Midleton GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
19 Cork Co. Co.	**Rivers:**.Dower, Owennacurra, Dungourney, Womanagh, Dissour. **Lakes:** Aderry, Ballyhonock, Ballybutler.	Ballyvergan Marsh (000078), Ballyquirk Pond (001235), Clasharinka Pond (001183), Loughs Aderry and Ballybutler (000446)	136

Topography	This GWB occupies the floor of an elongate east west trending valley in east Cork. The valley is bounded to the north and south by parallel east west trending ridges which comprise the Ballinhassig and Knockadoon GWBs respectively. The valley floor is generally flat to gently undulating. Ground elevations range from 2–30 m OD. Areas of higher ground occur along the centre of the valley (20-30 m OD) but ground is generally lower along the valley margins, and in the east of the body near the coast (<20 m OD). The ready weathering & erosion of the thin shaly limestones which occur at the margins of the body is thought to be responsible for the topographic lows along the edges of the valley. In the west of the body large surface water channels extending to Lough Mahon intersect the body partially surrounding Little Island and Fota Island. These areas are considered to have sufficiently similar hydrogeology to be described as part of the Midleton GWB.	
Geology and Aquifers	**Aquifer categories**	The main aquifer category in this GWB is: **Rkd**: Regionally important karstified aquifer dominated by diffuse flow. A narrow area (12 km^2 in total) around the margins of the body has an aquifer category of: **Ll:** Locally important aquifer, moderately productive only in local zones
	Main aquifer lithologies	The main aquifer lithology in this GWB is Dinantian Pure Unbedded Limestones (primarily Waulsortian Limestone Formation). Some Dinantian Pure Bedded Limestones occur in the centre of the body. A narrow area (12 km^2 in total) around the margins of the body is composed of Dinantian Lower Impure Limestones.
	Key structures	During the Variscan Orogeny, rocks in South Munster were compressed from the south into a series of folds on east west axes. Subsequent erosion stripped the more soluble Carboniferous Limestones from the fold crests or ridges (anticlines) exposing the harder, more resistant sandstones underneath. The Carboniferous Limestones were preserved in the fold troughs (synclines) which today line elongate east-west trending valleys separated by the intervening sandstone ridges. This body lies in the east of the Cork Syncline. Extensive fracturing and faulting accompanied the folding of the rocks. The ridges and valleys are cut by series of shear faults trending approximately north-south and a series of thrust faults with a general east-west trend. The major north-south shear faults are paralleled by a very well developed system of vertical or near-vertical north-south joints which are very evident in exposures in quarries and caves in East Cork. These joints are commonly spaced at intervals of about 0.5 to 2 metres (Wright, 1979).
	Key properties	The pure unbedded limestones of the South Munster region are highly productive. Faults and joints were enlarged by karstification as groundwater moved through the limestones. There are numerous surface karst features in these limestones, (e.g. swallow holes, collapse features and closed depressions) and extensive cave systems (e.g. Carrigtohill, Midleton and Cloyne). The strong structural influence on the development of karstification is demonstrated by cave plans from Southeast Cork (e.g. Poulnahorka Caves, Castlemartyr, Co Cork) where the main passages or 'galleries' have developed along north-south joints in the order of 1 to 6 metres apart (Wright 1979). Transmissivity in the pure unbedded limestones can range up to a few thousand m^2/d. Pumping tests in the same rock type in the Cloyne GWB to this south of this body gave a range of transmissivity of 200 to over 2000 m^2/day, and 900 - 13,000 m^2/d for a water supply borehole near Dungarvan, Co Waterford (Dungarvan GWB, SERBD). Groundwater gradients within the pure unbedded limestones are low, around 0.001-0.002. (Wright & Gately 2002). There are a large number of wells with Excellent (>400 m^3/d) and Good (100-400 m^3/d) yields and the large "Dower Spring" occurs in this GWB. Springs in the pure unbedded limestone range in size from small to large, but have reliable discharges. Tracer tests carried out within this GWB recorded groundwater flow velocities of 30 m/h between Carrignashinny swallow hole and Dower Spring and 16.5 m/h between Dower Ford swallow hole and Dower Spring (Wright & Gately 2002). The pure bedded limestones are also highly productive although less evidence of extensive karstification is currently recorded. In the impure limestones, transmissivities are lower; they will generally be in the range 5-20 m^2/d but may be higher where karstification has occurred. Storativity is low in all bedrock aquifers. Groundwater storage may be enhanced by overlying sand and gravel deposits which are in continuity with the underlying limestone.

