I.1 Assessment of Atmospheric Emissions

The existing activities commenced in March 2007.

The ambient air quality has been satisfactory at all time and there are no records of complaints or concerns regarding same.

The management of the activities take care to minimize handling on-site during periods of very dry and warm weather. They also take care to wet surfaces in the event of excess dust arising.

No specific dust dispersion modelling has been or is proposed to be carried out because there were never concerns expressed regarding dust generation at the site.

Consequent on the above item there are no significant atmospheric impacts.

I.2 Assessment of Impact on Receiving Surface Water

Refer to *Table I.2 Surface Water Quality.*

For a detailed hydraulic report refer to I.2 *(2) Impact on the Peastinagh River catchment and on the River Martin catchment of the proposed infill at Ivy House Bridge*.

There is a surface water ditch running across the road to the site. This runs along the main road side of the landfill. The quality of this water could impact on watercourse monitoring point #1. This water was sampled for microbiological quality at the locations shown, *Drawing No. 26 Sampling Points.*

This ditch showed good quality and is not impacted by the landfill. It has, however, a slight bearing on the quality at watercourse monitoring point # 1.

It is not possible to sample from the Peastinagh above the confluence with the ditch from across the road because the Peastinagh is covered coming into the confluence.

I.3 Assessment of Impact of Sewage Discharge

There are no emissions to the existing sewage system from the site.

I.4 Assessment of Impact of ground/groundwater emissions

No contaminated materials are allowed to be deposited on site at any time.

Only the following inert materials refer to the European Waste Catalogue and Hazardous Waste List, January 2002, is accepted on the site:

- **<u>17 05 04 Soil and Stone</u>**

- **17 01 07 Mixture of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06**

- **No other waste types are permitted** to be deposited at this facility.

Consequent on the above items there is no added risk to groundwater quality.

All materials are subject to inspection procedures before being deposited on-site; refer I.4 *(2) Operating Instructions & Procedures in Respect to Waste Control.*

No damaging effects to the groundwater will arise from the materials allowed on site.

No groundwater quality monitoring is proposed.

I.5 Ground and/or groundwater contamination

There is no evidence of ground and/or groundwater contamination on the site.

Currently the refuelling of equipment is brought on site via an oil tanker. In the unlikely event of on-site oil storage occurs, it has been specified in the current permit that if, it were ever to be installed, a refuelling station will have the appropriate concrete bunding, to ensure that no contamination to the ground or groundwater occurs, refer *Drawing No. 27 'Fuel Bunding'.*

No contaminated materials are allowed to be deposited on site at any time.

Only the following inert materials refer to the European Waste Catalogue and Hazardous Waste List, January 2002, is accepted on the site:

- **17 05 04 Soil and Stone**

- **17 01 07 Mixture of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06**

- **No other waste types are permitted** to be deposited at this facility.

Consequent on the above items there is no added risk to ground and/or groundwater quality.

All materials are subject to inspection procedures before being deposited on-site; refer I.4 *(2) Operating Instructions & Procedures in Respect to Waste Control.*

I.6 Noise Impact

The following noise levels and limits are and will continue to be adhered to.

Noise levels emanating from the proposed development when measured at the site boundaries do not exceed 55 dBa (15 minute L_{eq}) between the hours of 08.00 am and 06.00 pm Monday to Friday and between the hours of 08.00 am and 02.00 pm on Saturdays. Noise does not exceed 45 dBa (15 minute L_{eq}) at any other time.

Construction activities shall be carried out such that no noise nuisance is caused to adjoining residence.

The permit holder has ensured that hedgerows and mature trees are retained. This maintains the natural noise buffer.

Noise from construction activities are as follows:

- Transport to and from the site
- Machinery operating within the site
- Both the above are truck and operational vehicle noises. These levels do not exceed the above stated 55 dBa inclusive of the 5 dBa penalty for tone and impulse.

I.7 Assessment of Ecological Impacts & Mitigation Measures

When site filling is nearing its completion and appreciable stone is picked out by hand. Topsoil is recovered and relayed on the surface to a depth of 225 mm. Topsoil is then raked and grass seed is planted at a rate of 40 g/m^2. Grass seed planting is only done during the grass growing season. This will result in a "green field" final product. This final product is consistent with other fields in the area. It will be fully usable for agricultural purposes consistent with the area generally.

Table I.2(i) SURFACE WATER QUALITY

(Sheet 1 of 2) Monitoring Point/ Grid Reference: Watercourse Monitoring Point #1 W 58430 89065

Parameter	Results (mg/l)				Sampling method[2] (grab, drift etc.)	Normal Analytical Range[2]	Analysis method / technique
	29/01/09	09/02/09	Date	Date			
pH	6.9				Grab		ET 1243 APHA 2005:4500:B:H
Temperature	8.7°C				“ ”		
Electrical conductivity EC	396 uS/cm				“ ”		ET0581
Ammoniacal nitrogen NH_4-N	1.7				“ ”		ET 0383 MEWAM 1981
Chemical oxygen demand	<15				“ ”		ET 0673 APHA 2005:5220:C
Biochemical oxygen demand	<4				“ ”		ET 0663 APHA 2005:5210:B
Dissolved oxygen DO	9.4				“ ”		ET0701
Calcium Ca	46.5				“ ”		APHA 2005 3111:B
Cadmium Cd	<10 ug/l				“ ”		APHA 2005 3111:B
Chromium Cr	-----				-----		-----
Chloride Cl	24				“ ”		ET 2444 APHA 2005:4500:Cl:D
Copper Cu	0.01				“ ”		APHA 2005 3111:B
Iron Fe	600 ug/l				“ ”		APHA 2005 3111:B
Lead Pb	-----				-----		-----
Magnesium Mg	7.5				“ ”		APHA 2005 3111:B
Manganese Mn	120 ug/l				“ ”		APHA 2005 3111:B

Surface Water Quality (Sheet 2 of 2)

Parameter	**Results (mg/l)**				**Sampling method (grab, drift etc.)**	**Normal Analytical Range**	**Analysis method / technique**
	29/01/09	**09/02/09**	**Date**	**Date**			
Mercury Hg	-----				-----		-----
Nickel Ni	<10 ug/l				Grab		APHA 2005 3111:B
Potassium K	4.2				" "		APHA 2005 3111:B
Sodium Na	14.0				" "		APHA 2005 3111:B
Sulphate SO_4	37				" "		ETC981
Zinc Zn	20 ug/l				" "		APHA 2005 3111:B
Total alkalinity (as $CaCO_3$)	68				" "		ET0581
Total organic carbon TOC	-----				-----		-----
Total oxidised nitrogen TON	12.2				" "		ET 2353 APHA 2005:4500:NO3:I
Nitrite NO_2	0.06 (as N)				" "		ET 0431 CMWT BDH 1973 2nd Ed
Nitrate NO_3	12.2 (as N)				" "		ET 044 APHA 4500
Faecal Coliforms (/100mls)	-----	460 MPN/ 100mls			" "		MT0482/APHA 2005 9221B
Total Coliforms (/100mls)	-----	43 MPN/ 100mls			" "		MT0492/APHA 2005 9221E.1
Phosphate PO_4	0.13 (as P)				" "		ET G021 based on ISO 6838:2004

Table I.2(i) SURFACE WATER QUALITY

(Sheet 1 of 2) Monitoring Point/ Grid Reference: Watercourse Monitoring Point #2 W 57970 88443

Parameter	Results (mg/l)				Sampling method[2] (grab, drift etc.)	Normal Analytical Range[2]	Analysis method / technique
	29/01/09	09/02/09	Date	Date			
pH	6.8				Grab		ET 1243 APHA 2005:4500:H:B
Temperature	9.0°C				" "		-----
Electrical conductivity EC	936 uS/cm				" "		ET 0562 APHA 2005:2510:B
Ammoniacal nitrogen NH_4-N	28.5 (as N)				" "		ET 0383 MEWAM 1981
Chemical oxygen demand	40				" "		ET 0673 APHA 2005:5220:C
Biochemical oxygen demand	4				" "		ET 0663 APFA 2005:5210:B
Dissolved oxygen DO	7.7				" "		ET0701
Calcium Ca	100.5				" "		APHA 2005:3111B
Cadmium Cd	<10				" "		APHA 2005:3111B
Chromium Cr	-----				-----		-----
Chloride Cl	42				" "		ET 2444 APHA 2005:4500:Cl:D
Copper Cu	0.01				" "		APHA 2005:3111B
Iron Fe	490 ug/l				" "		APHA 2005:3111B
Lead Pb	-----				-----		-----
Magnesium Mg	13.6				" "		APHA 2005:3111B
Manganese Mn	440 ug/l				" "		APHA 2005:3111B

Surface Water Quality (Sheet 2 of 2)

Parameter	**Results (mg/l)**				**Sampling method (grab, drift etc.)**	**Normal Analytical Range**	**Analysis method / technique**
	29/01/09	**09/02/09**	**Date**	**Date**			
Mercury Hg	-----				-----		-----
Nickel Ni	<10 ug/l				Grab		APHA 2005:3111B
Potassium K	13.0				" "		APHA 2005:3111B
Sodium Na	27.0				" "		APHA 2005:3111B
Sulphate SO_4	208				" "		ETC981
Zinc Zn	30 ug/l				" "		APHA 2005:3111B
Total alkalinity (as $CaCO_3$)	146				" "		ET0581
Total organic carbon TOC	-----				-----		-----
Total oxidised nitrogen TON	11.1				" "		ET 2353 APHA 2005:4500:NO2:I
Nitrite NO_2	0.48 (as N)				" "		ET 0431 CMWT BDH 1973 2nd Ed
Nitrate NO_3	10.5 (as N)				" "		ET 044 APHA 4500
Faecal Coliforms (/100mls)	-----	9 MPN/ 100mls			" "		MT0482/APHA 2005 9221B
Total Coliforms (/100mls)	-----	2,400 MPN/ 100mls			" "		MT0492/APHA 2005 9221E.1
Phosphate PO_4	0.07 (as P)				" "		ET G012 based on ISO 6838:2004

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IMPACT ON THE PEASTINAGH RIVER CATCHMENT AND ON THE RIVER MARTIN CATCHMENT OF THE PROPOSED INFILL AT IVYHOUSE BRIDGE

1. The proposed site is located immediately south of Ivyhouse Bridge. This is close to the sources of the Peastingagh River and of the River Martin.
   There are no river gauges on either river close to this location.

2. The flow in the Peastinagh River is estimated by identifying its catchment. Reference is then made to An Foras Forbartha / ESB publication which identifies flows for each catchment in the country.

   - The unitised regional flow duration curves in this region , Cork C and Cork E , gives a maximum of 80 l/s per m2 per 1m rainfall.
   - The annual rainfall is calculated from the average of the two closest gauges at CSET Mallow and Shournagh i.e. 1309 mm/y and 1219 mm/y averaging at 1261 mm/y.
   - The catchment size is measured at = 0.84 sq.km .

   This gives a maximum flow rate resulting from run off the fields to the Peastinagh of :

   80 l/s x 1261/1000 x 0.84 / 1.0 = 0.084 m3/s.

3. The above is based on An Foras Forbartha / ESB publication 1984. This does not account for increased flow due to paving. The additional runoff due to paving is estimated as follows:

   Total paved area in the catchment = 0.013 sq.km
   Time of concentration to Ivyhouse Bridge is estimated as
   Tc = 0.65 km @ 1 m/s = 10.8 mins
   Reference is made to EC Dillons analysis of rainfall. This shows rainfall maximum for 10.8 mins as 2.4 inches / hr = 60 mm/hr.
   Consequently the additional flow due to paving is estimated at :

   13,000 m2 x 60/ 1000 x 1 hr / 3600 secs = 0.216 m3/s

4. The total max flow is therefore

   0.084 (runoff from total area) + 0.216 (runoff from roadway) = 0.3 m3/s

5. The Peastingagh was cross sectioned and bed elevations were measured. This is summarized as follows :

Above Ivyhouse Bridge (new route)	cross section	= 2.0 w x 0.3 d (metres)
	bed slope , i	= 0.009
Below Ivyhouse Bridge	cross section	= 1.5 w x 0.3 d (metres)
	bed slope , i	= 0.043
At Ivyhouse Bridge	section	0.6 w x 0.38 h (metres)
	bed slope , i	= 0.048

Capacities calculated as follows :

$$V = \frac{1.49}{n} \times r^{2/3} \times i^{1/2}$$ (imp units)

V = velocity ft/s
n = roughness = 0.025 (value at Ivyhouse Bridge taken at 0.015 for stone)
r = hydraulic radius in ft
i = bed slope

For above Ivyhouse Bridge , (new route)
V = 1.9 ft/s = 0.58 m/s
Q = VA = 0.58 m/s x 0.3 m x 2.0 m = 0.348 m3/s
Above greater than total flow max of 0.3 – OK

For below Ivyhouse Bridge ,
V = 4.39 ft/s = 1.34 m/s
Q = VA = 1.34 m/s x 0.3 m x 1.5 m = 0.60 m3/s
Above greater than total flow max of 0.3 – OK

For at Ivyhouse Bridge ,
Taken just flowing full with hydraulic radius calculated by area over total perimeter.
V = 5.0 ft/s = 1.52 m/s
Q = VA = 1.52 m/s x 0.6 m x 0..38 m = 0.34 m3/s
Above greater than total flow max of 0.3 – OK

6. The downstream impact of the infill above Ivyhouse Bridge is to reduce any floodwater storage above Ivyhouse Bridge. The quantity of floodwater stored above is small on account of the adequacy of the waterways leading from the area. This is evidenced from the capacity calculated in 5 above.

Check on existing channel above Ivyhouse Bridge as follows:

Cross Section = 4.0 w x 0.3 d (metres)
Bed Slope , i = 0.0025

V = 1.49 x r x i

V = 2.85 f/s = 0.87 m/s
Q = VA = 0.87 m/s x 4.0 m x 0.3 m = 1.04 m3/s
Above greater than total flow max of 0.3 m3/s
Consequently no backup of significance should occur.

The actual quantity of floodwater stored is difficult to accurately assess. The The extent of standing water is marked and dated 22nd Nov , 05 on the site survey drawing no MC 0512 - 05/1. Rainfall records for Nov 05 show Cork had 96% of the normal rainfall for period 1961 to 1990. Nov is historically one of the higher months for rainfall. Consequently the level on the survey date is reasonably close to maximum conditions. The area draining to the Peastinagh shown under water measures at 2300 m2. Estimate a mean depth of 0.3 m. This gives a volume of 690 m3.

To estimate change in storage , the volume stored in the new drain above Ivyhouse Bridge must be deducted from the above. At very maximum conditions this , from 5 above , is close to 0.3 m deep. Consequently the volume stored is calculated as 0.3 m x 2.0 m x 600 m = 360 m3.

Therefore storage is reduced by 330 m3 (690 – 360).

