Clare-Corrib GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km²)
30 Galway, Mayo Roscommon Co.Co's	**Rivers**: Abbert River, Black River Cregg River, Dalgan River Grange River, Killaclogher River Kilshanvy River, River Clare River Nanny, Sinking River Togher River, Waterdale River **Lakes**: Corrib	000296 LISNAGEERAGH BOG AND BALLINASTACK TURLOUGH 000247 SLIEVE BOG 001237 BOYOUNAGH TURLOUGH 000224 ALTORE LAKE 000301 LOUGH LURGEEN BOG/GLENAMADDY TURLOUGH 000215 RATHBAUN TURLOUGH 001282 KILTULLAGH LOUGH 000263 DRUMBULCAUN BOG 000297 LOUGH CORRIB 000323 RICHMOND ESKER NATURE RESERVE 000289 KNOCKAVANNY TURLOUGH 000295 LEVALLY LOUGH 001254 DERRINLOUGH BOG 001255 DERRYNAGRAN BOG AND ESKER 000282 KILLOWER TURLOUGH 000331 TURLOUGH O'GALL 000234 BELCLARE TURLOUGH 001319 SUMMERVILLE LOUGH 001294 LOUGH HACKET 001288 KNOCKMAA HILL 000385 ROSTAFF TURLOUGH 002038 CASTLE HACKETT SOUTERRAIN 001322 TURLOUGH MONAGHAN 001788 TURLOUGHCOR 001280 KILLACLOGHER BOG 000307 LOUGH TEE BOG 001709 TIAQUIN BOG 000311 MONIVEA BOG 000287 KILTULLAGH TURLOUGH	~1422