	Thickness	The Dinantian Pure Unbedded Limestones (Waulsortian Limestone) are at least 600m thick in the Cork Syncline (Sleeman & Pracht, 1994). Most groundwater flow may occur 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. However deeper flows can occur. Boreholes have intersected major zones of fissuring at depth at Cloyne (Cloyne GWB), where a major zone of fissuring occurs at approximately 41 m below ground level, i.e. approximately 20 m below OD, and at Ringaskiddy (Carrigaline GWB), where major water inflows occur down to 40 m below OD (Wright, 1979). In the past sea level is estimated to have been approximately 50-60 m below present day OD, the level to which the now infilled channel of the River Lee was eroded (Farrington, 1959) enabling karstification at depth. Today this region is an example of a drowned karst terrain. In the Impure Limestones at the margins of this GWB, most groundwater flow occurs in an upper weathered layer of a few metres and a zone of interconnected fissures often not extending more than 15 m from the top of the rock, although occasional deep inflows associated with major faults can be encountered. Impure limestones are also much less susceptible to karstification.
Overlying Strata	**Lithologies**	This GWB is primarily covered by glacial till of varying permeability. West of Castlemartyr, and in some smaller areas east of Castlemartyr, the subsoil is generally of 'moderate' permeability. East of Castlemartyr there are areas with 'low' permeability subsoil. Sand and gravel deposits ('high' permeability) also occur in many areas within this GWB. Several small surface sand and gravel deposits have been identified within this GWB by Teagasc mapping, the most extensive being south of Ballynacorra. Drilling has revealed extensive sand and gravel deposits at Carrigtohill (Carrigtohill GWB) and in the northeast of the GWB between Youghal and Killeagh over 10 m of gravel was recorded beneath 8 m of clayey till. Frequent areas of rock outcrop and shallow rock occur in this GWB, particularly in the centre and towards the west of the body. *Subsoil Types identified in Midleton GWB by Teagasc Parent Material Mapping (Draft): Alluvium (A); Sandstone sands and gravels (Devonian) (GDSs); Marine sands and gravels (MGs); Made Ground (Made); Beach/raised beach sand (Mbs); Estuarine sediments (silts/clays) (Mesc); Marine Silts (Msi); Rock outcrop and rock close to surface (Rck); Till – Devonian Sandstone Till (TDSs), Limestone Till (TLs).*
	Thickness	There are many areas with subsoils of <3m where rock outcrop is common, particularly along the centre of the body, east of Castlemartyr, around Midleton and much of Little Island. Along the northern side of the GWB, between Killeagh and Youghal, is an area of deep subsoil where depths of >20 m are recorded. East of Carrigtohill and north of Fota Island up to 60 m of sand and gravel have been recorded (Carrigtohill GWB). Elsewhere subsoil depths of 5-10m are frequently recorded, although isolated points of deep and shallow subsoil do occur. The underlying pure unbedded limestone in this valley is highly karstified and likely to have a very irregular bedrock surface. Subsoil depths in these areas can therefore be highly variable within short distances.
	% area aquifer near surface	
	Vulnerability	This GWB has many areas of Extreme Vulnerability, particularly along the centre of the valley, in an area east of Castlemartyr, around Midleton and on Little Island. The remainder of the body west of Castlemartyr is generally of High Vulnerability. East of Castlemartyr there are some areas of Extreme and High Vulnerability coinciding with areas of shallower subsoil, but in general where subsoil depths are >3 m the remaining area is of Moderate Vulnerability.