The impact of reducing the storage in this upper region of the catchment by 330 m3 is not significant. At Mourneabbey , 3.5 km downstream , where the Peastinagh flows into the Clyda , the impact can be assessed from the following:

Total catchment of Peastingagh @Mourneabbey = 24 sq. km
Total rainfall for say month of November = 111 mm x 24 sq km
= 2,664,000 m3
The storage reduction equates of 330 m3 equates to 0.00013 of this.
The storage reduction is consequently of very little significance.

7. The impact on the River Martin side is of less significance than the Peastinagh side. This is because only some 20% the area between the N20 and the railway drained to the R.Martin is impacted. The line and gradient of the R.Martin is unchanged. The R.Martin flows under the railway 0.7 km from its high point.

Similar to 2 above . The catchment is measured 0.75 sq.km.
This gives a maximum flow rate from run off the fields to the R. Martin of:

80 l/s x 1261/1000 x 0.75/1.0 =0.076 m3/s

Similar to 3 above . Total paved area in catchment is 0.010 sq.km.
Time of concentration to crossing is estimated as
Tc =0.70 km@1 m/s = 11.7 mins
EC Dillons analysis of rainfall shows 11.7 mins as 2.1 inches/hr = 53 mm/hr.
Consequently additional flow due to paving is estimated at ;

7500 m2 x 53/1000 x 1hr / 3600 secs = 0.110 m3/s

Consequently total max flow is therefore:

0.076 (runoff from area) + 0.110 (runoff from roadway) = 0.186 m3/s

8. R.Martin cross section is average 1.5 wide x 0.3 deep.(metres)
Bed slope is average of 0.007

Capacity calculates at

$$V = \frac{1.49}{n} \times r^{2/3} \times i^{1/2}$$

= 1.80 f/s = 0.55 m/s
Q = VA = 0.55 m/s x 1.5 m x 0.3 m = 0.247 m3/s
Above greater than total flow max of 0.186 m3/s – OK, doesn't surcharge.

At railway crossing cross section is 0.6 x 0.6 stone section
Velocity at max flow is 0.186 / 0.6 x 0.6 = 0.52 m/s .... OK , surcharge , if any not significant as head loss is minimal over 10 m length of crossing under railway.

9 . The loss of upstream storage in the R.Martin is not of any significance. The storage reduction is small and the channel capacity above indicates that storage is not required.

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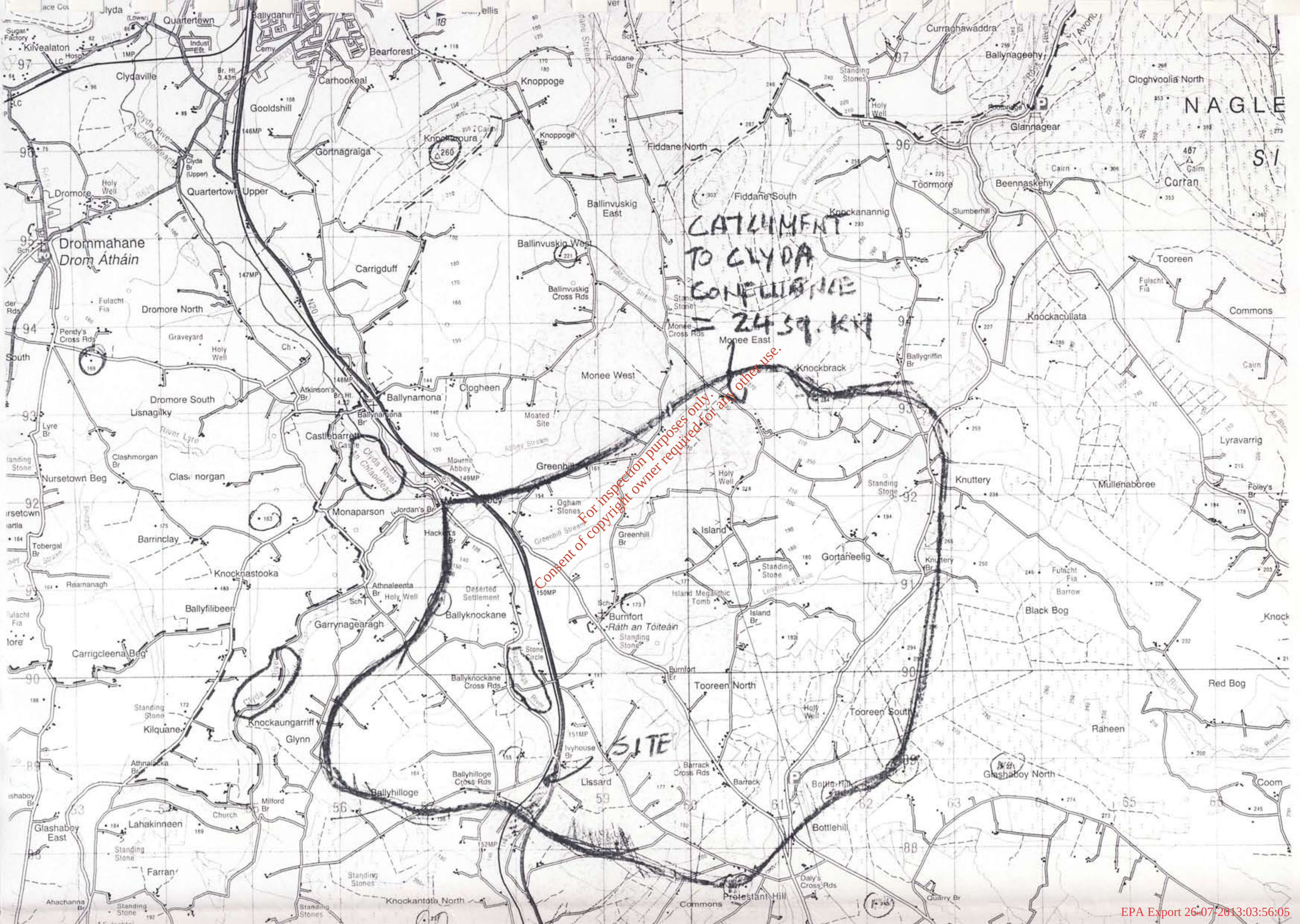
The stream bed and the wet area at the head of the river is being filled with stone with protective cover to allow flow to continue. Consequently there will be a loss of some 75% of cross section of flow in this region. This is not significant because rising water , if any , is the only contributor to flow in this covered area as surface runoff and the road runoff does not drain in this covered channel.

Michael Mescal
Chartered Engineer

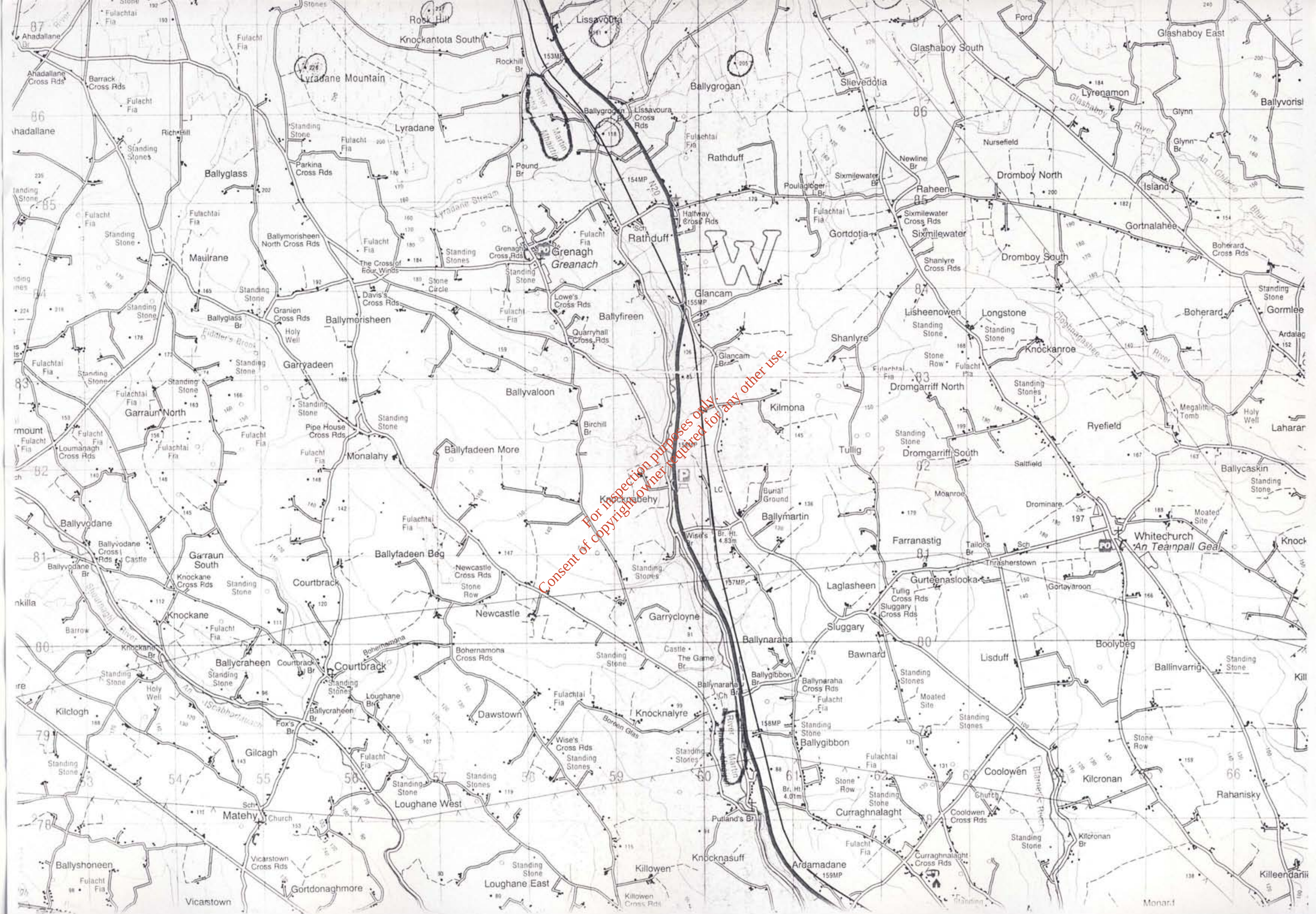
04/01/07

Attachments:

- 1/50,000 – showing Peastingagh and Martin complete (marked OS map enclosed)
- 1/10,000 - showing features
- 'Small Scale Hydroelectric Potential for Ireland' 1985 , AFF
- Extracts from Drainage Records
- Prof EC Dillons Rainfall
- Extract from 'Sewers' by Bevan & Rees



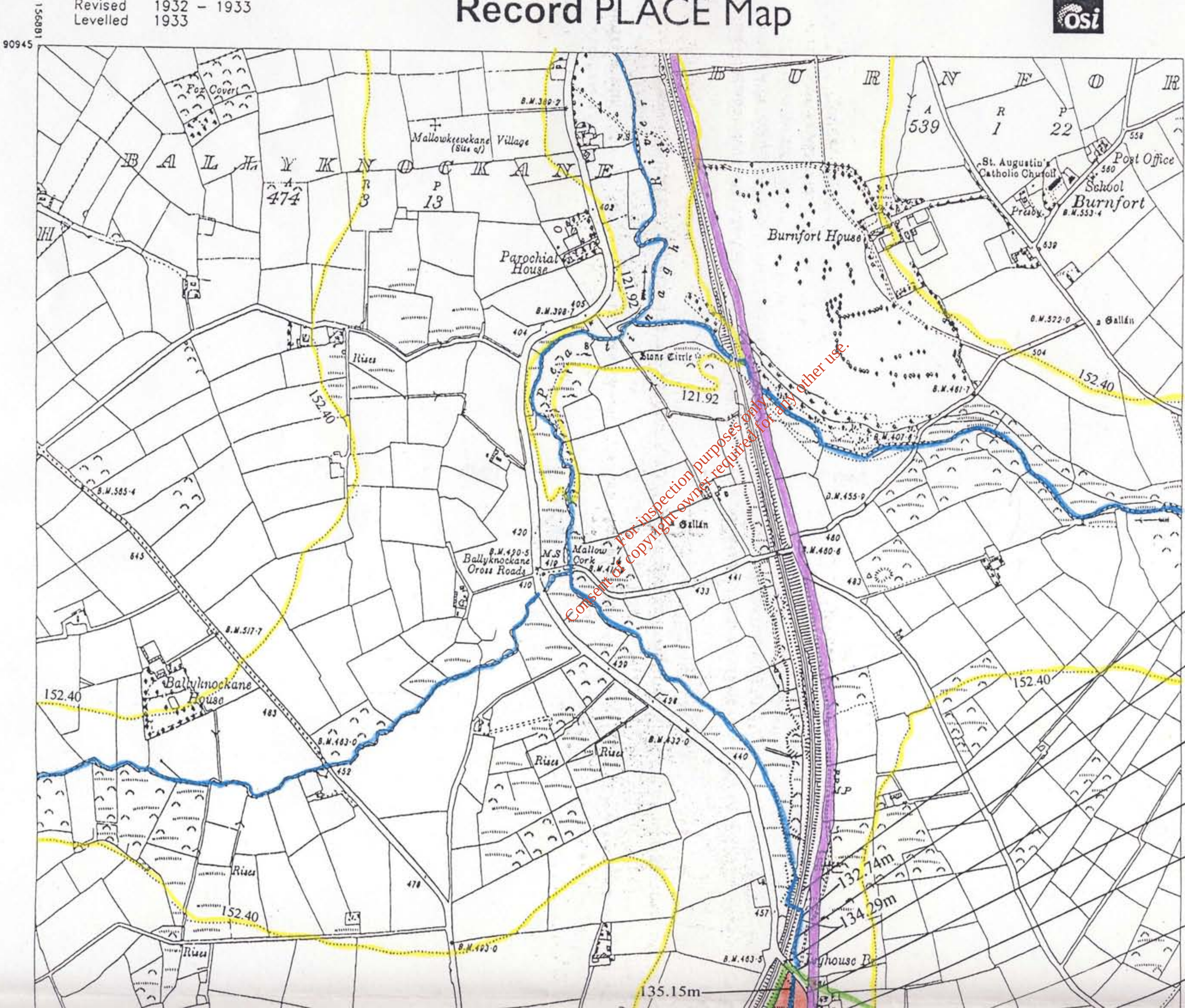
CATCHMENT TO CLYDA CONFLUENCE = 24 SQ. KM
SITE
NAGLE
Drommahane
Drom Áthain
Quartertown
Quartertown Upper
Bearforest
Carhookeal
Knoppoge
Gooldshill
Clydaville
Gortnagraiga
Fiddane North
Fiddane South
Ballinvuskig East
Ballinvuskig West
Carrigduff
Dromore North
Dromore South
Monee West
Monee East
Knockbrack
Knockanannig
Toormore
Beennaskehy
Glannagear
Curraghawaddra
Ballynageehy
Cloghvoolia North
Corran
Tooreen
Commons
Knockacullata
Lyravarrig
Knuttery
Mullenaboree
Ballynamona
Clogheen
Castlebarrett
Mourne Abbey
Greenhill
Monaparson
Island
Gortaneelig
Nursetown Beg
Clashmorgan
Lisnagilky
Barrinclay
Knocknastooka
Ballyfilibeen
Garrynagearagh
Ballyknockane
Burnfort
Ráth an Toiteáin
Black Bog
Red Bog
Raheen
Tooreen North
Tooreen South
Carrigcleena Beg
Knockaungarriff
Glynn
Kilquane
Lissard
Ballyhilloge
Glashaboy North
Bottlehill
Lahakinneen
Glashaboy East
Farran
Protestant Hill
Commons
Knockantota North
Clyda River
An Chlaoideach
N20



