Tynagh GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
25 - Kilcrow/ Cappagh/ Coos Clare and Galway Co. Co.'s	Rivers: Shannon (Lower), Brosna, Kilcrow, Lisduff, Duniry, Cappagh, Woodford, Coos, Bow, Derrainy, Killadulisk. Streams: Eyrecourt, Drumkeary, Rostollus. Loughs: Fullaghans, Derg, Ballin, Aloe, Black, Cregg, Alewnaghta.	Lough Derg (000011), Loughatorick South Bog (000308), Cloonamirran Wood (001686), Kilnaborris Bog (000284), Eskerboy Bog (001264), Moorfield Bog (001303), Barroughter Bog (000231), Slieve Aughty Bog - Moyglass and Woodford (001229), Pollnaknockaun Wood Nature Reserve (000319), Cloonoolish Bog (000249), Cloonmoylan Bog (000248), Meneen Bog (000310), River Shannon Callows (000216).	766

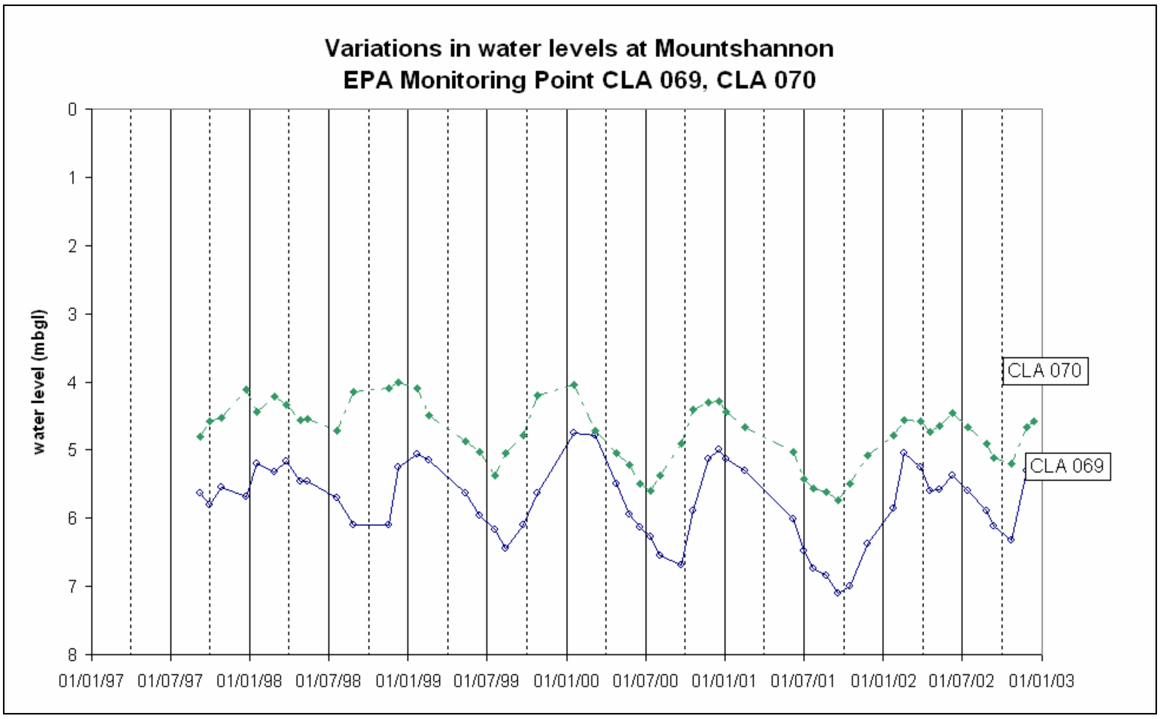
Topography		The groundwater body is shaped roughly like an upside-down triangle, with the long axis oriented N-S. Elevation within the GWB ranges from 30 mAOD along the shore of Lough Derg (along the SE boundary) to 378 mAOD at Cappaghbaun Mountain in the southwest of the GWB. The topography ranges from mountainous in areas underlain by the resistant sandstones and mudstones of the Devonian Old Red Sandstones and Silurian rocks, where elevations are generally >80 mAOD, to flat-lying in areas underlain by impure limestones, where elevations are typically 40-60 mAOD. Overall, elevation decreases eastwards. River flows are predominantly southwards and eastwards, to Lough Derg and the River Shannon.
Geology and Aquifers	Aquifer categories	The GWB aquifers are predominantly **Ll:** Locally important aquifers which are moderately productive only in local zones. In the southwest, the uplands are underlain by **Pl:** Poor aquifers which are generally unproductive except for local zones. There is a small area (5 km^2) of karstified limestone in the east of the GWB that would be an **Rk**^{d}: Regionally important karstified aquifer dominated by diffuse flow, except that it is too small to sustain regional flow.
	Main aquifer lithologies	Dinantian Upper Impure Limestones dominate the north and northeast; Devonian Old Red Sandstones and Silurian Metasediments and Volcanics occupy the west and southwest of the GWB; Dinantian Lower Impure Limestones, Dinantian Pure Unbedded Limestones, Dinantian (early) Sandstones, Shales and Limestones, and Dinantian Pure Bedded Limestones occupy a NW-SE strip between the Upper Impure Limestones and Devonian rocks.
	Key structures	The major structures affecting the distribution of rock types and hence aquifer types are large anticlinal and synclinal folds, and major faults. The older and more resistant rocks that form the Aughty Mountains occur within the cores of the anticlines that are found in the southwest of the GWB. The younger impure and pure limestones are found preserved in the cores of the synclines, in the lowlands. Fold axes trend ENE-WSW. There are several major faults with the same orientation as the fold axes crossing the GWB. The most notable are the Derrybrown-Ferbane Fault, which continues along a sinuous, offset trace into Co. Offaly, and the North Tynagh Fault, which controls base metal mineralisation. There are a few NW-SE trending faults cross-cutting the main ENE-WSW structural grain. Compression during the folding also caused fracturing and jointing of the rocks.
	Key properties	In the Silurian rock unit in the Slieve Felim mountains to the south of this GWB, a site investigation undertaken for a proposed landfill found that permeabilities in the top 30 m of rock ranged from 0.00036 to 0.76 m/d. A zone of higher permeability, 150-200 m wide, 12-14 m deep and 2.2 km long was delineated on the site. The transmissivity estimated for this zone was 27-82 m^2/d (Deakin, Daly and Coxon, 1998). At Templederry, in Nenagh GWB, early time pumping test data indicate a transmissivity of around 5 m^2/d. For the ORS in this GWB, there are no data; transmissivities will be low, but mainly better than in the Silurian rocks, especially toward junction with the Dinantian (early) Sandstones, Shales and Limestones. Within the Dinantian Lower Impure Limestones, transmissivities are likely to be in the range 2-20 m^2/d, with most values at the lower end of the range. Dinantian (early) Sandstones, Shales and Limestones aquifer properties are less good than this. A pumping test in the Dinantian Pure Unbedded Limestones (Waulsortian limestones) at Shinrone in west Co. Offaly indicated a transmissivity of approximately 27 m^2/d. At Tulla in Co. Clare, transmissivity in the same rock unit is estimated as 13 m^2/d. These values are probably at the middle to higher end of the range. Within all rock units, storativities are low. Groundwater gradients in the upland areas may be steep (up to 0.1). In lower-lying areas, groundwater gradients on the order of 0.01 to 0.04 may be the norm. Storativities in all rocks are low. Porosity values of approximately 0.015 are likely to be representative of the ORS and Lower Impure Limestones in Co. Clare. *(data sources: Rock Unit Group Aquifer Chapters, GWPS Reports, Source reports, see references)*
	Thickness	The Silurian, ORS and Lower Impure Limestone aquifers are more than several hundreds of metres thick. However, the effective flowing thickness of these aquifers is usually ≤15 m, this thickness comprising a weathered zone of a few metres and a connected fractured zone below this. Isolated deeper inflows may occur where faults or significant fractures are intercepted by boreholes. The maximum thickness of Dinantian (early) Sandstones, Shales and Limestones is less than 100 m. Again, groundwater flow is confined to the top 15 m in the main. In the Pure Unbedded Limestones east of Lough Derg, epikarst has been observed that has a thickness of up to 1-2 m. Below this, the thickness of the bedding (around 5-10 m) and/ or jointing and faulting controls the inflow intervals.

Overlying Strata	Lithologies	*[Information to be added at a later date]*
	Thickness	The groundwater body is large and with varied topography, hence the subsoil thickness varies quite widely. From the quite limited available data, depth to bedrock appears to be greater in the southern part of the GWB than the north. In the southern part of the GWB, subsoil thickness varies between 1 and 35 m. Near the break in slope many of the boreholes have depths to bedrock greater than 10 m. In the lowland areas in the northern half of the GWB, available data indicate that subsoils are generally 1-10 m thick, and mainly less than 3 m. Occasional DTBs of up to 30 m may be associated with karstic collapse features that have been infilled with subsoils. Outcrops occur mainly along ridges or incised river valleys in the upland areas in the south, along parts of the shore of Lough Derg, and in the northern half of the GWB, which coincides with the area underlain by Pure Unbedded Limestones.
	% 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 via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. In general, due to the generally low permeability of the aquifers within this GWB, a proportion of the recharge will discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer. Where permeable gravelly subsoils cover parts of the GWB, however, they will act as a 'store' of groundwater and somewhat mitigate this rapid through-flow. A swallow hole in Upper Impure Limestones accept point recharge from surface waters, as do the turloughs in low water table conditions.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Springs and large known abstractions (m^3/d)	Whitegate WS (3 springs, total 275 m^3/d), Mountshannon WS (1 bore, 1 spring, each 230 m^3/d), Cappaghbaun Park WS (22 m^3/d), Scarrif WS (1 new borehole 180 m^3/d, *2 back-up boreholes near reservoir, total 135 m^3/d, are in the adjacent Lough Graney GWB*), Moyglass/Loughrea GWS (132 m^3/d), Cappagh GWS (unknown, <175 m^3/d), Oldhort GWS (unknown, <153 m^3/d), Killeen/Polltaloon GWS (unknown, <109 m^3/d), Muingbawn GWS (unknown, <65 m^3/d), Tiernascragh No 2 GWS (7 m^3/d), Leitrim More GWS (unknown, <153 m^3/d), Newtowndaly East GWS (9 m^3/d), Newtowndaly GWS (19 m^3/d), Eyrecourt/ Laurencetown GWS (Meelick pump) (unknown), Eyrecourt/ Laurencetown GWS (Fahy's pump) (unknown), Eyrecourt/ Laurencetown GWS (≤ 65 m^3/d), Eyrecourt/ Laurencetown GWS (Redmount Hill pump) (≤ 9 m^3/d), Eyrecourt GWS (Esker) (59 m^3/d), Cloonlahan/Claremaden GWS (50 m^3/d), Clonfert GWS (18 m^3/d), Kylemore Abbey (80 m^3/d), Killoran/Ballinasloe GWS (69 m^3/d), Killallaghton GWS (43 m^3/d), Eyrecourt WS (182 m^3/d), Woodford WS (200 m^3/d). *[More information to be added at a later date]*
	Main discharge mechanisms	Groundwater discharges to surface water in several ways. In the uplands, groundwater emerges at many springs on the hill slopes, and then feeds streams. Many of the springs in the SE of the GWB are located close to breaks of slope where the shallow groundwater intercepts the ground surface. The locations of faults and juxtaposed rock units is also thought to contribute to the locations of spring points in these areas. In the lowland areas in the north of the GWB, springs tend to occur in the lowest areas. Groundwater discharges to the gaining streams and rivers crossing the GWB. Low specific dry weather flows along the Kilcrow and Cappagh Rivers of 0.15 and 0.24 l/s/km^2, respectively, indicate that the upper impure limestone, pure bedded limestone and lower impure limestone aquifers have low storage capacity and cannot sustain high summer baseflows to the rivers. A specific DWF of 0.47 l/s/km^2 is measured on the Woodford River, which drains the ORS uplands; this slightly higher, but still low, specific DWF probably reflects some contribution from sandy till and alluvium along the river's course rather than being reflective of the storage capacity of the bedrock aquifer. Groundwater also discharges at the edges of bogs and within bogs as 'flushes'.

	Hydrochemical Signature	There are limited hydrochemical data available for this GWB. From available data and by analogy with the similar Nenagh and Slieve Felim GWBs, it is likely that groundwaters from all aquifers within this groundwater body have a calcium-bicarbonate signature. Hardness, alkalinity and electrical conductivities will vary between the aquifers, however. Groundwaters from the Silurian strata are likely to range from slightly hard to hard (90–360 mg/l $CaCO_3$), with alkalinities ranging from 60 to 270 mg/l (as $CaCO_3$) and electrical conductivities from 260–600 µS/cm. pHs will be neutral. The majority of samples are at the upper end of the range. At springs, or other systems where throughput is rapid, groundwaters have limited dissolved solids. In the Old Red Sandstone aquifers, groundwaters are moderately hard (145-235 mg/l as $CaCO_3$) with moderate alkalinities (140-225 mg/l as $CaCO_3$) and electrical conductivities (310-440 µS/cm), and neutral pHs. The groundwater is characterised by relatively low calcium and magnesium concentrations, but elevated iron and magnesium. It has been demonstrated that at low pumping rates water does not reside long enough in the well for oxidation to occur, thereby resulting in elevated Fe and Mn in small domestic supplies (Applin *et al*, 1989). Lead at the Mountshannon spring source has frequently exceeded the EU MAC. A high lead anomaly in the subsoils was found over much of the area by an exploration company and is associated with the base metal mineralisation in the area. other types of mineralisation such as zinc (Zn) and barium (Ba) have also been detected in the groundwater. Lead concentrations at the Whitegate source and surrounding areas are low (<0.02 mg/l) although the springs are located close to the large mineral-hosting fault. In the Dinantian (early) Sandstones, Limestones and Shales, the Lower Impure Limestones and the Upper Impure Limestones, groundwaters will be hard to very hard (typically ranging between 380–450 mg/l), with high electrical conductivities (650–800 µS/cm) often observed. Alkalinity is also high, but less than hardness (250-370 mg/l as $CaCO_3$). Within the Impure Limestones, iron and manganese concentrations frequently fluctuate between zero and more than the EU Drinking Water Directive maximum admissible concentrations (MACs). Hydrogen sulphide can often reach unacceptable levels. These components come from the muddy parts of these rock units and reflect both the characteristics of the rock-forming materials and the relatively slow speed of groundwater movement through the fractures in the rock allowing low dissolved oxygen conditions to develop. The bedrock strata of the Silurian and Old Red Sandstone aquifers are **siliceous**. The pure and impure limestones and the mixed sandstone, limestone and shale sequences are **calcareous**.
Groundwater Flow Paths		These rocks are devoid of intergranular permeability; groundwater flow occurs in fractures and faults. In the main, the rocks are dependent on fracturing and fissuring to enhance their permeability. At the Whitegate public supply, it is thought that most of the flow originates in the shallow zone near the top of the aquifer, and that faulting in the area acts as both high transmissivity zones that concentrate groundwater flow and as groundwater flow barriers. The pure limestones may have had their transmissivity enhanced further by dissolution of calcium carbonate along fracture and bedding planes. Karst features (swallow hole, turloughs) are also observed in the Upper Impure Limestones. Zones of high permeability can be encountered near fault zones and in areas of intensive fracturing. Permeabilities in the upper few metres are often high although they decrease rapidly with depth. In general, groundwater flow is concentrated in the upper 15 m of the aquifer. Evidence of the relatively low permeabilities is provided by the drainage density and flashy runoff response to rainfall in areas underlain by Silurian and Devonian rocks. Areas underlain by Pure Unbedded Limestones are generally well-drained. This is due to the probable presence of an epikarstic layer. Where Upper Impure Limestones underlie the surface, the area is poorly-drained; this is probably a combination of the flat topography and the low aquifer transmissivity. Water levels in Silurian rocks are shallow, usually less than 15 m below surface. Water levels within the ORS unit are generally less than 15 m below ground surface although this varies depending on topography. In the low-lying areas underlain by impure limestones, groundwater levels are between 2 and 10 mbgl. Next to the rivers, water levels will be closer to ground level. Seasonal water level variations recorded by the EPA at various places within the GWB are generally less than 2 m; in some cases this reflects monitoring near groundwater discharge zones. Groundwater flow paths are generally short, with groundwater discharging to springs, or to the streams and rivers that traverse the aquifer. Many of the springs are located close to breaks of slope where the shallow groundwater intercepts the ground surface. Flow directions are expected to approximately follow the local surface water catchments. Overall, groundwater flow is eastwards and southeastwards to Lough Derg. Generally speaking, these rocks are unconfined, except where the aquifers are overlain by raised bogs, which have very low permeability clayey bases.
Groundwater & Surface water interactions		Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. The streams crossing the aquifer are gaining. Many of the springs are located close to breaks of slope where the shallow groundwater intercepts the ground surface. There are several marshes and wetlands in the area. At Shannon Callows, there is a 'petrifying stream' with associated species-rich calcareous flush. Lough Derg, as well as receiving surface water input, will be sustained by groundwater flow. At most of the raised bogs designated as NHAs, groundwater upwells at the edges or in the middle of the bogs, and flushes the areas with mineral rich water. Swallow holes and caves accept point recharge from surface waters. Specific Dry Weather Flows of rivers flowing across ORS, and Lower and Upper Impure Limestone aquifers are low (0.47, 0.15 and 0.24 $l/s/km^2$ respectively). This indicates that aquifer storage is low and cannot sustain significant summer baseflows to the rivers.

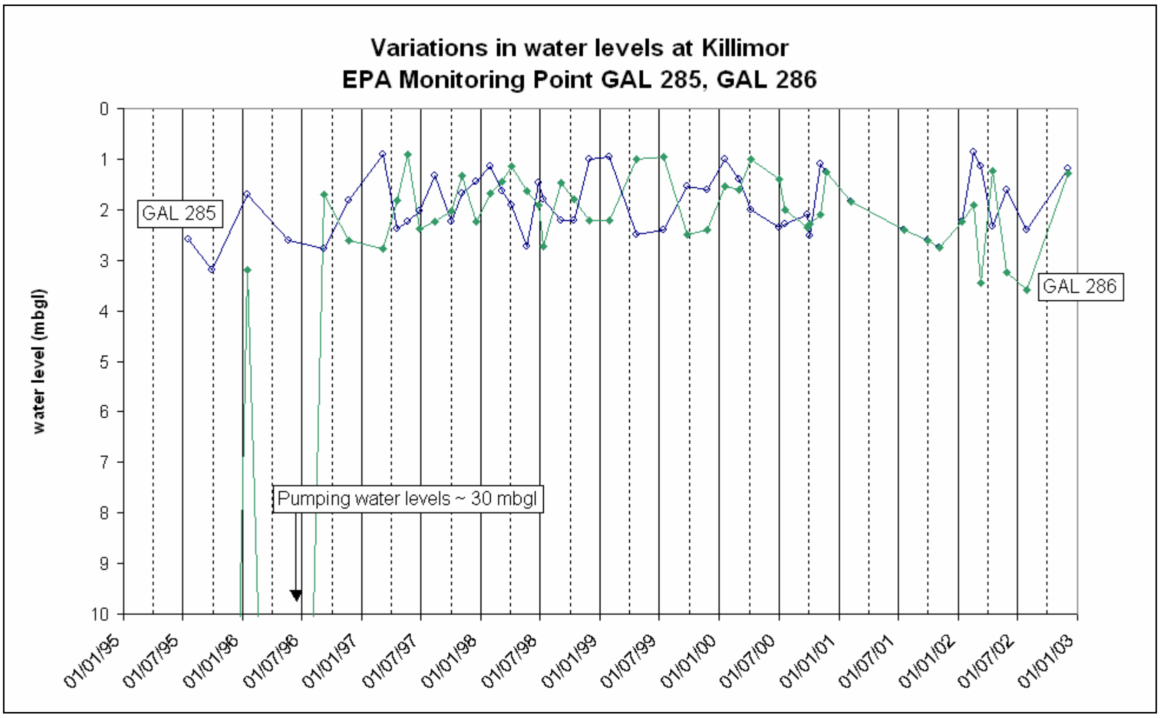
Conceptual model	• The groundwater body is bounded to the west, north and northeast by surface water catchments, to the southeast and south by Lough Derg. • The groundwater body is comprised of generally low transmissivity and storativity rocks. The older rock units (i.e., Silurian and Devonian) are likely to have the lowest transmissivities, whereas the Pure Unbedded and Upper Impure (i.e. younger rock units) will have better flow properties. Where gravels, extensive alluvium or very sandy till overlies the bedrock aquifer, this can contribute to the storage. • Flow occurs along fractures, joints and major faults. The faults within the ORS act both as groundwater flow conduits and barriers. Within the pure limestones and to a much more limited extent the Upper Impure Limestones, transmissivity may have been enhanced further by dissolution of calcium carbonate along fracture and bedding planes. Flows in the aquifer are typically concentrated in a thin zone at the top of the rock. An epikarstic layer probably exists at the top of the Pure Unbedded Limestones, at least in the vicinity of Lough Derg. • Recharge occurs particularly in the upland areas, and where rock outcrops, or subsoils are thin. Much of the potential recharge runs off in the upland areas. Where the water table is close to the surface in upland or lowland areas, potential recharge may be rejected. • Aquifers within the GWB are mainly unconfined. They are probably only confined where raised bogs with low permeability clayey bases overlie the aquifers. Depending upon the local topography, the water table can vary between a few metres up to >10 m below ground surface. Overall, groundwater flow follows topography, flowing generally eastwards and southeastwards. Locally, groundwater flows to the surface water bodies. Flow path lengths in the upland and lowland areas are short (≤ 300 m). The increased hydraulic gradient, due to the sloping topography in the upland areas, will allow groundwater to flow faster than if it were flowing through a similar rock type in low-lying land. • Groundwater discharges to springs and to the numerous streams and rivers crossing the aquifer, and to Lough Derg. Springs occur especially where changes in topography around the base of the Slieve Aughty cause the water table to intersect the ground surface. • Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. There are several ecosystems in the GWB dependent on groundwater, including mineralised flushes and turloughs. Groundwater and surface water interactions require special attention where the terrestrial ecosystems within this GWB are dependant on a sustainable balance between the two.
Attachments	Groundwater hydrographs (Figures 1, 2, 3 and 4), Hydrochemical signature (Figure 5).
Instrumentation	Stream gauges: 25008, 25009, 25017, 25019*, 25020*, 25110*, 25147, 25152, 25238, 25240, 25258, 25305, 25306, 25307, 25316, 25319. *(* stations marked with an asterisk have specific dry weather flows calculated for them.)* EPA Water Level Monitoring boreholes: Mountshannon (CLA 069) (CLA 070), Duniry (GAL 150), Killimor (GAL 285) (GAL 286), Kilalaghton (GAL 436). EPA Representative Monitoring boreholes: Nenagh Co-op (Killimor) (GAL 121)
Information Sources	Applin, K. R. and N. Zhao (1989) The Kinetics of Fe(11) Oxidation and Well Screen Encrustation. *Ground Water*, Vol 27, No 2. Cronin, C. and Deakin, J. (1999) *Whitegate Public Supply-Groundwater Source Protection Zones*. Geological Survey of Ireland Report to Clare Co. Co., 7 pp. Daly, D., Cronin, C., Coxon, C. and Burns, S-J (1998) *County Offaly Groundwater Protection Scheme.* Geological Survey of Ireland Report to Offaly Co. Co., 54 pp. Deakin, J. and Daly, D. (2000) *County Clare Groundwater Protection Scheme*. Geological Survey of Ireland Report to Clare Co. Co. (draft), 71 pp. Hunter Williams, N., Motherway, K. & Wright, G.R. (2002) *Templederry WS, Groundwater Source Protection Zones*. Geological Survey of Ireland, 18 pp. Jones, C. (1998) *An Investigation into Elevated Lead Concentrations in Goundwater used for Drinking Water; Mountshannon Co. Clare*. Unpublished M.Sc. thesis, Trinity College Dublin. Aquifer chapters: Devonian Old Red Sandstones; Dinantian Lower Impure Limestones; Dinantian Pure Unbedded Limestones; Dinantian Upper Impure Limestones; Silurian Metasediments and Volcanics; Dinantian Pure Bedded Limestones.
Disclaimer	Note that all calculations and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Figure 1: Groundwater hydrograph



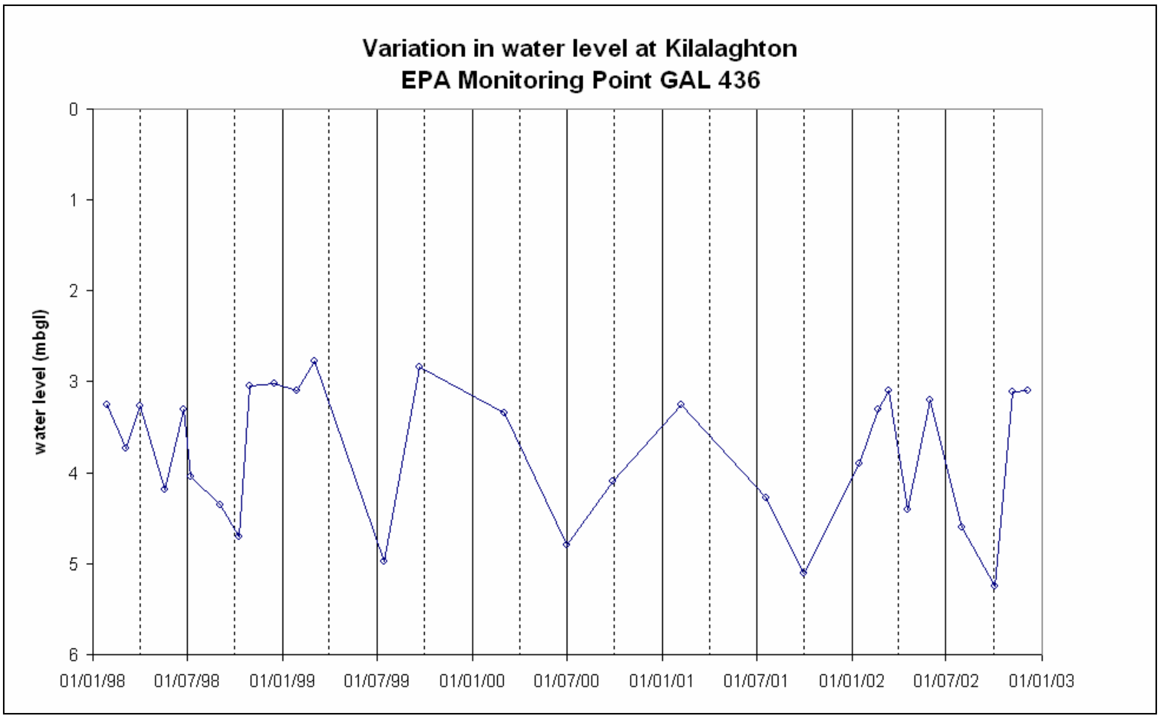
NB: these wells are in the Devonian Old Red Sandstone, near the boundary with the Devonian (early) Sandstones, Limestones and Shales.

Figure 2: Groundwater hydrograph



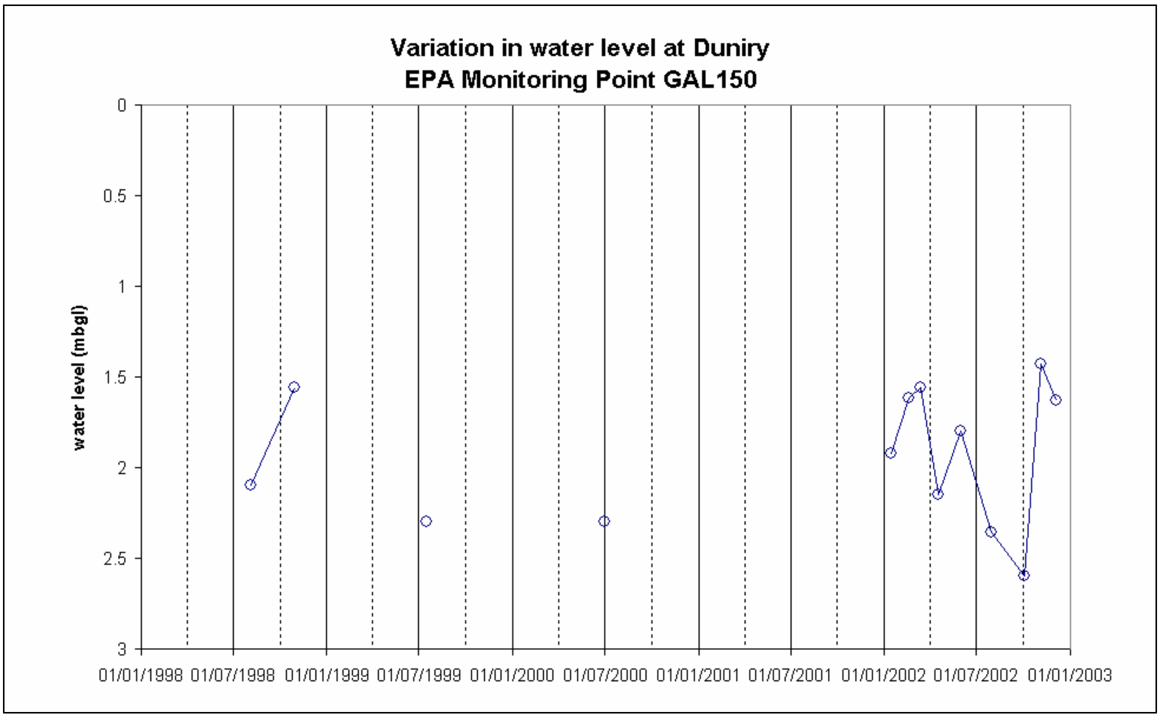
NB: these wells are in the Dinantian Upper Impure limestone, near the faulted boundary with the Dinantian Lower Impure Limestones.

Figure 3: Groundwater hydrograph



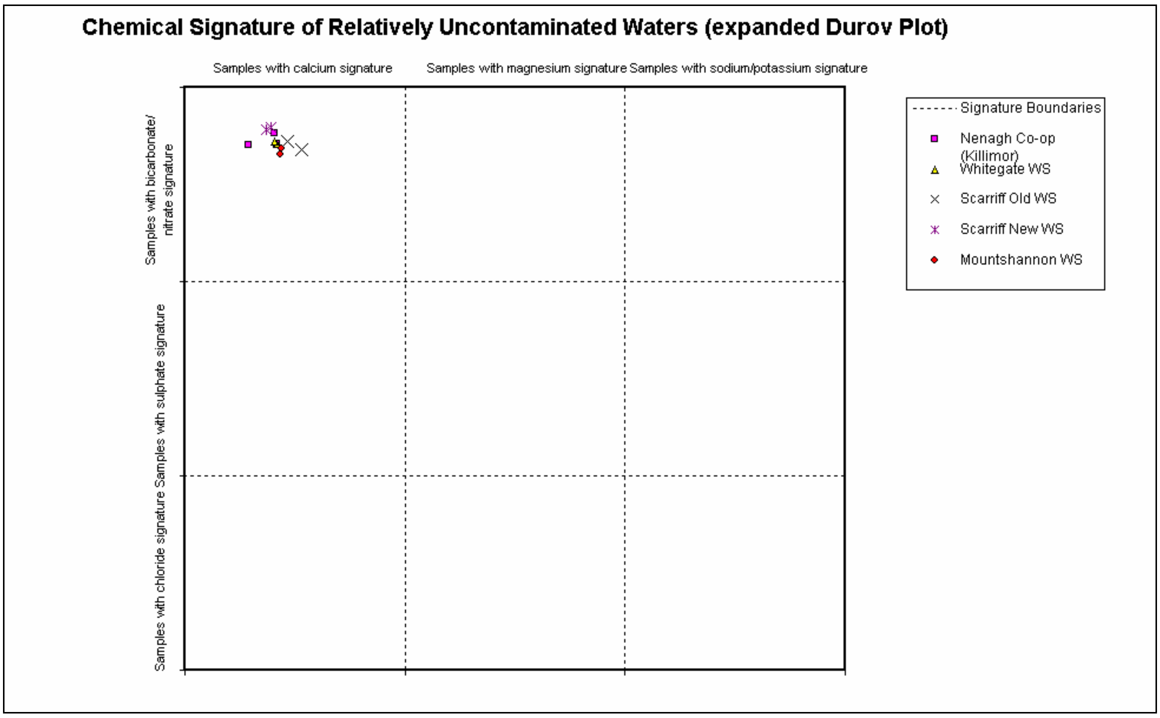
NB: this well is in the Dinantian Upper Impure limestone, near the northern boundary of the GWB.

Figure 4: Groundwater hydrograph

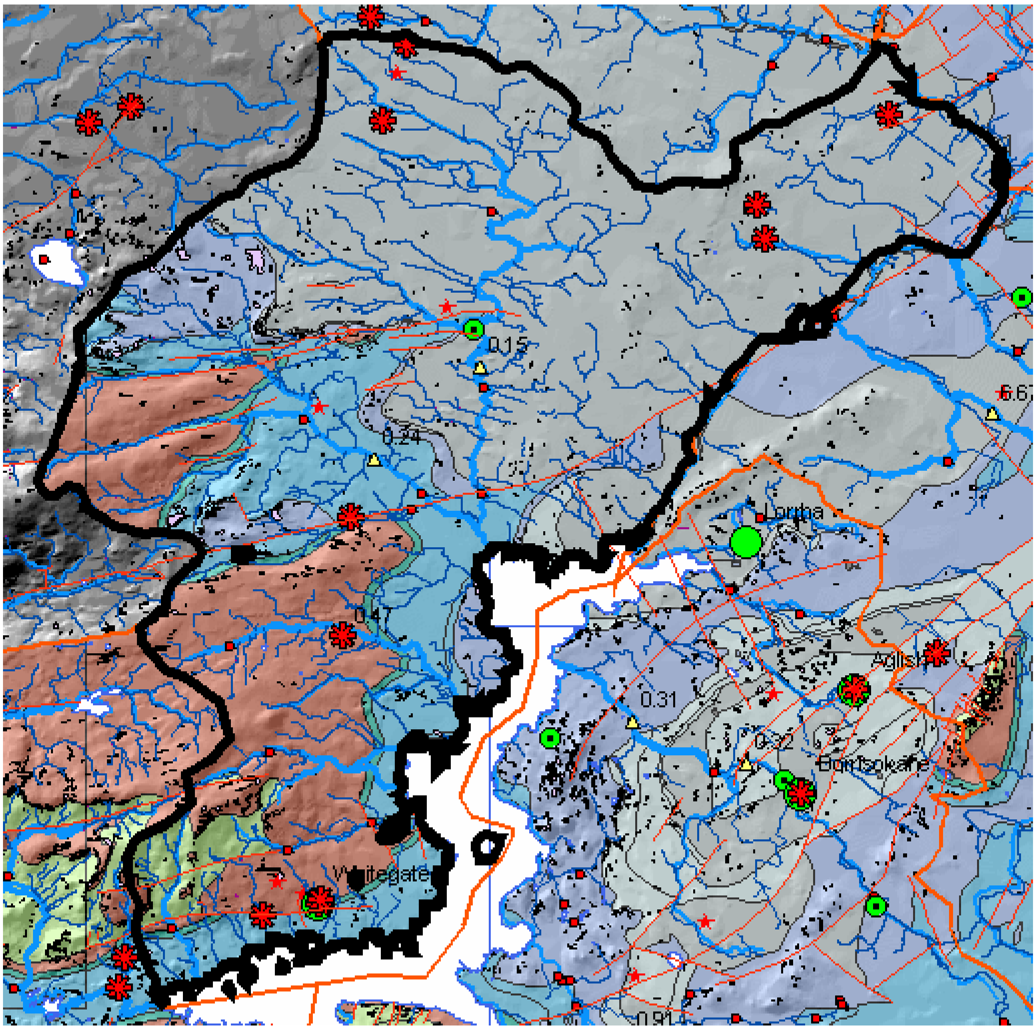


NB: this well is in the Dinantian Lower Impure limestone, near the centre of the GWB.

Figure 5: Hydrochemical signature



NB: *Nenagh (Killimor) abstracts water from Dinantian Upper Impure Limestones, whilst Whitegate WS Scarriff WS and Mountshannon WS abstract groundwater from Devonian Old Red Sandstone strata.*



Rock units in GWB

Rock unit name and code	Description	Rock unit group
Grey Calp (CDgc)	Dark grey conglomeratic limestone & shale	Dinantian Upper Impure Limestones
Lucan Formation (LU)	Dark limestone and shale (Calp)	Dinantian Upper Impure Limestones
Slevoir Formation (SV)	Muddy limestone & calcareous shale	Dinantian Upper Impure Limestones
Terryglass Formation	Grey calcarenitic & oolitic limestone	Dinantian Pure Bedded Limestones
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones
Ballynash Member (BAbn)	Wavy-bedded cherty limestone, thin shale	Dinantian Lower Impure Limestones
Lower Limestone Shale (LLS)	Sandstone, mudstone & thin limestone	Dinantian (early) Sandstones, Shales and Limestones
Ayle River Formation (AR)	Mudstone, siltstone, conglomerate	Devonian Old Red Sandstones
Maghera Cornstone Member (SGmc)	Massive nodular carbonate	Devonian Old Red Sandstones
Kilanena Formation (KA)	Greywacke, siltstone and shale	Silurian Metasediments and Volcanics