Recharge	**Main recharge mechanisms**	The sandstone ridges to the north and south of this GWB (Ballinhassig & Knockadoon GWBs), provide abundant runoff which recharges the limestone aquifer in the valley. A small volume of groundwater may cross as through-flow from the sandstones into this GWB. In the GWB itself both point and diffuse recharge will occur. Swallowholes and collapse features provide the means for point recharge to the karstified aquifer. Diffuse recharge will occur over the entire GWB 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. There are some low-lying areas with a high water table, where a proportion of the effective rainfall is rejected due to lack of storage space in the aquifer. Groundwater in this body generally shows a rapid response to recharge. Where gravels overlie the karstified aquifer they provide a permeable pathway for recharge. They can also augment storage in the aquifer. The generally 'moderate' permeability subsoils in the west of the body will generally not restrict percolation of recharge. In the east of the body where some areas of 'low' permeability subsoil occur percolation of recharge may be restricted. However, variability in subsoil depths due to the underlying karstified limestone means that even in areas with lower permeability subsoil, opportunities for recharge to areas of shallower limestone can still occur.
	Est. recharge rates	

Discharge	**Large springs and high yielding wells (m^3/d)**	*Note: The following data need to be checked and updated by RBD Project Consultants.* Data from GSI Well Database: Dower Spring (Whitegate RWSS) - Estimated average discharge 32,880 m^3/day (1979); Average abstraction (4545 m^3/d). Knockgriffin, Dawn Meats (IMP), Midleton – (1200 m^3/d) Knockgriffin, Frioscandia Building – (1200 m^3/d) Ballycrenane Beg, Imokilly Co-Op Creamery , Mogeely – (1091 m^3/d) Ballintubbrid West TW3 (Carrigtohill Industrial Estate) - (852 m^3/d) Additional data from EPA Groundwater Sources List: Rossmore (W Ellis & Sons) spring (909 m3/d) Carrigtohill (John A Wood Ltd) bore (909 m3/d)
	Main discharge mechanisms	Groundwater discharges to springs within the GWB and to the rivers and streams crossing the GWB. Rivers overlying the limestones in the South Munster Synclines have relatively high dry weather flows representing contributions from the underlying aquifer.
	Hydrochemical Signature	The groundwater in this body is dominated by calcium and bicarbonate ions. Hardness can range from moderately hard to very hard (200 to >400 mg/l (as $CaCO_3$). Spring waters tend to be softer as throughput is quicker and there is less time for the dissolution of minerals into the groundwater. Groundwater alkalinity is high, up to 400 mg/l (as $CaCO_3$). Alkalinity is generally less than hardness, indicating that ion exchange (where calcium or magnesium are replaced by sodium) is not significant. These hydrochemical signatures are characteristic of clean limestone. Like hardness and alkalinity, electrical conductivities (EC) can vary greatly. Typical limestone water conductivities are of the order of 500-700 µS/cm. Lower values suggest that the residence times of some of the sources are very short, for example at the Dower Spring (Midleton GWB) where conductivities average 396 µS/cm. This value reflects a karstic system with rapid flow velocities. Chloride levels in groundwater in this body can be elevated near the coast. 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 subsoil 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 public supply wells in the same rock type in the nearby Cloyne GWB is demonstrated in an expanded Durov plot in Figure 2 below.
Groundwater Flow Paths		These rocks are devoid of intergranular permeability. Groundwater flow occurs in the many faults and joints, enlarged by karstification. Past depression of the sea level enabled karstification at depth, which further enhances the permeability of these rocks. Because of the high frequency of fissures in this region, overall groundwater flow is thought to be diffuse, although solutionally enlarged conduits and cave systems occur. Groundwater flow occurs in an upper shallow highly karstified weathered zone in which groundwater moves quickly in rapid response to recharge. Below this is a deeper zone where there are two components to groundwater flow. Groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation. In addition there is a more dispersed slow groundwater flow component in smaller fractures and joints outside the larger conduits. The water table is generally within 10 m of the surface, except for the more elevated parts of the limestone aquifers, and the typical annual fluctuation of the water table ranges up to 6 or 7 m (Wright 1979). Hydrographs for two wells within this GWB, Attiquin (4 km west of Dower Spring) and Ballyquirk (3 km northeast of Dower Spring) (Figures 1 and 2) show annual fluctuation of water levels in the limestone of about 3-5 metres. At Dower Spring the natural water level normally varies by less than half a metre from winter to summer, although extreme flood events can add a further 0.3 m or so to this figure (Wright & Gately, 2002). Groundwater is generally unconfined. The highly permeable aquifer supports a regional scale flow system. Groundwater flow paths can be up to several kilometres long, but may be significantly shorter in areas where the water table is very close to the surface. Regional groundwater flow is towards the rivers draining the valley, to the sea in the east and to Lough Mahon and the surface water channels to the west and south west of the body. The limestones in this body are frequently overlain by sand and gravel deposits in hydraulic continuity with the underlying bedrock. Where present they provide a permeable pathway for recharge to the karstic aquifer and where saturated provide additional storage for the underlying bedrock aquifer. At Carrigtohill, the deposits are large enough, with sufficient saturated thickness, to be a locally important gravel aquifer (Lg) (Carrigtohill Gravel GWB).
Groundwater & Surface water interactions		The nature of the karstic system leads to rapid interchanges of water between surface and underground. Swallow holes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body. Several ponds and small lakes with fluctuating water levels and exposed mud edges in summer, that appear to be at least partially fed by groundwater, occur in this GWB: (Ballyquirk Pond (001235), Clasharinka Pond (001183), Loughs Aderry and Ballybutler (000446). Near the coast tidal effects may be experienced in boreholes or springs, and brackish water may be encountered. Ballyvergan Marsh (000078) a freshwater coastal marsh near Youghal is unlikely to be dependent on water from the limestone aquifer as it occurs in an area of deep subsoil where low permeability clayey till overlies gravel.

Conceptual model	• This GWB occupies the floor of an elongate east west trending valley in east Cork. The body is generally flat to gently undulating (2-30 mAOD) with ground elevation at centre of the valley often higher than at the valley margins. • The GWB is bounded to the north and south by the contact with the low permeability sandstones and mudstones of the Ballinhassig and Knockadoon GWBs respectively. It is bounded to the east by the coast and to the west by Lough Mahon and the large urban development of Cork City. • The GWB is composed mainly of diffusely karstified, highly permeable pure limestones with a narrow underlying layer of less permeable impure limestone around the margins of the body. To the north and south of the body are ridges of low permeability sandstones. • The regional structural deformation that created the characteristic South Munster sandstone ridge (anticline)-limestone valley (syncline) topography was accompanied by intense fracturing and high frequency jointing (N-S jointing dominates) within the limestone synclines. Subsequent karstification of these openings has significantly enhanced the permeability of the pure limestones. Karst features such as cave systems, sinking streams, springs, swallow holes and other collapse features are common in this GWB. Karstification is known to extend well below present sea levels, and is estimated to extend to depths of 50 to 60 m below O.D. Malin Head. • Groundwater flows through the many faults and joints formed by deformation that were subsequently enlarged by karstification. Most groundwater flow occurs in an upper shallow highly karstified weathered zone of a few metres thick in which groundwater moves quickly in rapid response to recharge. Below this is a deeper zone where there are two components to groundwater flow. Groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation (influence of N-S jointing). In addition there is a more dispersed slow groundwater flow component in smaller fractures and joints outside the larger conduits. Generally this connected fractured zone extends to about 30 mbgl in pure limestones, however in the pure bedded limestones of the South Munster region, deep inflows from major zones of fissuring have been encountered to 40-50 mbgl. • Groundwater in this body is unconfined. The water table is generally less than 10 metres below the surface with an average annual fluctuation up to 6 metres. Groundwater gradients are very flat in the permeable limestones (0.001-0.002). The highly permeable aquifer can support regional scale flow systems. Groundwater flow paths can be up to several kilometres long, but may be significantly shorter in areas where the water table is very close to the surface. Overall groundwater flow is to the rivers draining the valley and ultimately to the sea in the east and to Lough Mahon and the surface water channels to the west and south west of the body. • Recharge to this GWB is both point and diffuse. The ridges to the north and south of this GWB (Knockadoon & Whitegate GWBs) provide runoff which supplies recharge to the limestone aquifer in the valley. Swallow holes, collapse features and sinking streams provide the means for point recharge to the karstified aquifer. Diffuse recharge will occur over the entire GWB via rainfall percolating through the subsoil. The lack of surface drainage in much of this GWB indicates that potential recharge readily percolates into the groundwater system. Some areas of low permeability subsoil in the east of the body may restrict percolation of recharge in areas where they are present in sufficient thickness. A relatively small volume of groundwater may cross as through-flow into this GWB from the adjacent low transmissivity GWBs. • There are many areas of Extreme Vulnerability within this GWB, particularly along the centre of the valley, in an area east of Castlemartyr, around Midleton and on Little Island. Outside areas of Extreme Vulnerability the remainder of the body west of Castlemartyr is generally of High vulnerability, while east of Castlemartyr there are areas of Moderate Vulnerability due to the presence of > 5 m 'low' permeability subsoils. In a highly karstified aquifer such as this GWB the underlying limestone will have a very irregular surface. Subsoil depths in this GWB can therefore be highly variable within short distances. • The limestones in this body are frequently overlain by sand and gravel deposits which are in hydraulic continuity with the underlying bedrock. Where present they provide a permeable pathway for recharge to the karstic aquifer and where saturated provide additional storage for the underlying bedrock aquifer. At Carrigtohill, the deposits are large enough, with sufficient saturated thickness, to be a locally important gravel aquifer (Lg) (Carrigtohill Gravel GWB) • There is a high degree of interaction between surface water and groundwater in this GWB. Swallow holes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body.
Attachments	Hydrochemical Signature (Figure 1); Groundwater Hydrograph (Figure 2)
Instrumentation	**Stream gauges:** 19002, 19003, 19005, 19019, 19022, 19025, 19029, 21016. **EPA Water Level Monitoring boreholes:** Ballyquirk (COS 73), Ballynabointra (COS 74). **EPA Representative Monitoring points:** None
Information Sources	Farrington A (1959) The Lee Basin Part one: glaciation. Proc. R. Ir. Acad. 60B (3), 135-166. Kelly C (2000) Conna Water Supply Scheme (village bore): Groundwater Source Protection Zones. Report to Cork County Council (Northern Division). Geological Survey of Ireland. Sleeman AG, Pracht M (1994) *Geology of South Cork. A geological description of South Cork to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 25.* Geological Survey of Ireland, 59pp Wright G, Gately C (2002) *Whitegate Regional WaterSupply Scheme (Dower Springs)*. Groundwater Source Protection Zones. Geological Survey of Ireland Report, 19pp. Wright G (1979) Groundwater in the South Munster Synclines. In: Hydrogeology in Ireland, Proceedings of a Hydrogeological Meeting and associated Field Trips held in the Republic of Ireland from 22 to 27 May, 1979. Published by the Irish National Committee of the International Hydrological Programme.
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: Hydrochemical signature
(GSI Monitoring as part of Source Protection Report)

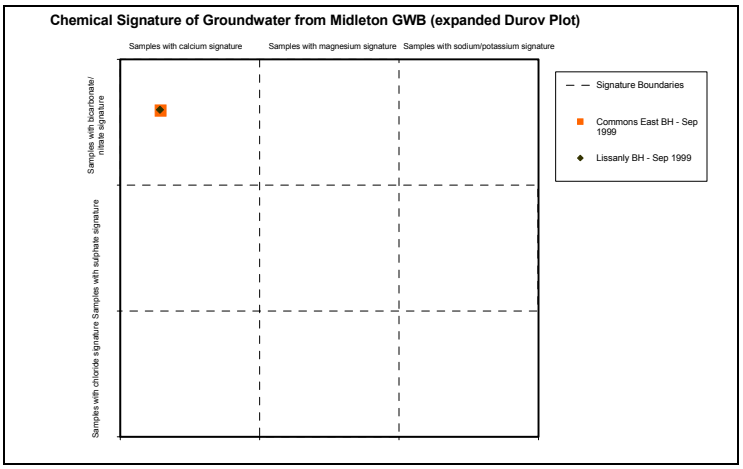
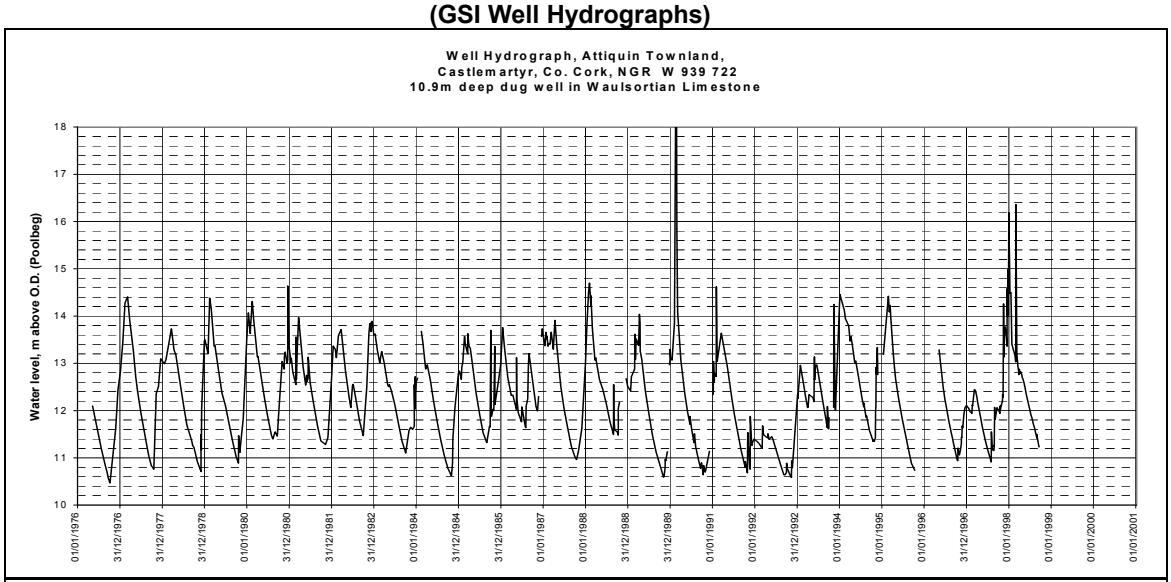
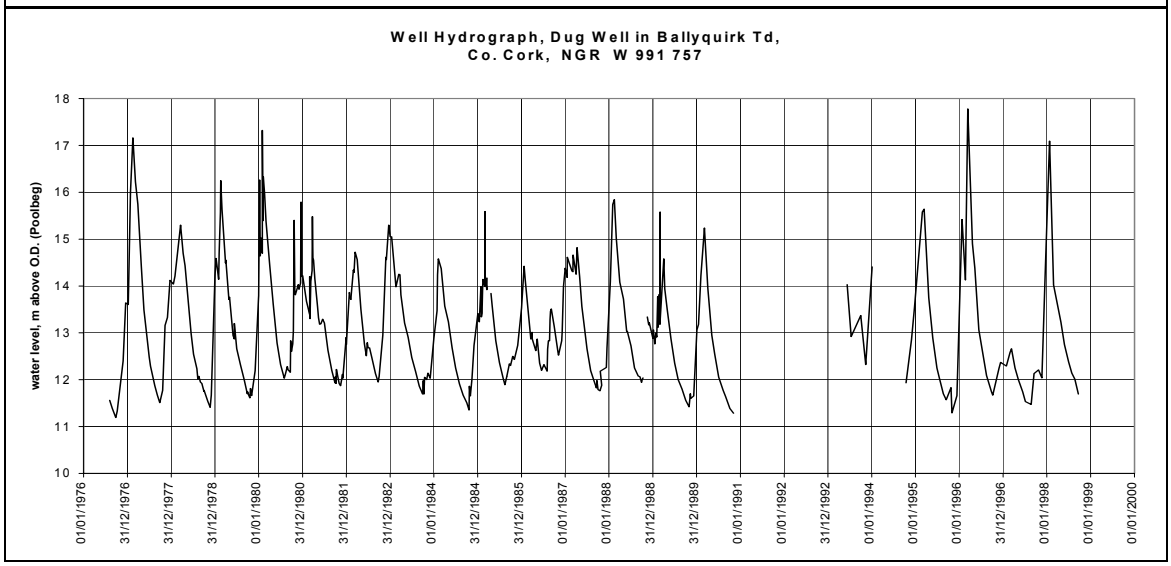
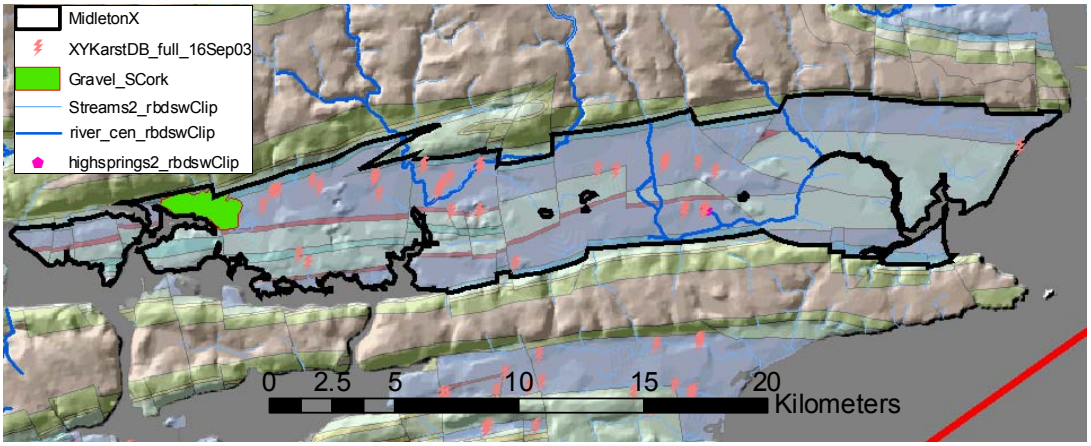


Figure 2: Groundwater hydrographs
(GSI Well Hydrographs)





Midleton GWB (For Reference)



List of Rock units in Midleton GWB

Rock unit name and code	Description	Rock unit group
Clashavodig Formation (CV)	Oolitic, peloidal, cherty fine limestone	Dinantian Pure Bedded Limestones
Little Island Formation (Ll)	Massive and crinoidal fine limestone	Dinantian Pure Unbedded limestones
Cork Red Marble Formation (CK)	Red brecciated calcilutite limestone	Dinantian Pure Bedded Limestones
Waulsortian Limestones (WA)	Massive unbedded fine-grained limestone	Dinantian Pure Unbedded limestones
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones