Ballincollig 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:** Bride, Lee, Glasheen, Tramore. **Lakes:** Ovens, Quarry, Cork.	Douglas River Estuary (001046), Cork Lough (001081), Ballincollig Cave (001249)	70.2

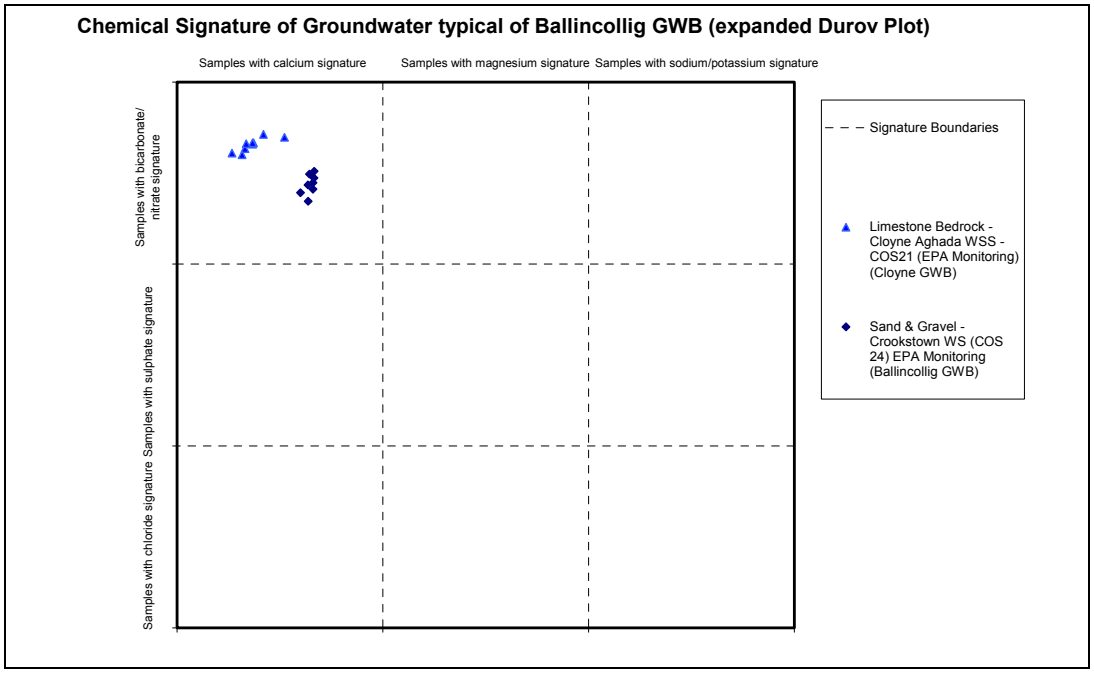
Topography	This GWB occupies the floor of an elongate E-W to ENE-WSW valley extending west from Cork City. The valley is bounded to the north and south by parallel E-W ridges of the Ballinhassig GWB. The valley floor is generally flat to gently undulating. Ground elevations range 5-60 m AOD, being lowest in the east of the body, generally < 30 m OD. West of Ovens ground elevations range 40-60 m OD. Part of the valley floor is the River Lee flood plain, which joins the valley just west of Ballincollig and flows eastwards along the northern edge of the body, and its tributary the River Bride which flows eastwards across the western half of the body.	
Geology and Aquifers	**Aquifer categories**	The main aquifer category in this GWB is: **Rk^d**: Regionally important karstified aquifer dominated by diffuse flow. Some narrow areas around the margins of the body have 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. Small areas of Pure Bedded Limestones (1.3 km^2) also occur. Areas of Dinantian Lower Impure Limestones and Dinantian Mudstones and Sandstones (Cork Group) and Dinantian Old Red Sandstones occur along the margins of the body, in particular along the north of the body.
	Key structures	During the Variscan Orogeny, rocks in the region were compressed from the south into a series of folds on E-W axes. Subsequent erosion stripped the more soluble limestones from the fold crests or ridges (anticlines) exposing the harder, more resistant sandstones underneath. The limestones were preserved in the fold troughs (synclines) which today line elongate E-W trending valleys separated by sandstone ridges. This GWB lies in the west 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 N-S and a series of thrust faults with a general E-W trend. The major N-S shear faults are paralleled by a very well developed system of vertical or near-vertical N-S 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 South Munster 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 karstification is demonstrated by cave plans from southeast Cork (e.g. Poulnahorka Caves, Castlemartyr) where the main passages or 'galleries' have developed along N-S 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 east of Cork Harbour 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). In this GWB several wells with 'Excellent' yields (>400 m^3/d) occur as well as many wells with 'Good' yields (100-400 m^3/d). In 1978, the large Castlemore Quarry, approx. 750 m northeast of Crookstown, was reported to be pumping out over 300,000 m^3/day, an indication of the productivity of the limestones in the area. The Dinantian Mudstones and Sandstones (Cork Group) less productive and transmissivities are significantly lower. The transmissivity values calculated from pumping test data for a County Council Source at Robert's Cove in the same rock type as that occurring in this GWB (Cuskinny Member of Kinsale Formation KNcu) range between 10 and 13 m^2/d. This borehole lies close to a localised fault zone where transmissivity is likely to be at the high end of expected range. Along the northern side of the body, particularly along the Lee Valley, but also further west along the Bride river valley, deep sand and gravel deposits occur. They vary in depth across the Lee and Bride valley areas from several metres to approximately 40 m thick. In many places they are overlain by a layer of alluvium. Estimates of permeability from particle size analyses of sand and gravel deposits in the west of the body near Crookstown were approximately 50 m/d. Assuming an aquifer thickness of 10 metres, this gives a transmissivity of 500 m^2/d. Porosity is estimated at 0.03. Hydraulic gradient of the sand and gravel has been estimated to be in the order of 0.001 (Kelly & Wright 2002 –Crookstown). The overlying sand and gravel deposits are in hydraulic continuity with the underlying bedrock and will provide the bedrock aquifers with additional storage.

	Thickness	The Dinantian Pure Unbedded Limestones in this area are 500-600 m thick (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 which intersect major zones of fissuring at depth have been observed in Waulsortian Limestone at Cloyne, Co Cork (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 40m below OD (Wright, 1979). In this GWB a borehole at Togher in Cork City encountered a major fissure at 34-36 m bgl and in a borehole in Ballyphehane, also in the south of the city, water entries were recorded at 14, 57.6, 59.1, 60.7, 63.4, 67.1 m bgl, representing major water bearing fissures. 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 the limestones in this region are an example of a drowned karst terrain. In the Dinantian Mudstones and Sandstones (Cork Group) that occur 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 overlain by alluvium, sand and gravel deposits and some glacial till. There are large areas of alluvium in the west of the body, north of Crookstown and west of Kilcrea Abbey. The limited drilling records for the area indicate that the alluvium overlies fluvioglacial gravel. Teagasc mapping identifies a large sand/gravel deposit west of Ovens, and a smaller sand/gravel deposit south of Castlemore. Further east, along the River Lee flood plain on the northern side of the body, sand and gravel deposits are covered by layers of till and alluvium. Areas of rock outcrop and shallow rock are common in the east of the body south of the River Lee flood plain. The urban area of Cork City and its suburbs, and associated paved areas, occupy a large area in the east of the body. Alluvium is generally considered to be of 'moderate' permeability while sand and gravel deposits are 'high' permeability. Glacial tills in this area are also considered to be of 'moderate' permeability. *Subsoil Types identified in Ballincollig GWB by Teagasc Parent Material Mapping (Draft): Alluvium (A); Sandstone sands and gravels (Devonian & Carboniferous) (GDSs) & (GDCSs); Made Ground (Made); Estuarine sediments (silts/clays) (Mesc); Rock outcrop and rock close to surface (Rck); Till – Devonian Sandstone Till (TDSs).*
	Thickness	Subsoil depth varies considerably within this GWB. In the eastern half of the body, the River Lee flows along the northern side of the body. Available data indicate that depth to bedrock in the river flood plain generally ranges 10-30 m. Depths of 50 m have been recorded in site investigations in Cork City. To the south of the River Lee flood plain, frequent areas of rock and shallow rock occur. Away from rock outcrop subsoil depths of up to 10 m are generally encountered although isolated areas of deeper subsoil also occur. The underlying pure unbedded limestone in this valley is highly karstified and likely to have a very irregular bedrock surface, hence subsoil depths can be highly variable within short distances. In the west of the body, areas of rock outcrop and shallow rock are less frequent, but depth to bedrock data are sparse. Around Castlemore there is a small area where subsoil is generally <3 m and some isolated areas of outcrop occur towards the southern margin of the body. Elsewhere in the west of the body subsoils are expected to be >3 m and it is likely that fluvioglacial deposits of >10 m occur in many areas. At Crookstown WS borehole, bedrock is >28 m bgl.
	% area aquifer near surface	
	Vulnerability	Most of the area is of High Vulnerability. Frequent areas of Extreme Vulnerability occur in the east of the body where rock outcrop and shallow rock are common. Some small areas of Moderate Vulnerability occur in the west of the body. 'High' permeability subsoils (sand and gravel deposits) >3 m deep are classed as High Vulnerability irrespective of thickness (DELG/EPA/GSI, 1999).
Recharge	**Main recharge mechanisms**	The sandstone ridges to the north and south of this GWB (Ballinhassig GWB) 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 caves allow point recharge to the karstified aquifer. Diffuse recharge will occur over the entire GWB. The sand and gravel deposits provide a highly permeable pathway for recharge, and can also augment storage in the aquifer. The 'moderate' permeability alluvium that overlays much of the west of the body will generally not restrict percolation of recharge. The large urban area of Cork City and associated extensive paved areas may restrict recharge to the underlying aquifer in that area.
	Est. recharge rates	

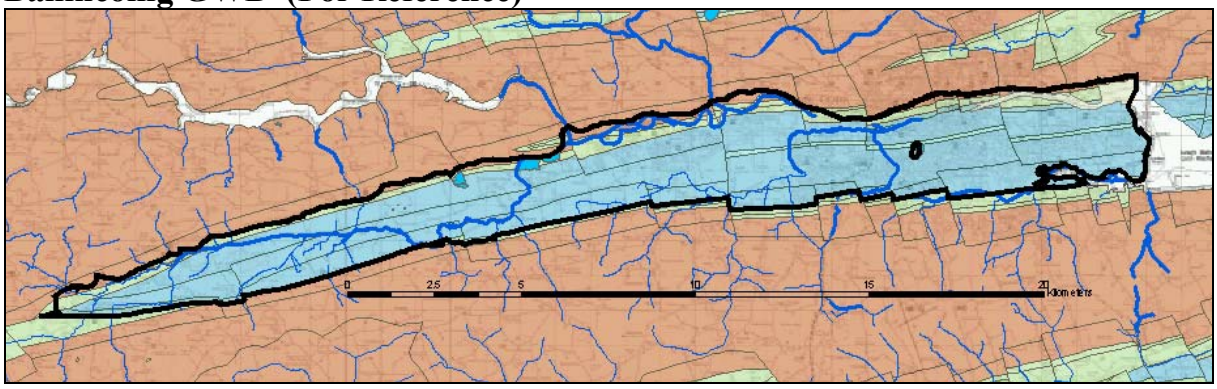
Discharge	**Large springs and high yielding wells (m^3/d)**	*Note: The following data need to be checked and updated by RBD Project Consultants.* Data from GSI Well Database: Togher-Southern Fruit (576 m3/d) Cork Milk Products-Ballyphehane (1528 m3/d) Additional data from EPA Groundwater Sources List: Ballyphehane-Co-op (1528 m3/d) Lunham Bros, Tramore Rd (455 m3/d) Cork City, Beamish and Crawford (573 m3/d)
	Main discharge mechanisms	Groundwater discharges to the rivers and streams crossing the GWB or through sands and gravels that are in hydraulic continuity with the rivers.
	Hydrochemical Signature	There are currently no EPA Representative Monitoring Points in the bedrock aquifer in this GWB. Data from other GWBs with similar limestone bedrock indicate that the groundwater will be dominated by calcium and bicarbonate ions. Hardness is likely to range from moderately hard to very hard (200 mg/l to >400 mg/l (as $CaCO_3$)). Groundwater alkalinity will be high, up to 400 mg/l (as $CaCO_3$). Like hardness and alkalinity, electrical conductivities (EC) can vary greatly. Typical limestone water conductivities are 500-700 µS/cm. Chloride levels in groundwater in this body can be elevated near the coast. The pure limestone bedrock is highly karstified. Where overlying strata are thin or absent, as in the southeastern quarter of the body, microbial pollution can travel very quickly from the surface into the groundwater system due to the high level of interaction between groundwater and surface water in karstic aquifers. The bedrock aquifer in this body is overlain by extensive sand and gravel deposits. Data from Crookstown WS, which abstracts from gravel deposits in the west of the body, show hardness ranging 96-108 mg/l (as $CaCO_3$), alkalinity 57-88 mg/l (as $CaCO_3$) and EC 282-306 µS/cm. The hydrochemical signature from a public supply well in the same rock type in the nearby Cloyne GWB is demonstrated in an expanded Durov plot in Figure 1 below.
Groundwater Flow Paths		The pure limestone bedrock has no intergranular permeability. Groundwater flows in the many faults and joints, enlarged by karstification. Past depression of the sea level enabled karstification at depth, which further enhances the permeability. Due to the high frequency of fissures in this region, overall groundwater flow is thought to be diffuse in nature, although solutionally enlarged conduits and cave systems do 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: interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation, and 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, and 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 where the water table is very close to the surface. Regional groundwater flow is away from the ridges to the north and south, towards the rivers draining the valley and to Lough Mahon in the east. The limestones in this body are frequently overlain by sand and gravel deposits which are in hydraulic continuity with the underlying bedrock and provide a permeable pathway for recharge to the karstic aquifer, and where saturated provide additional storage for the underlying bedrock aquifer.
Groundwater & Surface water interactions		The karstic system allows rapid interchanges of water between surface and underground. Swallowholes and caves receive surface water, and groundwater is discharged to surface as springs or as baseflow to rivers crossing the groundwater body. In this GWB, in addition to the general surface water interactions with the karstic aquifer, Cork Lough (001081) and the Douglas River Estuary (001046) are NHAs within this GWB which may be influenced by groundwater.

Conceptual model	• This GWB occupies the floor of an elongate east west trending valley extending west from Cork city. The body is generally flat to gently undulating (5-60 m OD), generally < 30 m OD in the east, 40-60 m OD west of Ovens. The River Lee joins the valley just west of Ballincollig and flows eastwards along the northern edge of the body, and its tributary the River Bride flows eastwards across the western half of the body. • The GWB is bounded to the east by the coast and Lough Mahon. To the south the boundary is the contact with the low permeability sandstones and mudstones of the Ballinhassig GWB. Along the northern side of the body, the contact between the pure unbedded limestones and the underlying mudstones and sandstones (as shown on the 1:100,000 GSI Bedrock map) occurs 400-800 m into the valley floor, beneath alluvium and deep sand and gravel deposits. The northern boundary of the body extends to the edge of the valley floor, thus some areas of low permeability mudstones and sandstones along the northern margin of the body are also included within the body. • The GWB is composed mainly of diffusely karstified, highly permeable pure limestones. To the north and south of the body are ridges of low permeability sandstones and mudstones. Overlying the bedrock in the GWB are glacial sand and gravel deposits. These vary in depth across the Lee and Bride Valley areas from several metres to approximately 40 m thick. The sand and gravel deposits provide a permeable pathway for recharge to the karstic aquifer and where saturated provide additional storage for the underlying bedrock aquifer. Along the northern boundary of the body these deposits overly the mapped contact between the pure unbedded limestones and the underlying mudstones and sandstones. The mudstones and sandstones that occur along the northern margin of the body are less productive than the overlying karstified limestones. • The pure unbedded limestones in the synclinal valleys of South Munster are generally intensely fractured and have high frequency jointing and their permeability has been enhanced by subsequent karstification. Karst features such as caves, swallowholes and other collapse features occur in this GWB. • Groundwater flows through faults and joints formed by deformation and subsequently enlarged by karstification. Most groundwater flow occurs in an upper shallow highly karstified weathered zone 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. Groundwater gradients will be 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 away from the ridges to the north and south, towards the rivers draining the valley and ultimately to Lough Mahon in the east. • Recharge to this GWB is both point and diffuse. The ridges to the north and south of this GWB (Ballinhassig GWB) provide runoff which recharges the limestone aquifer in the valley. Diffuse recharge will occur over the entire GWB. Swallowholes, collapse features provide the means for point recharge to the karstified aquifer. A relatively small volume of groundwater may cross as through-flow into this GWB from the adjacent low transmissivity GWBs. • Most of the GWB is of High Vulnerability. Many areas of Extreme Vulnerability occur in the east of the body where rock outcrop and shallow rock are common. In this highly karstified aquifer the underlying limestone will have a very irregular surface. Subsoil depths in this GWB can therefore be highly variable within short distances. • There is a high degree of interaction between surface water and groundwater in GWB underlain by karstified limestone.
Attachments	Hydrochemical Signature (Figure 1)
Instrumentation	**Stream gauges:** 19012, 19016*, 19049, 19050 **EPA Water Level Monitoring boreholes:** **EPA Representative Monitoring points:** Crookstown WS (COS 24) – in Gravels
Information Sources	Cronin C, Daly D, Meehan R, Johnston P (1997) *Dungarvan Public Supply Groundwater Source Protection Zones*. Geological Survey of Ireland. DELG/EPA/GSI (1999) *Groundwater Protection Schemes*. Department of the Environment and Local Government, Environmental Protection Agency & Geological Survey of Ireland. Farrington A (1959) The Lee Basin Part one: glaciation. Proc. R. Ir. Acad. 60B (3), 135-166. Kelly D, Wright G (2002) *Crookstown Water Supply -Groundwater Source Protection Zones.* Geological Survey of Ireland, 13pp. Sleeman A G, 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 Kelly D, Leader U, Wright G (2002) *South Cork Groundwater Protection Scheme*. Report to Cork County Council (South). Geological Survey of Ireland. Wright G, Gately C (2002) *Whitegate Regional WaterSupply Scheme (Dower Spring)*. Groundwater Source Protection Zones. Report to Cork County Council (South). Geological Survey of Ireland, 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
(EPA Representative Monitoring)



Ballincollig GWB (For Reference)



List of Rock units in Ballincollig GWB

Rock unit name and code	Description	Rock unit group
Little Island Formation (LI)	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 lime-mudstone	Dinantian Pure Unbedded Limestones
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones
Old Head Sandstone Formation (OH)	Flaser-bedded sandstone & minor mudstone	Dinantian Mudstones and Sandstones (Cork Group)
Cuskinny Member (Kncu)	Flaser-bedded sandstone & mudstone	Dinantian Mudstones and Sandstones (Cork Group)
Gyleen Formation (GY)	Sandstone with mudstone & siltstone	Devonian Old Red Sandstones