Rock Hill
Lissavoura
Knockantota South
Ahadallane
Ahadallane Cross Rds
Barrack Cross Rds
Lyradane Mountain
Rockhill Br
Ballygrogan
Slievedotia
Glashaboy South
Glashaboy East
Lyrenamon
Glashaboy River
Ballyvorisl
Lyradane
Richhill
Ballyglass
Parkina Cross Rds
Pound Br
Ballygrogan Br
Lissavoura Cross Rds
Rathduff
Nursefield
Newline Br
Dromboy North
Island
Glynn
Glynn Br
Sixmilewater Br
Poulagloger Br
Raheen
Sixmilewater Cross Rds
Sixmilewater
Gortnalahee
Lyradane Stream
Ballymorisheen North Cross Rds
The Cross of Four Winds
Grenagh Cross Rds
Grenagh
Greanach
Halfway Cross Rds
Gortdotia
Dromboy South
Boherard Cross Rds
Maulrane
Stone Circle
Davis's Cross Rds
Lowe's Cross Rds
Ballyfireen
Glancam
Shanlyre Cross Rds
Lisheenowen
Longstone
Boherard
Gormlee
Ardalag
Granien Cross Rds
Ballymorisheen
Ballyglass Br
Holy Well
Fiddler's Brook
Quarryhall Cross Rds
Glancam Br
Shanlyre
Knockanroe
Clogheenagashee River
Garryadeen
Ballyvaloon
Dromgarriff North
Kilmona
Garraun North
Pipe House Cross Rds
Monalahy
Ballyfadeen More
Birchill Br
Tullig
Dromgarriff South
Megalithic Tomb
Ryefield
Laharan
Loumanagh Cross Rds
Saltfield
Ballycaskin
Knocknahehy
Burial Ground
Ballymartin
Moanroe
Drominare
Moated Site
Ballyvodane
Ballyvodane Cross Rds
Castle
Ballyvodane Br
Garraun South
Knockane Cross Rds
Ballyfadeen Beg
Newcastle Cross Rds
Courtbrack
Wise's Br
Farranastig
Tailor's Br
Thrasherstown
Whitechurch
An Teampall Geal
Gurteenaslooka
Tullig Cross Rds
Sluggary Cross Rds
Laglasheen
Gortavaroon
Newcastle
Garrycloyne
Knockane
Barrow
Shournagh River
Knockane Br
Ballycraheen
Courtbrack Br
Bohernamona
Bohernamona Cross Rds
Castle
The Game Br
Ballynaraha
Sluggary
Bawnard
Boolybeg
Lisduff
Ballinvarrig
Holy Well
Loughane Br
Ballycraheen Br
Fox's Br
Dawstown
Knocknalyre
Ballygibbon Br
Ballynaraha Cross Rds
Ballynaraha Ch Br
Kilclogh
Gilcagh
Boreen Glas
Wise's Cross Rds
Ballygibbon
Coolowen
Kilcronan
Rahanisky
Loughane West
Matehy
Church
Putland's Br
Curraghnalaght
Coolowen Cross Rds
Kilcronan Br
Ballyshoneen
Vicarstown Cross Rds
Gortdonaghmore
Loughane East
Killowen
Knocknasuff
Ardamadane
Curraghnalaght Cross Rds
Killeendaniel
Vicarstown
Killowen Cross Rds
Monard

Surveyed 1842
Revised 1932 - 1933
Levelled 1933

Record PLACE Map



CROSSING 2 x 0.6 x 0.6

í = 0.043
SECTION = 1.5w x 0.3d

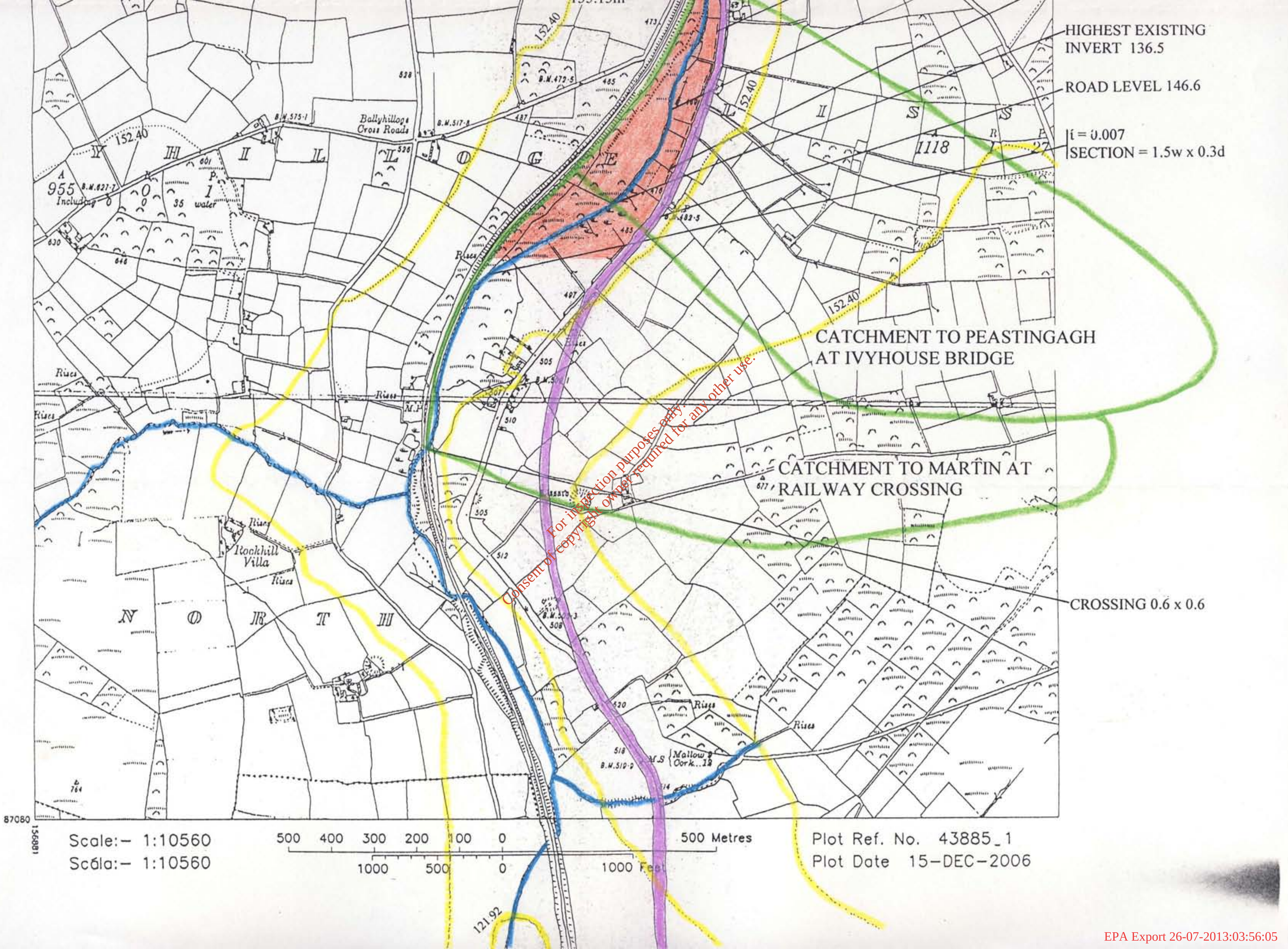
@ CROSSING
SECTION = 0.6w x 0.38d
í = 0.048

ROAD LEVEL 138.10

í = 0.009 (NEW DITCH)
SECTION = 2.0w x0.3d

í = 0.0025 (EXIST. DITCH)
SECTION = 4.0w x 0.3d

HIGH POINT OF NEW DITCH 141.2



HIGHEST EXISTING INVERT 136.5
ROAD LEVEL 146.6
i = 0.007
SECTION = 1.5w x 0.3d
CATCHMENT TO PEASTINGAGH AT IVYHOUSE BRIDGE
CATCHMENT TO MARTIN AT RAILWAY CROSSING
CROSSING 0.6 x 0.6
Ballyhilloge Cross Roads
Rockhill Villa
152.40
121.92
Scale:- 1:10560
Scála:- 1:10560
500 Metres
1000 Feet
Plot Ref. No. 43885_1
Plot Date 15-DEC-2006

DEPARTMENT OF ENERGY
IRELAND

SMALL-SCALE HYDRO-ELECTRIC POTENTIAL OF IRELAND

WATER RESOURCES DIVISION
AN FORAS FORBARTHA

CIVIL WORKS DEPARTMENT
ELECTRICITY SUPPLY BOARD

OCTOBER 1985

To be purchased from the Department
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Price: £10.00

Chapter 2

Hydrological Analysis

Introduction

2.1 The hydro power available at any site on a river is directly proportional to the fall at that site and to the flow in the river. Consequently the information needed to estimate the hydro power at any site is the height of the fall and the magnitude and frequency of river flows at the site. While in general the determination of the fall or head is a comparatively simple matter, for purposes of this report a method of extrapolation had to be developed so that flow data from gauged catchments could be applied to derive the frequency distribution of flows at all sites including those in ungauged catchments. A synthetic method termed the *regional unit flow duration curve* was employed for this purpose.

Flow Duration Curves (FDC's)

2.2 A flow duration curve is a graph of flow rate versus its exceedence percentile i.e. percentage of time when a given flow rate is equalled or exceeded. The bases for the derivation of regional flow duration curves are the flow duration curves produced from good quality records of daily mean flows from all suitable hydrometric gauging stations. The existing data available from approximately 185 gauging stations representing all the gauged catchments within the survey area were chosen for analysis.

2.3 Tables of daily mean flows were already available for some gauging stations. Where the data were in the form of chart records of water level at the gauging site these records were processed to derive tables of daily mean flows for each calendar year over the period of the record. Flow duration curves were then produced from the tables of daily mean flows.

2.4 The catchment area (in km^2) contributing to flow at the site and the long term average rainfall (in m) on that catchment were calculated for each gauge site. Catchment areas were measured by planimetering $\frac{1}{2}$" to 1 mile scale Ordnance Survey maps and rainfall was determined from $\frac{1}{4}$" to 1 mile scale isohyetal maps based on observations over the period 1941-1970.

Derivation of Regional Flow Duration Curves

2.5 Using the values of catchment area and rainfall each flow duration curve was normalised to a unit flow duration curve by dividing the flow ordinates by the appropriate catchment area and rainfall. The unit flow duration curve for a site represents the flow at that site generated by 1 km^2 of contributing catchment with an annual average rainfall of 1 metre. Unit flow duration curves are the basis for the derivation of regional unitised flow duration curves.

2.6 Unitised flow duration curves were produced for 185 hydrometric gauging stations throughout the country. The bodies responsible for data collection at these sites include

Local Authorities, the Office of Public Works and the Electricity Supply Board. Various lengths of records existed for the different gauge sites and the quality of the data also varied to some degree. This resulted in the reduction of the number of unitised curves selected for analysis. Thirty-one of the derived unitised FDC's were considered unsuitable for one or more of the following reasons:—

(i) The period of record was too short.

(ii) Flows at some gauging stations were seriously influenced by upstream storage.

(iii) The rating curve for the gauging station i.e. the relationship between water level and measured flows was of poor quality.

(iv) Where a particular gauging station was located close to another station with a longer period of record, then the station with the shorter period of record was excluded.

2.7 A total of 154 unitised FDC's were thus used in the determination of regional unitised FDC's. The hydrometric gauging stations to which these relate are listed in Appendix B.

2.8 Having normalised a set of standard flow duration curves with respect to catchment area and average rainfall, the variation in the resulting family of curves from that area depends almost completely on catchment geology and soil, assuming that a standard period of record was employed. Having regard to the quality of the hydrological data available, it was inevitable that considerable variation in flow duration curves would emerge. This was due to several factors which arose from a combination of particular local flow conditions, the use of FDC's from sites with small catchments and high rainfall, the inclusion of variable periods of flow records and the absence of information relating to specific geological and soil types. Typical variations in derived FDC's can be seen in Fig. 2.1 which compares 13 curves for gauging stations all in the catchment area of the river Suir. It was decided therefore that the regions to which a particular group of FDC's applied should be small to compensate for the possible inaccuracies arising from the various sources. Consequently the procedure of selecting regions on a county basis was adopted.

2.9 When a particular group of unit FDC's were considered to adequately represent flow conditions within a region a statistical curve fitting technique was applied to find the curve of best fit for the group. *This curve is then the unitised regional flow duration curve and it indicates the variation in flow rate generated by 1 km² of contributing catchment with an annual rainfall of 1 m anywhere within that region.* A total of 85 regional flow duration curves have been derived using the unit FDC's from 154 hydrometric gauging stations. A total of five maps were prepared to outline all 85 regions for which unitised flow duration curves were derived. These regions and their corresponding unitised regional flow duration curves are shown in Appendix C. In Figure 2.2 the unitised regional flow duration curve for a typical region is shown as an overlay on the group of FDC's in Figure 2.3 which describes that region.

2.10 *Hydrological records show that the mean flow in a natural watercourse is approximately equal to the 30 percentile flow.* The 30% exceedance coefficient of the unitised regional flow duration curve is therefore taken to be the provisional mean flow coefficient for that region. The mean flow at any site can be estimated by multiplying the relevant provisional mean flow coefficient by that catchment area to the site and the average rainfall on that catchment. Unique flow duration characteristics for the site can be established by applying the same parameters to the complete unitised regional FDC.

2.11 The level of installed generating capacity (maximum power output) appropriate to any hydroelectric power site can be determined only when the design parameters of head and flow are established. The measurement of head is usually a relatively simple matter.

The design flow rate of the installation may be chosen to be equal to the mean river flow rate or to some multiple of this flow. The adoption of a particular proportion of the mean

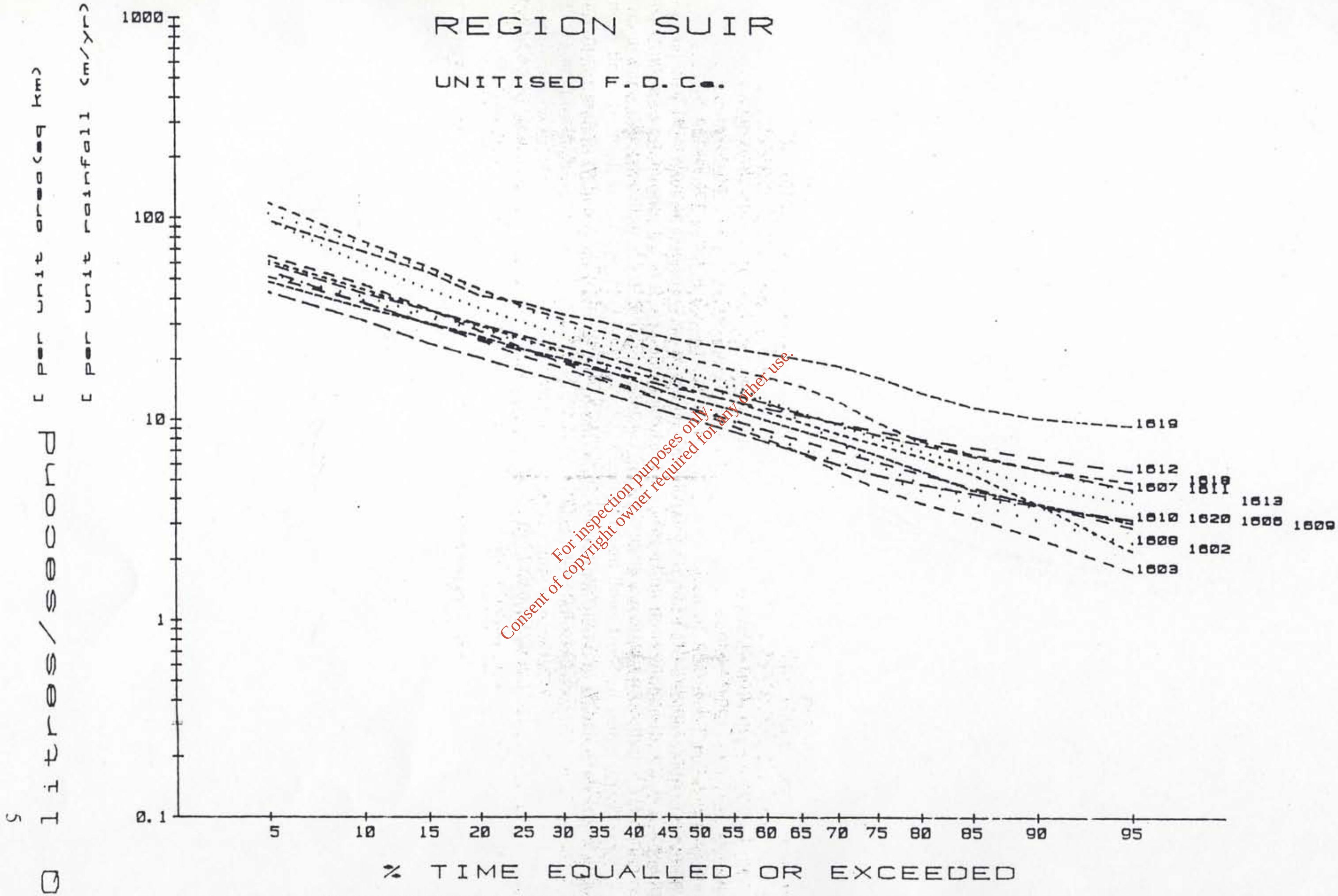


FIG. 2.1 THE VARIATION IN UNITISED FLOW DURATION CURVES FOR THE RIVER SUIR CATCHMENT

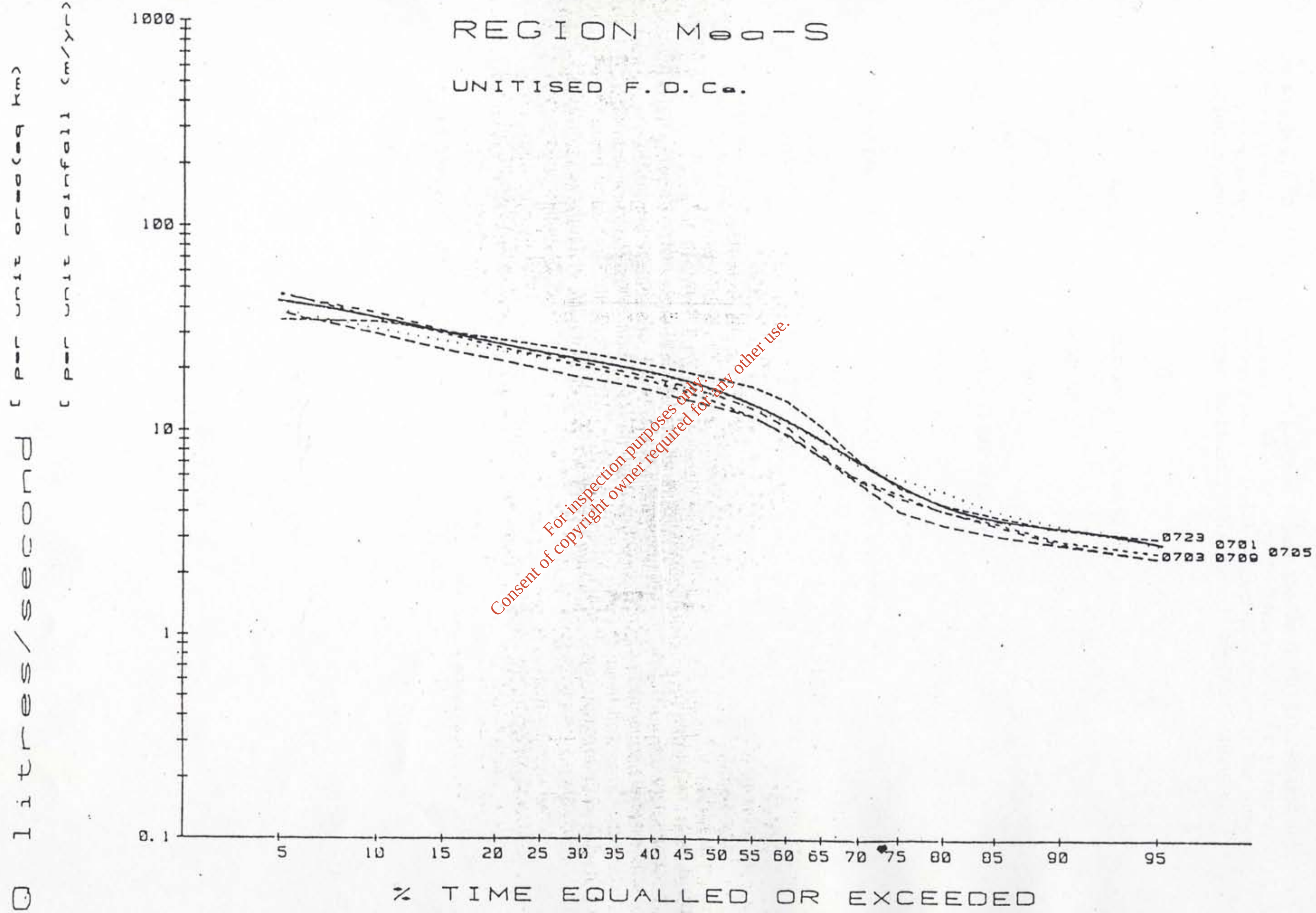


FIG. 2.2 UNITISED REGIONAL FLOW DURATION CURVE FOR REGION MEA—S

FIG. 2.3 UNITISED FLOW DURATION CURVES WHICH DETERMINE REGION MEA—S flow as a design flow is based on river size, geomorphology, the condition of intake channels and weirs, power demand, access and the disadvantages to fishery and amenity interests. Knowing the design head, the design flow rate and the expected efficiency of the turbine unit at full capacity the installed capacity of the site is obtained from the relationship

$$P = 9.81\ QH\eta$$

where P = maximum power output (kW)

H = Head (m)

Q = flow (m^3/s)

η = efficiency at full capacity

1,000 litres = $1m^3/s$

The Use of Flow Duration Curves in Annual Energy Calculations:

2.12 The expected annual energy output is also of prime importance to the developer. The calculation of this energy potential is based entirely on the derived flow duration curve for the particular site. While the design flow rate will be the upper limit of turbine operation, the lower limit of operation is typically between 25% and 40% of the design flow depending on turbine characteristics. The effect of altering this limit is not large however, since not only are the volumes comparatively small at the lower end of the curve but the efficiency is less than for higher flows. *The lower limit of turbine operation is taken as 25% of the full capacity discharge.*

2.13 In Figure 2.4 a typical flow duration curve is plotted with time as abscissa and discharge as ordinate. The area under this curve represents the volume of water passing the site in unit time. The quantity used to produce electricity corresponds to the area ABCDF where A is the discharge when installed capacity is fully employed and G is one quarter of that volume.

The *annual energy coefficient* for the installation Ce is defined as this area multiplied by 9.81 (g) and 8,760 (the number of hours in a year). Since the area, and consequently the annual energy coefficient, is a function of the particular percentage of the mean flow (Q_m) which is chosen as the design flow (Q), it is necessary that a range of energy coefficients be available to the designer. For this study energy coefficients have been calculated for values of Q in the range of 1.65 Qm down to 0.2 Qm.

The *annual energy potential* of the site is given by

$$E = Ce\ ARH\eta$$

where E = Annual energy in kilowatt hours (kWh)

Ce = Annual energy coefficient

A = Catchment area (km^2)

R = Average rainfall (m/year)

H = Design Head (m)

η = Overall efficiency

The coefficients are listed in Tables C2-C6 of Appendix C.

Curve plotted to linear scales to emphasise the slope of the FDC

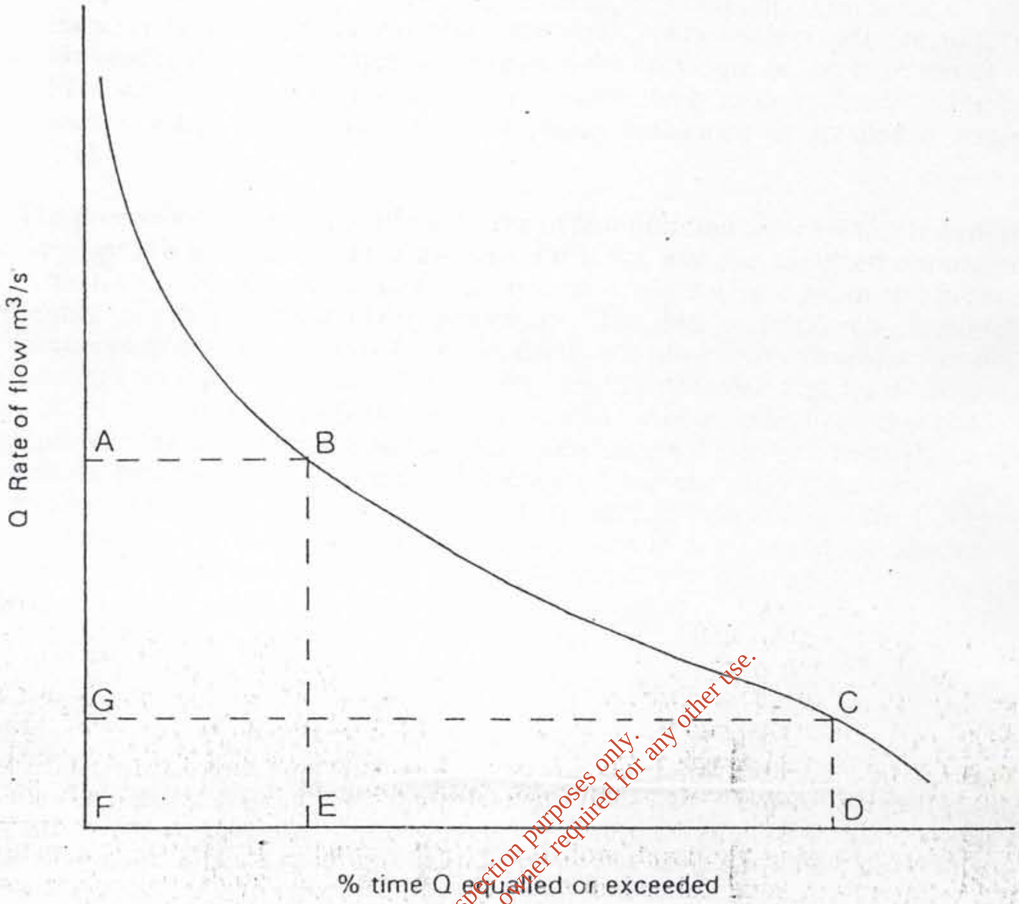


FIG. 2.4 TYPICAL FLOW DURATION CURVE

Possible Errors

2.14 The procedure outlined above to obtain the flow duration characteristics at all potential sites was simple and efficient having regard to the large number of sites where this information was required. However, it should be recognised that it is a synthetic method and there are possible inaccuracies arising both from the derivation of regional FDC's and in their application to ungauged catchments.

(a) The flow duration curves used to derive the regional curve should ideally be based on a standard period of record of daily mean flows. Relatively large differences in the length of records were inevitable due to the large number which were analysed.

(b) The basic FDC's do not take into account the effects of catchment geology and soil type.

(c) The regional flow duration curve is derived from a number of FDC's from a particular region. It represents the general flow conditions and does not show the effects of particular local conditions. Most of the curves are from river sites with relatively large catchment areas and mean average annual rainfall. Many of the actual sites investigated have small catchment areas and high average annual rainfall. The effect of decrease in area is to increase the influence of local conditions.

(d) Catchment areas have been drawn by study of the topography with no allowance being taken of geology.

(e) Water abstractions and storage will have appreciable effects on some of the flow duration curves used in the analysis which will not be evident in the regional FDC. However, the overall effect is to reduce the curvature of the extremities of the FDC while leaving the central section comparatively unaltered and it is the central section which is most important for energy generation as detailed in paragraph 2.13.

2.15 The preceding paragraphs outline the use of flow duration curves in the determination of the appropriate level of installed capacity for a site and the expected annual energy output from the installation. It is evident that this curve forms a basic parameter in assessing the potential of any particular hydro power site. The data in relation to regional flow duration curves given in Appendix C can be used by a prospective developer to obtain a flow duration curve for a site anywhere in the country provided that he determines the catchment area contributing to flow at the site and the average rainfall on that catchment. The additional pieces of information required to estimate the energy potential of a site are the available head and the expected efficiency of the chosen turbine/generator. The procedure involved in the application of the data is outlined fully in Appendix C. However, before committing himself to any sizeable investment in a particular development, the developer would be well advised to obtain the advice of a competent engineer on scheme feasibility and optimisation.

Appendix B

List of Hydrometric Gauging Stations used for FDC Analysis
Distribution of Stations

New 5 digit No's
0141 → 01041

Station No.	River	Name of Station	Grid Ref.	Catchment Area km²	Rainfall mm/yr.
0141	Deele	Sandy Mills	H273 990	113	1293
0142	Finn	Dreenan Br.	H152 945	353	1713
0351	Blackwater	Faulkland Br.	H704 379	126	1026
0611	Fane	Moyles Mill	H918 076	230	1073
0613	Dee	Charleville	O044 907	307	907
0614	Glyde	Tallanstown	N953 978	270	943
0621	Glyde	Manfieldstown	O023 952	321	928
0623	Dee	Drumgoolestown	O030 909	302	907
0625	Dee	Burley Br.	N925 896	176	930
0626	Glyde	Aclint	N893 981	144	1072
0630	Big	Ballygoly	J152 100	12	1220
0631	Flurry	Curralhir	J083 143	46	1104
0633	White	Coneyburrow Br.	O056 893	54	957
0701	Tremblestown	Tremblestown	N755 577	150	950
0703	Castlerickard	Blackwater	N716 489	179	850
0705	Boyne	Trim	N802 568	1282	913
0706	Moynalty	Fyanstown	N790 757	179	980
0709	Boyne	Navan Weir	N878 667	1610	898
0710	Blackwater	Liscarton	N846 689	717	984
0711	Blackwater	O'Daly's Br.	N652 805	294	1043
0712	Boyne	Slane Castle	N949 738	2408	920
0714	Yellow	Garr Br.	N532 369	44	912
0717	Moynalty	Rosehill	N720 852	74	1070
0723	Athboy	Athboy	N717 640	98	982
0802	Delvin	Naul	O132 612	37	850
0803	Broadmeadow	Fieldstown	O116 503	72	854
0804	Ward	Owens Br.	O132 464	42	817
0805	Sluice	Kinsealy Hall	O220 417	10	780
0806	Mayne	Hole in the Wall	O222 415	16	780
0807	Broadmeadow	Ashbourne	O087 524	34	869
0901	Ryewater	Leixlip	O005 364	215	836
0902	Griffeen	Lucan	O005 352	38	826
0905	Cannock	Clondalkin	O083 321	60	879
0999	Liffey	Burgage Br.	—	288	1356
1002	Avonmore	Rathdrum	T197 883	233	1727
1003	Avonmore	Laragh	T146 965	107	1646
1004	Glenmacrass	Laragh	T143 965	28	1978
1017	Ballyman	Ballyman	O227 187	3	1050
1101	Owenavorragh	Boleany	T170 560	148	961
1201	Slaney	Scarrawalsh	S983 450	1036	1108
1213	Slaney	Rathvilly	S882 844	185	1231
1214	Bann	Pallis Br.	T116 683	15	1200
1215	Bann	Ferns	T030 493	161	1105
1216	Boro	Dunanore	S960 364	175	1108
1301	Corock	Goffs Br.	S874 180	56	1060
1302	Corock	Foulkesmill	S854 183	64	1050
1303	Owenduff	Mullinderry	S814 158	90	1050
1404	Figile	Clonbulloge	N609 235	268	850
1405	Barrow	Portarlington	N540 126	398	981
1406	Barrow	Pass Br.	N623 109	1096	897
1418	Barrow	Royal Oak	S689 614	2415	882
1419	Barrow	Levitstown	S705 876	1660	877
1423	Barrow	Graiguenamanagh	S727 418	2795	896
1424	Burren	Coolasnachta	S818 567	6	1182
1432	Triogue	Kyle Br.	N437 038	31	875
1433	Owenass	Mountmellick	N452 082	91	1104
1434	Barrow	Bestfield Lock	S717 797	2060	840

Station No.	River	Name of Station	Grid Ref.	Catchment Area km²	Rainfall mm/yr.
1501	Kings	Annamult House	S543 443	443	991
1502	Nore	Johns Br.	S506 561	1605	979
1503	Dinan	Dinan Br.	S479 628	298	1024
1504	Nore	McMahons Br.	S418 797	491	1018
1506	Nore	Brownsbarn Br.	S617 391	2388	978
1507	Nore	Kilbricken	S362 899	343	1063
1509	Kings	Callan	S415 438	201	1034
1510	Goul	Ballyboodin Mills	S368 774	159	934
1511	Nore	Mount Juliet	S550 422	2201	974
1521	Delour	Annagh Br.	S441 717	72	1315
1602	Suir	Beakestown	S092 552	512	970
1603	Clodiagh	Rathkennan	S051 530	246	1177
1605	Multeen	Aughnagross	R991 413	87	1197
1606	Multeen	Ballinaclogh	R985 408	75	1180
1607	Aherlow	Killardry	S017 294	273	1360
1608	Suir	New Br	S001 341	1120	1030
1609	Suir	Cahir Park	S052 228	1602	1075
1610	Anner	Anner Br.	S253 256	422	984
1612	Tar	Tar Br.	S107 134	228	1332
1613	Nier	Fourmilewater	S166 135	91	1394
1618	Glengalla	Knockballiniry	S076 117	12.5	1580
1620	Clodiagh	Portlaw	S449 154	124	1345
1701	Mahon	Kilmacthomas	S395 065	62	1360
1702	Tay	Fox's Castle	S340 004	33	1437
1802	Blackwater	Ballyduff	W965 991	2338	1159
1804	Awbeg	Ballynamona	R656 076	324	1064
1805	Funshion	Downing Br.	R822 020	363	1190
1806	Blackwater	Mallow	W525 973	1058	1303
1909	Butlerstown	Broghill	W736 763	43	1216
1914	Lee	Dromcarra	W296 675	184	1964
1915	Shournagh	Healys Br.	W606 730	210	1219
1918	Shournagh	Tower Br.	W590 746	160	1234
1920	Owencurra	Ballyedmond	W859 766	75	1224
2009	Stick	Belgooly	W663 540	37	1150
2102	Coomhola	Coomhola	V998 548	65	2168
2103	Owvane	Ballylickey	W010 536	77	1861
2104	Mealagh	Inchiclough	W027 511	46	1809
2105	Adrigole	Adrigole	V813 505	27.6	2128
2203	Brown Flesk	Dicksgrove	Q976 145	272	1354
2204	Owgarriff	Owgarriff Weir	W000 856	7	2800
2205	Torc	Torc Weir	V967 838	8	2504
2206	Flesk	Flesk	V970 892	325	1747
2301	Galey	Inch Br.	Q957 363	196	1120
2302	Feale	Listowel	Q996 333	646	1336
2306	Feale	Neodata	R115 269	300	1425
2402	Camoge	Grays Br.	R580 404	231	978
2403	Loobagh	Garoose	R549 274	129	1051
2404	Maigue	Bruree	R550 304	246	1002
2405	Morningstar	Athlacca	R557 343	140	1002
2406	Maigue	Creggane	R533 273	88	950
2506	Brosna	Ferbane	N115 244	1207	931
2513	Brosna	Newells Br.	N383 423	221	975
2514	Silver	Millbrook	N135 188	165	992

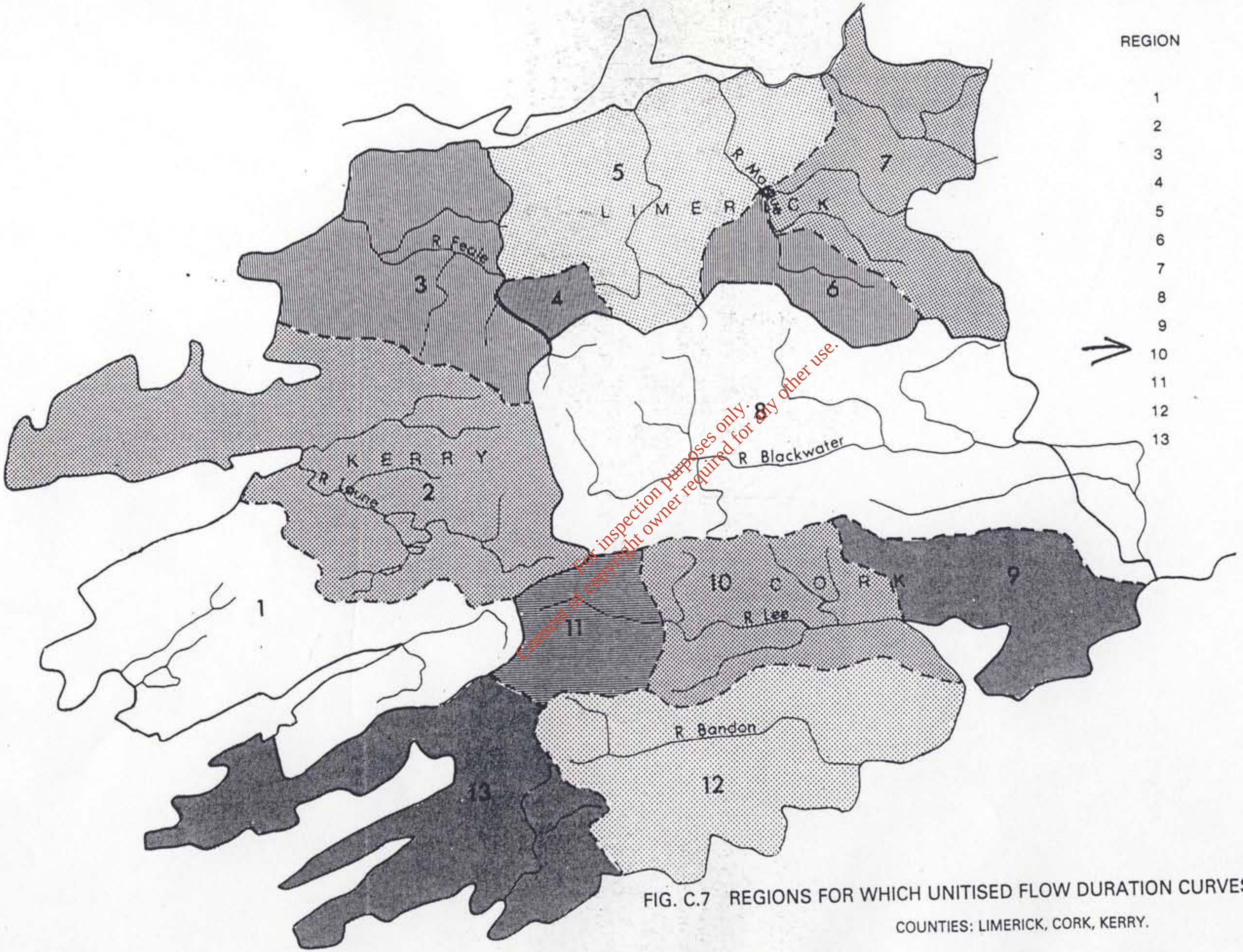
Station No.	River	Name of Station	Grid Ref.	Catchment Area km²	Rainfall mm/yr.
2519	Cappagh	Conicar	M752 071	125	1151
2520	Killimor	Killeen	M796 111	197	999
2521	Little Brosna	Croghan	N053 056	493	958
2522	Camcor	Syngefield	N080 046	160	1042
2525	Ballyfinboy	Ballyhooney	R862 959	160	919
2527	Ollatrim	Gourdeen	R886 797	118	1077
2529	Nenagh	Clarianna	R860 822	301	1117
2530	Graney	Scarriff	R640 843	279	1280
2544	Kilmastulla	Coole Br.	R712 693	95	1157
2605	Suck	Derrycahill	M824 426	1050	1057
2606	Suck	Willsbrook	M692 756	182	1080
2612	Boyle	Tinnecarra	G770 019	520	1135
2614	Lung	Banada Br.	M634 943	222	1116
2619	Camlin	Mullagh	N116 759	260	981
2620	Camlin	Argar	N181 793	126	997
2701	Claureen	Inch Br.	R301 755	48	
3007	Clare	Ballygaddy	M420 539	458	1148
3061	Corrib	Wolf Tone Br.	M294 249	3111	1338
3204	Owenglin	Clifden	L670 504	32	1846
3301	Glenamoy	Glenamoy	F895 337	73	1459
3304	Owenmore	Kilsallagh	F956 207	166	1591
3306	Owenduff	Srahnamanragh	F812 154	121	1752
3401	Moy	Rahans	G243 180	1911	1280
3403	Moy	Foxford	G267 039	1750	1270
3410	Moy	Cloonacannana	G388 024	471	1298
3424	Pollagh	Kiltimagh	M332 893	128	1175
3501	Owenmore	Ballynacarrow	G639 219	299	1163
3502	Owenbeg	Billa Br.	G638 257	90	1428
3503	Unshin	Ballygrania	G6 97 257	212	1181
3505	Ballisodare	Ballisodare	G669 290	658	1206
3511	Bonet	Dromahaire	G805 309	294	1394
3610	Annalee	Butlers Br.	H408 104	774	1020
3615	Finn	Anlore	H537 256	155	1058
3616	Annalee	Rathkenny	H540 114	522	1030
3618	Dromore	Ashfield Br.	H575 140	233	1020
3620	Blackwater	Killywillan	H203 146	95	1325
3627	Woodford	Ballyhendy	H250 156	324	1272
3631	Cavan	Lisdarn	H414 069	62	1008
3678	Derrygooney L.	Derrygooney	H693 108	77	1000
3679	L. Bawn	Corlea	H716 116	67	1000
3801	Ownea	Clonconwall	G765 927	109	1684
3805	Owengarva	Glenties	G870 935	7	1900
3901	Swilly	Newmills	C117 092	49	1569
3903	Crana	Tullyarvan	C349 330	99	1429

Now 5 digit Nos.

Table C1

County	Regions	Designation	Stations Used
Carlow	2	CAR-O	1213, 1216, 1424
		CAR-M	1418, 1423, 1434
Cavan	3	CAV-E	3610, 3616, 3618
		CAV-N	3620, 3627
		CAV-S	0711, 0717, 3631
Clare	2	CLA-SH	2530
		CLA-F	2701
Cork	6	COR-O	1909, 1920
		COR-C	1915, 1918 ← 19015 + 19018
		COR-KE	2102, 2103, 2104, 2105
		COR-S	2009
		COR-E	1802, 1804, 1805, 1806
		COR-LW	1914
Donegal	4	DON-W	3801
		DON-EE	0141, 0142, 3901
		DON-IO	3903
		DON-L	3805
Dublin	5	DUB-C	0805, 0806, 0902
		DUB-N	0802
		DUB-B	0803, 0804
		DUB-S	0905, 1017
		DUB-L	0999, 0906
Galway	5	GAL-NE	2605, 2606, 2612, 2614
		GAL-W	3204
		GAL-E	2519, 2520
		GAL-C	3061
		GAL-M	3007
Kerry	3	KER-CK	2102, 2103, 2104, 2105
		KER-N	2301, 2302, 2306
		KER-C	2203, 2204, 2205, 2206
Kildare	6	KID-M	1405, 1406, 1419, 1433, 1434, 1507, 1510, 1504
		KID-L	0999, 0906
		KID-RY	0901
		KID-H	1213
		KID-BA	1405, 1406, 1419
		KID-BO	0703, 0714
Kilkenny	2	KIK-O	1501, 1503, 1509
		KIK-M	1502, 1504, 1506, 1511
Laois	2	LAO-L	1405, 1406, 1419, 1433, 1434, 1507, 1510, 1504
		LAO-H	1432, 1521
Leitrim	1	LEITM	2629, 3511, 3620, 3627
Limerick	4	LIM-E	2402, 2405
		LIM-CW	2302, 2404
		LIM-C	2403, 2404, 2406
		LIM-W	2306
Longford	1	LONFD	2619, 2620
Louth	4	LOU-C	0613, 0614, 0621, 0623, 0625, 0626
		LOU-F	0611
		LOU-S	0633
		LOU-N	0630, 0631

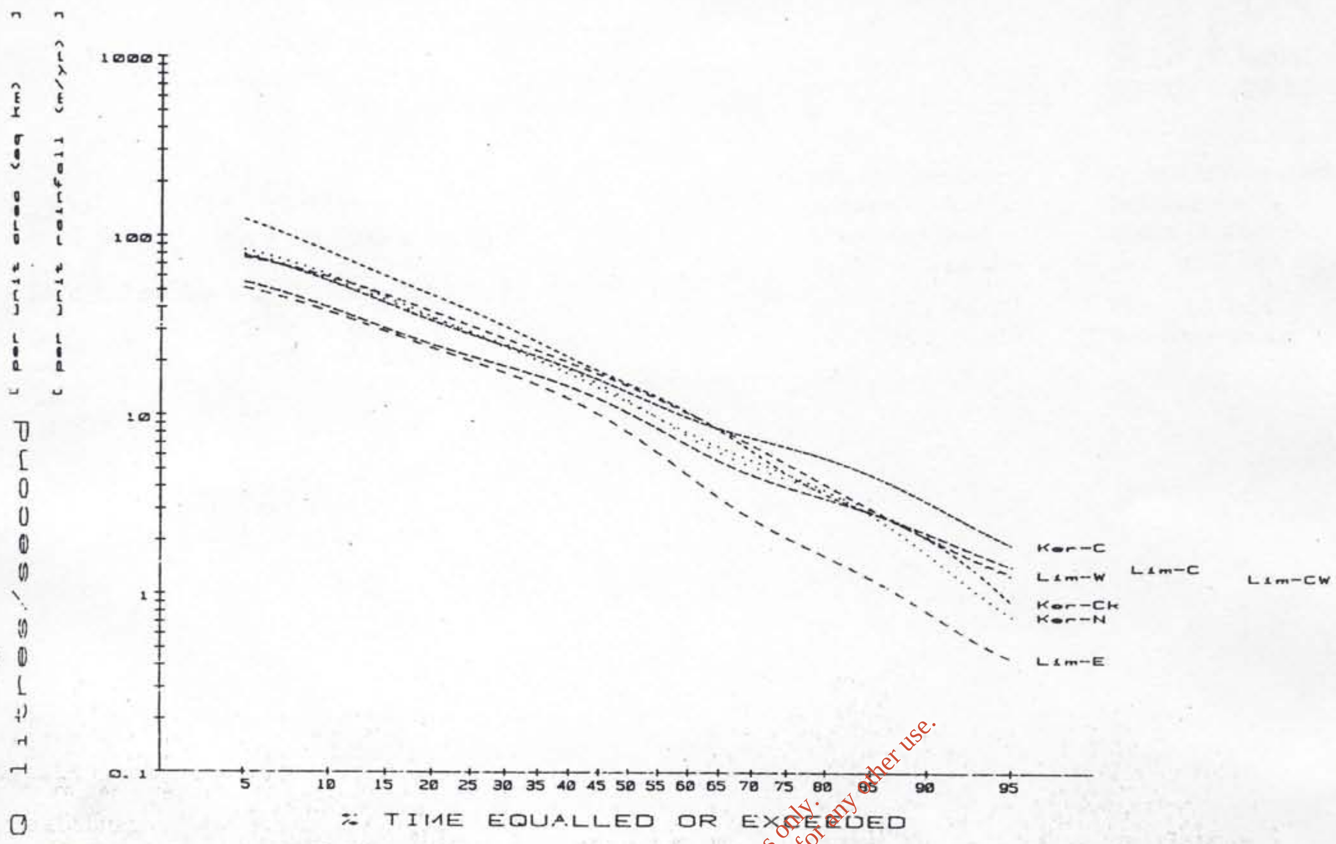
County	Regions	Designation	Stations Used
Mayo	4	MAYO-M	3401, 3403, 3410, 3424
		MAYO-H	3204
		MAYO-S	3007, 3424
		MAYO-W	3301, 3304, 3306
Meath	4	MEA-S	0701, 0703, 0705, 0709, 0723
		MEA-D	0625, 0626
		MEA-N	0706, 0710, 0711, 0712, 0802
		MEA-B	0807, 0901
Monaghan	5	MON-A	3678, 3679
		MON-G	0626
		MON-D	3616, 3618
		MON-F	0611
		MON-N	0351, 3615
Offaly	2	OFF-B	2506, 2514, 2521, 2522
		OFF-E	1404, 1405
Roscommon	1	ROS	2605, 2606, 2612, 2614
Sligo	1	SLIGO	3501, 3501, 3503, 3505, 3511
Tipperary	5	TIP-S1	1602, 1603, 1610
		TIP-S2	1605, 1606, 1607, 1612
		TIP-SM	1608, 1609
		TIP-NA	2525, 2527
		TIP-NB	2544, 2529
Waterford	1	WAT	1612, 1613, 1618, 1620, 1701, 1702
Westmeath	3	WES-M	2506, 2514, 2521, 2522
		WES-B	2513
		WES-E	0703, 0705, 0714, 0723, 1404
Wexford	3	WEX-B	1301, 1302, 1303
		WEX-R	1101
		WEX-C	1201, 1214, 1215, 1216
Wicklow	6	WIC-S1	1213
		WIC-S2	1201, 1214
		WIC-CR	1214
		WIC-R	1002
		WIC-C	1017, 1101
		WIC-M	0999, 1002, 1003, 1004, 1017



REGION	DESIGNATION
1	KER-CK
2	KER-C
3	KER-N
4	LIM-W
5	LIM-C
6	LIM-CW
7	LIM-E
8	COR-E
9	COR-O
10	COR-C
11	COR-LW
12	COR-S
13	COR-KE

FIG. C.7 REGIONS FOR WHICH UNITISED FLOW DURATION CURVES WERE DERIVED.

COUNTIES: LIMERICK, CORK, KERRY.



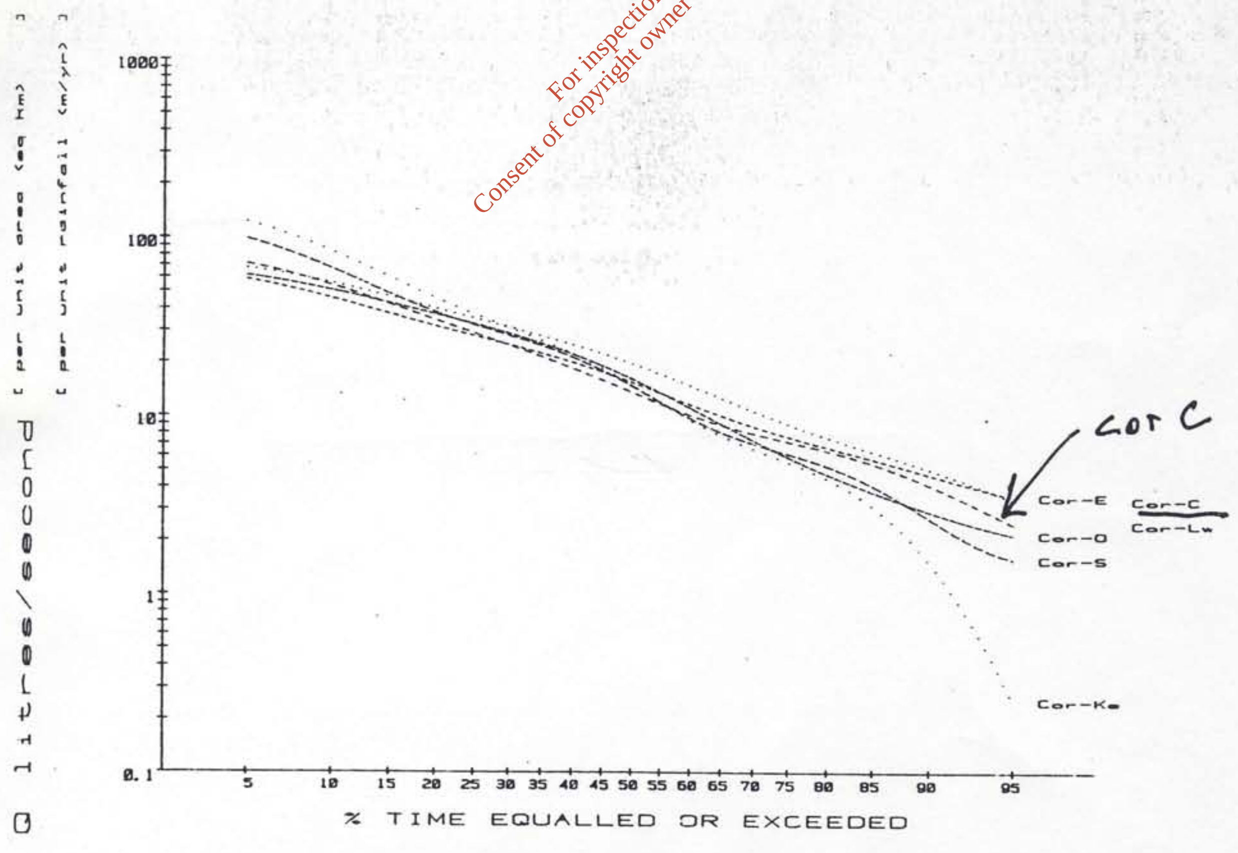
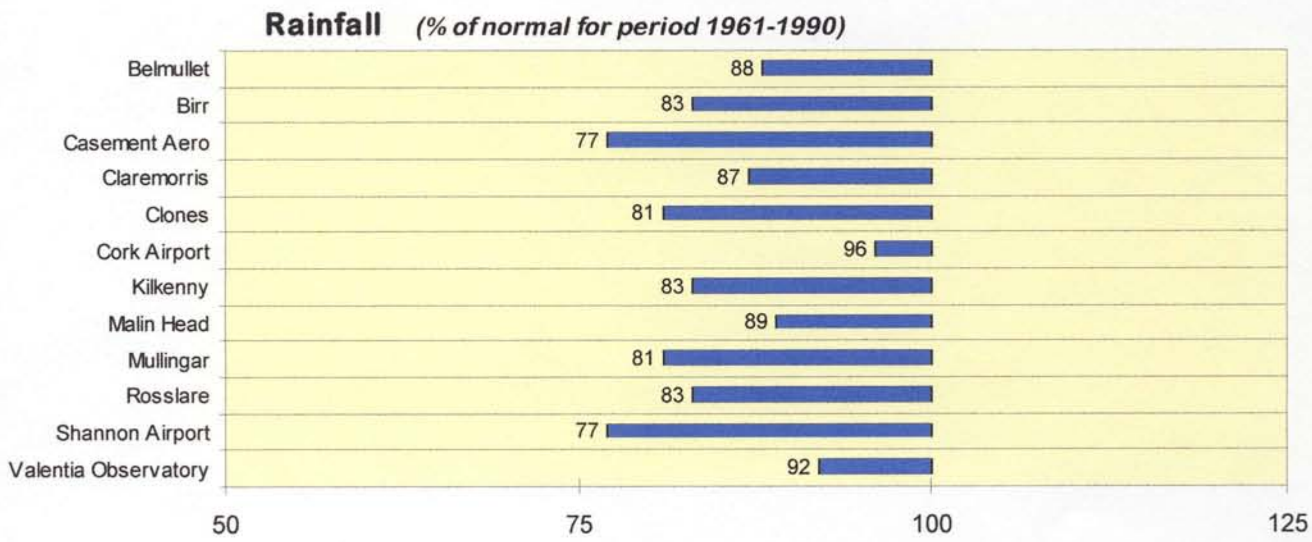
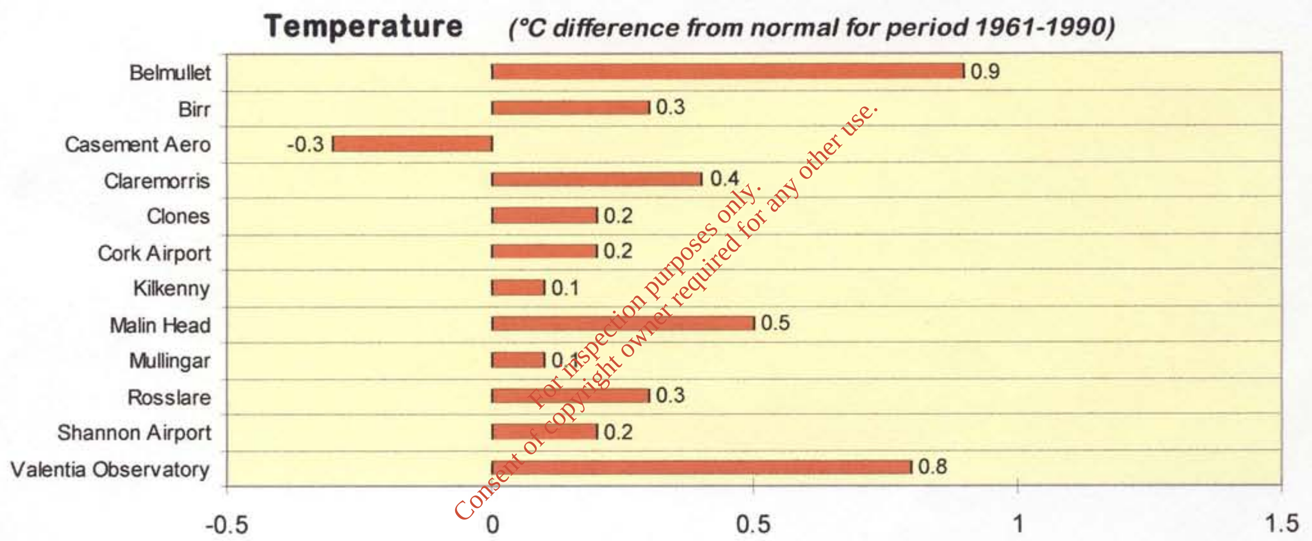
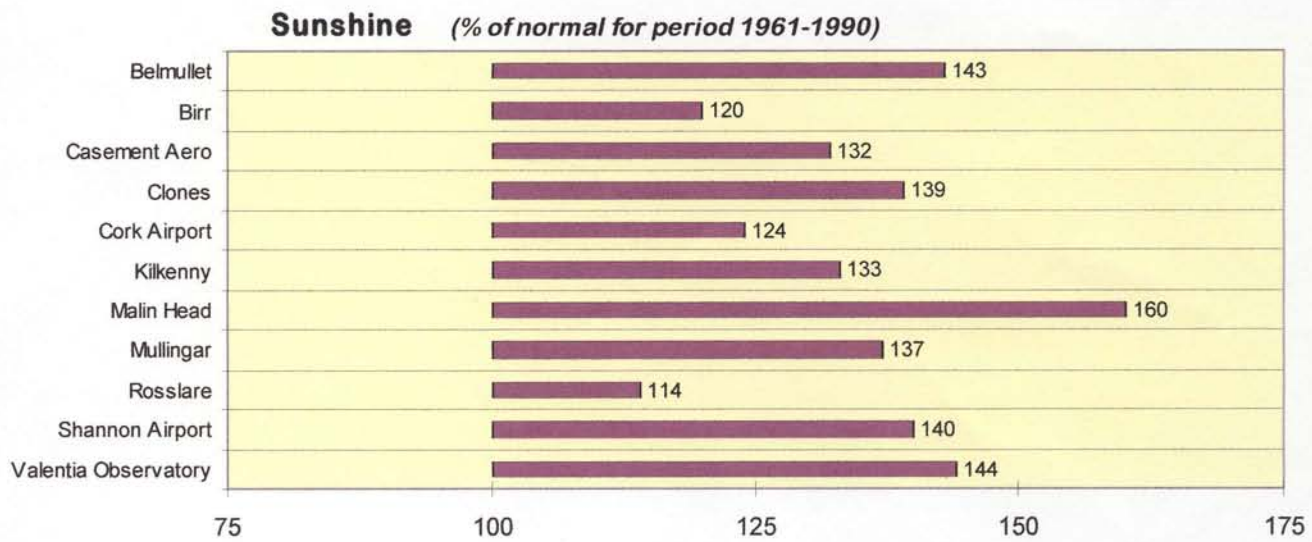


FIG. C8 UNITISED REGIONAL FLOW DURATION CURVES

November 2005 Percentage / Difference from 1961-90 monthly normals







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Home - Climate - 30 Year Averages - Cork Airport

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30 Year Averages

Please choose a 30 year average report from any station by clicking on the map (the links below:

1	Belmullet	8	Kilkenny
2	Birr	9	Malin Head
3	Casement	10	Mullingar
4	Claremorris	11	Roches Point
5	Clones	12	Rosslare
6	Cork Airport	13	Shannon Airport
7	Dublin Airport	14	Valentia

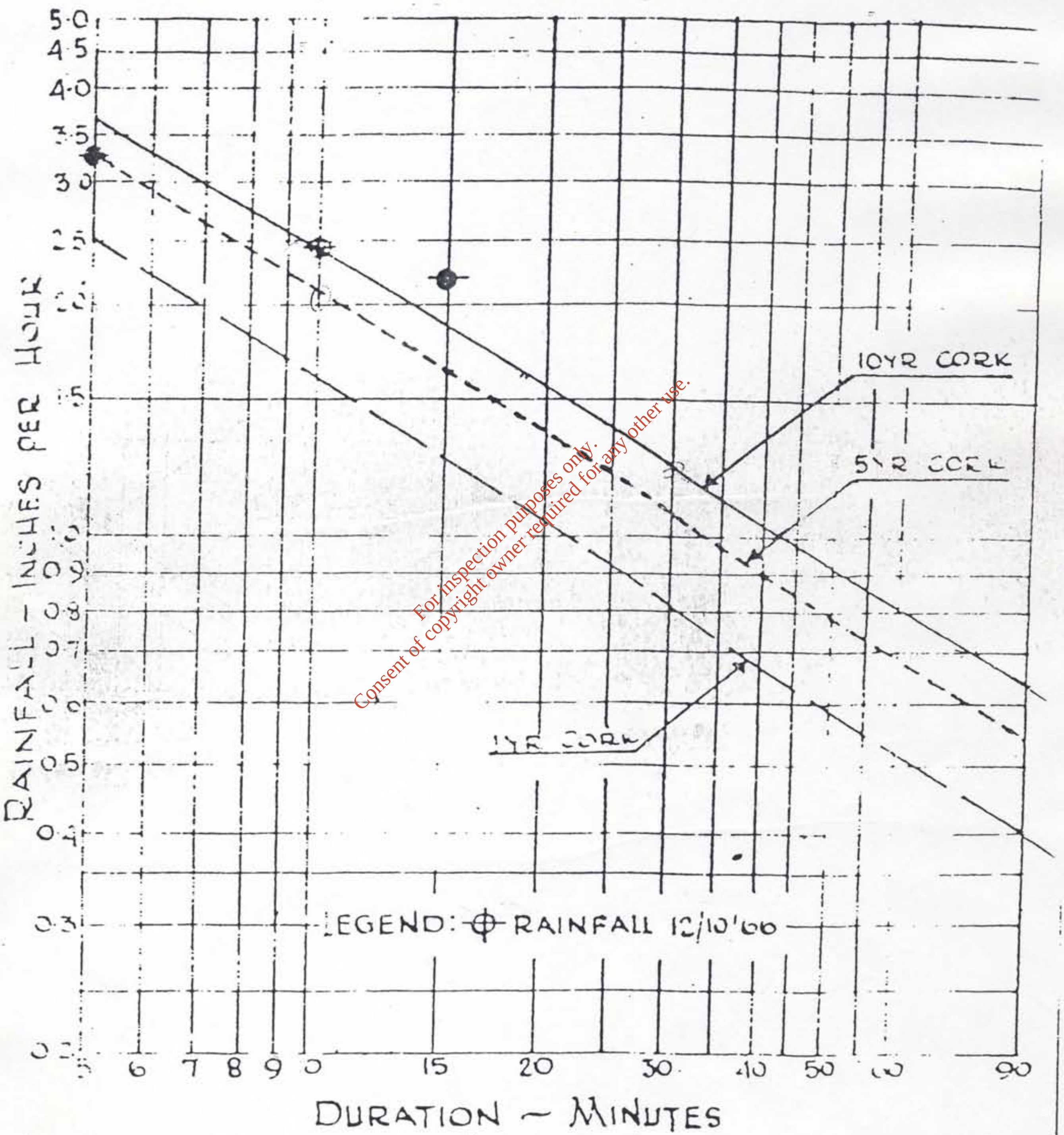
CORK AIRPORT

monthly and annual mean and extreme values

1962-1991

TEMPERATURE *(degrees Celsius)*	*jan*	*feb*	*mar*	*apr*	*may*	*jun*	*jul*	*aug*	*sep*	*oct*	*nov*	*de*
mean daily max.	7.6	7.5	9.3	11.3	13.8	16.6	18.5	18.2	16.0	13.1	9.9	8.
mean daily min.	3.6	2.5	3.1	4.2	6.5	9.2	11.1	10.9	9.4	7.5	4.5	3.
mean	5.1	5.0	6.2	7.7	10.2	12.9	14.8	14.5	12.7	10.3	7.2	6.
absolute max.	12.6	13.5	15.5	20.5	23.6	25.7	28.7	27.5	24.7	19.0	15.9	13
absolute min.	-8.5	-8.6	-6.1	-2.4	-0.9	2.4	4.8	4.9	2.3	-0.4	-3.3	-5
mean no. of days with air frost	6.7	5.6	3.4	1.8	0.1	0.0	0.0	0.0	0.0	0.0	2.4	3.
mean no. of days with ground frost	15.0	12.7	12.0	9.4	2.9	0.2	0.0	0.0	0.4	2.6	9.5	12
RELATIVE HUMIDITY *(%)*												
mean at 0900UTC	90	90	88	83	81	81	83	86	88	91	90	9
mean at 1500UTC	84	80	75	71	71	72	72	73	76	82	83	8
SUNSHINE *(hours)*												
mean daily duration	1.70	2.28	3.51	5.21	6.02	5.73	5.40	5.14	4.13	2.80	2.16	1.:
greatest daily duration	7.3	9.3	11.8	13.8	15.4	15.9	15.4	14.2	12.8	9.9	8.5	6.
mean no. of days with no sun	11	9	6	4	2	3	2	2	4	7	9	1
RAINFALL *(mm)*												
mean monthly total	138.3	115.6	98.7	67.7	83.4	68.8	66.4	88.7	96.4	125.4	111.1	13:

CURVES TAKEN FROM PROF. E.C. DILLON'S PAPER "THE ANALYSIS OF 35-YEAR AUTOMATIC RECORDINGS OF RAINFALL AT CORK" I.C.E.I, 1954



CORK CORPORATION

CHART SHOWING RAINFALL OF 12TH OCTOBER, 1966 IN RELATION TO 1, 5 AND 10 YEAR RAIN STORM CURVES FOR CORK

For how unseemly it is when you are speaking about sewers to use high-sounding expressions.

Cicero, *Orator*, xxi.

THEORY, DESIGN, SPECIFICATION AND CONSTRUCTION

A REFERENCE BOOK FOR CIVIL, MUNICIPAL, AND SANITARY ENGINEERS AND A TEXT-BOOK FOR STUDENTS

BY

EDWARD VAUGHAN BEVAN

Chief Engineering Assistant, Engineer's Dept., Harrow
Formerly Chief Main Drainage Assistant, Cardiff.

AND

BERNARD TREVELYAN REES

B.Sc., A.M.I.C.E., A.M.Inst.M. & Cy.E.
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SECOND EDITION

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LONDON

CHAPMAN & HALL LTD.

37 ESSEX STREET W.C.2

1950

VARIATIONS IN VALUE OF n AVERAGE ACCORDING TO ALBERT WOLLHEIM, A.M.I.C.E.

Material of Sewer.	Condition of Surface.			
	Perfect.	Good.	Fair.	Bad.
Glazed stoneware pipe	0·010	0·011	0·013	0·015
Brickwork, ordinary	0·012	0·013	0·015	0·017
Brickwork, glazed	0·011	0·012	0·013	0·014
Rendering, cement mortar	0·011	0·012	0·013	0·015
Rendering, neat cement	0·010	0·011	0·012	0·013
Ashlar, dressed	0·013	0·014	0·015	0·017
Iron (cast) uncoated	0·012	0·013	0·014	0·015
Iron (wrought) and steel	0·011	0·012	0·013	0·014

TABLE II

VALUES OF n ACCORDING TO PROFESSOR LEA, D.Sc.

	n
Very smooth cement and planed boards	0·009 to 0·01
Smooth boards, bricks, concrete	0·012 to 0·013
Smooth, covered with slime or tuberculated	0·015
Rough ashlar or rubble masonry	0·017 to 0·019
Very firm gravel or pitched with stones	0·02
Earth, in ordinary condition free from stones and weeds	0·025
Earth, not free from stones and weeds	0·030
Gravel in bad condition	0·035 to 0·040
Torrential streams with rough stony beds	0·05

TABLE III

VALUES OF n IN THE FORMULA OF GANGUILLET AND KUTTER, DETERMINED FROM RECENT EXPERIMENTS, ACCORDING TO PROFESSOR LEA, D.Sc.

	n
Rectangular wooden flume, very smooth	0·0098
Wood pipe 6 ft. diameter	0·0132
Brick, washed with cement, basket-shaped sewer, 6 ft. × 6 ft. 8 in., nearly new	0·0130
Brick, washed with cement, basket-shaped sewer, 6 ft. × 6 ft. 8 in., one year old	0·0148
Brick, washed with cement, basket-shaped sewer, 6 ft. × 6 ft. 8 in., four years old	0·0152
Brick, washed with cement, circular sewer, 9 ft. diameter, nearly new	0·0116
Brick, washed with cement, circular sewer, 9 ft diameter, four years old	0·0133
Old Croton aqueduct, lined with brick	0·015
New Croton aqueduct	0·012
Sudbury aqueduct	0·01
Glasgow aqueduct, lined with cement	0·0124
Steel pipe, wetted, clean, 1897 (mean)	0·0144
Steel pipe, 1899 (mean)	0·0155

VALUES OF n ACCORDING TO PROFESSOR COLEMAN, D.Sc.

Kutter and Ganguillet :	n
Channels lined carefully with planed boards or smooth cement	0·01
,, ,, with common boards	0·012
,, ,, ,, ashlar or neatly-jointed brickwork	0·013
,, ,, ,, rubble masonry	0·017
,, ,, ,, earth in brooks or rivers	0·025
Streams with detritus or aquatic plants	0·03

Although the Kutter formula is cumbersome to manipulate, given a reliable value for n, the results obtained can be used with confidence.

It has been found that the variation of i produced only a small variation in the value of the coefficient C, and that if a slope of 1 in 1000 be taken as standard ($i = 0{\cdot}001$) then the difference will not be appreciable.

This enables the coefficient C to be written as :

$$\left[\frac{41{\cdot}6 + \dfrac{1{\cdot}811}{n} + \dfrac{0{\cdot}00281}{0{\cdot}001}}{1 + \left(41{\cdot}6 + \dfrac{0{\cdot}00281}{0{\cdot}001}\right)\dfrac{n}{\sqrt{m}}}\right]$$

and as m for any known pipe has a definite value, and if the value of n is also known, we can reduce the rather unwieldy form to a constant and thus arrive at the fundamental Chezy form $v = C\sqrt{mi}$. These constants for a comprehensive series of pipe sizes will be found in Table V ($n = 0{\cdot}013$).

Example

Find the coefficient C in the Kutter and Ganguillet formula if the slope of the pipe which is running full is 1 in 1000, the diameter is 2 feet, and the material of the sewer is glazed stoneware in perfect condition (for then $n = 0{\cdot}010$. See TABLE I). Then find the velocity in feet per second and the discharge in cubic feet per second.

$$\text{Hydraulic mean depth } m = \frac{A}{P} = D/4 = 2/4 = 0{\cdot}5$$

$$\text{Hydraulic gradient } = i = \frac{1}{1000}$$

$$\text{Then } \quad C = \left[\frac{41{\cdot}6 + \dfrac{1{\cdot}811}{n} + \dfrac{0{\cdot}00281}{i}}{1 + \left(41{\cdot}6 + \dfrac{0{\cdot}00281}{i}\right)\dfrac{n}{\sqrt{m}}}\right]$$

The formula put forward by Manning took the form:

$$v = C\sqrt[3]{m^2}\sqrt{i}$$

or

$$v = \frac{1{\cdot}486}{n}\cdot\sqrt[3]{m^2}\sqrt{i}$$

where n is the coefficient of rugosity according to Kutter.

Crimp and Bruges.

This is the formula in most general use among engineers in this country and is as follows:

$$v = 124\sqrt[3]{m^2}\sqrt{i}$$

Observations carried out from time to time have justified its use. The convenient form allows the engineer to convert it into:

$$v = K^1\sqrt{i} \text{ and } Q = K\sqrt{i}$$

By using the constants given in Table VIII and inserting values for $\sqrt{i}$, velocities and discharges for pipes from 6 inches to 60 inches diameter may be found.

If we consider in connection with the Manning formula, that C is equal to $1{\cdot}486/n$, then there emerges the following comparison with the constant of the Crimp and Bruges formula:

$$124 = \frac{1{\cdot}486}{n}$$

Therefore

$$n = \frac{1{\cdot}486}{124} = 0{\cdot}012,$$

so that the Crimp and Bruges formula is practically the same as the Kutter formula with a value of $n = 0{\cdot}012$. Similarly, if we wish to use the formula with a value of $n = 0{\cdot}013$ it is simple to arrive at the appropriate value of C by the above method; in this case it would be $C = 1{\cdot}486/0{\cdot}013 = 114{\cdot}3$.

Diagrams for the easy use of the Crimp and Bruges formula are given farther on in this chapter.

Example

By using the Crimp and Bruges formula find the velocity and discharge per second of a 15-inch diameter pipe laid at a gradient of 1 in 100.

$$V = 124\sqrt[3]{m^2}\sqrt{i}.$$

Circular Pipes

Crimp and Bruges Formula

Values of A, m, $\sqrt[3]{m^2}$, and K^1 (constant for Velocity) and K (constant for Discharge)

$v = 124\sqrt[3]{m^2}\sqrt{i}$ feet per second

Diam. in Inches.	Area in Square Feet.	m in Feet.	$\sqrt[3]{m^2}$	For Velocity in Feet per min. K^1 in $v = K^1\sqrt{i}$	For Discharge in Cubic Feet per min. K in $Q = K\sqrt{\ }$	Diam. in Inches.
6	0·1963	0·1250	0·2500	1,880	366	6
9	0·4418	0·1875	0·3276	2,440	1,076	9
12	0·7854	0·2500	0·3969	2,960	2,320	12
15	1·2272	0·3125	0·4605	3,420	4,200	15
18	1·7641	0·3750	0·5200	3,860	6,850	18
21	2·4053	0·4375	0·5763	4,280	10,320	21
24	3·1416	0·5000	0·6300	4,680	14,720	24
27	3·9761	0·5625	0·6814	5,060	20,160	27
30	4·9087	0·6250	0·7310	5,440	26,700	30
33	5·9396	0·6875	0·7790	5,800	34,420	33
36	7·0686	0·7500	0·8255	6,140	43,420	36
39	8·2958	0·8125	0·8707	6,480	53,740	39
42	9·6211	0·8750	0·9148	6,800	65,480	42
45	11·045	0·9375	0·9579	7,120	78,720	45
48	12·566	1·0000	1·0000	7,440	93,500	48
51	14·186	1·0625	1·0412	7,740	109,900	51
54	15·904	1·1250	1·0817	8,040	128,000	54
57	17·721	1·1875	1·1214	8,340	147,840	57
60	19·635	1·2500	1·1604	8,640	169,520	60

The hydraulic mean depth $m = \frac{A}{P} = \pi/4D^2 \div \pi D = D/4$

$$= 0{\cdot}3125$$

$$\sqrt[3]{m^2} = 2/3 \log \text{ of } 0{\cdot}3125$$
$$= 0{\cdot}666 \times -0{\cdot}50516 = -0{\cdot}33677$$
$$\text{Antilog } -0{\cdot}33677 = \bar{1}{\cdot}66323$$
$$= 0{\cdot}4605$$

Then

$$V = 124\sqrt[3]{m^2}\sqrt{i}$$
$$= 124 \times 0{\cdot}4605 \times \sqrt{\frac{1}{100}}$$
$$= 124 \times 0{\cdot}04605 = 5{\cdot}72 \text{ feet per second.}$$

OPERATING INSTRUCTIONS AND PROCEDURES IN RESPECT TO WASTE CONTROL

1. Site supervisor to inspect each load on arrival at site.
   Should load contain material not authorised he is not to permit driver to deposit on site and he is to instruct driver to exit the site.

2. Site supervisor to inspect that the drivers paperwork is in order.
   If not in order he is to require paperwork be correct before accepting the load.

3. Site supervisor to inspect that the drivers truck permit identification markings are in order.
   If not in order he is to require identification be in place before accepting the load.

4. Site supervisor is to ensure he obtains all of the information required for filling out Template 3 record. This includes Source , Description , EWC Code , Tonnage or m3 , Destination in Landfill , Waste Collector , Vehicle No , Permit No , Vehicle Reg No, Name of Who Checked Load at this site, Initial of Supervisor.

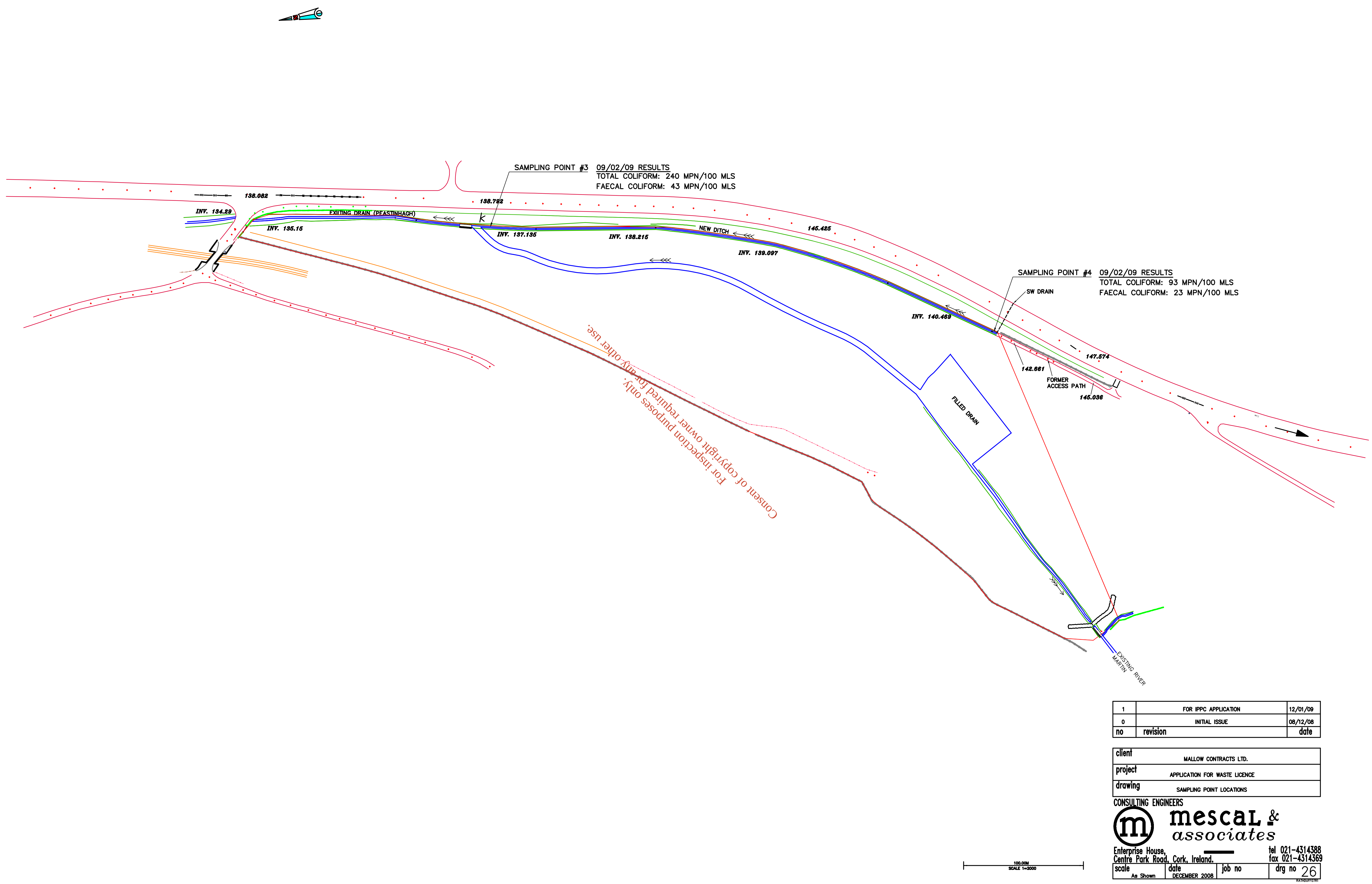
5. Upon completion of clearance of material , paperwork, truck permit marking and obtaining all aforesaid details the site supervisor is to direct the driver where to g to and where to deposit his material.

6. Upon depositing the material the site supervisor is to ensure that the truck exits the site via the truck wash. Therein he is to ensure the truck is adequately washed prior to re entry onto the public road.

7. The site supervisor is to ensure the public road condition throughout the day for cleanliness. He is to ensure that it is cleaned if required.

8. Site supervisor is to ensure completion of the record for each load in the Template 3 Record Book daily.

ENSURE THAT ALL PEOPLE INVOLVED IN WASTE CONTROL ARE FAMILIAR WITH THE ABOVE PROCEDURE.



no	revision	date
1	FOR IPPC APPLICATION	12/01/09
0	INITIAL ISSUE	08/12/08

client: MALLOW CONTRACTS LTD.

project: APPLICATION FOR WASTE LICENCE

drawing: SAMPLING POINT LOCATIONS

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scale	date	job no	drg no
As Shown	DECEMBER 2008		26

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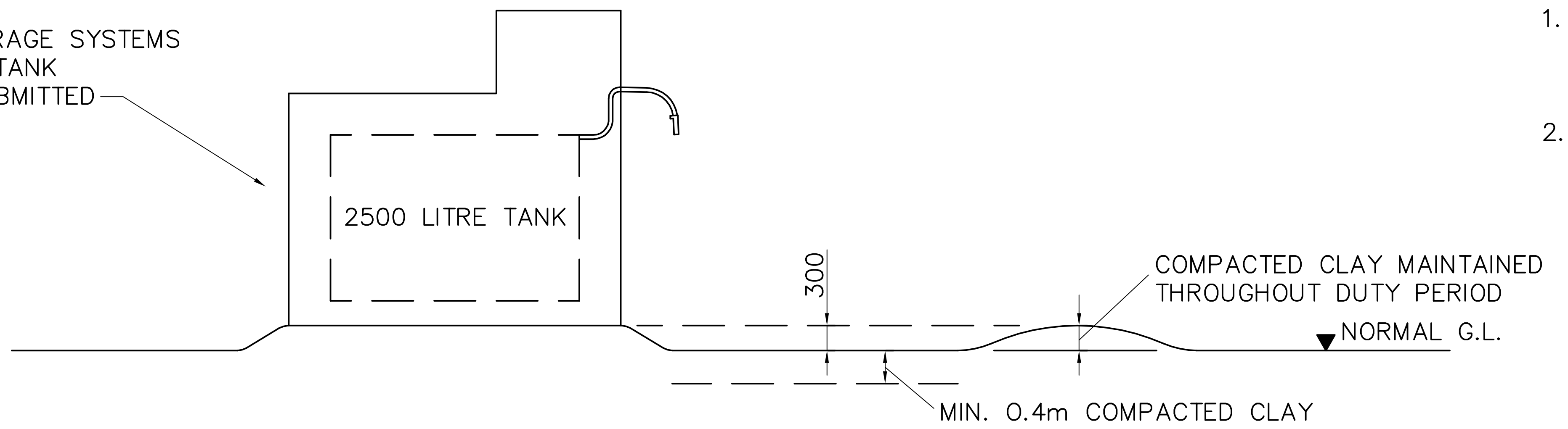
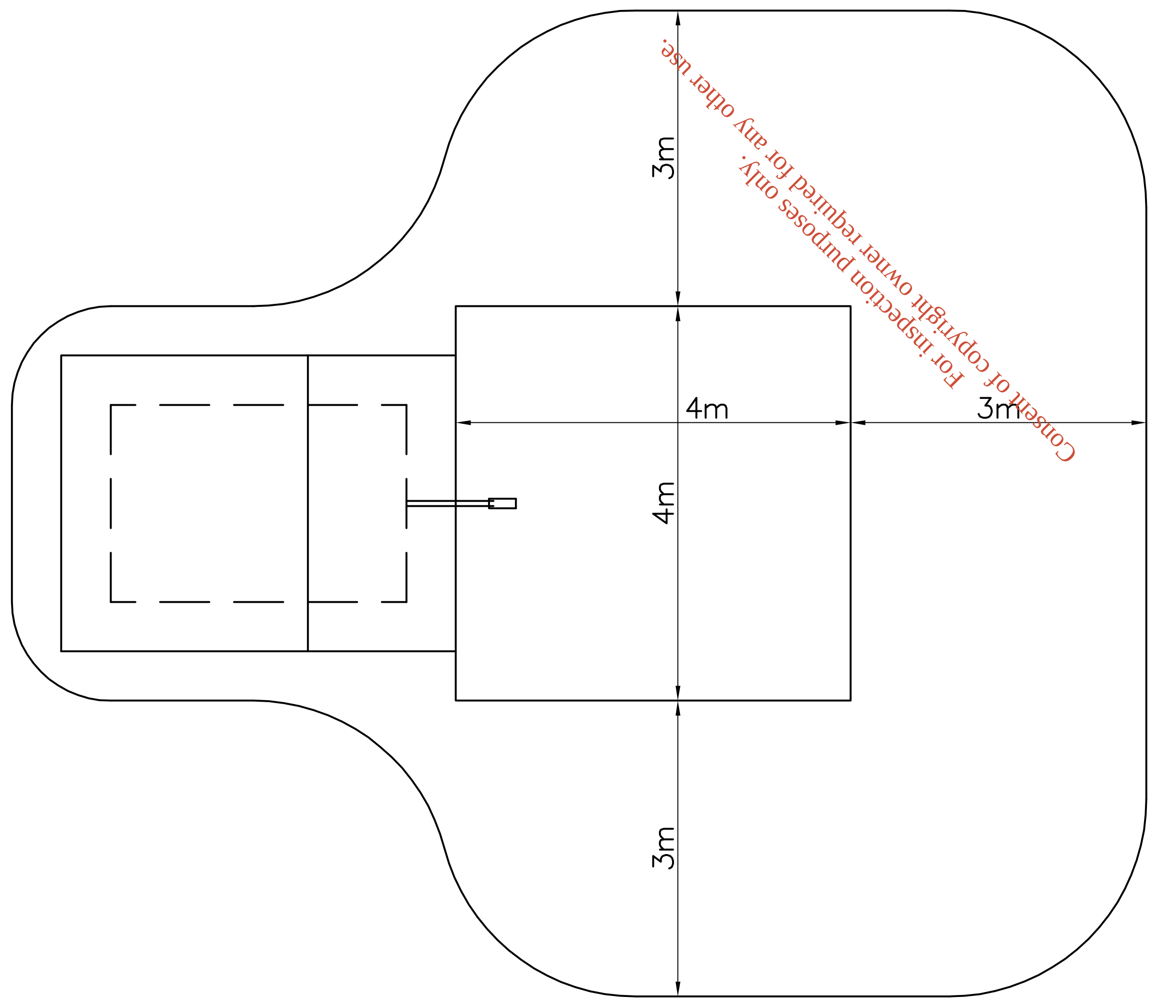


SECTION



PLAN

FUEL BUNDING

NOTES:–

1. LOCATION OF REFUELING WILL BE RELOCATED SEVERAL TIMES AS THE WORKS PROCEED OVER 3 YEAR PERIOD
2. PROCEDURE FOR ANY MOTOR REQUIRING FUEL TO LOCATE FUEL TANK ACCESS WITHIN BUNDED AREA PRIOR TO FILLING

no	revision	date
1	FOR IPPC APPLICATION	12/01/09
0	INITIAL ISSUE	18/12/06

client	MALLOW CONTRACTS LTD
project	APPLICATION FOR WASTE MANAGEMENT PERMIT
drawing	FUEL BUNDING

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scale	date	job no	drg no
NTS	DECEMBER 2006		27

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