Tullamore GWB: Summary of Initial Characterisation.

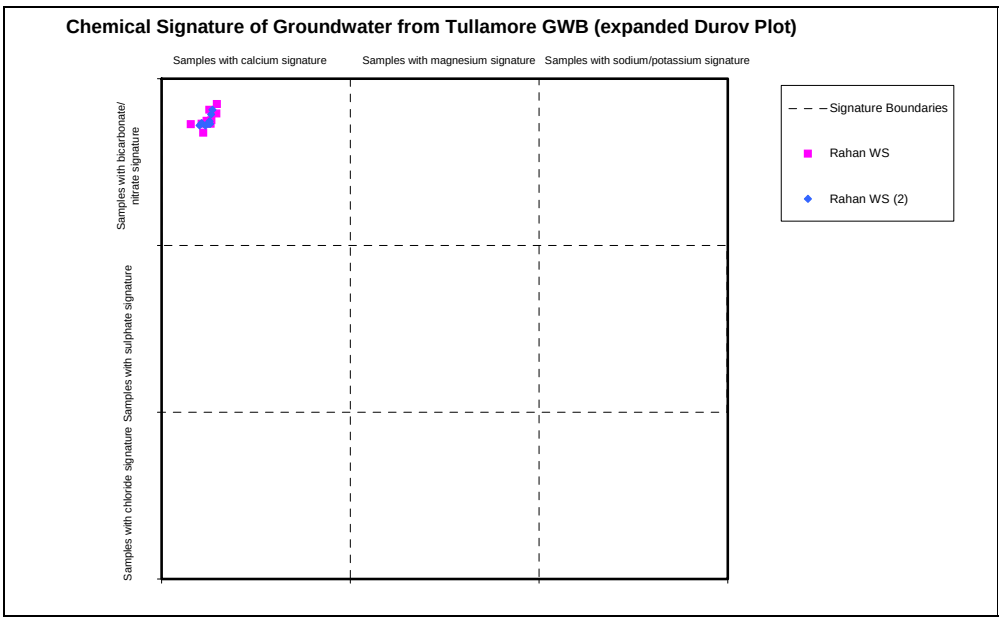
Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
25 – Brosna Offaly & Westmeath Co. Co.'s	**Rivers**: Brosna, Silver, Clodiagh, Tullamore, Boora, Little. **Streams:** Derrycooly, Pollagh. **Loughs:** Black, Forran, Pallas, Turlough.	(000916) Pallas Lough; (000909) Lough Coura; (000572); (000571) Charleville Wood (includes a lake); Clara Bog – *the northeastern boundary of this GWB touches on outer edge of esker ridge within the Clara Bog SAC – Clara Bog itself occurs within the Clara GWB.*	222

Topography	Ground elevations in this GWB range from 50-120 mAOD. The highest ground is along the southeastern side of the body south of Blue Ball and in the extreme northeast of the body The highest point occurs south-southwest of Blueball. Overall the ground slopes gently to the northwest. Most of the body is relatively flat and low lying with much of the area below 80 mAOD. Esker ridges form narrow bands of higher ground. The lowest ground occurs on the northwestern side of the body, near the river channels of the Clodiagh, the Silver (Kilcormac) and the Silver (Tullamore) Rivers.	
Geology and Aquifers	**Aquifer categories**	The main aquifer category in this GWB is: **Rkd:** Regionally important karstified aquifer dominated by diffuse flow. There is a small area (3.8 km^2) with an aquifer category of: **Ll:** Locally important aquifer which is moderately productive only in local zones. *The bedrock aquifer is overlain in some places by a potential locally important sand & gravel aquifer* ***(Lg).***
	Main aquifer lithologies	This GWB is composed of Dinantian Pure Bedded Limestones with a small area (3.8 km^2) of Dinantian Pure Unbedded Limestones.
	Key structures	The major structural features (large folds and major faults) in the region in which this GWB occurs have a northeast southwest orientation. Knockshigowna Fault runs northeast to southwest along the southeastern boundary of the body bringing the Dinantian Pure Bedded Limestones into contact with the less permeable Dinantian Pure Unbedded Limestones and the Dinantian Upper Impure Limestones of the Geashill GWB. Small northeast southwest trending anticlinal and synclinal features are recorded in the northeast of the body. This GWB is cross cut by a number of northwest to southeast trending normal faults that are spaced at approx. 5 km intervals. Dips over the body are generally to the southeast ranging from 5-20^o. Due to the thick till cover in this region much of the structure is poorly exposed at the surface and has been inferred from drilling information.
	Key properties	This GWB consists primarily of highly permeable Dinantian Pure Bedded Limestones. Modelled transmissivities from work carried out at groundwater sources at Tully and Hollimshill, Co Offaly, were 140 and 650 m^2/d respectively (Kelly, 2001). Field transmissivities of 52-530 m^2 d^{-1} have been recorded at Hollimshill and 13 m^2/d at Tully. Modelled permeability was 4.5 m/d at Tully and 13 m/d at Hollimshill. Aquifer properties at Agall Spring, Co Offaly are estimated to be similar to those at Hollimshill and possibly higher as it is a spring with a high discharge. Permeability at Agall Spring has been estimated to be about 20 m/d with porosity taken to be about 0.02 (Kelly, C. 2001). Analysis of data from a 10 hr pumping test of groundwater supply boreholes at Kilcormac gave transmissivity estimates of 20-40 m^2 d^{-1}. The groundwater gradient is relatively flat within the permeable limestone aquifer. The natural hydraulic gradient is estimated to be approximately 0.002 (Kelly, 2001 – Tully WS). High permeability zones caused by fissuring in the vicinity of faults may be present across the area and may cause local changes to the hydraulic gradient. Pure Bedded Limestones, such as those found in this GWB can be susceptible to karstification, which enhances the permeability of the rocks although few karst features are currently recorded for this GWB. Storativity in such aquifers will be low. The transmissivity of the small area of Dinantian Pure Unbedded Limestones is expected to be lower that that of the Pure Bedded Limestones, with similar properties to rocks of the same type in the adjoining Geashill GWB. While sand & gravel deposits overly the bedrock in several places in this GWB, the main aquifer is likely to be the limestone bedrock. The sand & gravel deposits are likely to provide storage for groundwater and probably maintain yields in dry weather.
	Thickness	The Dinantian Pure Bedded Limestones in this region are generally over 100 m thick. Most groundwater flow is thought to occur in the upper 30 m of the rock, in a highly weathered layer a couple of metres thick, and a zone of interconnected fissures below this. However deeper water strikes can occur.
Overlying Strata	**Lithologies**	A Teagasc Parent Material Map is not currently available for County Offaly or County Westmeath. Information from the National Soil Survey, Soils of County Westmeath (An Foras Talúntais 1977) shows that the GWB is generally overlain by limestone till and gravely limestone till. The Offaly Groundwater Protection Scheme Quaternary Geology Map identifies areas of peat (large area north of the centre of the body, and smaller areas elsewhere in the body), gravel deposits (including some esker deposits), till, till with gravel and alluvium overlying this GWB. *(The gravel deposits overlying this body were identified in the Offaly Groundwater Protection Scheme as a Potential Locally Important Gravel Aquifer).* *[Information to be added at a later date]*

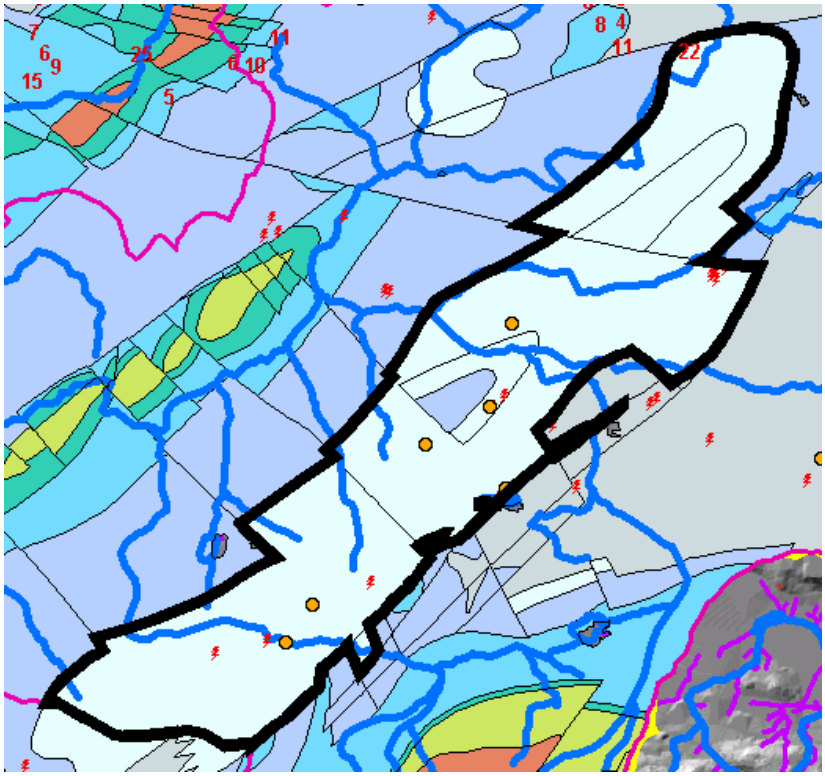
	Thickness	Available data on subsoil thickness indicate a general subsoil thickness of 5-10 m over the GWB. Areas of shallower subsoil do occur, with small areas of outcrop occurring within the body, particularly in the vicinity of Tullamore and east of Kilcormac. Some points of up to 33 m subsoil have also been recorded in the north of the body.
	% area aquifer near surface	[Information to be added at a later date]
	Vulnerability	A Groundwater Vulnerability map is not currently available for County Westmeath. A Groundwater Vulnerability Map has been prepared as part of the County Offaly Groundwater Protection Scheme. Most of the area of this GWB in County Offaly has been designated High Vulnerability. One broad area of Moderate Vulnerability occurs to the north of the centre of the body. Small more isolated areas of Extreme Vulnerability occur throughout the body, including areas in the vicinity of Tullamore and east of Kilcormac.
Recharge	**Main recharge mechanisms**	Diffuse recharge will occur throughout this GWB via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. The highest amount of diffuse recharge will occur at rock outcrop and where subsoils are thinnest and most permeable. Subsoil permeability has not currently been mapped in detail in County Westmeath. In County Offaly the many sand and gravel deposits are considered to have a 'high' permeability, and provide a permeable pathway for percolation of recharge to the underlying aquifer. The sand and gravel deposits can also act to augment storage in the aquifer. It is likely that there will be some recharge from adjoining low permeability GWB's. The zone of contribution to the Holmshill water supply boreholes in County Offaly which are located in this GWB includes an area in the adjoining Geashill GWB.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	**Large springs and high yielding wells (m^3/d)**	Agall Spring (Rahan WSS) (1000 m^3 /d); Tully Boreholes (Rahan WSS) (432 m^3 /d); Hollimshill Boreholes (Rahan WSS) (455 m^3 /d); Ballyboy GWS(176 m^3 /d); Kilcormac WSS (455 m^3 /d); Sillogue Spring, Durrow (4546 m^3/d) – this spring draws water mainly from Dinantian Pure Bedded Limestones with some contribution from overlying gravels.
	Main discharge mechanisms	The main discharges are to the large springs which occur within the body and to the streams and rivers crossing the body.
	Hydrochemical Signature	The groundwater in this body is calcium bicarbonate water type, reflecting the predominance of limestone bedrock and, in areas not underlain by limestone, of overlying limestone tills. As a consequence, it is generally hard (251-350 mg/l) to very hard (>350 mg/l). The hydrochemical signature of groundwater from the Rahan WS scheme which draws it was water from springs and boreholes in the pure bedded limestone of this body is demonstrated in an expanded Durov plot in Figure 1 below. Electrical conductivity values in groundwater from the Rahan WS are quite high (540-715 µS cm^{-1}), in line with what is expected from water from a limestone aquifer.
Groundwater Flow Paths		The bedrock in this GWB is generally devoid of intergranular permeability. Groundwater flows diffusely through fissures, joints and along bedding planes. In the pure bedded limestones of this GWB fissuring is generally well developed and interconnected and support regional-scale flow systems. Flow path lengths can be up to several kilometres in length. There is some evidence of karstification, which where it occurs will enhance the permeability of the rock. Groundwater is generally unconfined in this GWB. Water levels will broadly reflect the topography within the body however topographic highs formed by some esker ridges have been shown to have no effect on the water table due to the highly permeable nature of the deposits. Overall groundwater flow is towards the rivers crossing the body, and westwards towards the River Brosna. Current data in the GSI well database show static water levels ranging from 3-32 m below surface in this GWB with water levels frequently > 10 m below surface. Water levels will be closer to ground level in the vicinity of the rivers. There are sand and gravel deposits overlying the body in many areas. These deposits are in hydraulic continuity with the underlying bedrock aquifer. Whilst often not sufficient to constitute a gravel aquifer these deposits provide storage for the underlying bedrock aquifer. The large Silloge Spring near Durrow County Offaly is supported mainly by the underlying limestone with contribution from the overlying gravel deposits. Water level records for are less variable than would be expected for a high permeability limestone aquifer, which is attributed to the controlling influence of the available storage from the overlying sand and gravel deposits.
Groundwater & Surface water interactions		Pallas Lough (000916) occurs south of the centre of the body, on the southwestern boundary with the Geashill GWB. It is a small lake, marshy on its margins and underlain by shallow peat deposits which are probably less than 3m. It is not know whether the peat is underlain by bedrock or by high permeability gravely subsoil. The lake receives water from its catchment from both surface runoff and shallow groundwater flow. There are no surface outlets from the lake therefore it seems likely that water from the lake enters the groundwater through the lake bed (Kelly, C. 2001). There is no evidence of karstification in the vicinity of the lake.

Conceptual model	• This GWB consists of an elongate northeast southwest trending area north and north west of the Slieve Bloom Mountains. The body is bounded to the northwest and southeast by the contact with the low permeability Dinantian Pure Unbedded Limestones and Dinantian Upper Impure Limestones of the Clara and Geashill GWBs respectively. The body meets the adjoining Birr GWB to the southwest, along the surface water catchment boundary between the Brosna and Little Brosna catchments • Ground elevations range from 50-120 mAOD. Highest along the southeastern side of the body, lowest along the northwestern side. Most of the body is flat and low lying with much of the area below 80 mAOD. Esker ridges form narrow bands of higher ground. • The GWB is composed of Dinantian Pure Unbedded Limestones, typically a high transmissivity limestone. Groundwater flows diffusely through fissures, joints and along bedding planes. Current records of karst features are limited in this GWB, however pure limestones are susceptible to karstification, and where it occurs it will enhance the permeability of the rock. • Diffuse recharge will occur throughout this GWB via rainfall percolating through the subsoil. Much of the overlying subsoil consists of high permeability sand and gravel deposits which will provide a permeable pathway for recharge to the underlying aquifer. There is likely to be some additional recharge from adjoining low permeability GWB's. • Groundwater discharges to the streams and rivers crossing the body and to the large springs which occur within the body. • The groundwater in this body is generally unconfined. Most of the groundwater flow will be concentrated in an upper highly weathered layer and in a zone of interconnected fissures, possibly enlarged by karstification in some areas, generally extending to a depth of 30 m. Deep water strikes in more isolated faults/fractures can be encountered. Typically Dinantian Pure Bedded Limestones, such as those founding this GWB, have a degree of interconnection between fractures zones and they generally support regional scale flow systems. Flow paths can potentially be several kilometres in length. Groundwater gradients are relatively flat within the permeable limestone. Water levels will broadly reflect the topography within the body however topographic highs formed by some esker ridges have been shown to have no effect on the water table due to the highly permeable nature of the deposits. • Overlying sand and gravel deposits are in hydraulic continuity with the underlying bedrock aquifer and in many areas partially contribute to well and spring yields and provide additional storage for the aquifer. • Most of the area of this GWB is of High Vulnerability with some small isolated areas of Extreme Vulnerability and an area of Moderate Vulnerability north of the centre of the body. • Pallas Lough, County Offaly, which is a protected area within this GWB has no surface outflow and is believed to discharge to groundwater via the lake bed.
Attachments	Hydrochemical Signature (Figure 1).
Instrumentation	**Stream gauges:** 25016, 25033, 25036, 25119, 25145, 25149, 25201, 25202, 25216, 25219, 25220, 25254, 25325 EPA Water Level Monitoring boreholes: None **EPA Representative Monitoring points:** Rahan WS - (OFF 019), (OFF 021).
Information Sources	Daly, D., Cronin, C., Coxon, C. and Burns, S-J (1998) *County Offaly Groundwater Protection Scheme*. Geological Survey of Ireland Report to Offaly Co. Co., 54 pp. Cronin C., Daly, D., and R. Flynn, 1999. *Hollimshill Public Supply. Groundwater Source Protection Zones.* Geological Survey of Ireland Report, 12 pp. Cronin C., Daly, D., and R. Flynn, 1998. *Tully Public Supply. Groundwater Source Protection Zones*. Geological Survey of Ireland Report, 18 pp. Kelly, C. 2001. *Agall Water Supply Scheme. Groundwater Source Protection Zones.* Geological Survey of Ireland Report. Kelly, C. 2001. *Kilcormac Water Supply Scheme. Groundwater Source Protection Zones.* Geological Survey of Ireland Report. Kelly, C. 2001. *Ballyboy Water Supply Scheme. Groundwater Source Protection Zones.* Geological Survey of Ireland Report. Gately, S., Sommervill, I., Morris, J.H., Sleeman, A.G. and Emo, G., 2003. *Geology of Galway-Offaly. A Geological description of Galway-Offaly, and adjacent parts of Westmeath, Tipperary, Laois, Clare and Roscommon to accompany the bedrock geology 1:100,000 scale map series, Sheet 15.* With contributions from W. Cox (Minerals), T.Hunter-Williams (Groundwater) and R. van den Berg and E. Sweeney (Carboniferous Volcanics), edited by A.G. Sleeman (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: Hydrochemical signature
(EPA Representative Monitoring)



Tullamore GWB (For Reference)



List of Rock units in Tullamore GWB

Rock unit name and code	Description	Rock unit group
Visean Limestones (undifferentiated) (VIS)	Undifferentiated limestone	Dinantian Pure Bedded Limestones
Allenwood Formation (AW)	Thick-bedded limestone, locally peloidal	Dinantian Pure Bedded Limestones
Waulsortian Limestone (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones

NOTES on Tullamore GWB

1.1.1 3 FRACTURED SHELF LIMESTONES

Pure shelf limestone units are preserved in the core of the Borrisokane Syncline, and occur in a southwest - northeast strip from the area around the east of Lough Derg to north of Tullamore. The rock units, which include Undifferentiated Visean limestones, plus the Terryglass, Borrisokane, Oldcourt and Allenwood Formations, are capable of yielding significant amounts of water.

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In North Tipperary three springs at Aglish, Borrisokane, and Riverstown with low flows of about 1,000 m^3/d, greater than 1,100 m^3/d, and more than 545 m^3/d respectively, are used for public supply. In Co. Offaly, three large public supplies and one group scheme supply and draw water from this aquifer within the area of Sheet 15. These supplies, at Gormagh Bridge (Tullamore UDC), Agall, Hollimshill and Tully (Rahan Water Supply), and Kilcormac Water Supply have a combined daily abstraction of approximately 4,500 m^3.

In addition, Sillogue spring near Durrow, which has an estimated discharge of 4,000 m^3/d is one of the largest springs in Co. Offaly, although it is not yet used for public supply. The Agall source acts as a spring in winter and a dug well in summer. The sands and gravels south of the spring are thought to provide a significant contribution to the outflow and yield.

Relatively high permeabilities, summarised in Table 3, are indicated by pumping tests and numerical modelling of the wells at Hollimshill and Tully, and by numerical modelling of the springs at Aglish and Borrisokane. Wells drilled at Gormagh Bridge (Ardan source) gave exceptionally high yields when tested - up to 3,000 m^3/d in one well, with an estimated specific capacity, transmissivity and permeability of 240 m^3/d/m, 330 m^2/d and 27 m/d, respectively.

Location	**Transmissivity m^2/d**	**Permeability m/d**	**Specific yield (effective porosity)**
Hollimshill	510	12	0.02
Tully, Rahan	140	4.5	0.02
Aglish	-	10	0.03
Borrisokane	-	18.5	0.05

Table 3 Hydrogeological data for Hollimshill and Tully Wells, and the springs at Aglish and Borrisokane

In addition to sometimes elevated manganese and iron concentrations, groundwater from this aquifer is generally hard to very hard, with a calcium bicarbonate ($CaHCO_3$) hydrochemical signature.

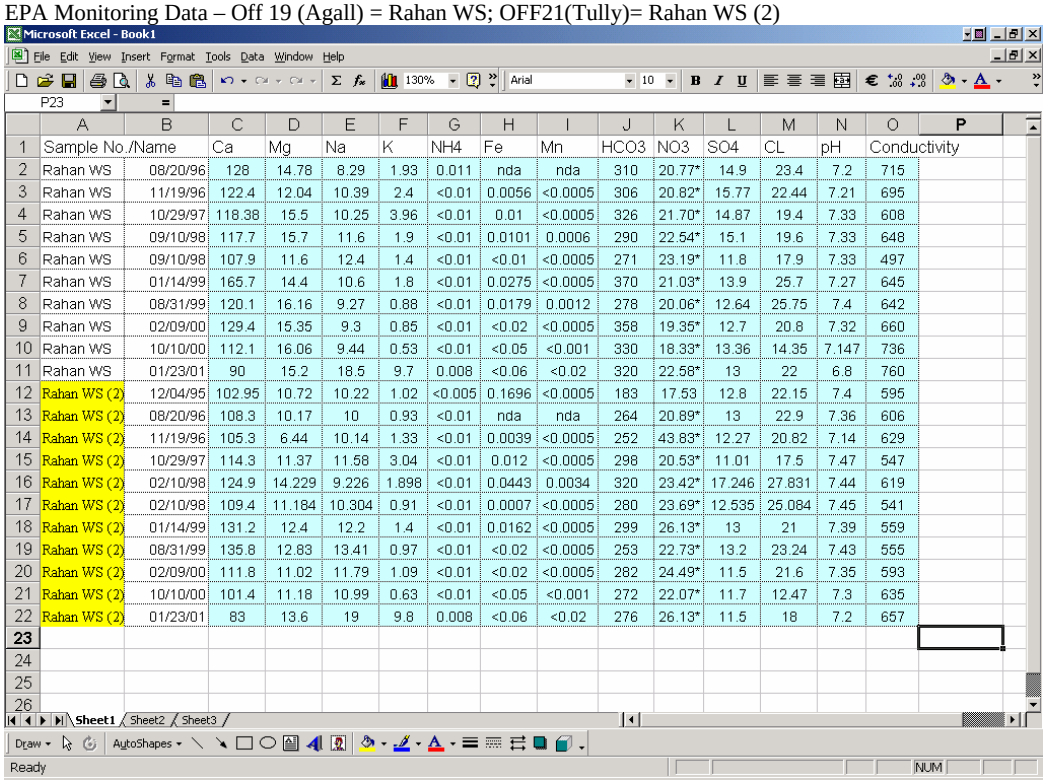
A few karst features such as turloughs, swallow holes and springs are present in this aquifer. However, the available information indicates relatively limited karstification compared with truly karstic aquifers, and this aquifer is classified as a Regionally Important Fractured Aquifer.

In general, the bedded limestones, because of their purity, are susceptible to solution and karstification. The absence of clay minerals within the limestone beds and generally shale-free nature also makes them more brittle than their impure limestone counterparts, resulting in the greater development of fracturing, and hence permeability.

The rock unit's permeability depends on the presence of fissures, faults and joints along which groundwater can flow. Jointing developed in the limestones has allowed the percolation and flow of water in an extensive fracture network. Bedding planes can also act as preferential flow pathways. The enlargement by solution of these planar features often further enhances the bulk permeability of the pure bedded limestones. Karstification can be

accentuated along structural features such as fold axes and faults and can result in high permeability and throughput in relatively narrow zones.

EPA Monitoring Data – Off 19 (Agall) = Rahan WS; OFF21(Tully)= Rahan WS (2)



Microsoft Excel - Book1

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Sample No./Name		Ca	Mg	Na	K	NH4	Fe	Mn	HCO3	NO3	SO4	CL	pH	Conductivity	
2	Rahan WS	08/20/96	128	14.78	8.29	1.93	0.011	nda	nda	310	20.77*	14.9	23.4	7.2	715	
3	Rahan WS	11/19/96	122.4	12.04	10.39	2.4	<0.01	0.0056	<0.0005	306	20.82*	15.77	22.44	7.21	695	
4	Rahan WS	10/29/97	118.38	15.5	10.25	3.96	<0.01	0.01	<0.0005	326	21.70*	14.87	19.4	7.33	608	
5	Rahan WS	09/10/98	117.7	15.7	11.6	1.9	<0.01	0.0101	0.0006	290	22.54*	15.1	19.6	7.33	648	
6	Rahan WS	09/10/98	107.9	11.6	12.4	1.4	<0.01	<0.01	<0.0005	271	23.19*	11.8	17.9	7.33	497	
7	Rahan WS	01/14/99	165.7	14.4	10.6	1.8	<0.01	0.0275	<0.0005	370	21.03*	13.9	25.7	7.27	645	
8	Rahan WS	08/31/99	120.1	16.16	9.27	0.88	<0.01	0.0179	0.0012	278	20.06*	12.64	25.75	7.4	642	
9	Rahan WS	02/09/00	129.4	15.35	9.3	0.85	<0.01	<0.02	<0.0005	358	19.35*	12.7	20.8	7.32	660	
10	Rahan WS	10/10/00	112.1	16.06	9.44	0.53	<0.01	<0.05	<0.001	330	18.33*	13.36	14.35	7.147	736	
11	Rahan WS	01/23/01	90	15.2	18.5	9.7	0.008	<0.06	<0.02	320	22.58*	13	22	6.8	760	
12	Rahan WS (2)	12/04/95	102.95	10.72	10.22	1.02	<0.005	0.1696	<0.0005	183	17.53	12.8	22.15	7.4	595	
13	Rahan WS (2)	08/20/96	108.3	10.17	10	0.93	<0.01	nda	nda	264	20.89*	13	22.9	7.36	606	
14	Rahan WS (2)	11/19/96	105.3	6.44	10.14	1.33	<0.01	0.0039	<0.0005	252	43.83*	12.27	20.82	7.14	629	
15	Rahan WS (2)	10/29/97	114.3	11.37	11.58	3.04	<0.01	0.012	<0.0005	298	20.53*	11.01	17.5	7.47	547	
16	Rahan WS (2)	02/10/98	124.9	14.229	9.226	1.898	<0.01	0.0443	0.0034	320	23.42*	17.246	27.831	7.44	619	
17	Rahan WS (2)	02/10/98	109.4	11.184	10.304	0.91	<0.01	0.0007	<0.0005	280	23.69*	12.535	25.084	7.45	541	
18	Rahan WS (2)	01/14/99	131.2	12.4	12.2	1.4	<0.01	0.0162	<0.0005	299	26.13*	13	21	7.39	559	
19	Rahan WS (2)	08/31/99	135.8	12.83	13.41	0.97	<0.01	<0.02	<0.0005	253	22.73*	13.2	23.24	7.43	555	
20	Rahan WS (2)	02/09/00	111.8	11.02	11.79	1.09	<0.01	<0.02	<0.0005	282	24.49*	11.5	21.6	7.35	593	
21	Rahan WS (2)	10/10/00	101.4	11.18	10.99	0.63	<0.01	<0.05	<0.001	272	22.07*	11.7	12.47	7.3	635	
22	Rahan WS (2)	01/23/01	83	13.6	19	9.8	0.008	<0.06	<0.02	276	26.13*	11.5	18	7.2	657	
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Sheet1 Sheet2 Sheet3

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