Carrick on ShannonGWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface features	Associated terrestrial ecosystem(s)	Area (km^2)
26 – Shannon Upstream Roosky Roscommon, Leitrim, Sligo & Mayo Co Co's	**Rivers:** Eslin, Clogher, Boyle, Killukin, Lung, Breedoge, Kinard, Owenur, Anaderryboy, Mountain, Owennaforeesha, Scramoge, Strokestown, Lissaphobble, Rowan, Anagalliagh, Finisclin, Rooskey, Carricknabrahe, Finlough, Mantua, Clooncraff. **Streams:** Lissydaly **Loughs**: Doolaughan, Derryeen, Black, Naseer, Carrickkevy, Keel, Bran, Costre, Kilmaddaroe, Laundry, Oakport, Coothall, Eidin, Conway, Rowan, Scaradaun, Drumcollop, Aghakilconnell, Funshinagh, Annaghearly, Effrinagh, Loughtown, Urlaur, Cloonacolly, Cloonagh, Errit, Crossbeg, Crossard, Roe, Loughanlea, Loughannamona, Derrycreen, Gara, Figh, Clogher, Corry, Cavetown, Treanamarly, Lisdaly, Cartron, Lowfield, Ballagh, Corbally, loughaun, Tully, Toomore, Rodeen, Bracken, Nahincha, Dooneen, Nablahy, kilglass, Laure, Loughanduff, Garrymona, Cloonahee, Incha, Elia, Namweelia, Cunny, O'Donra, Drimmon, Rathmore, O'Morgan, Ballyoughter, Bellavahan, Clooncullllaan, Grange, Clooneyn-Blakeney, Killeen, simon's, Illanowen, O'Donnellan, Loughanammer, Feeny, Duff, Drinaun, Ean, Annaghmore, Aneeg, Patrick, Gal, Nablasbarnagh, Conny Beg, Conny More, Nafulla, Rogers, Lea, Cloonsreane, Saggart, Flasky, Beg, Caudagh, Headford, Gortconnellan/Spa, Mucklaghan, Drumgilra/Gortinty, Bofin, Cloonfree, Fin, Ardakillin, Loughandoughil, Loughanragh, Shad, Coggal, Loughannasool, Loughannatryna.	(001643) Lough Drumharlow; (001636) Fin Lough; (000592) Bellanagare Bog; (000604) Derrinea Bog; (000607) Errit Lough; (001632) Drumalough Bog; (001626) Annaghmore Lough; (000605) Derrycanan Bog; (000587) Lough Gara; (001652) Tullaghan Bog; (000603) Cornaveagh Bog; (000591) Bella Bridge Bog; (001642) Lough Boderg and Lough Bofin; (001222) Ardagh Bog; (000614) Cloonshanvill Bog; (000608) Kilglass and Grange Loughs; (001627) Corbally Turlough; (000612) Mullygollan Turlough; (001617) Ardakillin Lough; (000594) Brierfield Turlough; (001648) Shad Lough; (001643) Drumharlow; (001402) Annaghearly Lough; (000587) Lough Gara.	928

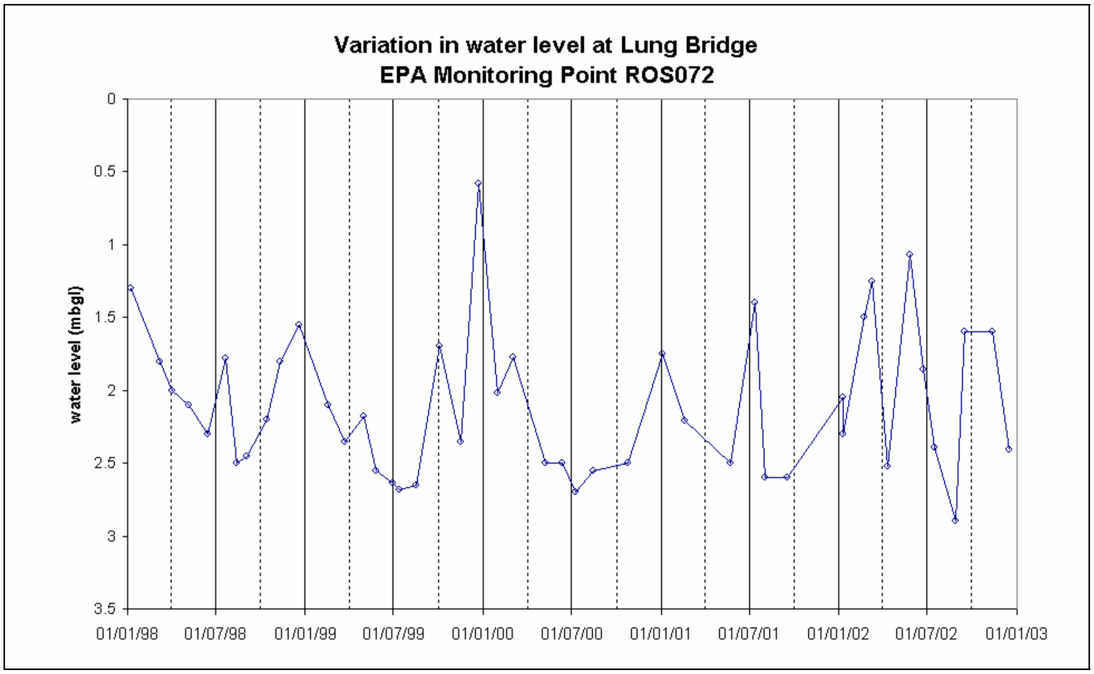
Topography		This GWB has a varied topography. In the east of the body, east of Elphin and Tulsk and in the vicinity of the River Shannon, ground elevations are 40-50 mAOD. There are a large number of lakes separated by small low hills. Within this low-lying area, an elevated area occurs north of Stokestown rising to 160 mAOD. Ground elevations are higher to the west, north and in the extreme north east of the body (60-170 mAOD). South and southeast of Boyle, the Plains of Boyle (80-110 mAOD) extend southwards to Elphin. In the west of the body ground elevations rise to 120-140 mAOD along the boundary with the adjoining GWBs. Dumlins are common in the body, generally increasing in number and size to the east of the body. Areas of peat and cut peat are common, becoming more common towards the northwest of the body. There are areas within the body where surface drainage is limited or absent (e.g. south of Boyle) reflecting the karstified nature of the underlying bedrock.
Geology and Aquifers	**Aquifer categories**	**Rk^c:** Regionally important karstified aquifer dominated by conduit flow.
	Main aquifer lithologies	This GWB is composed primarily of Dinantian Pure Bedded Limestones. Some small isolated areas of Dinantian Pure Unbedded Limestone occur within the body.
	Key structures	Mapping of faults is limited in this area where exposure is poor and there is little major variation in the rock lithology. Major faults are mapped along the northwestern side of the Strokestown Inlier and the Castlerea Inlier. The dips over the GWB area are generally less than 10^o, except near faults, where steeper dips result from fault drag. The Strokestown Inlier forms part of the south-eastern boundary of this body.
	Key properties	Karstification is widespread in this GWB. Current records of karst features are considered to represent only a fraction of existing features. As with most karstic systems, permeability and transmissivity data are very variable. Transmissivity in karstified aquifers with conduit flow can range up to a few thousand m^2/d. Pumping tests reported by Longworth (1987) and Ibbotson (2000) for wells in the Dinantian Pure Bedded Limestone in this GWB gave transmissivity values of 15-30 m^2/d and 100 m^2/d (Ballymore Limestone) and 50 m^2/d (Oakport Limestone). The aquifer supports high and intermediate springs. Rapid groundwater flow velocities have been recorded. Tracer tests carried out to Rockingham Spring source in the north of the body, recorded minimum velocities of 218 m/hr and 279 m/hr (Lee & Kelly, 2003). Tracer tests carried out in the adjoining Suck South GWB recorded groundwater flow velocities ranging from 68 to 110 m/hr in the vicinity of Longford and Silver Island Springs and Killeglan Springs. Rapid velocities recorded for groundwater in these areas imply flow through relatively sizeable conduits. Groundwater gradients calculated in the vicinity of Rockingham Spring source were low, ranging from 0.015 (Ballymore Limestone) to 0.01 (Oakport Limestone) (Lee & Kelly 2003). In karstified Pure Bedded Limestone such as that found in this GWB, enlargement of the fracture network by solution, and the generally well connected and widespread fracture systems result in a highly permeable aquifer with rapid groundwater flow. Storativity in this aquifer will be low. Small isolated areas of pure unbedded limestones occur within this GWB. These pure unbedded limestones are considered less susceptible to karstification due to their massive nature. The permeability of these rocks is generally low but they can develop local zones of enhanced permeability.

	Thickness	The Dinantian Pure Bedded Limestones are generally well 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. Boreholes drilled around Rockingham Spring indicate fracture zones in the first 20 m (Lee & Kelly, 2003). These fractures are likely to act as the major conduits for groundwater flow.
Overlying Strata	**Lithologies**	There are large areas cut peat, which include lands reclaimed for grassland, concentrated particularly in the west of the body and in the extreme south. Many smaller areas of cut peat occur throughout the body. Areas of outcrop and shallow rock occur throughout the body, often more frequent on higher ground. There are some gravel deposits in the west of the body near Errit Lough. These gravel deposits are of 'high' permeability. Large areas of till of various types and origin cover the remainder of the body. The till in the north of the body is of 'low' permeability. The areas of cut peat in the north of the body are also classed as 'low' permeability. The 'low' permeability underlying subsoil is likely to control the permeability where the peat deposits are thinner. The till is described as 'CLAY' (BS5930). The overall poor drainage is indicated by the high frequency of rushes and drainage ditches. The soils map records mainly heavy textured gley and peat in this region, which also indicate low permeability. The till in the south of the body (extending north as far as Tulsk) is of 'moderate' permeability. The till is described as 'SILT' or 'SAND'. The region between Elphin and Tulsk also has subsoil of 'moderate' permeability, however the subsoil has a higher degree of mixed sediments. *Subsoil Types identified in body by Teagasc Parent Material Mapping: Alluvium (A), Esker (Bas Esker), Cut Peat (Cut), Gravels (GLs), Rock outcrop and rock close to surface (Rck), Karstified Limestone outcrop and karstified limestone close to surface (KaRck), Lake sediment (L), Till – Lower Palaeozoic Sandstone and Shale Till (TLPSsS) & Limestone Till (TLs) Devonian and Carboniferous Sandstone & Sandstone and Shale Till (TDSs, TDCSs, TDCSsS) & Namurian Sandstone and Shale Till (TNSsS)*
	Thickness	Areas of outcrop and shallow rock occur throughout the body, often more frequent on higher ground. There are large areas with less than 3 m of subsoil cover. Areas of deeper subsoil (5-20 m) are concentrated in the extreme west of the body, just west of the centre of the body near the Castlerea Bellanagare GWB, southwest of Carrick on Shannon and in the east of the body around Kilglass Lough.
	% area aquifer near surface	[Information to be added at a later date]
	Vulnerability	There are large areas of Extreme vulnerability within this body, including areas south of Boyle, around Frenchpark, northwest of Strokestown and in the southwest of the body. Areas in the vicinity of swallow holes and dolines (which allow point recharge) are delineated as extremely vulnerable. Some swallow holes and dolines occur in areas of reasonably thick peat cover (6-9 m). The main areas of Moderate and Low vulnerability are concentrated in the extreme west of the body, just west of the centre of the body near the Castlerea Bellanagare GWB, southwest of Carrick on Shannon and in the east of the body around Kilglass Lough. *A Groundwater Vulnerability Map has been prepared for County Roscommon as part of a Groundwater Protection Scheme.*
Recharge	**Main recharge mechanisms**	Both point and diffuse recharge occur in this GWB. Swallow holes and collapse features provide the means for point recharge. Diffuse recharge will occur over the entire GWB via rainfall percolating through the subsoil. Where the GWB is covered by 'low' permeability subsoil this can restrict percolation of recharge and increase runoff. Despite the presence of peat and low permeability till, point recharge to the underlying aquifer still occurs by means of swallow holes and collapse features/dolines. Dolines have been recorded even in area of thick peat deposits. (Hickey et al, 2002). In areas where point recharge is common and/or subsoils are relatively thin, groundwater generally shows a rapid response to recharge. Where gravels overlie the karstic aquifer they provide a permeable pathway for recharge to the underlying karstic aquifer. They can also act to augment storage in the karstic aquifer.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	**Springs and large known abstractions (m^3/d)**	Rockingham Spring -Boyle-Ardcarn WS (ROS11) 6000 m^3/d; Bellanagara WS - Mount Druid (ROS9 – Spring) 3400 m^3/d; Cloonmagunaun GWS (ROS19 – Spring) 1100 m^3/d - From EPA Groundwater Sources List (Larger Sources – High & Intermediate Yielding Springs) Spring, Lissian (1429SEW086) 2790 m^3/d; Cloonmagunnaun Spring, Callow or Runnawillin (1429SEW093) 2791 m^3/d; Pollmore, Creevy (1429SEW098) 7000 m^3/d; Pollanabrick Spring, Aghadrestan (1429SEW099) 16380 m^3/d; Spring, Carrowreagh (1729SWW065) 3420 m^3/d – From GSI Sping Database – High Yielding Springs. *[This information is not complete – further data need to be added and yield data confirmed]*
	Main discharge mechanisms	The main discharges are to the streams and rivers crossing the body and to the large springs found within the body. In winter groundwater will discharge to the many turloughs found in the area.

	Hydrochemical Signature	The hydrochemistry of the carbonate rocks, especially pure limestones, is dominated by calcium and bicarbonate ions. Hardness can vary from slightly hard to very hard (typically ranging between 380–450 mg/l). Spring waters tend to be softer, as throughput is often quicker with less time for the dissolution of minerals into the groundwater. Groundwater alkalinity is variable, but can be high. Alkalinity is generally less than hardness indicating that ion exchange (where calcium or magnesium are replaced by sodium) is not a significant process. These hydrochemical signatures are characteristic of clean limestone and are frequently associated with lime-scale issues. Like hardness and alkalinity, electrical conductivities (EC) can vary greatly. Typical limestone groundwater conductivities are of the order 500–700 µS/cm. Lower values suggest that groundwater residence times are very short. In some springs and boreholes in karst areas, high turbidity occurs after heavy rainfall. Microbial pollution of groundwater in karstic aquifers is also a significant problem. Due to the high level of interaction between groundwater and surface water in karstic aquifers, microbial pollution can travel very quickly from the surface into the groundwater system. The normal filtering and protective action of the subsoils is often bypassed in karstic aquifers due to the number of swallow holes, dolines and large areas of shallow rock. The hydrochemical signature of groundwater from a number of public supplies within this body is demonstrated in an expanded Durov plot in Figure 2 below.
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). Flow velocities can be rapid and variable, both spatially and temporally. The rapid groundwater flow velocities recorded in this body indicate that a large proportion of groundwater flow takes place in enlarged conduit systems. The presence of high yielding springs in this body indicates that the permeability of the rock unit is high enough to permit the throughput of significant quantities of groundwater. They are indicative of regional-scale flow systems. Flow path lengths can be up to a several kilometres in length. Regional groundwater flow direction in the south and east of the body is broadly west to east, in the north of the body broadly southwest northeast and in the west of the body broadly south to north. Groundwater flow direction is influenced by a topographic high in the centre of the body. Locally groundwater flow directions can be highly variable due to the highly karstified nature of the bedrock. Low permeability rocks of adjoining GWBs can act as barriers to flow from the karstified pure bedded limestone of this GWB. Groundwater tracing in the catchment of the Rockingham Spring Source (Lee & Kelly 2003) demonstrated that groundwater in the pure bedded limestone (Oakport Limestone) is forced to move in a southwest to northeast direction at the contact with the impure limestone (Kilbryan Limestone), rather than from south to north as suggested by the topography. The flow direction is therefore parallel to the strike of the beds, and the geological contact between the Kilbryan and the Oakport Limestone. Groundwater in this GWB is generally unconfined. Water levels in karstified limestone which is dominated by conduit flow, generally show rapid response to rainfall. Water level data from a well within this GWB are shown in Figure 1 attached. In the west of the body near Errit Lough the bedrock is overlain by a small area of gravel deposits.. Geophysical work in the area has suggested a sand/gravel thickness of greater than 40 m of which 10-30 m may be saturated (Keohane, 1983). There are no borehole data available for the area at present however. Due the limited hydrogeological data these gravels have not been classified as an aquifer. These gravels will however provide a permeable pathway for recharge to the karstic aquifer and where saturated, may provide an element of storage for the underlying bedrock.
Groundwater & Surface water interactions		There is a high degree of interconnection between groundwater and surface water in this GWB. Numerous karst features such as turloughs, swallow holes, sinking streams, sparse or intermittent streams, limestone pavements, caves and large springs are evident. Surface streams sink frequently, draining through karst features into the groundwater system, providing rapid recharge to groundwater. Streams re-emerge as springs, after flowing as groundwater for some distance, to once again form significant surface streams. Many turloughs (seasonal lakes which are fed by groundwater as the watertable rises in winter) occur in this body. These turloughs support sensitive ecosystems which are highly dependant on groundwater. Because of the close interaction between surface water and groundwater in karstified aquifers, surface water and groundwater quality are also closely linked. Any contamination of surface water is rapidly transported into the groundwater system, and vice versa. There are a large number of associated terrestrial ecosystems within this GWB, many of which are highly dependant on groundwater.

Conceptual model	• This body occupies a large area in north County Roscommon south of the Curlew Mountains. It is bounded to the north by the contact with the Dinantian Lower Impure Limestones of the Curlew Mountains GWB. It is bounded to the west and south by topographic highs and groundwater divides that coincide with surface water catchment boundaries. It is bounded to the east, in part by the contact with the Dinantian Sandstones of the Scramoge North GWB and in part by the contact with various low permeability rocks of the Kilglass Dromod and Mohill GWBs. • The topography of the body is varied. Low-lying areas (40-50 mAOD) occur in the east of the body, where a large number of lakes are separated by small low hills. Higher ground occurs on the Plains of Boyle (80-110 mAOD) and on the south western boundary of the body (120-140 mAOD). Dumlins are common in the body, generally increasing in number and size to the east of the body. Areas of peat and cut peat are common, becoming more common towards the northwest of the body. There are areas within the body where surface drainage is limited or absent (e.g. south of Boyle) reflecting the karstified nature of the underlying bedrock and the high permeability or absence/thin occurrence of overlying subsoil. • The GWB is composed primarily of high transmissivity karstified limestone. Groundwater flows through a network of solutionally enlarged fissures and conduits. A large number of karst features such as dolines, swallow holes and turloughs occur within the body. Small areas of pure unbedded limestones are incorporated within this GWB. • Groundwater flows along interconnected fractures, joints, faults and bedding planes, many of which have been enlarged by solution. Much of the groundwater flow is concentrated in conduits. Rapid groundwater flow velocities have been recorded through groundwater tracing. • Recharge to this GWB is both point, though swallow holes and collapse features, and diffuse via rainfall percolating through the subsoil. The lack of surface drainage in several parts of this GWB indicates that potential recharge readily percolates into the groundwater system. Groundwater in this body generally shows a rapid response to recharge. • The groundwater in this body is generally unconfined. Most groundwater flow will be concentrated in the upper epikarstic layer and in a zone of interconnected fissures, enlarged by karstification, generally extending to a depth of 30 m. Deep water strikes in more isolated faults/fractures can be encountered. • In general in karstic aquifers, the degree of interconnection between fractures zones is high and they support regional scale flow systems. Flow paths can potentially be several kilometres in length. • Some areas in this GWB are of extreme groundwater vulnerability due to the thin nature of the subsoil, as well as the frequency of karst features. Groundwater storage in karstified bedrock is low and the potential for contaminant attenuation in such aquifers is limited. • Groundwater discharges to the streams and rivers crossing the body and to the large high yielding springs, many of which are used for water supply. • There is a high degree of interaction between surface water and groundwater in this GWB. Groundwater supports many sensitive terrestrial ecosystems, including turloughs, which are highly dependant on groundwater.
Attachments	Groundwater hydrographs (Figure 1); Hydrochemical Signature (Figure 2)
Instrumentation	Stream gauges: 25318, 26011, 26017, 26018, 26072, 26086, 26089, 26116, 26118, 26119, 26148, 26223, 26225, 26227, 26228, 26229, 26230, 26231, 26232, 26233, 26254, 26307, 26308. EPA Water Level Monitoring boreholes: Lung Bridge (ROS 072), Aghadrestan (ROS 075), Cloonmagunn (ROS 078), Cornaglia (ROS 079). EPA Representative Monitoring points: Boyle (Rockingham) RWSS (ROS011), Cloonmagunaun (ROS019), Strokestown WS (ROS043), Croghan GWS (ROS 055), Hollywell GWS (ROS065)
Information Sources	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 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. and Kelly, C. (2003) Boyle-Ardcarn Water Supply Scheme (Rockingham Spring), Groundwater Source Protection Zones. Geological Survey of Ireland Report to Roscommon Co. Co., 14 pp. Lee, M. & Daly D. (2003) *County Roscommon Groundwater Protection Scheme*. Main Report. Roscommon County Council & Geological Survey of Ireland, 54pp. Long, C. B., McConnell and Philcox, M.E. (2003) *A Geological Description of South Mayo, to accompany the bedrock geology 1:100,000 scale map series, Sheet 11, South Mayo.* With contributions by W. Cox and U. Leader. Geological Survey of Ireland. (Publication pending) MacDermot, C.V. Long C.B. and Harney S.J (1996) *Geology of Sligo-Leitrim: A geological description of Sligo, Leitrim and adjoining parts of Cavan, Fermanagh, Mayo and Roscommon, to accompany bedrock geology 1:100,000 scale map, Sheet 7, Sligo - Leitrim*. With contributions from K. Carlingbold, G. Stanley, D. Daly and R. Meehan. Geological Survey of Ireland, 100pp. Morris J.H., Somerville I.D. and MacDermot C.V. (2002). *Geology of Longford-Roscommon. A Geological Description to Accompany the Bedrock Geology 1:100,000 Bedrock Series Sheet 12*. With contributions by D.G. Smith, M. Geraghty, B. McConnell, K. Carlingbold, W. Cox, D. Daly. Geological Survey of Ireland, 121pp. (Publication pending)
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 hydrographs (EPA Groundwater Level Monitoring)



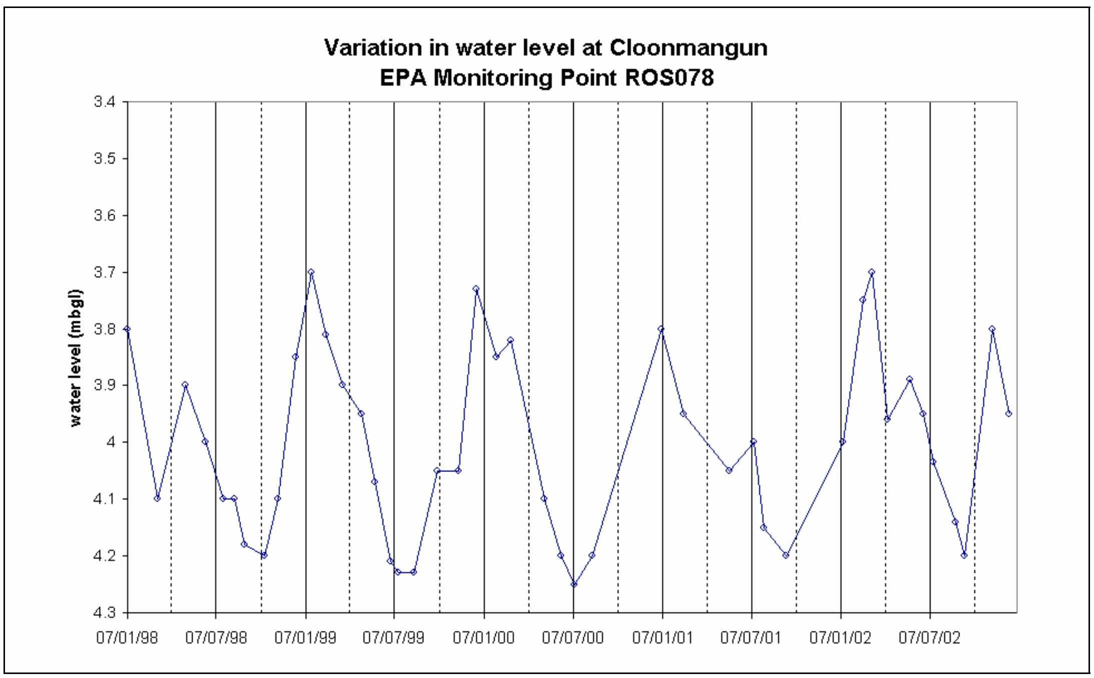
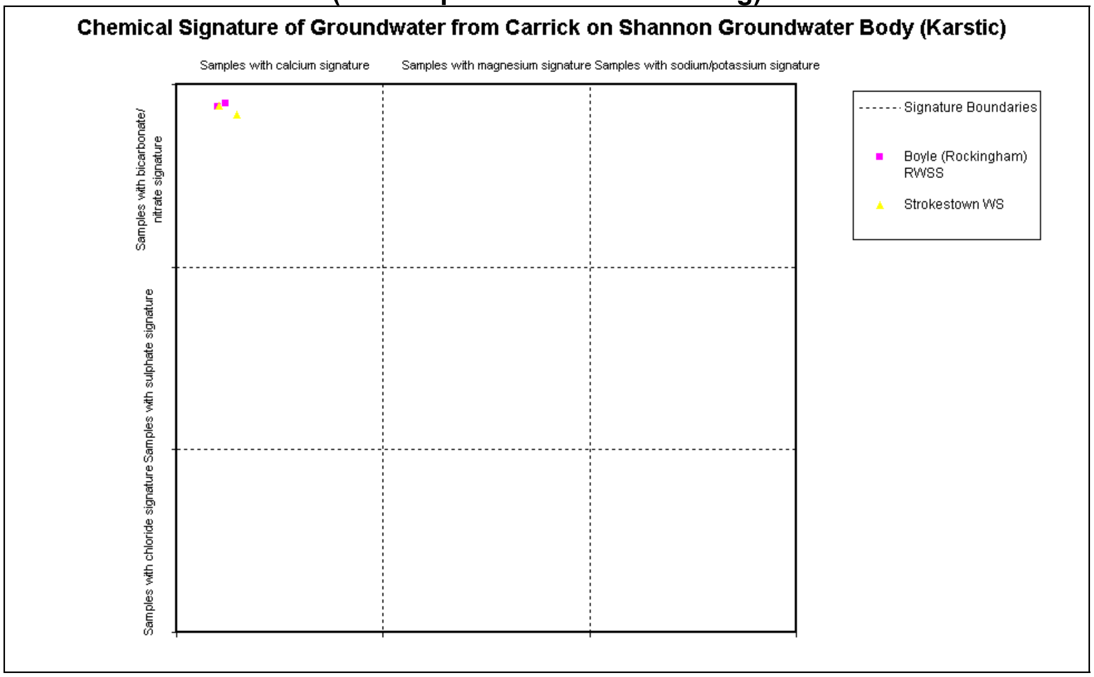
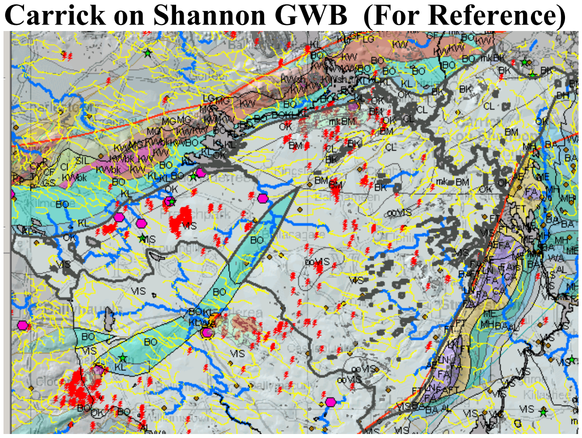


Figure 2: Hydrochemical signature
(EPA Representative Monitoring)



Carrick on Shannon GWB (For Reference)



List of Rock units in Carrick on Shannon GWB

Rock unit name and code	Description	Rock unit group
Visean Limestones (undifferentiated) (VIS)	Undifferentiated limestone	Dinantian Pure Bedded Limestones
Visean Limestones (undiff) & Oolitic limestone (ooVIS)	Undifferentiated limestone	Dinantian Pure Bedded Limestones
Oakport Limestone Formation (OK)	Pale grey massive limestone	Dinantian Pure Bedded Limestones
Ballymore Limestone Formation (BM)	Dark fine-grained limestone & shale	Dinantian Pure Bedded Limestones
Bricklieve Limestone Formation (BK)	Bioclastic cherty limestone	Dinantian Pure Bedded Limestones
Bricklieve Limestone Formation & Mudbank limestone	Bioclastic cherty limestone	Dinantian Pure Unbedded Limestones
Croghan Limestone Formation (CL)	Dark cherty limestone, shale	Dinantian Pure Bedded Limestones
Mudbank Limestones (mk)	Massive grey micritic limestone	Dinantian Pure Unbedded Limestones