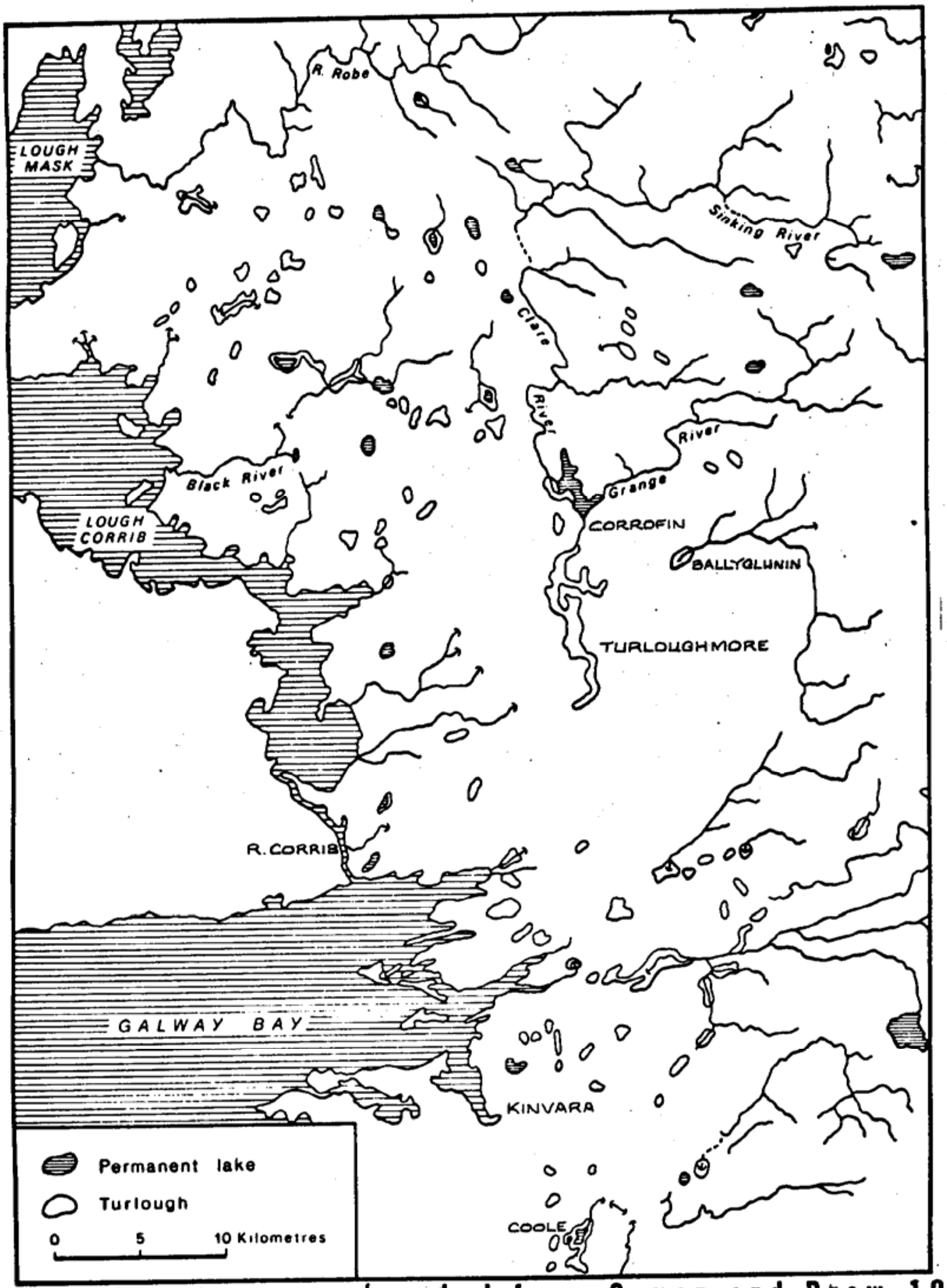
Topography		The land surface is characterised by small hills and low ridges, with ground elevations ranging from 10-160 mAOD. The topographic surface slopes gently westwards. Elevations are highest (100-160 mAOD) in the north (south of Ballyhaunis, west of Ballinlough) and south (just north of Monivea). To the west of a line running north-south from Claremorris to Athenry the elevation is 10-40 mAOD, and to the east of this line, the elevation is 40-70 mAOD.
Geology and Aquifers	**Aquifer categories**	The main aquifer category in this GWB is: **Rk^c:** Regionally important karstified aquifer dominated by conduit flow. There are some small areas (in the vicinity of Headford) with an aquifer category of: **Ll**: Locally important aquifer which is moderately productive only in local zones.
	Main aquifer lithologies	This GWB is composed primarily of Dinantian Pure Bedded Limestones. There are some small areas (in the vicinity of Headford) of Dinantian Pure Unbedded Limestones.
	Key structures	Few faults are mapped in this area; this may reflect the lack of major variation in the rock lithology. The dips over the GWB area are generally less than 10°, except near faults, where steeper dips result from fault drag. Shallow synclines aligned with the axes in an E-W direction cross the GWB.
	Key properties	**Karstification** is widespread in this GWB. Recorded karst features number 219, but are considered to represent only a fraction of existing features. A histogram showing the different types of karst features currently in the database is provided in Figure 3. **Transmissivity and Storativity:** Well yields are variable, being distributed through all the well yield categories. Using 60 wells located in the GWB, 59% are either "excellent" (>400 m^3/d) or "good" (100-400 m^3/d), and 23% are either "poor" (<40 m^3/d) or "failed", with the remainder "moderate" (40-100 m^3/d). The median yield is 131 m^3/d. Histograms showing the distribution of well yields and productivity are given in Figures 4 and 5. Note: productivity is an index relating specific capacity to yield - the higher the productivity the higher the transmissivity. Productivity values are distributed throughout all the productivity categories, indicating the variability of the aquifer properties throughout the GWB. Analysis of the areal distribution of the data suggests that it is difficult to predict the aquifer properties in any particular place, with a few possible exceptions. For instance, in the vicinity of Tuam the well yields that are "excellent" are accompanied by several large springs, and just north of Monivea there is a cluster of "failed" wells (also due in part to silting up of the boreholes) which suggests that there may be an increase in yield from south to north across the GWB. Water table levels have high annual variations, which indicates that the storage is low - approximately 0.01-0.02 (Daly, 1985). The springs in the GWB also reflect the low storativity as many of the spring flows rise and fall quickly in response to rainfall events. Furthermore during prolonged drought many springs cease to flow and well yields drop significantly.
	Continues next page	**Groundwater velocity:** Tracer tests indicate variable groundwater velocities. Furthermore, tracer test data illustrates anisotropy in the transmissivity, with higher east-west transmissivity. Groundwater velocities in the E-W domain are in the order of 100-450 m/hr, as evidenced by the following tests: Lassanny Swallow hole to Ballyhaunis spring (440m/hr); Ballyglunin Cave to Aucloggeen Spring (200m/hr). Groundwater velocities in the N-S domain are in the order of 6-35m/hr, as evidenced by the following tests: L.Hackett to Kilcoona spring (35m/hr); Pollnahallia to Bunatober spring (6m/hr). Extensive conduit systems exist, as exemplified by the Ballyglunin Cave system. The mapping of this system indicates conduit development along the N-S and W-E joint sets, with an overall dip to the west (Drew and Daly, 1993).

