels below thickening subsoils and then underneath the Dinantian Lower Impure Limestones (the Ballysteen Formation), it becomes confined. Water levels vary depending on topography, ranging from near-surface to depths of over 20 m. The hydrograph shown in Figure 1 was measured in a well near a discharge zone within the GWB, hence the water table ranges between 0-5 mbgl. The seasonal water table fluctuation is 5 m, which is higher than would be expected in a low-lying part of this GWB. It is possible that the summer water table is artificially lowered by abstraction. Artesian supplies may be obtained where boreholes penetrate the aquifer through the confining shaley beds of the overlying formations, or where subsoils are particularly thick and of low permeability. Confined groundwater circulating at depth discharges to the surface via large faults. Impermeable fault zones may also retard circulation, however, by isolating all or part of an aquifer block from another or by isolating the recharge area from the deepest parts of the formation. The general groundwater flow direction is naturally downhill radiating outwards in all directions (but mainly north-, south- and eastwards) from the high ground along the ridges. In the northwest of the GWB, flow is to the Clonshire River, and in the east, towards the River Maigue.
Groundwater & Surface water interactions		Groundwater in the Ballingarry springs is thought to come from both the bedrock aquifer and gravelly till deposits. Springs occurring on the hills slopes drain into the local streams. The larger streams and rivers crossing the GWB are considered to be in at least partial hydraulic continuity with the aquifer and gaining baseflow from the aquifer. Deakin (1995) considers that many of the small springs, rises and isolated ponds in the area are likely to be sourced from perched groundwater meaning that, in these areas, interaction between surface and groundwaters will be rapid.

Conceptual model	• The groundwater body is elongated ENE-WSW, comprising two ridges separated by a lower valley. It is bounded all around by the contact with the surrounding Dinantian Lower Impure Limestone (Ballysteen Limestone), under which the aquifer becomes confined. The upper units of the LLS (the Ringmoylan Shales - unmapped as a separate unit in this area) also confine the aquifer. The area comprises small hills; ground elevation decreases outwards from the ridges and also eastwards. • The groundwater body is predominantly comprised of high transmissivity fissured bedrock. The topmost unit of the Lower Limestone Shales (the Ringmoylan Shales) is shaley and low permeability. Specific yields in the sandstone are higher than most Irish bedrock aquifers. • Flow occurs along fractures, joints and major faults. In certain areas the rock cement has been dissolved and so the rock is crumbly and easily weathered. Here it may have intergranular permeability. The major faults may compartmentalise the aquifer in certain situations. • Recharge occurs particularly in the upland areas where rock outcrops or subsoils are thin. • Depending upon topography, the water table can vary between a few metres up to 20 m below ground surface. The aquifer becomes confined where it passes under the Lower Impure Limestones rock unit group, or under thick low permeability tills; here, wells are artesian. Groundwater flow follows topography, radiating outwards mainly to the north and south from the central ridge. Flow path lengths in the unconfined areas may be up to 1000's metres but, depending upon the topography, may be much shorter. Confined flow path lengths can be considerably long, and groundwater flow will be slow. There is evidence of some perching of groundwater. • Groundwater discharges to the rivers and streams crossing the aquifer, which are gaining, and near the contact with the overlying Lower Impure Limestones. Groundwater is also thought to discharge from depth, by flowing upwards along fault zones. Perched groundwater may feed small springs and streams emerging mid-way down the slopes. The Ballingarry WS spring is fed by groundwater that originates in both the bedrock aquifer and the overlying gravelly tills. • The Duckstown Gravel GWB overlies this bedrock GWB in the very western part of the body.
Attachments	Groundwater hydrograph (Figure 1), Hydrochemical signature (Figure 2).
Instrumentation	Stream gauges: 24005*, 24027, 24028, 24044. *(station marked with * has adjusted Specific Dry Weather Flow calculated for it)* EPA Water Level Monitoring boreholes: Glenwilliams (LIM156) EPA Representative Monitoring boreholes: N/A.
Information Sources	Daly, E.P. (1985) *Hydrogeology of the Kiltorcan Aquifer System.* Groundwater Section, GSI Internal Report. Aquifer chapter: Devonian Kiltocan-type Sandstone. Daly, E.P. (1988) The Kiltorcan Sandstone Aquifer. *Proceedings of Eighth Annual International Association of Hydrogeologists (Irish Branch) Seminar, Portlaoise.* Deakin, J., Daly, D. and Coxon, C. (1998) *County Limerick Groundwater Protection Scheme*. Geological Survey of Ireland Report to Limerick Co. Co., 72 pp. Deakin, J. (1995) *Clouncagh PS: Groundwater Source Protection Zones*, GSI Report to Limerick Co. Co., 6 pp. Deakin, J. (1995) *Ballingarry PS: Groundwater Source Protection Zones*, GSI Report to Limerick Co. Co., 6 pp. Deakin, J. (1995) *Kilcolman PS: Groundwater Source Protection Zones*, GSI Report to Limerick Co. Co., 7 pp. Deakin, J. (1995) *Ballyagran PS: Groundwater Source Protection Zones*, GSI Report to Limerick Co. Co., 11 pp. Deakin, J. (1995) *Bruree PS: Groundwater Source Protection Zones*, GSI Report to Limerick Co. Co., 6 pp. Aquifer chapters: Devonian Kiltorcan-type Sandstones; Dinantian (early) Sandstones, Limestones and Shales; Basalts & other Volcanic Rocks.
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: Groundwater hydrograph

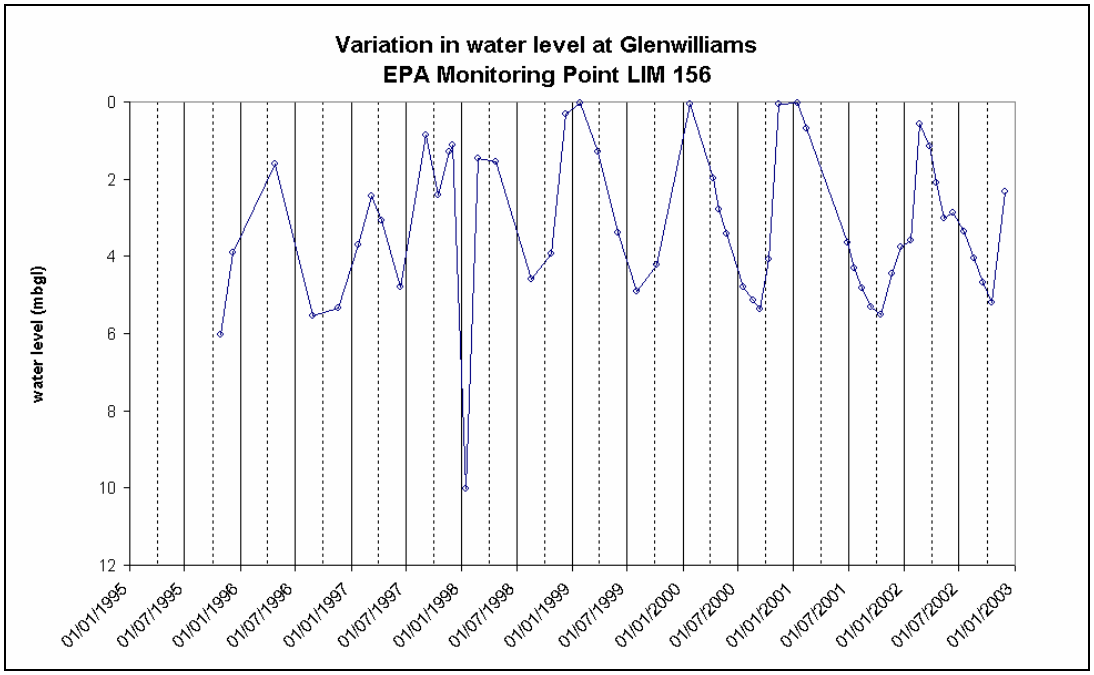
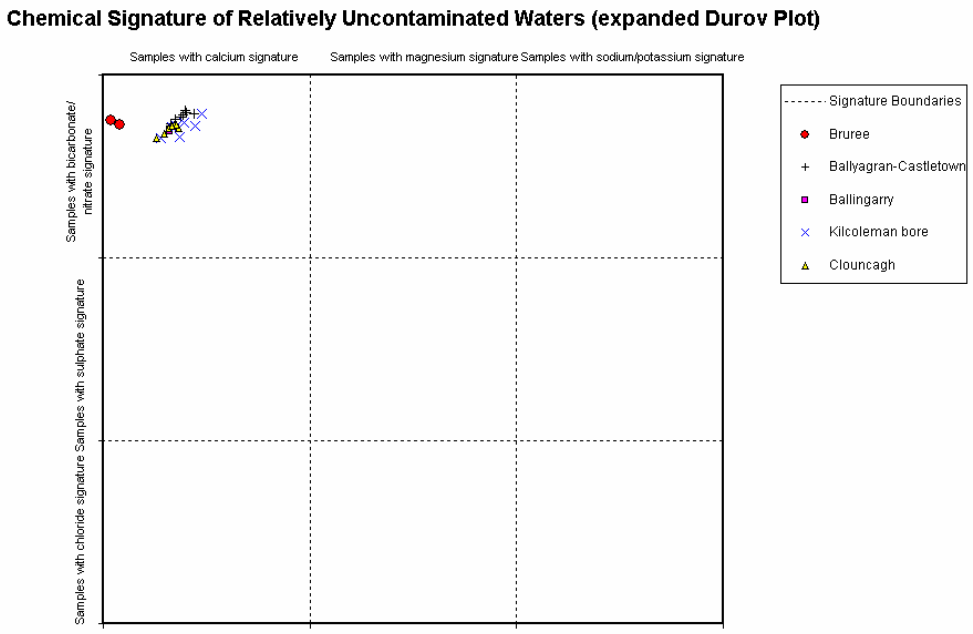
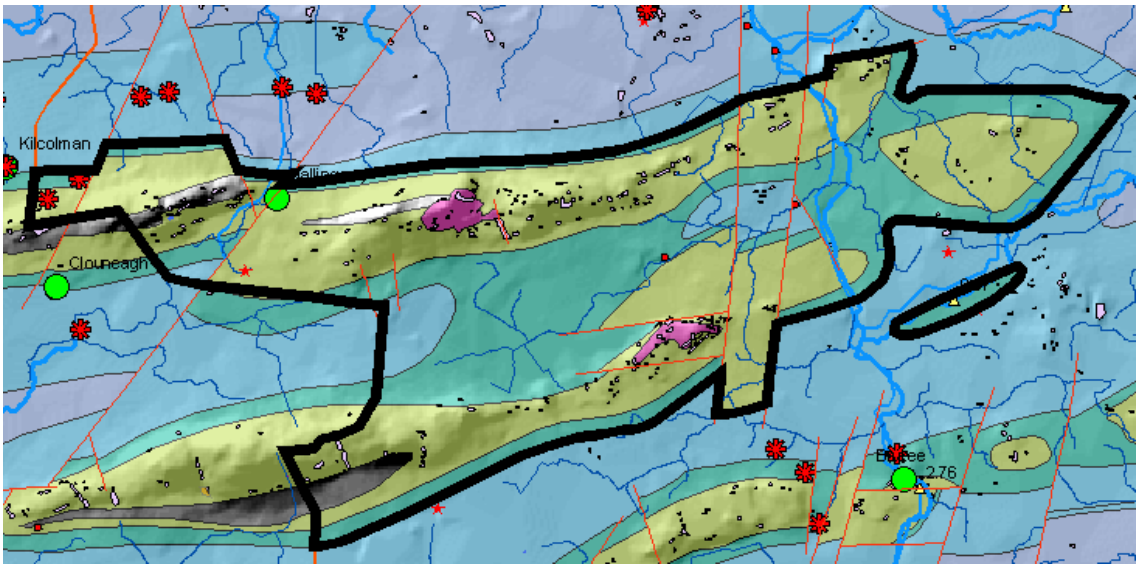


Figure 2: Hydrochemical signature



NB: data used to generate this plot are from Bruree, Ballingarry and Knockaderry GWBs.



Rock units in GWB

Rock unit name and code	Description	Rock unit group
Old Red Sandstone (undifferentiated) (ORS)	Red conglomerate, sandstone and mudstone	Devonian Kiltorcan-type Sandstones AND Devonian Old Red Sandstones
Lower Limestone Shales (LLS)	Sandstone, mudstone and thin limestone	Dinantian (early) Sandstones, Limestones and Shales
Ballysteen Limestone Formation (BA)		Dinantian Lower Impure Limestones
Volcaniclastic rocks (V)		Basalts and other Volcanic rocks