		Groundwater flow directions and gradients: Overall, flow directions are to the southwest, with all groundwater discharging to L. Corrib. Although, there are six surface water catchments within the GWB, a *key* aspect is that groundwater can flow across the surface water divides and beneath surface water channels, as evidenced by the tracer test data. Examples of this key property are listed as follows: 1) water that sinks at Ballyglunin Cave emerges at Aucloggeen Spring, which crosses two surface water catchments. 2) water sinking along an losing stretch of the River Clare remerges as the headwater of the Black River. 3) recent tracing tests in the Ballinlough area of Roscommon indicate a link across the Shannon RBD into the Western RBD, from Coolcam (Roscommon) to Meeltraun (Mayo). 4) water along an losing stretch of the Sinking River flows about 10 km underground to join the River Clare. Drew (1976 (a)) suggests that groundwater flow is concentrated along the axes of shallow synclines. Gradients are variable, irregular due to the uneven distribution of transmissivity and are in the order of 0.01-0.002 (Drew and Daly, 1993; Daly, 1985)).
	Thickness	The Dinantian Pure Bedded Limestones are generally over 100 m thick. Most groundwater flows in an epikarstic layer a couple of metres thick and in a zone of interconnected solutionally-enlarged fissures and conduits that extends approximately 30 m below this. Deeper inflows can occur in areas associated with faults or dolomitisation.
Overlying Strata	**Lithologies**	Till is the dominant subsoil type, covering approximately 65% of the GWB. Cutover Peat comprises 23% of the area, sand/gravel covers approximately 3% and alluvium 2%. A full breakdown of the subsoil lithology is given in Table 1. A large proportion of the sand/gravel forms a random hummocky topography, although long sinuous, braided ridges of sand/gravel (eskers) have also been deposited especially in the east. A small portion of the north eastern area of the GWB around Cloonfad is described under the Roscommon Groundwater Protection Scheme (Lee and Daly, 2003) The till in this area is described as “SILT” (BS 5930), and is classed as “Moderate” permeability. There are also areas of “clayey” till, often underlying areas of raised bog (Drew and Daly, 1993). The thin till cover over much of the west part of the area is generally free draining (Daly, 1985).
	Thickness	East of a line linking Athenry – Tuam – Dunmore, the subsoil is “generally thicker” (Daly, 1985; Drew and Daly, 1993). This is supported by the occurrence of rock at or near surface, which is generally restricted to the western and southwestern part of the GWB. Analysis of the available depth to bedrock borehole data is limited as most of the data are clustered in three main areas: western, northeastern and central (area around Tuam) parts of the GWB. Nevertheless the data show a *general* increase in subsoil thickness in an easterly direction: average depth to bedrock increases from 4 m to 9 m from the west to east. In addition, there are instances of depth to bedrock greater than 20 m around Dunmore (northeast of GWB). However, there are also pockets of deeper till in the southwestern part of the GWB.
	% area aquifer near surface	50% of the GWB to the west of the line Athenry – Tuam – Dunmore is only covered by shallow till. 4% of the total GWB area has rock at or near surface.
	Vulnerability	The vulnerability for a small portion of the north eastern area of the GWB around the area of Cloonfad is described in the County Roscommon Groundwater Protection Scheme (Lee and Daly, 2003). In this area the vulnerability classification is variable dependent on the depth to bedrock. For the rest of the area. *[Information to be added at a later date]*
Recharge	**Main recharge mechanisms**	Both point and diffuse recharge occur in this GWB. Diffuse recharge occurs over the GWB via rainfall percolating through the permeable subsoil. Despite the presence of peat and till, point recharge to the underlying aquifer occurs by means of swallow holes and collapse features/dolines. Dolines have been recorded even in areas of thick peat deposits (Hickey et al, 2002). Point recharge occurs via many small sinks that are present in the low permeability till areas where the subsoil is breached. Recharge also occurs along ‘losing’ sections of streams. There are well defined stretches of the River Clare, Sinking River and Abbert River that are losing (Daly, 1985; Drew and Daly, 1993).
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	**Large springs and large known abstractions (m^3/d)**	Large Springs: Corrandulla GWS (6764 m^3/d), Kilbannon GWS (5995 m^3/d), Mullacultra GWS (3270 m^3/d), Barnaderg Group Scheme (5000 m^3/d), Ballyhaunis WSS (12000 m^3/d), Tobernanny, Gortgarrow, Lettera Large known borehole abstractions: Gallagh GWS (523 m^3/d), Rusheens Tuam GWS (114 m^3/d), Roadstone Ltd (227 m^3/d), Belclare (114 m^3/d). *[Information to be added to and checked]*
	Main discharge mechanisms	The main groundwater discharges are to the streams, rivers and large springs found within the body. The large springs at Kilcoona, Bunatober and Aucloggeen and others issue from the bottom of a limestone scarp that is thought to represent an ancient shoreline of L. Corrib. Further these springs are likely to represent overflow springs and deeper groundwater flow discharges to outlets beneath the present day L. Corrib (Drew, 1993). In winter groundwater will fill the turloughs found in the area and partly discharge via the artificial channels that were installed to alleviate flooding.

	Hydrochemical Signature	The groundwater has a calcium bicarbonate signature. Two groundwater provinces are suggested by Drew and Daly (1993). Firstly, there is a shallow groundwater component that is characterised by high suspended solids and relatively low electrical conductivities (300-400 µS/cm). Springs that are fed by this component typically have a "flashy" throughput and often cease to flow during prolonged drought. Secondly, there is a deeper groundwater component that is characterised by relatively non-turbid groundwater with higher electrical conductivities (>450 µS /cm). Springs fed by this deeper component often have smoother hydrographs where there is a gradual change in discharge. Several large springs comprise both flow components, examples are Lettera, Tobernanny and Bunatober springs.
Groundwater Flow Paths		These rocks are generally devoid of intergranular permeability. Groundwater flows through fissures, faults, joints and bedding planes. In pure bedded limestones these openings are enlarged by karstification which significantly enhances the permeability of the rock. Karstification can be accentuated along structural features such as fold axes and faults. Groundwater flow through karst areas is extremely complex and difficult to predict. As flow pathways are often determined by discrete conduits, actual flow directions will not necessarily be perpendicular to the assumed water table contours, as shown by several tracing studies (Drew and Daly, 1993). The tracer tests show that groundwater can flow across surface water catchment divides and beneath surface water channels. Flow velocities can be rapid and variable, both spatially and temporally. Rapid groundwater flow velocities indicate that a large proportion of groundwater flow occurs in enlarged conduit systems. Groundwater flow in highly permeable karstified limestones is of a regional scale. Flow path lengths can be up to a several kilometres, for example 9.6 km from Ballyglunin Cave to Aucloggeen Spring. Overall, groundwater flow will be towards the River Clare and L. Corrib, but the highly karstified nature of the bedrock means that locally groundwater flow directions can be highly variable.
Groundwater & Surface water interactions		The area is drained by the River Clare and its tributaries, however the present day drainage network has been changed significantly by arterial drainage that took place early in the nineteenth century. Figures 1 and 2 show the pre/post arterial drainage network. According to Coxon and Drew (1983), much of the current stream network is a storm runoff system that is inactive during summer months. Thus, prior to drainage, streams sank underground via the turloughs present in the GWB. Many of the streams have well defined losing stretches where they lose water to the underground system (Daly, 1985). There is a high degree of interconnection between groundwater and surface water in karstified limestone areas such as in this GWB. Even though large areas of peat and tills overlie the body, collapse features in these areas provide a direct connection between the surface and the groundwater systems. The close interaction between surface water and groundwater in karstified aquifers is reflected in their closely linked water quality. Any contamination of surface water is rapidly transported into the groundwater system, and vice versa. Furthermore, there are a number of terrestrial ecosystems within this GWB with varying dependence on groundwater.

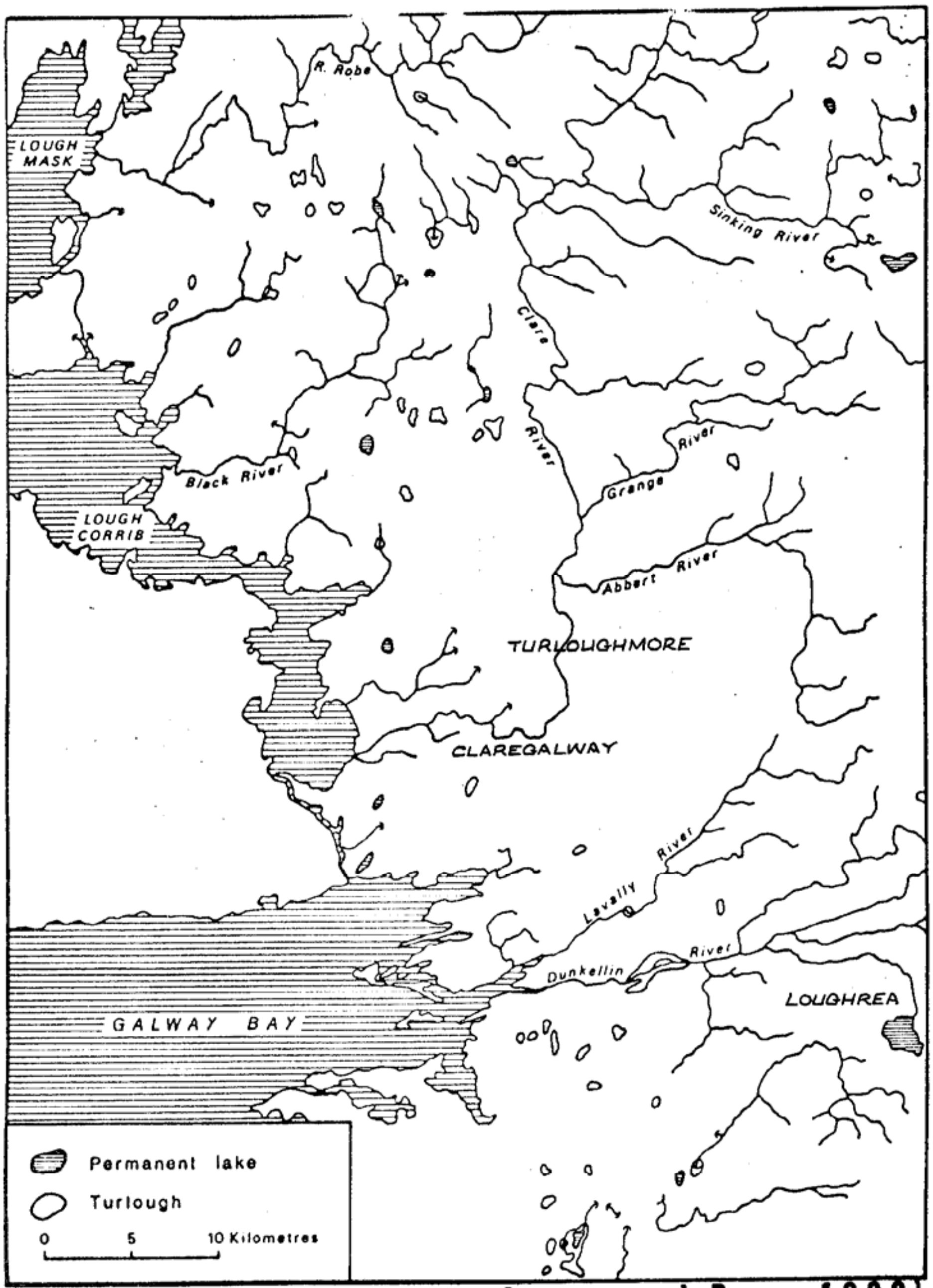
Conceptual model	• The north, south and west groundwater divides of this GWB are topographic highs that coincide with surface water catchment boundaries. It is bounded to the east by Lough Corrib. • The topography is undulating with ground elevations ranging from 10-160 mAOD. A large proportion of the body is overlain by till, which thickens in an easterly direction. • The area is principally drained by the River Clare and its tributaries, however the present day drainage network has been changed significantly by arterial drainage that took place early in the nineteenth century. Much of the current stream network is a storm runoff system and is inactive during summer months. Prior to artificial drainage, streams sank underground via a few turlough sinks in the GWB. • Within the GWB, surface water catchments are often bypassed by groundwater flowing beneath surface water channels and across surface water catchment divides. • A large number of karst features occur within the body. These include turloughs, caves, dolines, swallow holes and springs. • The GWB is composed primarily of high transmissivity karstified limestone (**Rk**^{c}). Transmissivity and well yields are variable. Storage in the GWB is low. • Groundwater flows through a network of solutionally enlarged bedding planes, fissures and conduits. • Rapid groundwater flow velocities have been recorded through groundwater tracing. The tracing indicates an anisotropy in the transmissivity, with faster groundwater flow velocities and higher transmissivity in an E-W direction, which may be linked to shallow E-W trending synclinal axes and steeper E-W hydraulic gradients. • Recharge in this GWB occurs via losing streams, point and diffuse mechanisms. Despite the presence of peat and till, point recharge to the underlying aquifer occurs by means of swallow holes and collapse features/dolines. • The groundwater in this body is generally unconfined but may become locally confined beneath thick, low permeability subsoil. Most of the groundwater flow occurs in the upper epikarstic layer and in a zone of interconnected solutionally enlarge bedding planes and fissures, generally extending to a depth of 30 m. • In general, the degree of interconnection in karstic systems is high and they support regional scale flow systems. Flow paths have been measured up to 10 kilometres in length. • Some areas in this GWB are of extreme vulnerability due to the thin nature of the subsoil, as well as the frequency of karst features, allowing point recharge. Groundwater storage in karstified bedrock is low and the potential for contaminant attenuation in such aquifers is limited. • The main discharges are to the rivers, large springs and L. Corrib. In winter groundwater discharges to the many turloughs and transmitted via the artificial channels that were installed to alleviate flooding. • There is a high degree of interaction between surface water and groundwater in this GWB. There are a number of terrestrial ecosystems within this GWB which have varying dependence on groundwater. • There are potentially two groundwater provinces within the GWB but this is uncertain. The groundwater has a calcium bicarbonate signature.
Attachments	Figures 1, 2, 3, 4 and 5.
Instrumentation	**Stream gauges:** 30002, 30003, 30004, 30006, 30007, 30010, 30011, 30012, 30013, 30014, 30015, 30020, 30022, 30023, 30024, 30025, 30026, 30029, 30030, 30032, 30040, 30045, 30053, 30055, 30071, 30101, 30103. **EPA Water Level Monitoring boreholes:** Lackagh, GAL287, Tuam (Coca Cola), GAL291, Shrule, MAY085 **EPA Representative Monitoring points:**
Information Sources	Daly, D. (1995) *A report on the Flooding in the Glenamaddy area.* Groundwater Section Report File 2.2.7. 34pp. Daly, D. (1992) *A report on the Flooding in the Claregalway area.* Groundwater Section Report File 2.2.7. 12pp. Daly, D. (1985) *Groundwater in County Galway with particular reference to its Protection from Pollution.* Geological Survey of Ireland report for Galway County Council. 98pp. Drew D.P. and Daly D. (1993) *Groundwater and Karstification in Mid-Galway, South Mayo and North Clare.* A Joint Report: Department of Geography, Trinity College Dublin and Groundwater Section, Geological Survey of Ireland. Geological Survey of Ireland Report Series 93/3 (Groundwater), 86 pp Drew, D.P. (1973a) *Hydrogeology of the north Co. Galway – south Co. Mayo lowland karst area, Western Ireland.* International Speleology 1973, III, Sub –section Ca. Drew, D.P. (1973b). *Ballyglunin core Co. Galway and the hydrology of the surrounding area.* Irish Geography Vol. 6, No. 5. pp 610-617. Doak, M. (1995) *The Vulnerability to Pollution and Hydrochemical Variation of Eleven Springs (Catchments) in the Karst Lowlands of the West of Ireland.* Unpublished M.Sc. thesis, Sligo Regional Technical College. Hickey, C., Lee, M., Drew, D., Meehan, R. and Daly D. (2002) *Lowland Karst of North Roscommon and Westmeath*. International Association of Hydrogeologists Irish Group. Karst Field Trip October 2002. Unpublished IAH Report. Lee, M. & Daly D. (2003) *County Roscommon Groundwater Protection Scheme*. Main Report. Roscommon County Council & Geological Survey of Ireland, 54pp. Hickey, C., Lee, M., Drew, D., Meehan, R. and Daly D. (2002) Lowland Karst of North Roscommon and Westmeath. International Association of Hydrogeologists Irish Group. Karst Field Trip October 2002. Unpublished IAH Report.
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 Pre Arterial Drainage.



(copied from Coxon and Drew, 1983)

Figure 2 Post Arterial Drainage



(copied from Coxon and Drew, 1983)

Figure 3 Histogram of Karst features in Clare-Corrib GWB

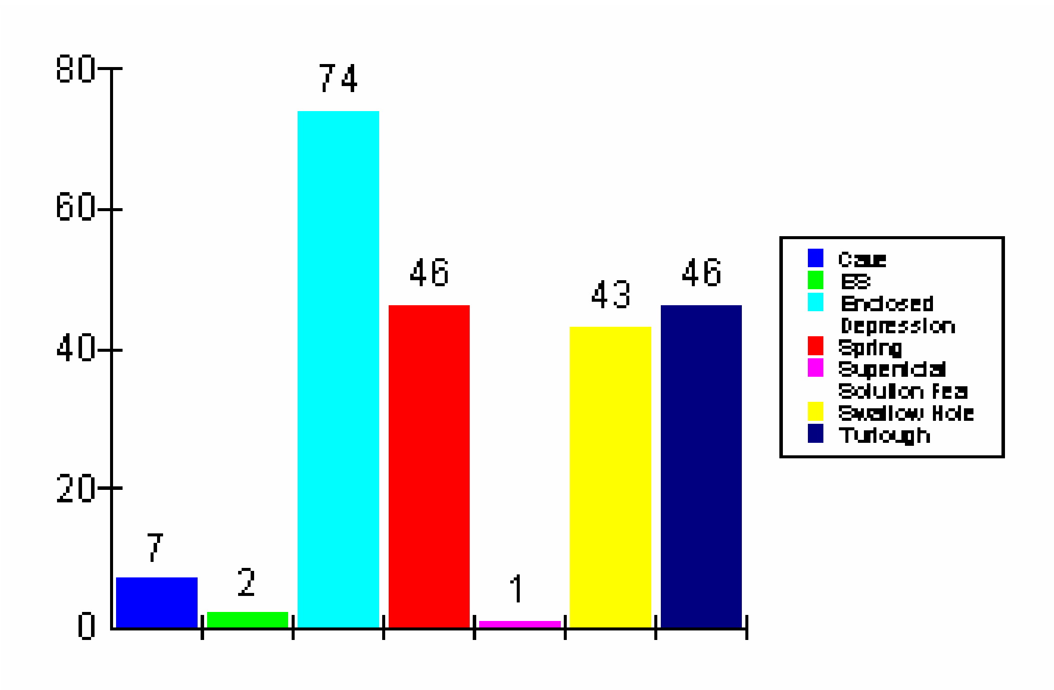


Figure 4 Histogram of Well Yields in Clare-Corrib GWB

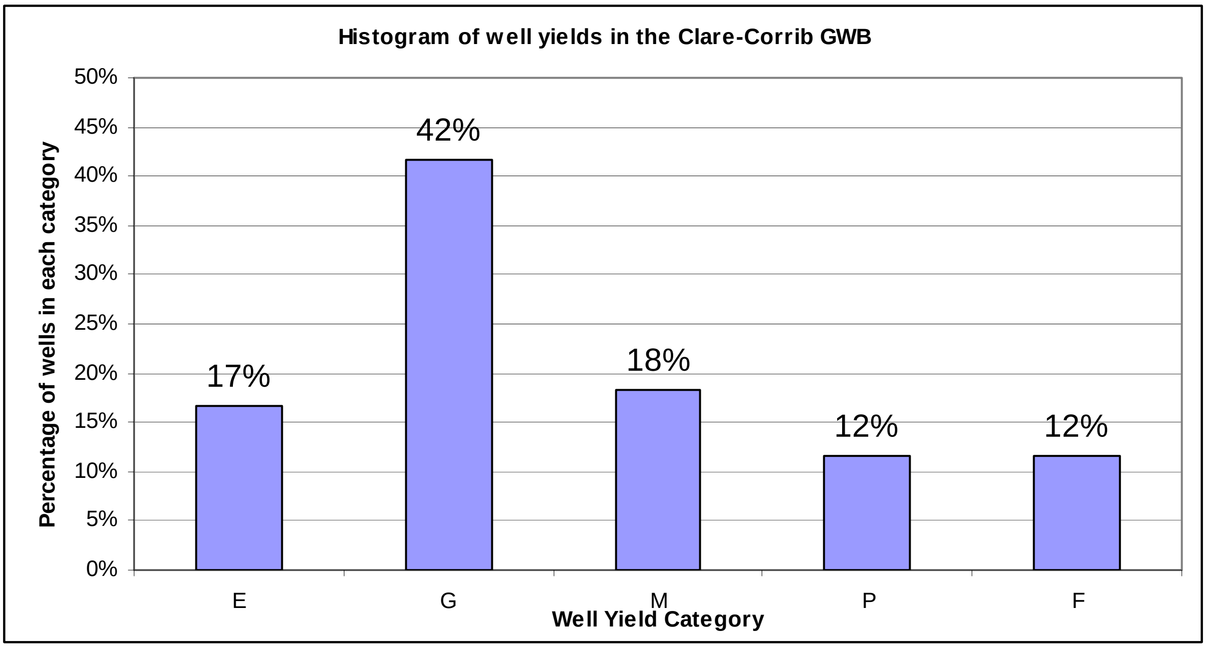


Figure 5 Histogram of Well Productivities in Clare-Corrib GWB

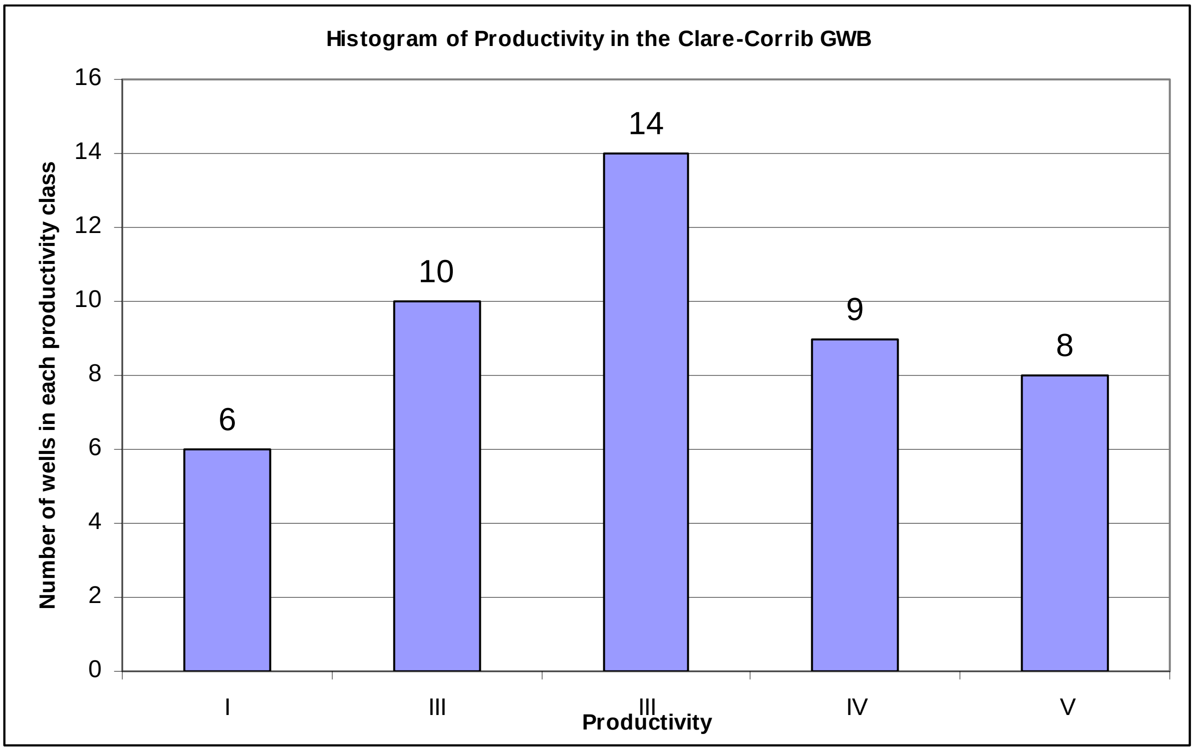
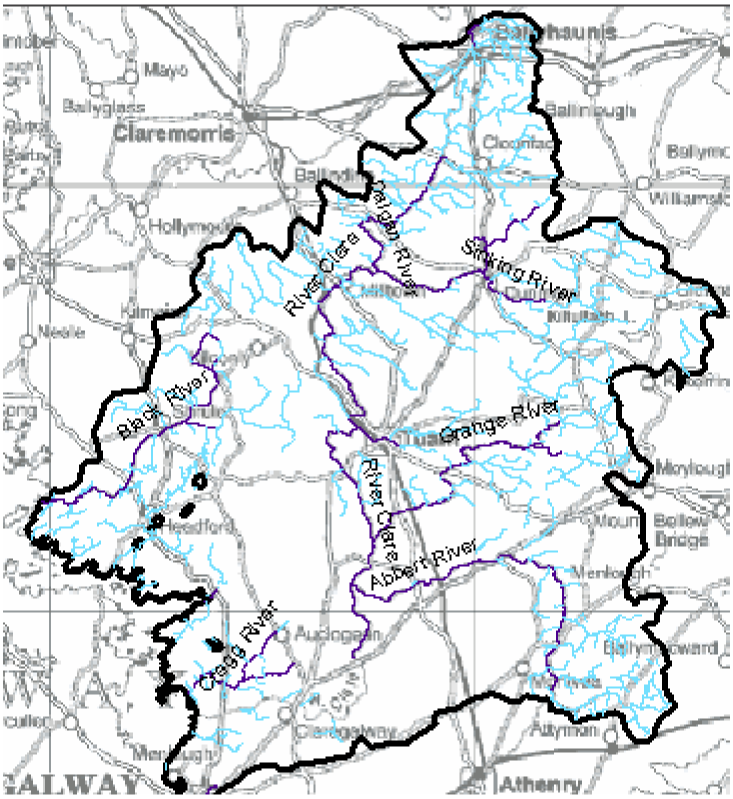


Table 1. Subsoil types in Clare-Corrib Groundwater.

PAR_MAT	Full name	Area sq m	% of GWB
TLs	Limestone Till	881175858	59.9%
TGr	Granitic Till	355611	0.0%
TDSs	Devonian Sandstone Till	72907274	5.0%
RsPt	Raised Peat	15612	0.0%
Rck	Rock	7076384	0.5%
nodata	nada	6512889	0.4%
Mrl	Marl	781353	0.1%
Made	Made Ground	7776478	0.5%
Lk_isle		513	0.0%
Lake		3857021	0.3%
L	Lake sediments undifferentiated	10777977	0.7%
KaRck	Karstified limestone bedrock at surface	53547458	3.6%
GLs	Limestone sands and gravels (Carboniferous)	45700893	3.1%
Esk	Eskers	1989472	0.1%
Cut	Cutover Peat	343496766	23.4%
BktPt	Blanket Peat	2558408	0.2%
BasEsk	Basic esker sands and gravels	5158629	0.4%
A	Undifferentiated alluvium	26211636	1.8%

Clare-Corrib GWB (For reference only)



List of Rock units in Clare-Corrib GWB

Unit Name	**Code**	**Description**	**Rock Unit**
Ardnasillagh Formation	AS	Dark cherty limestone, thin shale	Dinantian Pure Bedded Limestones
Aughnanure Oolite Formation	AU	Cross-bedded massive oolitic limestone	Dinantian Pure Bedded Limestones
Ballysteen Formation	BA	Dark muddy limestone, shale	Dinantian Lower Impure Limestones
~~Boyle Sandstone Formation~~	~~BO~~	~~Sandstone, siltstone, black mudstone~~	~~Dinantian Mixed Sandstones, Shales and Limestones~~
~~Cloonfad Felsite~~	~~CfFe~~	~~Felsite~~	~~Granites & other Igneous Intrusive rocks~~
Cong Canal Formation	NL	Medium to thick-bedded pure limestone	Dinantian Pure Bedded Limestones
Cong Limestone Formation	CO	Thick-bedded pure limestone	Dinantian Pure Bedded Limestones
Coranellistrum Formation	CT	Medium to thick-bedded pure limestone	Dinantian Pure Bedded Limestones
Illaunagappul Formation	IL	Limestone, thin shale partings	Dinantian Pure Bedded Limestones
Kilbryan Limestone Formation	KL	Dark nodular calcarenite & shale	Dinantian Lower Impure Limestones
Knockmaa Formation	KA	Thick-bedded pure limestone	Dinantian Pure Bedded Limestones
Lucan Formation	LU	Dark limestone & shale (Calp") "	Dinantian Upper Impure Limestones
Oakport Limestone Formation	OK	Pale grey massive limestone	Dinantian Pure Bedded Limestones
Oldchapel Limestone Formation	OC	Dark fine limestone & calcareous shale	Dinantian Pure Bedded Limestones
~~Owenriff Member~~	~~OUor~~	~~Dark limestone with thin shales~~	~~Dinantian Lower Impure Limestones~~
Two Mile Ditch Member	KAtm	Thick-bedded limestone, clay wayboards	Dinantian Pure Bedded Limestones
Visean Limestones (undifferentiated)	VIS	Undifferentiated limestone	Dinantian Pure Bedded Limestones
Waulsortian Limestones	WA	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones