Environet Solutions

Impact of Process Effluent Discharge on River Deel Estuary

for Pfizer Nutritionals Ireland Limited, Askeaton

Final

24th October 2011

Environet Solutions

Dungarvan Business Centre
Fairlane
Shandon
Dungarvan
Co. Waterford
Ireland
Tel: 058-51155
Fax: 058-51231
Email: info@environet.ie

www.environet.ie

Document Control

Status	Draft	Draft	Final
Date	12/8/2011	1/9/2011	24/10/2011
Version #	1	2	4
Approved			

This report has been prepared by Environet Consulting Ireland Ltd, with all appropriate care and diligence within the terms of the Contract with the client. This Contract incorporates our Terms and Conditions and takes account of the resources devoted to it by agreement with the client.

We disclaim any responsibility to the client and others in respect of any matters outside the scope of works.

This report is confidential to the client and we accept no responsibility to third parties to whom this report, or any part thereof, is made known. Such parties rely on the report at their own risk.

TABLE OF CONTENTS

1 Introduction

Pfizer Nutritionals Ireland Limited (Pfizer) is an IPPC licensed facility based at Askeaton, Co. Limerick. The site manufactures infant formula, mainly for the export market and is one of the largest such sites in the world. 600 staff are employed at the facility.

The IPPC licence was issued by the EPA on 23 January 2004 for the following activities;

The manufacture of dairy products where the processing capacity exceeds 50 million gallons of milk equivalent per year

and

The operation of combustion installations with a rated thermal input equal to or greater than 50 MW.

The EPA has examined all IPPC licenses to assess their compliance with recent amendments to legislation on the protection of waters as listed below;

SI 272 of 2009 – European Communities Environmental Objectives (Surface Waters) Regulations 2009

and

SI 9 of 2010 – European Communities Environmental Objectives (Groundwater) Regulations 2010

The EPA has decided that where process emissions are discharged directly to waters it will review those IPPC licenses in order to confirm compliance with the above legislation.

As there are no discharges to ground from the Pfizer facility this report will focus on assessing the appropriateness of current IPPC Licence emission limit values for process effluent discharges to the River Deel Estuary and their likely impact on surface waters in the context of the new Regulations.

1.1 Assumptions

The following assumptions have been made in order to facilitate the production of this report:

- That all relevant information has been made available to Environet in order to carry out a comprehensive assessment of the impact of process effluent discharges on the River Deel estuary.

2 Available Information

The following information was used in the production of this report;

- EO Regulations Review-simple assimilative capacity model for transitional waters, August 2011, EPA
- Pfizer IPPC Licence P0395-02
- Pfizer Emissions to Water monitoring data
- EPA Monitoring of River Deel (2001-2003) – Appendix A
- OPW Hydrometric Data for River Deel – Appendix B
- Deel Estuary RBMP Measures Report (2010) – Appendix C
- Aquafact Ltd. - Dispersion Study (2001) – Appendix D
- River Monitoring Technologies Ltd. - Deel Estuary Tidal Volume Estimates (2006) – Appendix E
- Summary Statistics for Estuaries and Coastal Waters 2007-2009 - Salinity – Appendix F

3 Impact Assessment

In order to assess the impact of the licensed ELVs on the Deel Estuary we need to confirm which licensed ELVs will be impacted by the Regulations.

The following table lists the parameters licensed by the EPA under the current IPPC licence and whether or not they are impacted by the Regulations.

Parameter	Impacted (Yes/No)	Discussion
BOD	Yes	The Regulations specify an EQS for transitional waters < 4.0 mg/l (95 %ile)
Suspended Solids	No	Not Applicable
Total Nitrogen	No	No EQS for transitional waters
Total Phosphorus (as P)	Yes	The Regulations specify an EQS for Molybdate Reactive Phosphorus of < 0.06 mg/l P (median)
OFG	No	No EQS for transitional waters
Ammonia	No	No EQS for transitional waters

Table 1: Impact of the Regulations

Please note that the Regulations also refer to specific hazardous substances such as the Specific Pollutants referenced in Table 10, the Priority Substances referenced in Table 11 and the Priority Hazardous Substances referenced in Table 12. As none of these substances are used at the facility they will not be dealt with as part of this assessment.

3.1 BOD

Treated effluent discharge from Pfizer is to the Deel Estuary. Assimlative capacity calculations were carried out as per the following EPA Guidance;

'EO Regulations Review – Simple assimilative capacity model for transitional waters', EPA, August 2011

The following formulae were applied;

$Q_d = (Q_e + Q_f)\, S_o/(S_o - S)$

Where;

Q_d = dilution flow rate (m^3/s)
Q_e = flow rate of the licensed discharge (m^3/s)
Q_f = flow rate of the river (m^3/s)
S_o = salinity of the open water (Lower Shannon Estuary) (psu)
S = salinity in vicinity of the discharge (psu)

Once Q_d is obtained the concentration of a discharged substance C (mg/l) is obtained using the following formula;

$C = C_b + (C_e - C_b) / (1 + (Q_d / Q_e))$

Where;

C_b = Background concentration of the parameter in question (mg/l)
C_e = Discharge Concentration (mg/l)

Q_e =	0.032	m^3/s	C_b =	2.3	mg/l
Q_f =	0.55	m^3/s	C_e =	40	mg/l
S_o =	23.645	psu	Q_e =	0.032	m^3/s
S =	1.805	psu	Q_d =	0.63	m^3/s
Q_d =	0.63	m^3/s	**C =**	**4.122**	**mg/l**

Table 2: BOD Assimilative Capacity Calculations

The EQS for BOD is < 4.0 mg/l. Therefore at the current discharge limits the EQS is breached by a marginal amount. However 95 %ile flow data for the river Deel was taken at 11 km upstream at Rathkeale. Therefore flows at Askeaton are expected to be considerably larger and are likely to ensure that the EQS is achieved.

The above data was collected from the following sources.

Data	Source
BOD	EPA Water Quality Mapping Station Number 1100. Location: Rathkeale Bridge. See Appendix A.
River Flow	Flow data was obtained from the OPW Hydrodata website. See Appendix B.
River Status	WFD River Basin Management Plan Deel Estuary July 2010. See Appendix C.

Table 3: Data Sources

In 2001 Aquafact International Services Limited completed a dispersion study on the Pfizer outfall. At the time ELVs were the same as those currently in place. The report (Appendix D) concluded as follows;

> *'The results of this study indicate that under current emission rates, the receiving waters are capable of diffusing the effluent with no significant impact on the surrounding environment'*

It should also be noted that the WFD RMBD report (Appendix C) considers that the current (July 2010) BOD status to be *High* on a scale of *High, Good, Moderate, Poor and Bad*.

3.2 Phosphorus

Molybdate Reactive Phosphorus (MRP) or Orthophosphate is the parameter that needs to be assessed with regard to compliance with the MRP EQS set in the Regulations for transitional water bodies.

Currently background median levels of MRP in the river are 0.17 mg/l. The EQS for the water body is set at 0.06 mg/l. Therefore regardless of the MRP EQS set for Pfizer discharges, it will not be possible to meet the EQS without other upstream measures being put in place.

Q_e =	0.032	m^3/s	C_b =	0.17	mg/l
Q_f =	4.74	m^3/s	C_e =	1	mg/l
S_o =	23.645	psu	Q_e =	0.032	m^3/s
S =	1.805	psu	Q_d =	5.16	m^3/s
Q_d =	5.16	m^3/s	**C =**	**0.175**	**mg/l**

Table 4: MRP Assimilative Capacity Calculations

The current ELV for Total P is 2 mg/l. Assuming MRP is approximately 50% of the total then the current implied limit of 1.0 mg/l means that Pfizer will only increase the background concentration of MRP by 0.005 mg/l. This will not adversely impact the receiving water and will not impact on measures to be undertaken elsewhere to return the water body to good status by 2021.

The Full Report for the Deel Estuary water body – July 2010 (Appendix C) makes it clear that approximately 85% of the phosphorus loading on this river system comes from agricultural sources. It also states that the water body is not at risk from IPPC licensed facilities.

4 Conclusions

The assimilative capacity report has concluded as follows;

- Only BOD and MRP ELVs need to be assessed as a result of the implementation of the new Regulations.
- The BOD EQS for the receiving water will be marginally exceeded due to the Pfizer discharge based on river flow monitoring 11 km upstream of the discharge and using 95% river flows. This is highly conservative and the reality is that emissions from Pfizer will not result in the EQS being exceeded.
- The Deel Estuary RBMP Measures Report confirms that the BOD status of the water body is high.
- The MRP levels in the receiving water are already above the EQS at 0.17 mg/l. The impact of the addition of the Pfizer discharge will be to increase the background MRP level by 0.005 mg/l. It is considered that this impact will not be a hindrance to other measures being put in place to ensure the Deel Estuary achieves Good Status by 2021.

Appendix A – EPA Monitoring Data

Station No: 1100 **Location:** Rathkeale Bridge **Date From:** 2001 **To:** 2003

A value displayed in **BOLD** indicates the value falls outside either an upper or lower threshold and highlights stations where there may be water quality problems.

Parameter	Parameter Units	Minimum	Median	Maximum	No of Samples	Source	Source Type
B.O.D	mg O21-1	**<2.0**	**2.3**	**6.4**	34	Limerick Co Co	LA
Conductivity	µS cm-1	321	504	570	13	Limerick Co Co	LA
Ortho-Phosphate	mg P 1-1	**0.09**	**0.17**	**0.88**	33	Limerick Co Co	LA
Oxidised Nitrogen	mg N 1-1	**4.0**	**7.2**	**18.3**	32	Limerick Co Co	LA
pH		**7.3**	**8.1**	**8.6**	32	Limerick Co Co	LA
Temperature	oC	**3.1**	**12.5**	**21.0**	33	Limerick Co Co	LA
Total Ammonia	mg N 1-1	**<0.02**	**0.09**	**0.44**	34	Limerick Co Co	LA

Close Window

Appendix B – OPW Hydrometric Data

OPW

HYDRO-DATA

Summary Statistics Data

GENERAL STATION DETAILS			
Station Name: Rathkeale	Station No: 24013	Watercourse: Deel	NGR: R 360 414
Catchment Area (km^2): 426	Catchment: Deel	Gauge Type: L/AR	Datum: Poolbeg

SUMMARY HYDROMETRIC STATISTICS
Annual Average Rainfall (mm)[1]: 1054
Est'd Annual Losses (mm)[1]: 489
Mean Annual Flow (m^3/s): 9.4526 (Data derived for the period 1972 to 2003)

STATION HISTORY
Period of Continuous Hardcopy Records: 1953 to 2005
Period of Digitised Record: 1972 to 2005

Note 1 : Data extracted from the Environmental Protection Agency publication 'Hydrological Data', July 1997

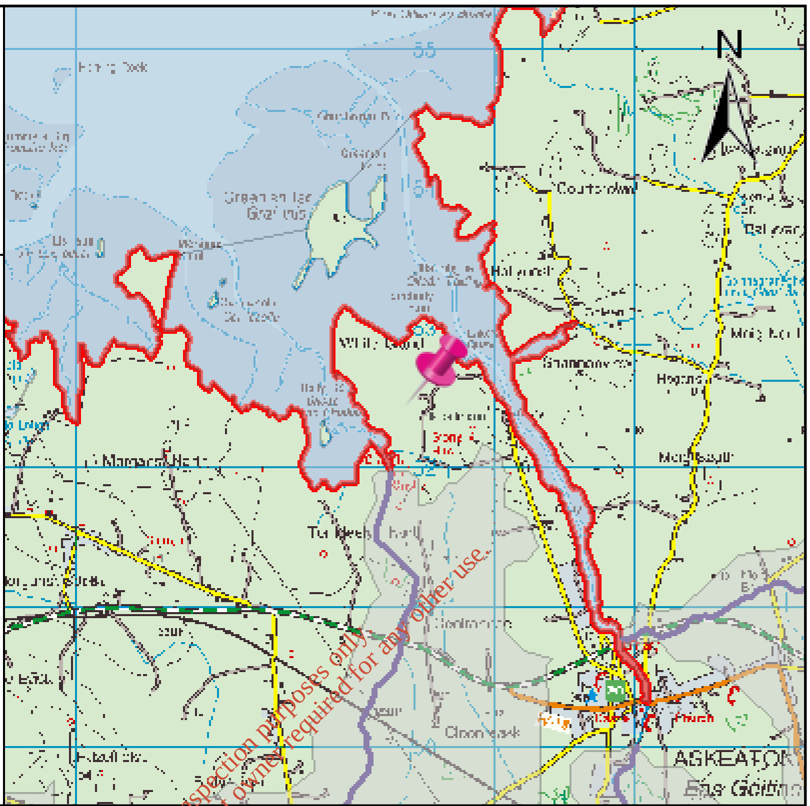
DURATION PERCENTILES							
Flows equalled or exceeded for the given percentage of time (m^3/s) (Data derived for the period 1972 to 2003)							
1%	5%	10%	50%	80%	90%	95%	99%
71.4	33.7	22.2	4.74	1.48	0.89	0.55	0.22
Levels equalled or exceeded for the given percentage of time (mAOD Poolbeg) (Data derived for the period 1972 to 2005)							
1%	5%	10%	50%	80%	90%	95%	99%
34.00	33.12	32.78	32.13	31.88	31.80	31.75	31.70

COMMENTS / NOTES
Low flow ratings truncated

Appendix C – Full Report for Water Body Deel Estuary – July 2010

water matters
'Our Plan'

Full Report for Waterbody Deel Estuary



River Basin Management Plans (RBMPs) have been published for all River Basin Districts in Ireland in accordance with the requirements of the Water Framework Directive. The WaterMaps viewer is an integral part of the River Basin Management Plan and provides access to information at individual waterbody level and at Water Management Unit level for all the River Basin Districts in Ireland.

The following report provides summary plan information about the selected waterbody (indicated by the pin in the map above) relating to its status, risks, objectives, and measures proposed to retain status where this is adequate, or improve it where necessary. Waterbodies can relate to surface waters (these include rivers, lakes, estuaries [transitional waters], and coastal waters), or to groundwaters. Other relevant information not included in this report can be viewed using the WaterMaps viewer, including areas listed in the Register of Protected Areas.

You will find brief notes at the bottom of some of the individual report sheets that will help you in interpreting the information presented. More detailed information can be obtained in relation to all aspects of the RBMPs at www.wfdireland.ie.

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

water matters
'Our Plan'

Summary Information:

Water Management Unit:	N/A
WaterBody Category:	Transitional Waterbody
WaterBody Name:	Deel Estuary
WaterBody Code:	IE_SH_060_0600
Overall Status:	Moderate
Overall Objective:	Restore 2021
Overall Risk:	1a At Risk
Heavily Modified:	No

shannon river basin district

Report data based upon final RBMP, 2009-2015.

The information provided above is a summary of the principal findings related to the selected waterbody. Further details and explanation of individual elements of the report are outlined in the following pages.

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

water matters
'Our Plan'

Status Report

Water Management Unit:	N/A
WaterBody Category:	Transitional Waterbody
WaterBody Name:	Deel Estuary
WaterBody Code:	IE_SH_060_0600
Overall Status Result:	Moderate
Heavily Modified:	No

	Status Element Description	Result
	Status information	
DIN	Dissolved Inorganic Nitrogen status	Moderate
MRP	Molybdate Reactive Phosphorus status	Moderate
DO	Dissolved oxygen as per cent saturation status	Good
BOD	Biochemical Oxygen Demand (5-days) status	High
PHY	Macroalgae - phytobiomass status	High
OPP	Macroalgae - opportunistic algae status	N/A
RSL	Macroalgae - reduced species list status	N/A
ANG	Angiosperms - Seagrass and Saltmarsh status	N/A
BIN	Benthic Invertebrates status	N/A
FIS	Fish status	Moderate
HYD	Hydrology status	N/A
MOR	Morphology status	At least Good
SP	Specific Pollutant Status	N/A
PAS	Overall protected area status	Less than good
ES	Ecological Status	Moderate
CS	Chemical Status	N/A
SWS	Surface Water Status	N/A
EXT	Extrapolated status	N/A
DON	Donor water bodies	N/A

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

n/a - not assessed

Status
By 'Status' we mean the condition of the water in the waterbody. It is defined by its chemical status and its ecological status, whichever is worse. Waters are ranked in one of 5 status classes: High, Good, Moderate, Poor, Bad. However, not all waterbodies have been monitored, and in such cases the status of a similar nearby waterbody has been used (extrapolated) to assign status. If this has been done the first line of the status report shows the code of the waterbody used to extrapolate.

You can read more about status and how it is measured in our RBMP Document Library at www.wfdireland.ie (Directory 15 Status).

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

water matters
'Our Plan'

shannon river basin district

Risk Report

Water Management Unit:	N/A	
WaterBody Category:	Transitional Waterbody	
WaterBody Name:	Deel Estuary	
WaterBody Code:	IE_SH_060_0600	
Overall Risk Result:	1a	At Risk
Heavily Modified:	No	

	Risk Test Description		**Risk**
	Hydrology		
THY1	Water balance - Abstraction	1b	Probably At Risk
	Marine Direct Impacts		
TMDI 1	Dangerous Substances		N/A
TMDI 2	OSPAR	1b	Probably At Risk
TMDI 3	UWWT Regs Designations		N/A
TMDI O	Marine Direct Impacts Overall - Worst Case	1b	Probably At Risk
	Morphological Risk Sources		
TM1	Channelisation		N/A
TM2	Deposition		N/A
TM3	Coastal Defences		N/A
TM4	Impoundments		N/A
TM5a	Built Structures - Port Tonnage		N/A
TM5b	Built Structures - Industrial Intakes		N/A
TM6	Intensive Landuse		N/A
TMO	Morphology Overall - Worst Case		N/A
TMO	Overall (MIMAS) Morphological Risk - Worst Case (2008)		N/A
	Overall Risk		
RA	Transitional Overall - Worst CaseOverall (MIMAS) Morphological Risk - Worst Case (2008)	1a	At Risk
	Point / MDI Worst Case		
TPOL	Worst case of Point Overall and MDI OverallOverall (MIMAS) Morphological Risk - Worst Case (2008)	1a	At Risk

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

water matters
'Our Plan'

	Point Risk Sources		
TP1	WWTPs (2008)	1a	At Risk
TP2	CSOs	2b	Not At Risk
TP3	IPPCs (2008)	2b	Not At Risk
TP4	Section 4s (2008)	2b	Not At Risk
TP5	WTPs/Mines/Quarries/Landfills		N/A
TPO	Overall Risk from Point Sources - Worst Case (2008)	1a	At Risk

Risk
By 'risk' we mean the risk that a waterbody will not achieve good ecological or good chemical status/potential at least by 2015. To examine risk the various pressures acting on the waterbody were identified along with any evidence of impact on water status. Depending on the extent of the pressure and its potential for impact, and the amount of information available, the risk to the water body was placed in one of four categories: 1a at risk; 1b probably at risk; 2a probably not at risk; 2b not at risk. Note that '2008' after the risk category means that the risk assessment was revised in 2008. All other risks were determined as part of an earlier risk assessment in 2005.

You can read more about risk assessment in our 'WFD Risk Assessment Update' document in the RBMP document library, and other documents at www.wfdireland.ie (Directory 31 Risk Assessments).

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

water matters 'Our Plan'

Objectives Report

Water Management Unit:	N/A
WaterBody Category:	Transitional Waterbody
WaterBody Name:	Deel Estuary
WaterBody Code:	IE_SH_060_0600
Overall Objective:	Restore 2021
Heavily Modified:	No

shannon river basin district

	Objectives Description	**Result**
	Extended timescale information	
E1	Extended timescales due to time requirements to upgrade WWTP discharges	2021
E2	Extended timescales due to delayed recovery of chemical pollution and chemical status failures	No Status
E3	Extended timescales due to winter dissolved nitrogen exceedances	No Status
E4	Extended timescales due to time requirements for status recovery	No Status
E5	Extended timescales from Northern Ireland Environment Agency	No Status
E0V	Overall extended timescale - combination of all extended timescales fields	2021
	Objectives information	
OB1	Prevent deterioration objective	No Status
OB2	Restore at least good status objective	No Status
OB3	Reduce chemical pollution objective	No Status
OB4	Protected areas objective	Restore 2021
OBO	Overall objectives	Restore 2021

Extended timescales
Extended timescales have been set for certain waters due to technical, economic, environmental or recovery constraints. Extended timescales are usually of one planning cycle (6 years, to 2021) but in some cases are two planning cycles (to 2027).

Objectives
In general, we are required to ensure that our waters achieve at least good status/potential by 2015, and that their status does not deteriorate. Having identified the status of waters (this is given earlier in this report), the next stage is to set objectives for waters. Objectives consider waters that require protection from deterioration as well as waters that require restoration and the timescales needed for recovery. Four default objectives have been set initially:-

Prevent Deterioration
Restore Good Status
Reduce Chemical Pollution
Achieve Protected Areas Objectives

These objectives have been refined based on the measures available to achieve them, the latter's likely effectiveness, and consideration of cost-effective combinations of measures. Where it is considered necessary extended deadlines have been set for achieving objectives in 2021 or 2027.

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

Measures Report

Water Management Unit:	N/A
WaterBody Category:	Transitional Waterbody
WaterBody Name:	Deel Estuary
WaterBody Code:	IE_SH_060_0600
Heavily Modified:	No

shannon river basin district

	Measures Description	**Applicable**
BC	Total number of basic measures which apply to this waterbody	18
BW	Directive - Bathing Waters Directive	No
BIR	Directive - Birds Directive	Yes
HAB	Directive - Habitats Directive	Yes
MAE	Directive - Major Accidents and Emergencies Directive	Yes
EIA	Directive - Environmental Impact Assessment Directive	Yes
UWT	Directive - Urban Waste Water Treatment Directive	Yes
PPP	Directive - Plant Protection Products Directive	Yes
NIT	Directive - Nitrates Directive	Yes
IPC	Directive - Integrated Pollution Prevention Control Directive	Yes
POI	Other Stipulated Measure - Control of point source discharges	Yes
DIF	Other Stipulated Measure - Control of diffuse source discharges	Yes
PS	Other Stipulated Measure - Control of priority substances	Yes
MOD	Other Stipulated Measure - Controls on physical modifications to surface waters	Yes
OA	Other Stipulated Measure - Controls on other activities impacting on water status	Yes
AP	Other Stipulated Measure - Prevention or reduction of the impact of accidental pollution incidents	Yes
TP1	WSIP - Agglomerations with treatment plants requiring capital works	Yes
TP2	WSIP - Agglomerations with treatment plants requiring further investigation prior to capital works	No
TP3	WSIP - Agglomerations requiring the implementation of actions identified in Shellfish PRPs	No
TP4	WSIP - Agglomerations with treatment plants requiring improved operational performance	Yes
TP5	WSIP - Agglomerations requiring investigation of CSOs	No
TP6	WSIP - Agglomerations where exisitng treatment capacity is currently adequate but predicted loadings would result in overloading	No
OTS	On-site waste water treatment systems	Yes
SHE	Shellfish Pollution Reduction Plan	No
IPR	IPPC licences requiring review	No
WPR	Water Pollution Act licences requiring review	Yes

Date Reported to Europe:July 2010

Date Report Created 10/08/2011

HQW	Protect high quality waters	No

Measures
Measures are necessary to ensure that we meet the objectives set out in the previous page of this report. Many measures are already provided for in national legislation and must be implemented. Other measures have been recently introduced or are under preparation. A range of additional potential measures are also being considered but require further development. Any agreed additional measures can be introduced through the update of Water Management Unit Action Plans during the implementation process.

You can read more about Basic Measures in 'River Basin Planning Guidance' and in other documents in our RBMP Document Library at www.wfdireland.ie.

Appendix D – Aquafact Ltd. Dispersion Study

Dye Study In The River Deel, Asketon, Co. Limerick.

Compiled By: Aqua-Fact International Services Ltd.,
12 Kilkerrin Park, Liosbaun, Tuam Rd.,
Galway.
Tel: 353 (0)91 756812, Fax: 353 (0)91 756888
Web Page: www.aquafact.ie, email: info@aquafact.ie

Table Of Contents

1. Introduction

Aqua-Fact International Services Ltd. was commissioned to carry out a dye study at the Wyeth Nutritional Ireland outfall location in the River Deel estuary, Asketon, Co. Limerick (Figure 1). The purpose of this survey was to determine the adequacy of the outfall to ensure that the location and extent of the mixing zone is compatible with protection of the receiving water. The emission license currently allows for a maximum discharge in any one day of 2,800m^3 of wastewater with a maximum rate per hour of 126 m^3. Diffusion experiments, involving both discrete and continuous released of rhodamine dye, are commonly performed to determine the mixing characteristics of near-shore sites. Monitoring the dilution and movement of the dye provides a means of determining the path that may be followed by a discharge and the rate at which dilution is likely to take place.

Photographs 1 and 2 show the nature of the Deel estuary during low water conditions. A central shallow channel is flanked by mud flats, their area varying along the length of the estuary. These mudflats are covered by water on high water (Photograph 4). The outfall point is located to the north of the plant (Photograph 3) with the town of Asketon to the southeast (Photograph 6).

2. Materials And Methods

2.1. Dye Study

Rhodamine WT, a dye designed specifically for water tracing studies, was released shortly after high and low water during both spring and neap tide conditions. Prior to release, the dye was diluted with methanol and distilled water to adjust its density close to that of the receiving water so that the dye dispersed through the water column. The resulting mixture was treated as a 100% concentrated tracer. A sample of this concentrate was diluted to 100µg/l and used as a standard to calibrate a direct reading fluorimeter. Once calibrated, all subsequent measurements with the fluorimeter are related to the original 100% tracer released into the water.

Two litres of tracer were released close to the outfall point on each drop (Photograph 3). After initial release the position and edges of the dye patch were recorded by DGPS fitted on the survey boat. Once the dye patch was sufficiently dispersed to allow in-situ measurements with the fluorimeter, transects were steered through the patch at regular intervals with the fluorimeter continuously recording dye concentrations. The position of the fluorimeter and time were noted with the DGPS as recording commenced and noted again when recording stopped as the boat moved away from the dye patch. Vertical profiles were taken within the dye patch when depths allowed. However, given the locations of the dye releases, i.e. close to shore, vertical profiles were not always possible due to shallow conditions. In general, the vertical profiles indicated that the dye was evenly dispersed through the water column.

Transects continued through the dye patch until either background levels were recorded throughout the general area of the patch or the dye dispersed over mud flats which were not accessible to the operators.

2.2 Drogues

Current tracking drogues, of the window-blind type were released into the water body at the same time as the dye (Photograph 3). Due to depth limitations, the drogues were only designed to track the currents prevailing at a water depth of one metre. The tracks of the drogues were monitored regularly and their positions were recorded using DGPS. Wind speeds were recorded regularly with a hand-held anenometer to account for any wind-induced influences, which may have been exerted, on the drogues and dye.

2.3. Current Measurements.

Currents were measured at regular intervals close to the outfall point with a direct reading current meter during the dye study. Due to depth limitations, only mid-water currents were recorded.

3. Results

3.1. Neap Tide

3.1.1. Dye Releases

Two litres of dye were released close to the outfall point (52° 36.676 N, 8° 58.831 W) at 10:28 on the 28th August 2001. Low water occurred at approximately 9:00 with high water at 15:00. Rhodamine WT was not released after high water as dye from the first drop was still in the vicinity of the initial release point. Weather conditions were good with no wind being recorded in the estuary.

Figure 2 presents concentrations recorded during each of the transects carried out on the 28th August 2001, while Figure 3(a-f) presents a visual interpretation of dye concentrations along these transects. On release, the dye expanded north and south in a narrow streak from the release point, extending from 52° 36.689 N, 8° 58.845 W to 52° 36.664 N, 8° 58.845 W by 10:27. At 11:00, the dye had diluted sufficiently to allow concentration readings with the fluorimeter. The first transect (not shown in Figure 3) followed a path along the estuary with the outfall its centre point. The maximum concentration recorded was approximately 500 µg/l with concentrated readings occurring over a short span. This maximum concentration is relatively low for initial transects, a fact which is highlighted by concentrations recorded later during transect T4 (see Figure 2) where the fluorimeter recorded the maximum recordable value (1238 µg/l) across the transect. This is due to the dye movement across the mudflats surrounding the main channel, which is initially inaccessible to the boat due to depth limitations. In the first 30 minutes of sampling (Figure 3a) the main dye patch remained in the wider area to the north of the outfall point (i.e. area to the left of photograph 4). Over the next two hours (Figure 3b, 3c), the plume slowly moves south towards the river dispersing across the channel as it progresses. However, as is evident from the dye concentration charts (Figure 2, T7-T14), the concentrated area of dye remained close to the side of the channel (Photograph 5). By 14:00, the mudflats surrounding the main channel were submerged and the dye began to disperse evenly across the channel as it moved south. Over the next two hours during the high water period, the dye remained in the channel just south of the outfall pipe. Transects 20-43 were taken during this period, the location of the dye plume clearly shown relative to the outfall point (Figure 3d & e). Maximum concentrations of dye (circa 300 µg/l) were similar during these transects (Figure 3). By 16:30, the tide had turned and was ebbing bringing the dye north towards the mouth of the estuary. Transects 45 to 51 (Figure 3f) show the progress of the dye along the channel. By 17:21, dye concentrations had fallen to near background levels with only low levels being picked up by the fluorimeter in transects (T52 & T53) taken along the length of the channel (see Figure 2). Following Transect 53, water depths had dropped to a level, which restricted boat access and did not allow further sampling.

3.1.2. Drogues

Two surface drogues were released at the same time as the dye close to the outfall location and their positions were regularly recorded by DGPS. The tracks of these positions are presented in Figures 4 & 5. Due to the depth limitations and the tendency of the water body to flood over the mudflats, both drogues had to be redeployed a number of times as they went to ground. Apart from the period 12:45 to 14:30, the drogues moved very little from the outfall location. This was due both to grounding on the side of the channel and low water currents. Even during the period prior to high water, where depth restrictions were not an issue, the drogues only moved approximately 600 m, giving them an average speed of just under 0.1ms^{-1}.

3.1.3. Current Measurements

The direct reading current meter was deployed regularly at the outfall location during the study. On each occasion, water movement was negligible and below the reliable detection limit of the meter (0.1ms^{-1}).

3.2. Spring Tide

3.2.1. Dye Releases

Two litres of dye were released close to the outfall point at 10:04 (52° 36.666 N, 8° 58.845 W) and again at 15:15 (52° 36.672 N, 8° 58.831 W) on the 5th September 2001. High water occurred at approximately 8:30 with low water at 14:30. Weather conditions were good with a moderate NW wind (3ms^{-1}) being recorded in the estuary.

Figure 6 presents concentrations recorded during each of the transects carried out on the 5th September 2001, while Figure 7(a-g) presents a visual interpretation of dye concentrations along these transects.

On the first release after high water, the dye expanded in an east-west direction in a narrow band, this band moving in a northerly direction from the release point. By 10:15 the plume had expanded to 52° 36.7244 N, 8° 58.8541 W; 52° 36.7376 N, 8° 58.8135 W; 52° 36.7470 N, 8° 58.8816 W; 52° 36.7538 N, 8° 58.8626 W.

At 10:24 the dye had diluted sufficiently to allow concentration readings with the fluorimeter. Transects D2 to D22 (Figure 6 and 7) clearly show the dilution of the dye plume as it moved in a northerly direction on the outgoing tide. Within an hour of release, recorded dye concentrations were significantly reduced although small pockets of the original concentrated plume were trapped in pools on the mudflats to the northeast of the outfall point. These pockets slowly released the dye into the main channel giving slightly elevated dye concentrations in localised areas as picked up in Transect 8-10. By 11:39, the main dye plume had been washed from the estuary with recorded dye concentrations being just above background levels in the transects taken after this time.

Following the release after low water, the dye moved in a southerly direction, the main plume keeping to the western shore of the channel. By 15:20, the dye plume had expanded from 52° 36.6682 N, 8° 58.8341 W to 52° 36.5846 N, 8° 58.8250 W. Dye concentrations were recorded with the fluorimeter from 15:37, the results of which are presented in Figure 6 and Figure 7d-7g, respectively. As the tide flooded along the channel, the dye moved with it in a relatively concentrated plume (Transects D24 –D31) until the water flowed onto the mudflats to the south of the outfall point. The dye dispersed over the mudflats at this time with little further progress along the channel towards the river (D32-D45). As the dye plume expanded over the mudflats, concentrations reduced as the flooding tide filled this area of the channel. Little change was noted to this situation over the following hour as water movement up the river was restricted by an elevated area of the river bed under the new bridge northwest of Asketon, its location outlined by rapids at low water. Once water levels had risen above this obstruction, low concentrations of dye were recorded (Transect D46) along the straight stretch of river at Asketon (Photograph 6). However, although reduced in concentration, the main area of dye remained in the bends just north of the abbey ruins, north of Asketon (D47-49).

3.2.2. Drogues

A surface drogues was released at the same time as both dye releases close to the outfall location and its positions were regularly recorded by DGPS. The track of the positions are presented in Figures 8 & 9. As recorded during the neap time study, depth limitations and the tendency of the water body to flood over the mudflats, the drogue had to be redeployed a number of times as it went to ground. Because of this tendency to go get stuck in the bottom, little can be determined from the drogue paths other than that the direction of movement was in keeping with the dye movement.

3.2.3. Current Measurements

Current measurements were made approximately every half hour during the study on the 5-09-01. Figure 10 presents the results of these measurements. Current direction was as expected with water moving out of the channel (northwesterly direction) on the ebb and into the channel (southeasterly) on the flood. Current velocities were relatively low on each occasion that measurements were made. A maximum current velocity of $0.15ms^{-1}$ was recorded at 12:00 during the ebbing tide while currents during the flood tide were generally below the reliable detection limit of the meter ($0.1ms^{-1}$).

4. Conclusions

In rivers and estuaries, the processes controlling the dispersion of dissolved and suspended pollutants are numerous and complicated. Among the factors that make a quantitative description hard are turbulence; the effects of topography, buoyancy, and tides; and the abundant non-linear interactions. These effects are particularly evident in the Deel estuary where a central shallow channel runs between banks of mud, which stretch out into mudflats on either side. With these difficulties in mind, the dye study carried out in the Deel estuary indicated relatively good dispersion properties in the vicinity of the outfall point. During both spring and neap conditions, the dye was washed from the estuary on the ebbing tide. It must be remembered that the dye (Rhodamine WT) was designed specifically to trace water movement and dispersion and low dye concentrations recorded at the end of the study reflect the ability of the fluorimeter to pick up minute traces of dye rather than the retention of effluent in the estuary. Additionally, effluent composed primarily of excess nutrients, as is the case here, will come under the influence of additional biological interactions e.g. algal uptake, which will further reduce concentrations in the area. Observations of the algal species and numbers on the riverbanks and mud flats in the vicinity of the outfall suggest that the effluent is having little effect on the environment under the present level of emission.

As expected, the intrusion of the effluent up the river is greater during spring tides compared to neaps with low concentrations of dye recorded at Asketon during the flooding spring tide. However, it is probable that this water would quickly return towards and out the mouth of the estuary on the subsequent ebb tide.

Current measurements recorded close to the outfall point were relatively low. This is probably due to the topography of the area at this point and the nature of water flow in this type of location. Estuarine water movement can be sporadic with riverbed obstructions and mud banks/flats having major effects. Stronger currents could have occurred between measurements, which would not have been recorded.

The results of this study indicate that under current emission rates, the receiving waters are capable of diffusing the effluent with no significant impact to the surrounding environment.

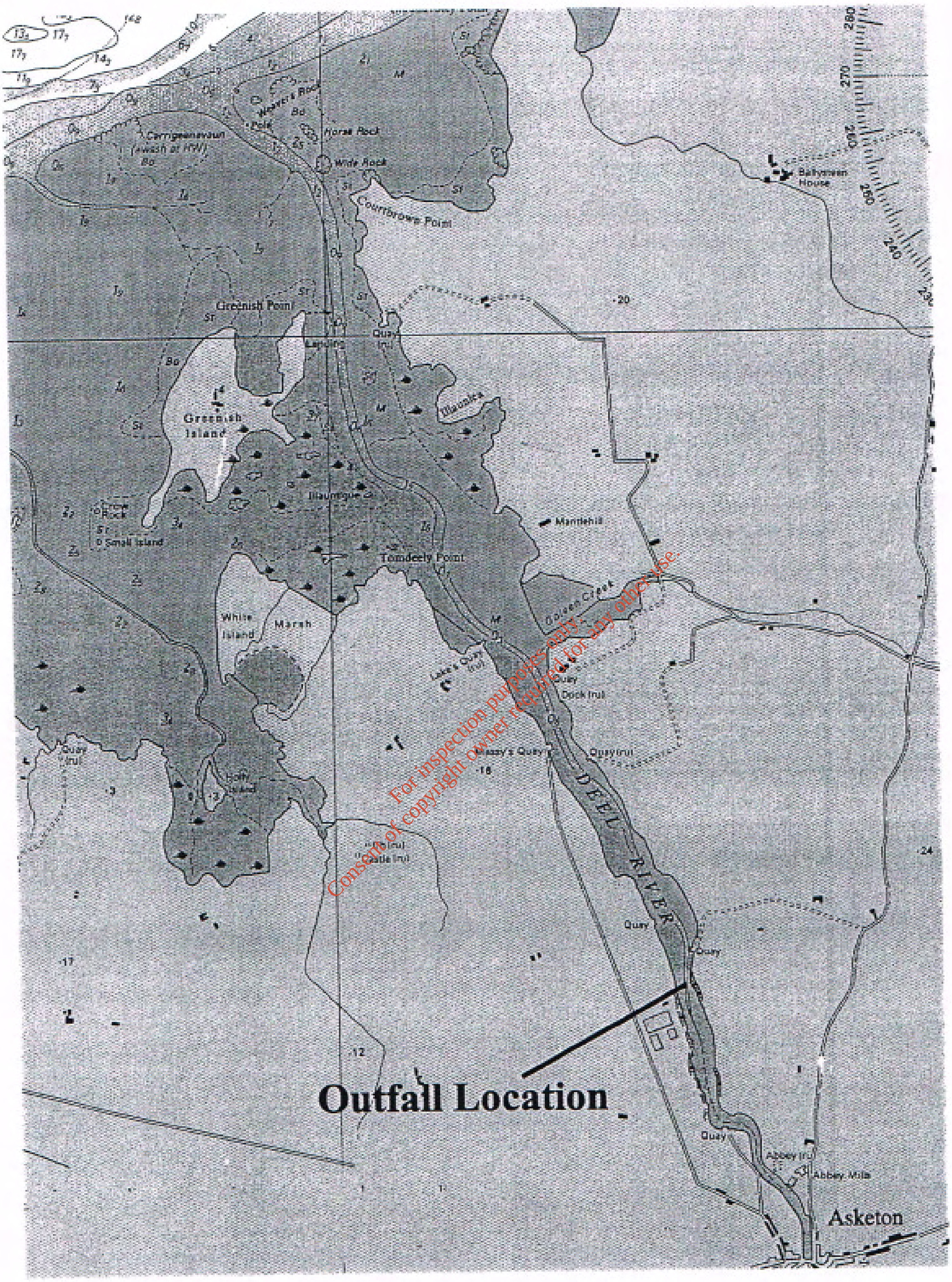
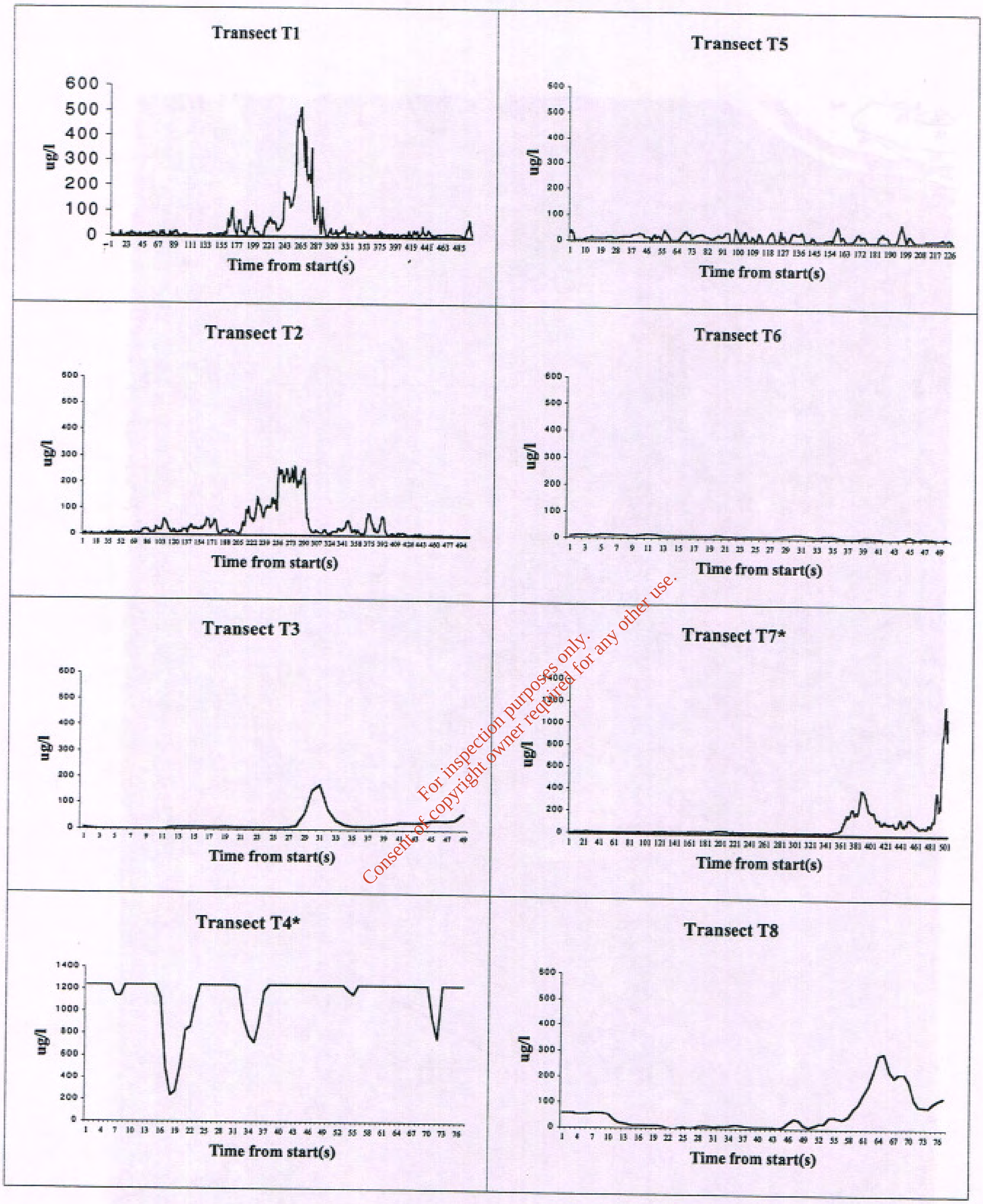
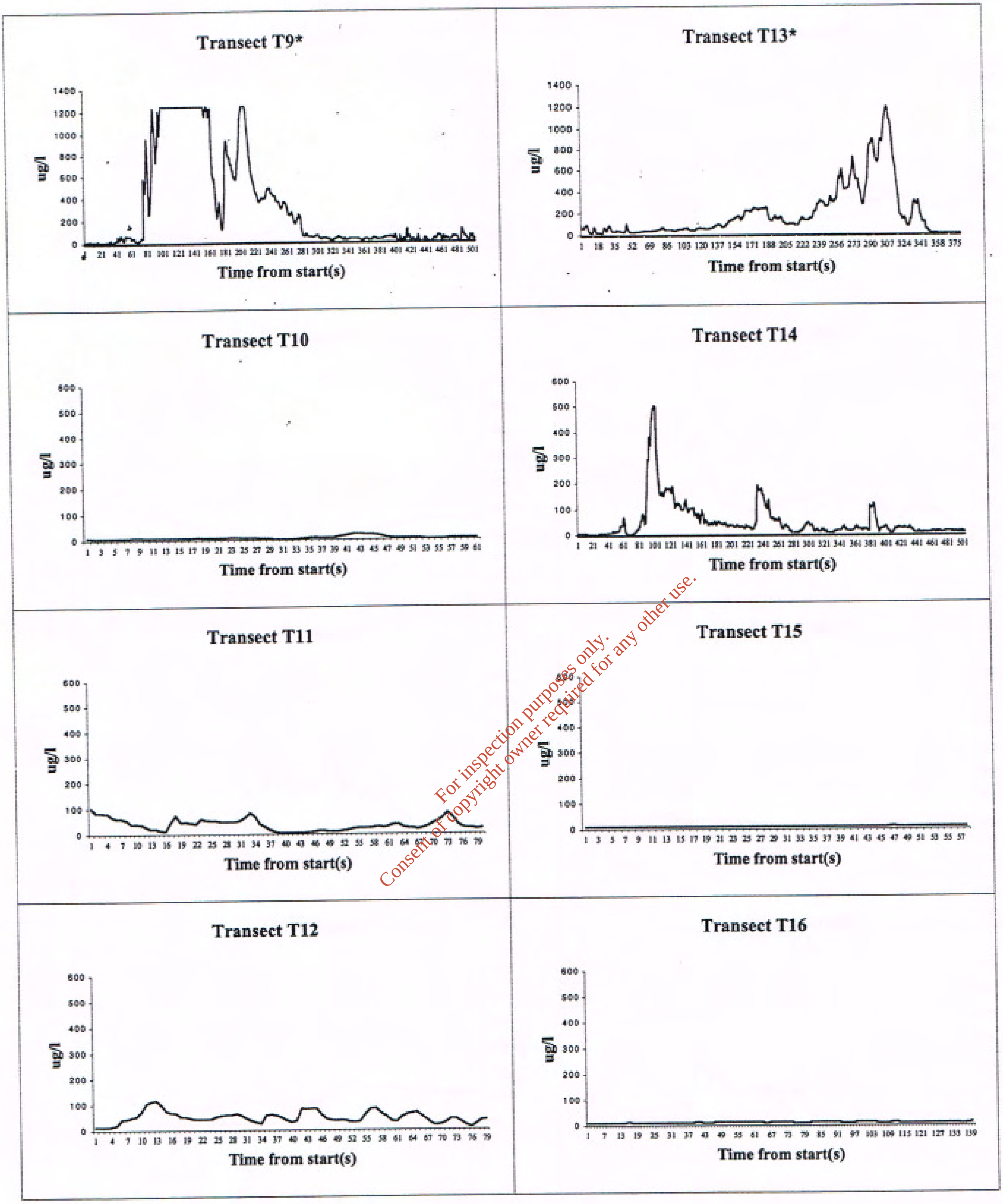


Figure 1. Outfall Location on the River Deel, Shannon Estuary, Co. Limerick



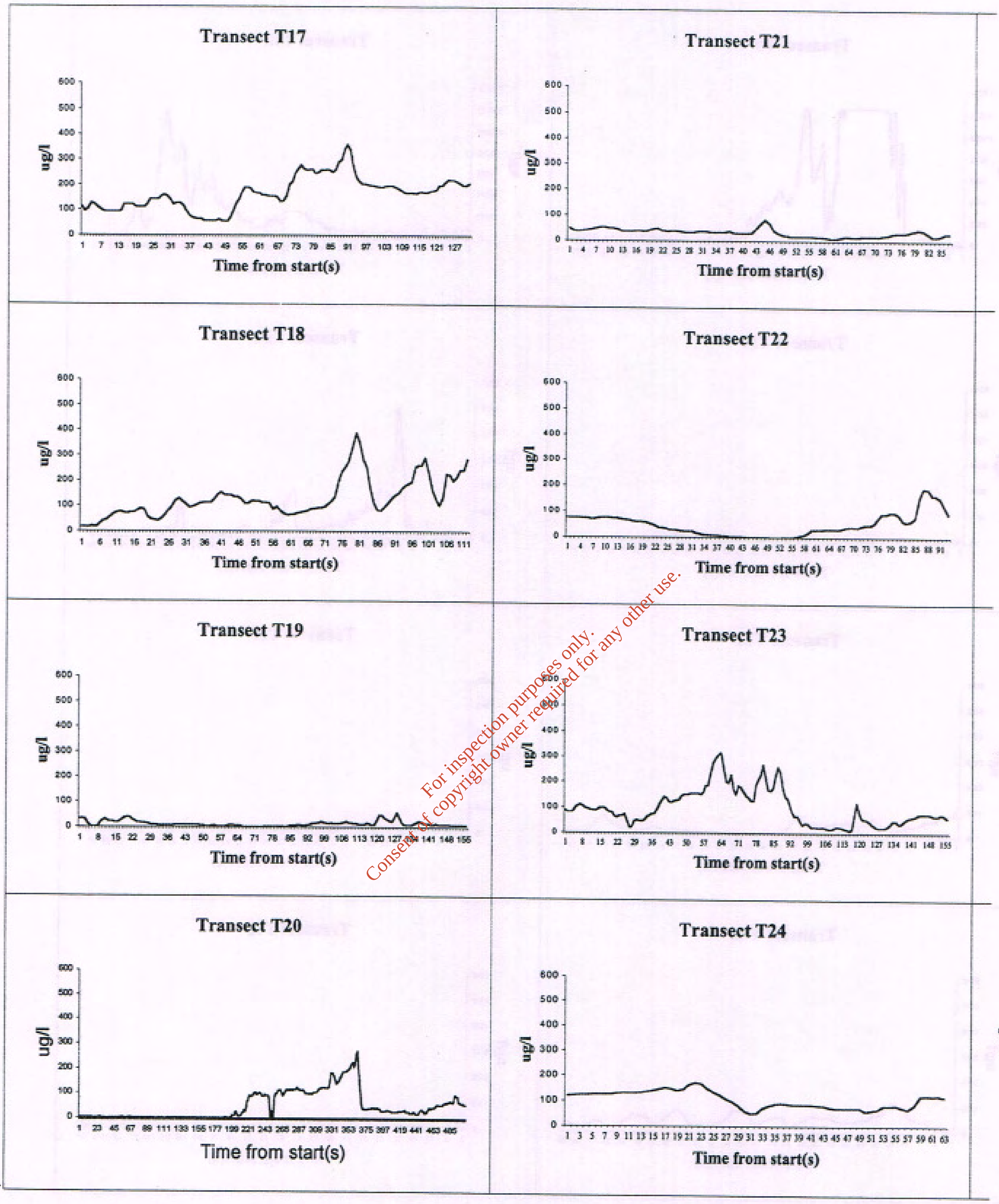
* notes different scale on y axis

Figure 2. Dye concentrations recorded during each of the transects, River Deel, 28-08-01



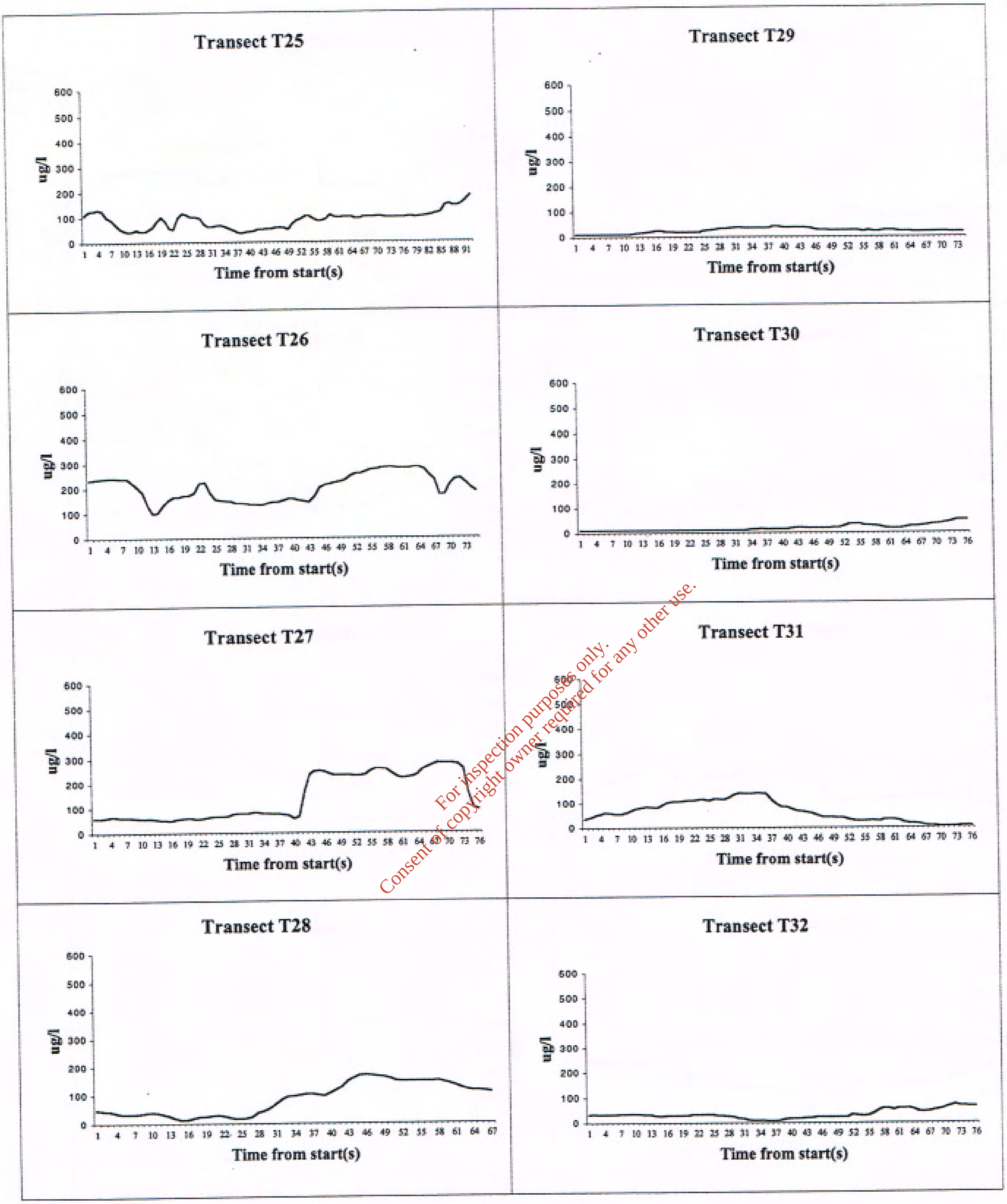
* notes different scale on y axis

Figure 2. Continued



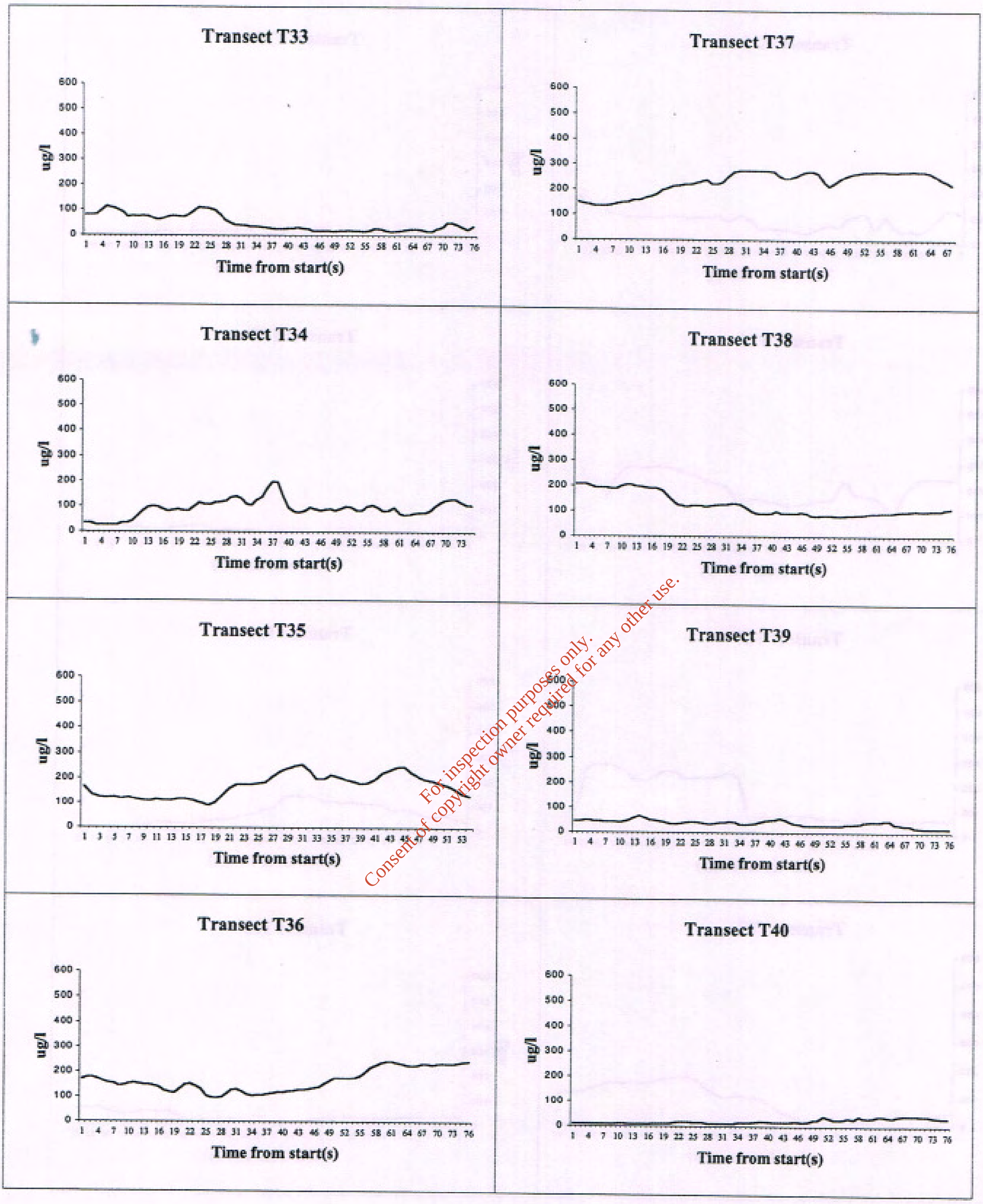
* notes different scale on y axis

Figure 2. Continued



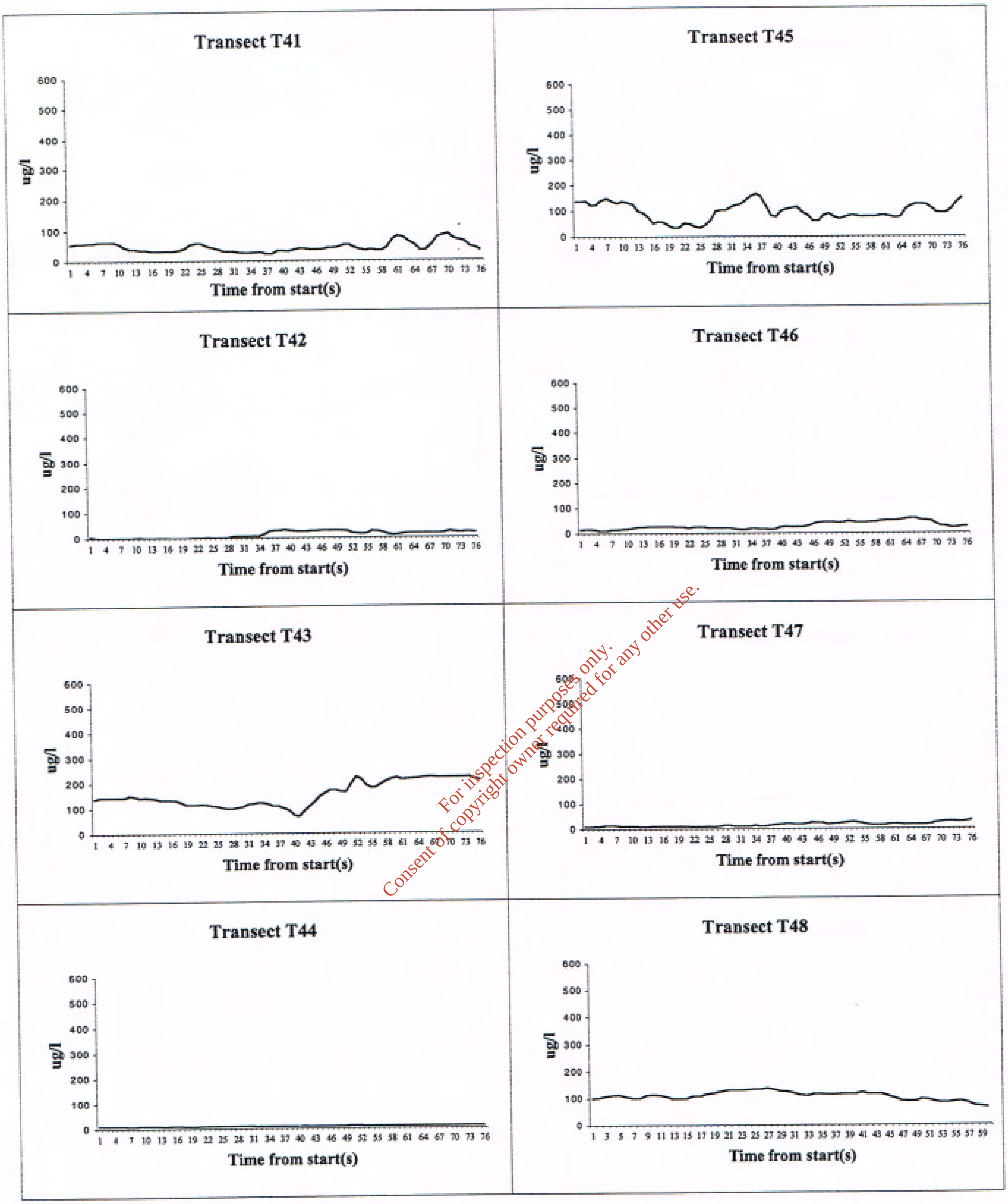
* notes different scale on y axis

Figure 2. Continued



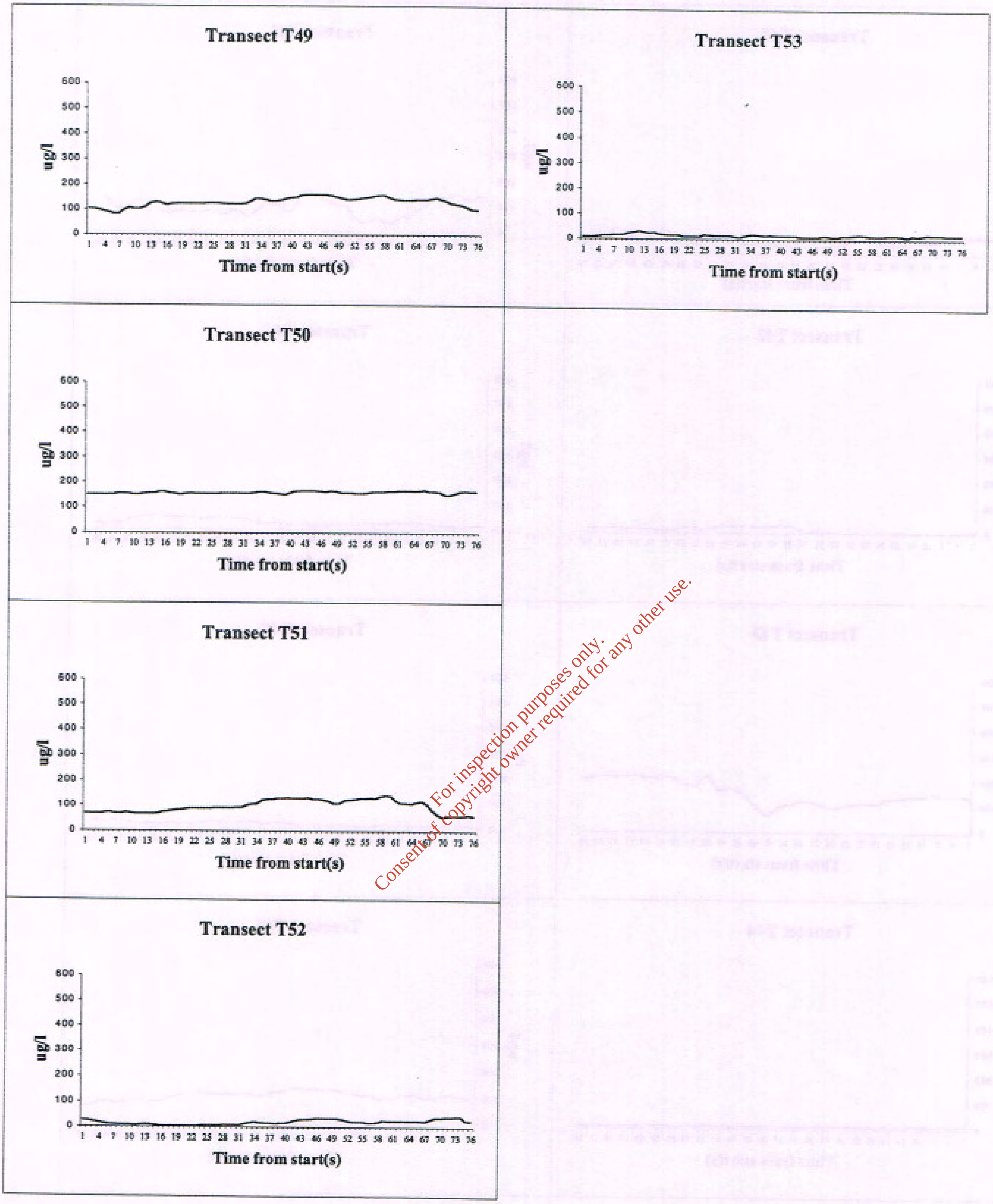
* notes different scale on y axis

Figure 2. Continued



* notes different scale on y axis

Figure 2. Continued



* notes different scale on y axis

Figure 2. Continued

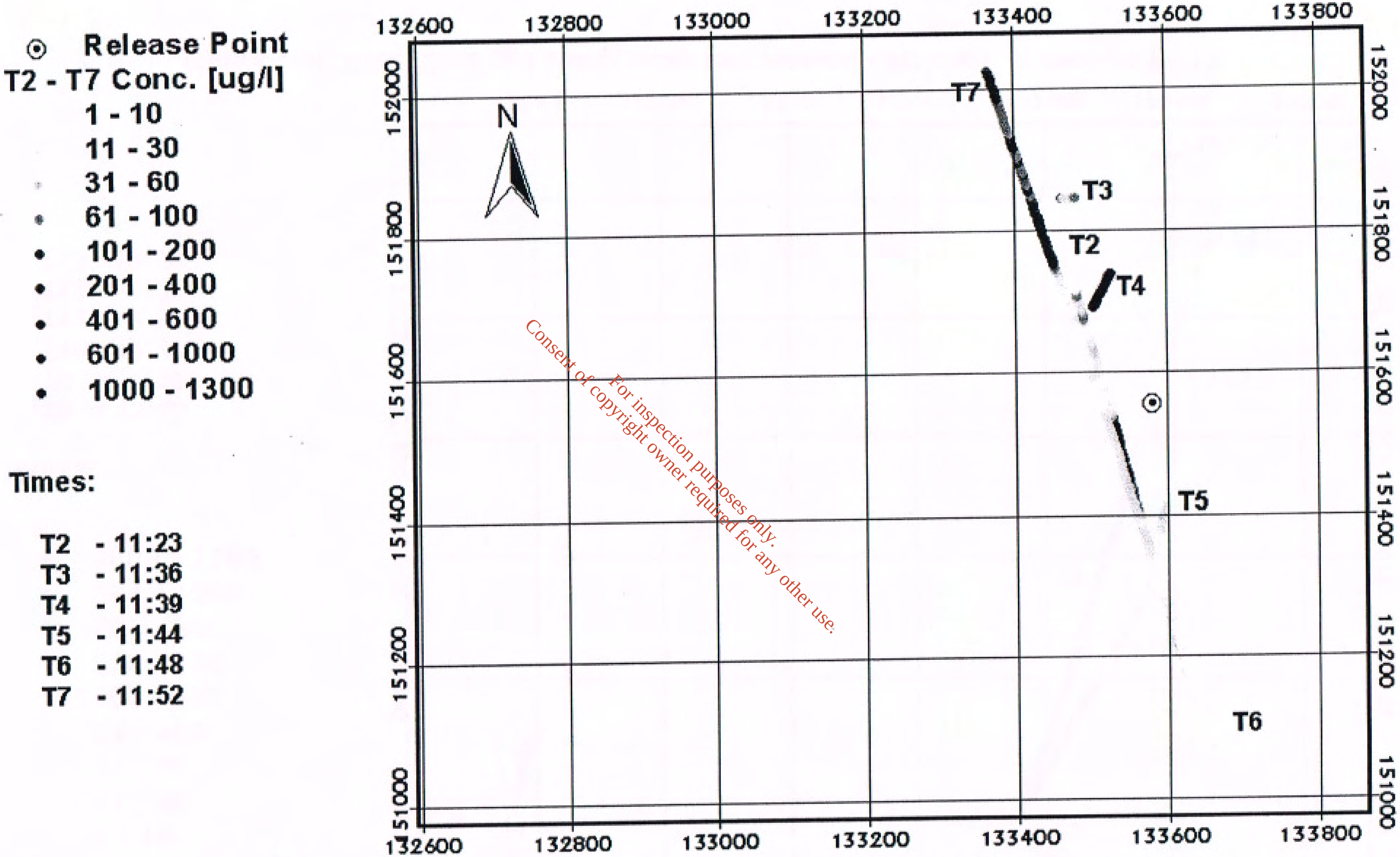


Figure 3(a): River Deel dye study, neap tide release - 28/08/01. Transects 2 - 7.

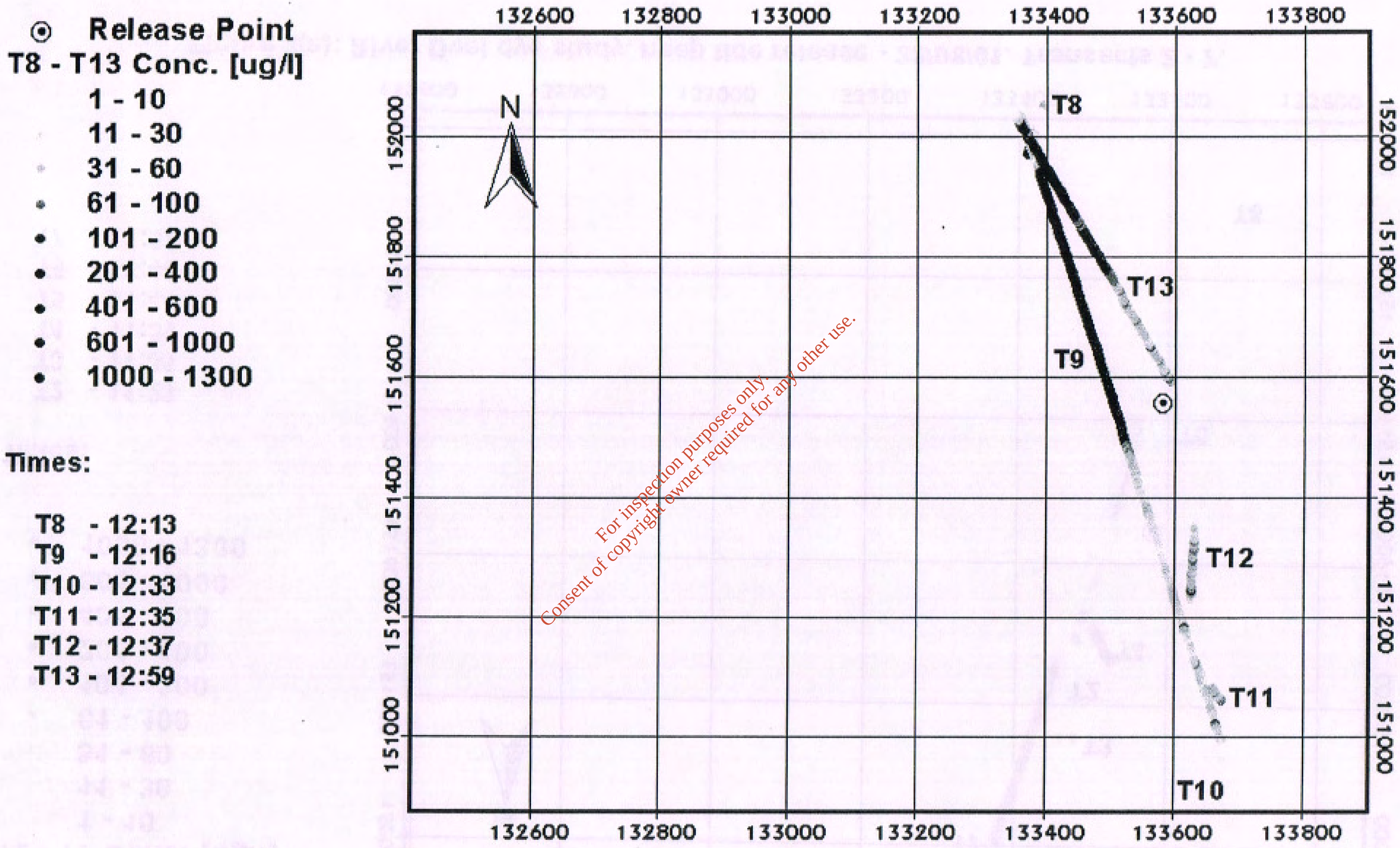


Figure 3(b): River Deel dye study, neap tide release - 28/08/01. Transects 8 - 13.

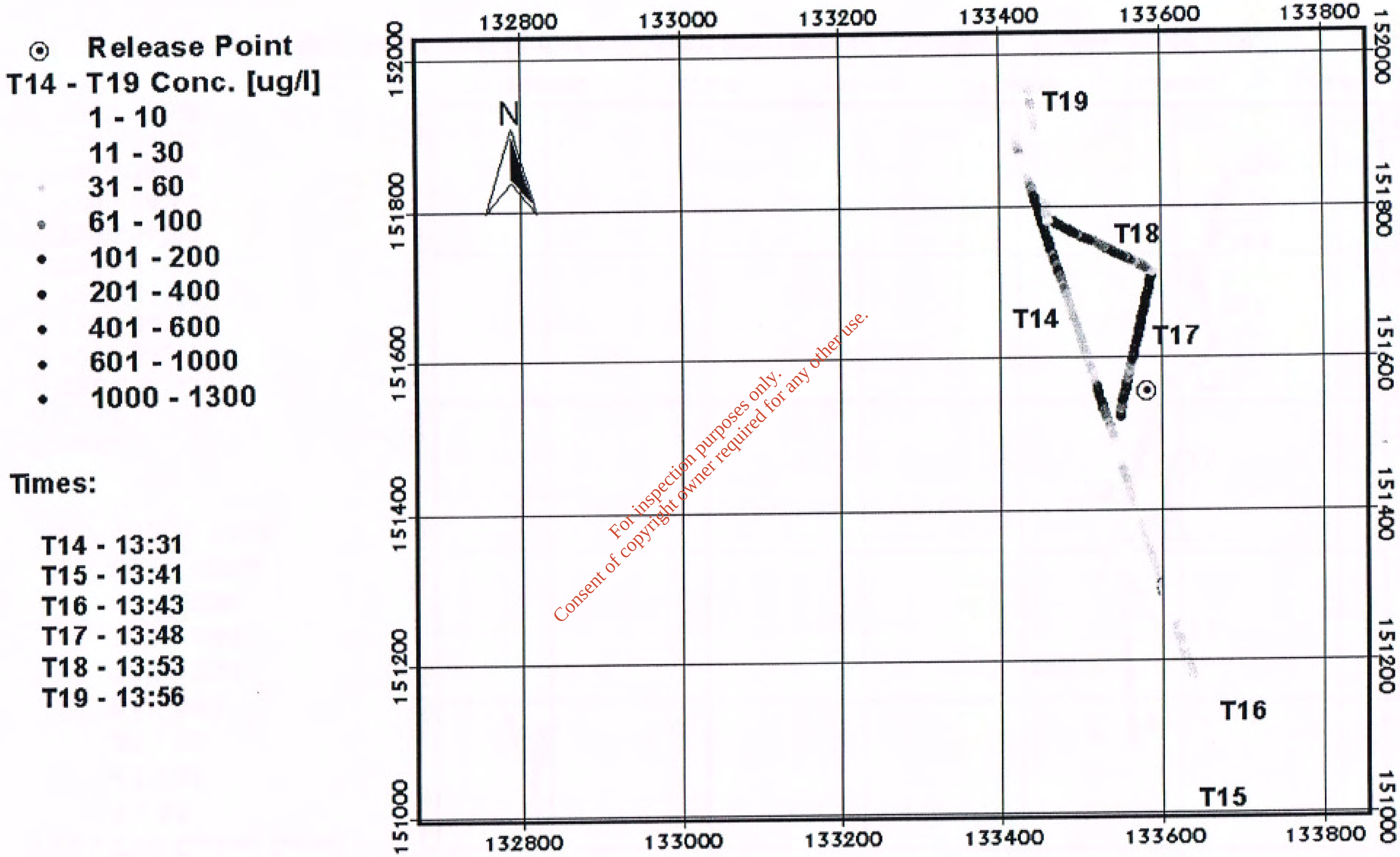


Figure 3(c): River Deel dye study, neap tide release - 28/08/01. Transects 14 - 19.

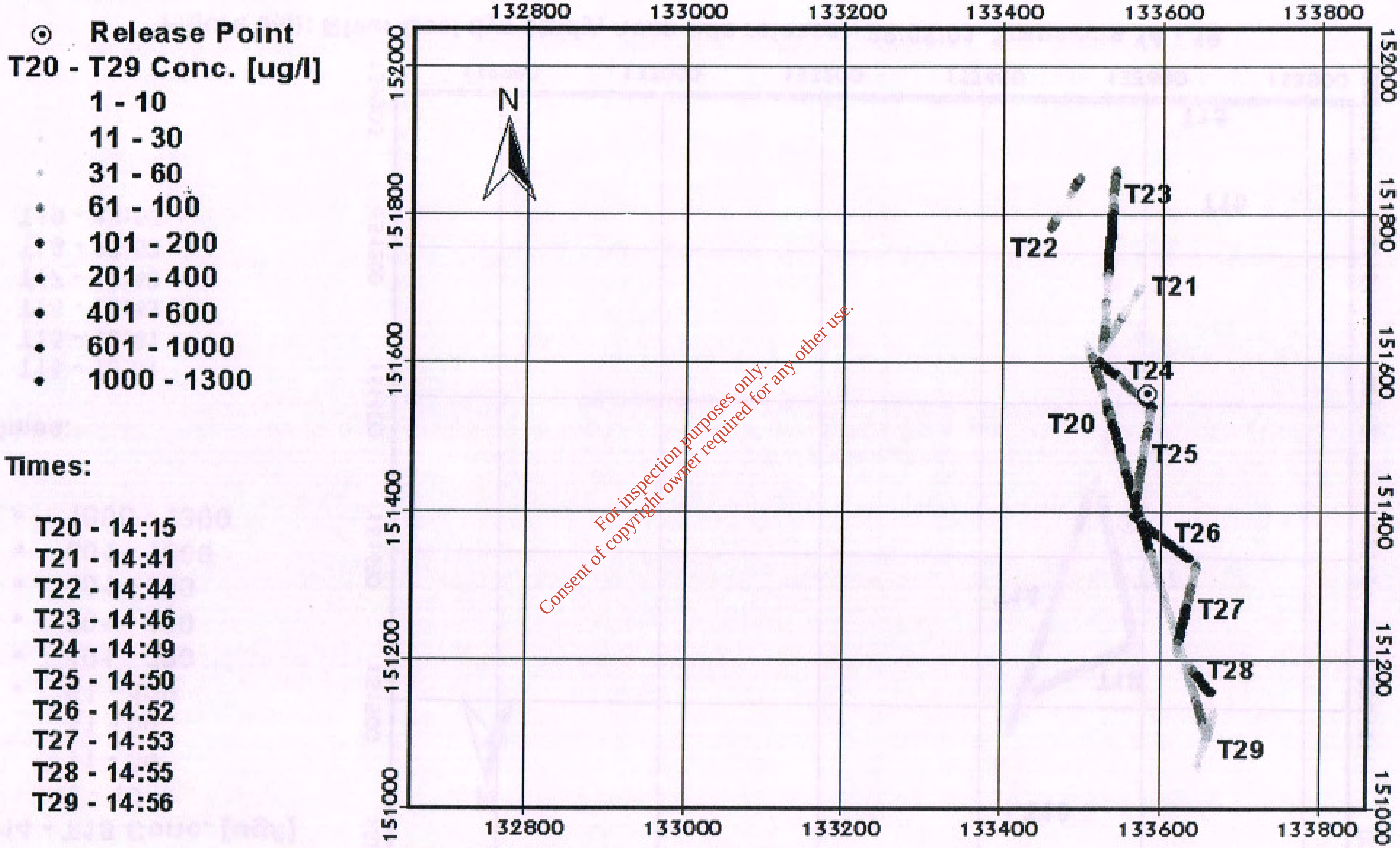


Figure 3(d): River Deel dye study, neap tide release - 28/08/01. Transects 20 - 29.

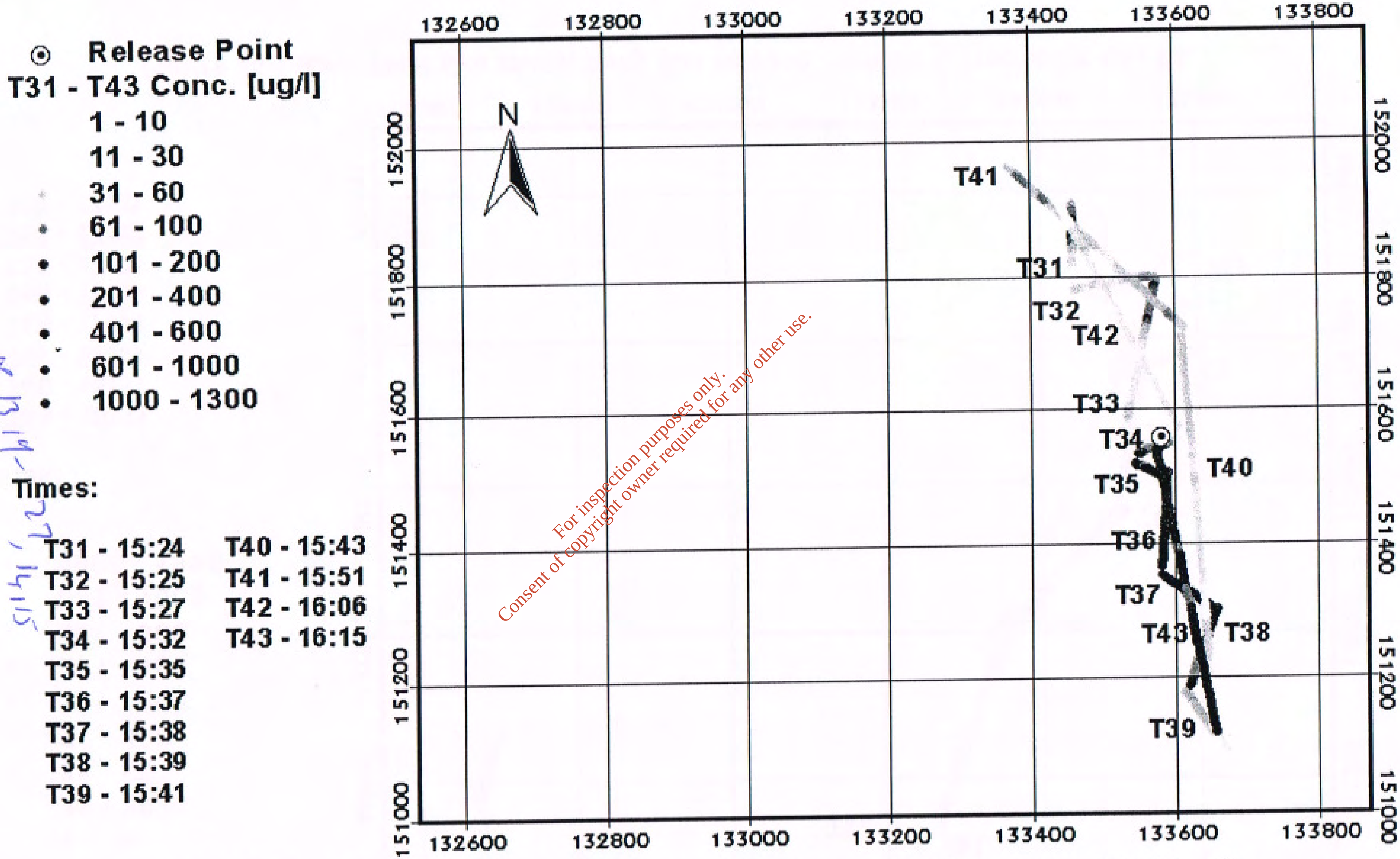


Figure 3(e): River Deel dye study, neap tide release - 28/08/01. Transects 31 - 43.

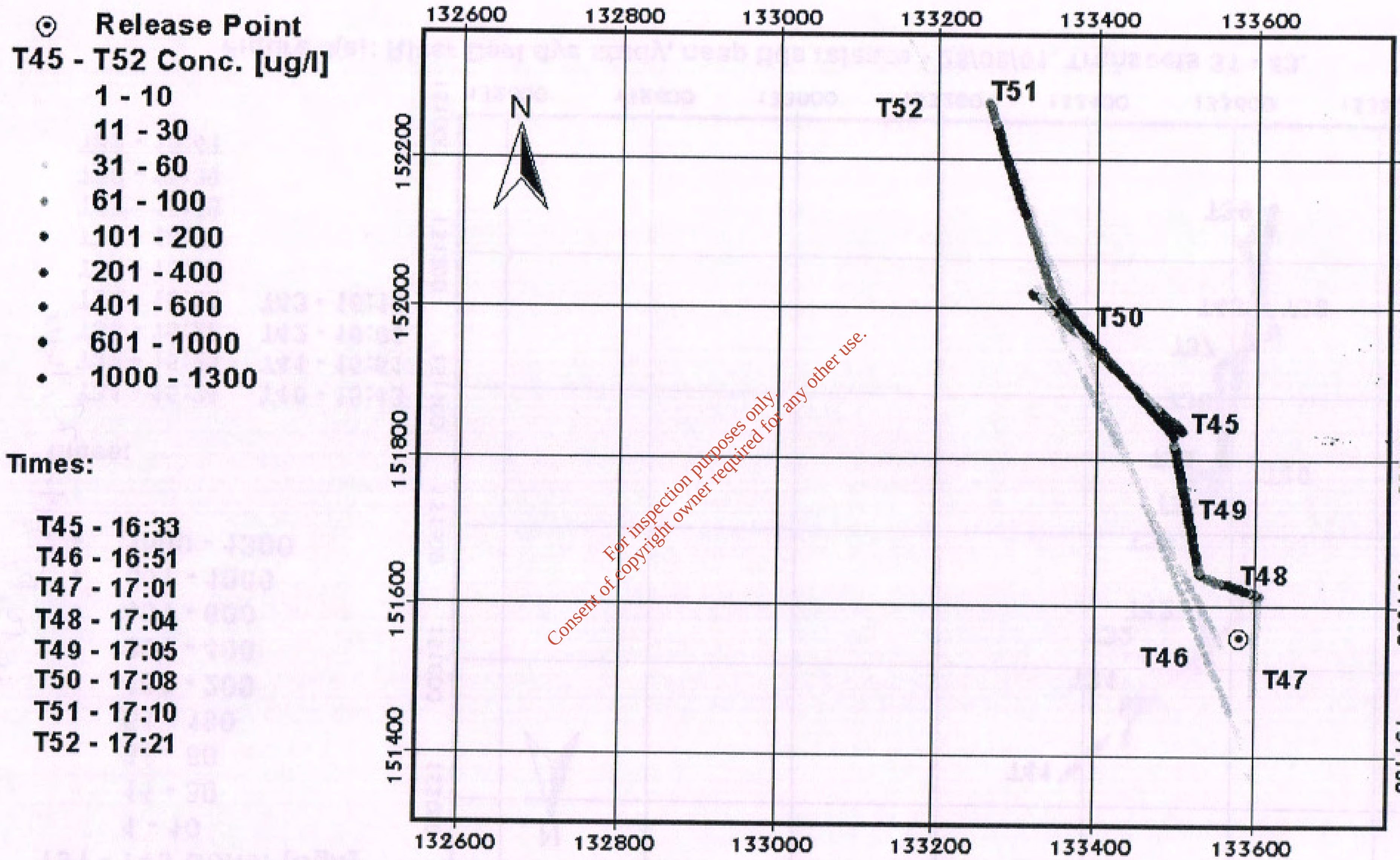


Figure 3(f): River Deel dye study, neap tide release - 28/08/01. Transects 45 - 52.

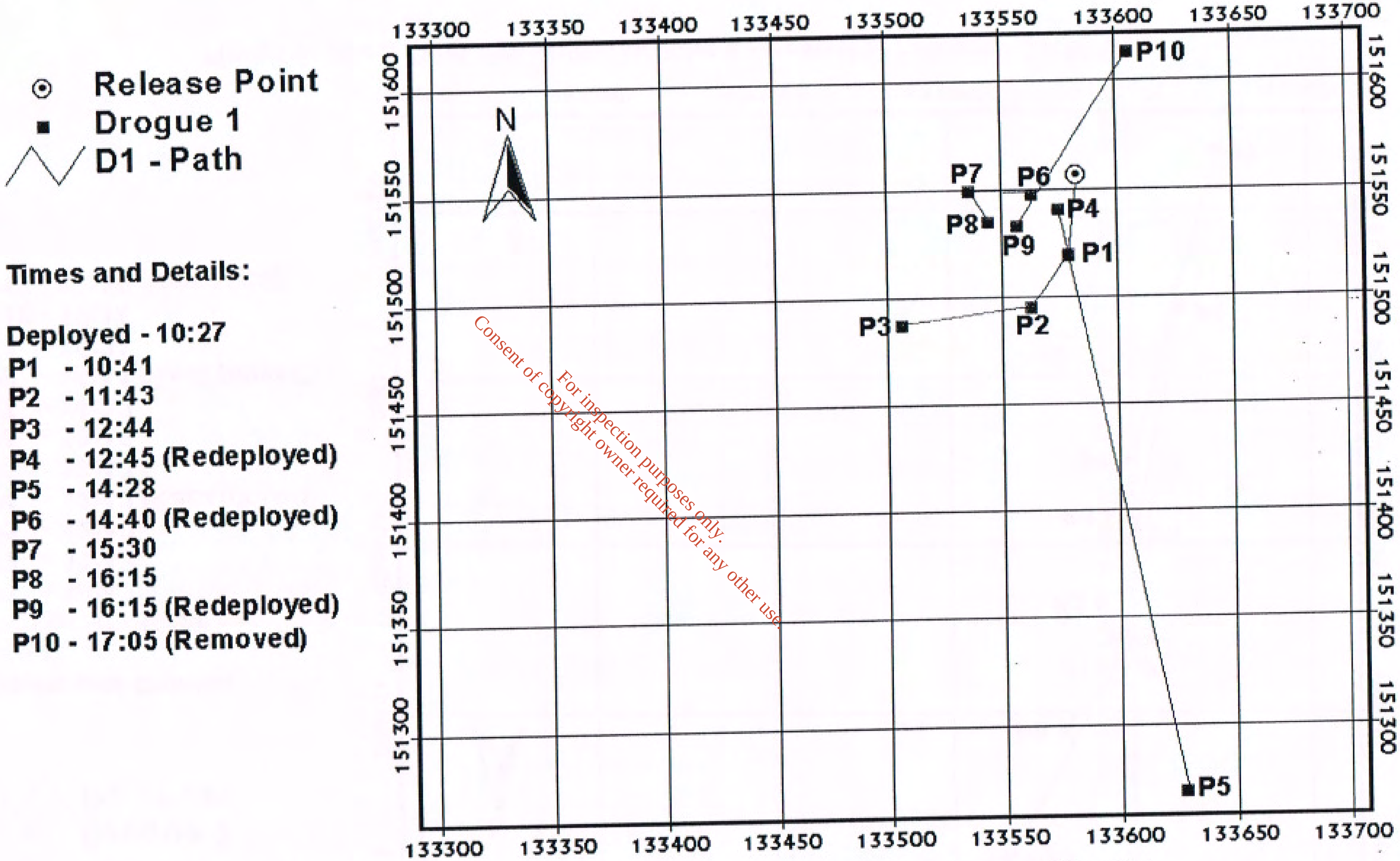


Figure 4: River Deel dye study, drogue 1 - neap tide release - 28/08/01

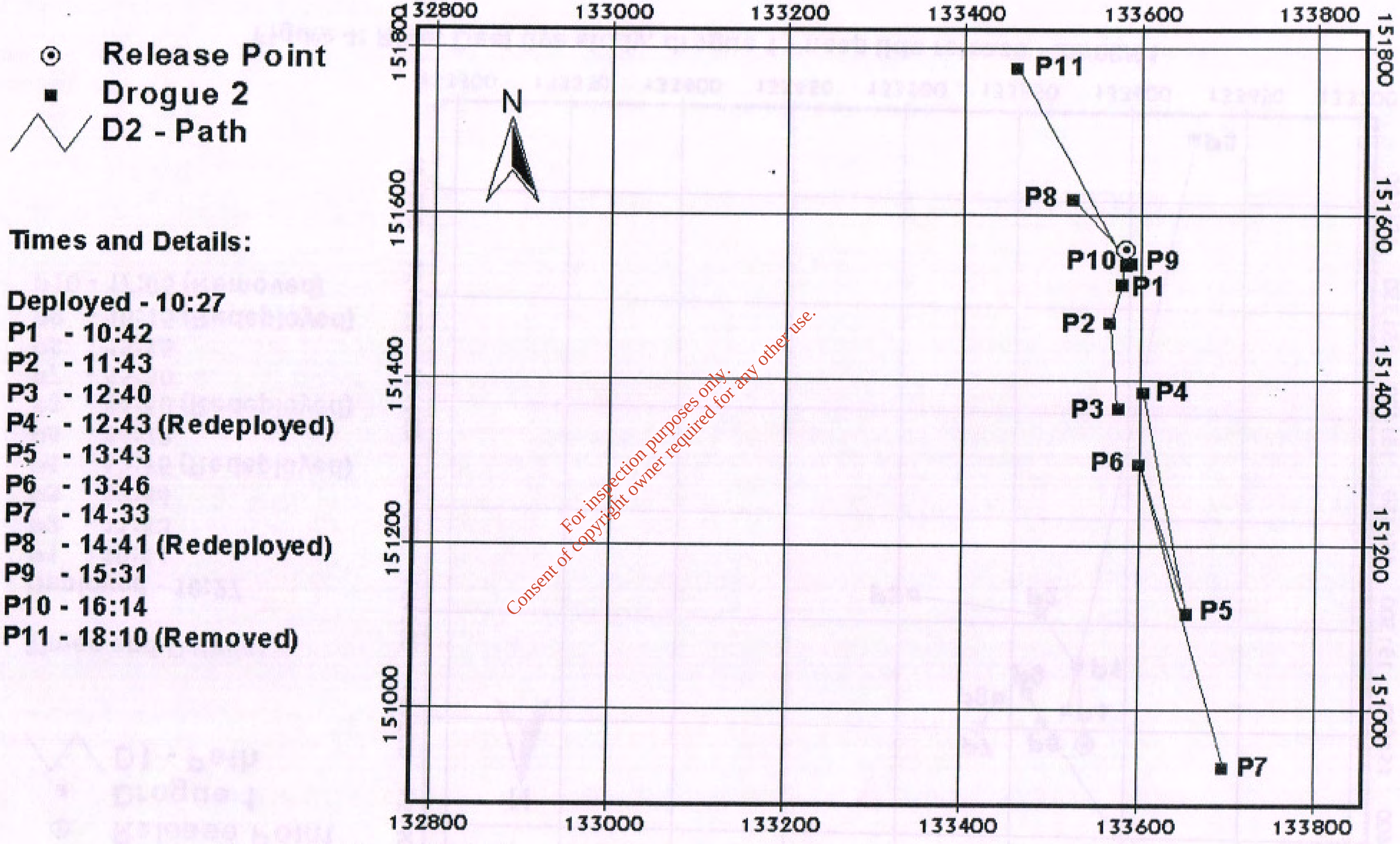


Figure 5: River Deel dye study, drogue 2 - neap tide release - 28/08/01.

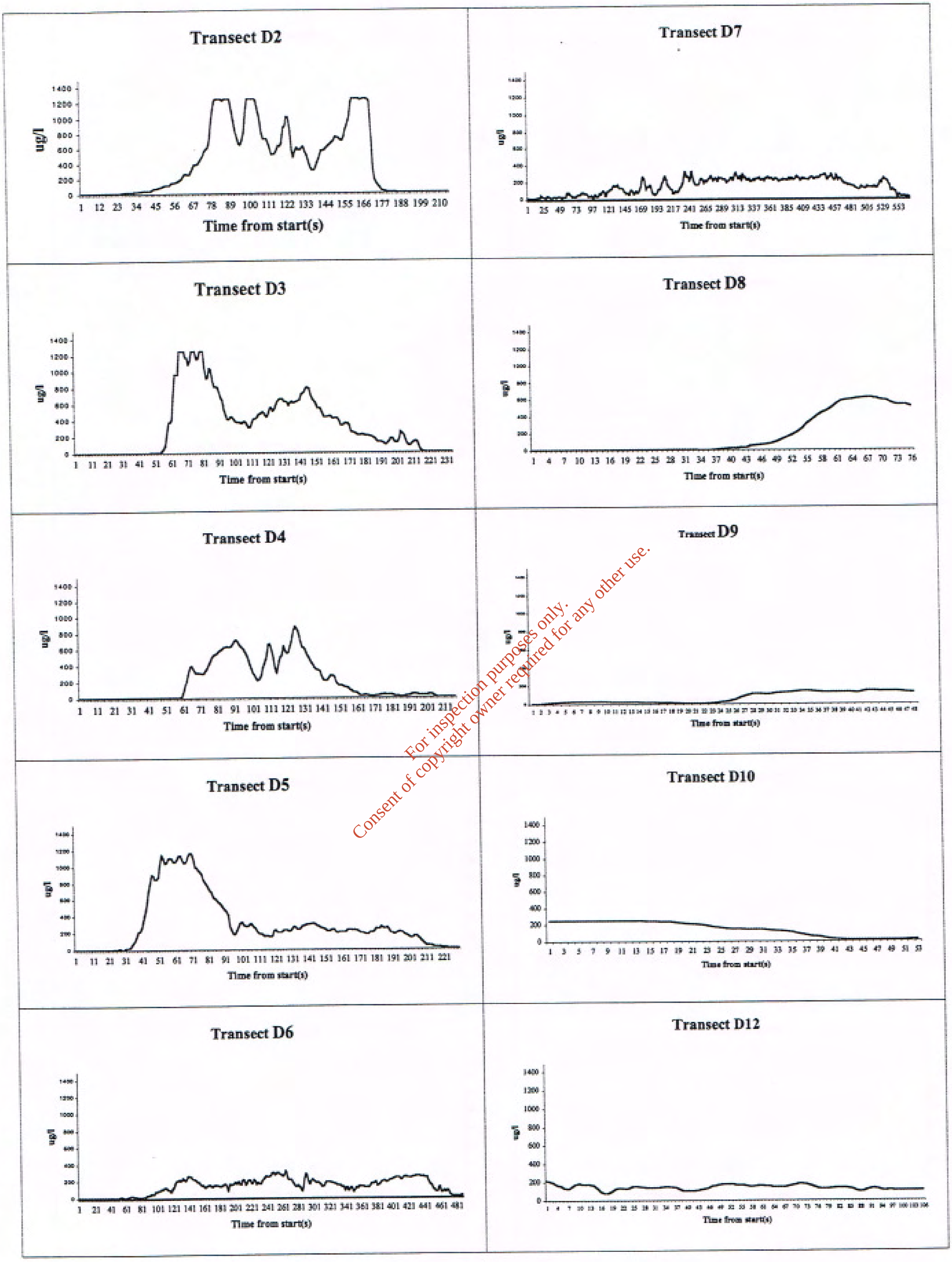


Figure 6. Dye concentrations recorded during each transect, River Deel, 5-9-01

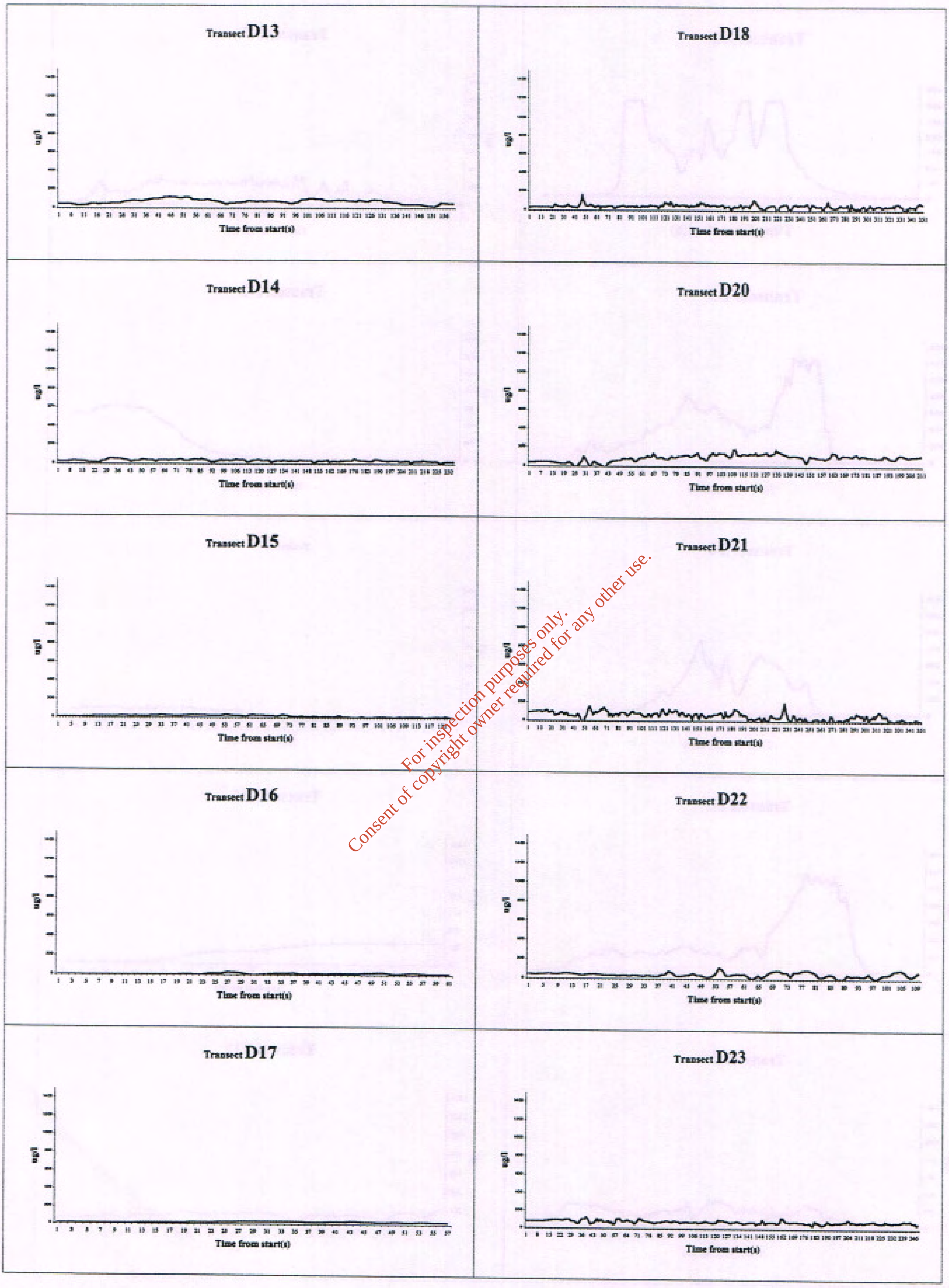


Figure 6. Continued

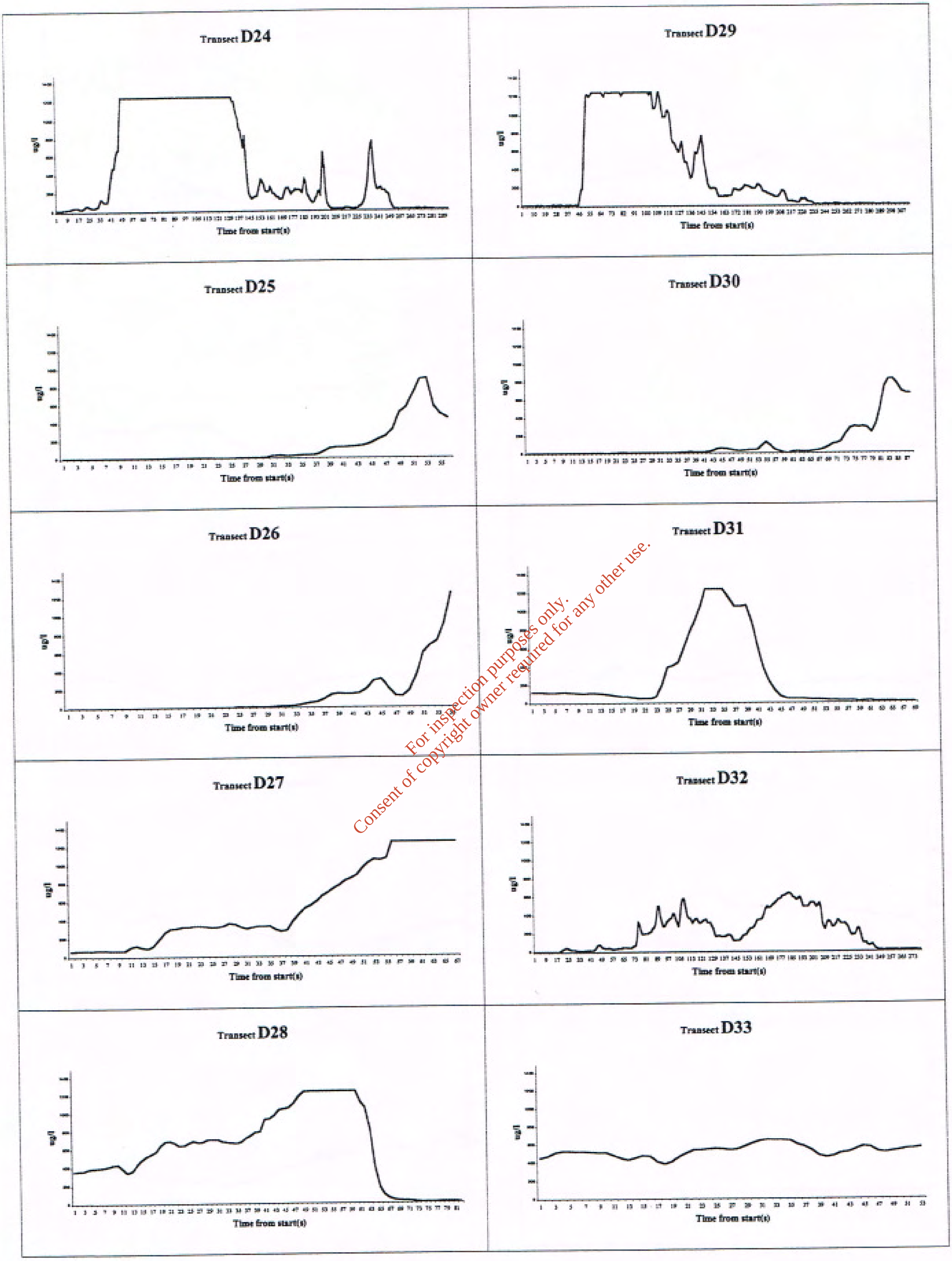


Figure 6. Continued

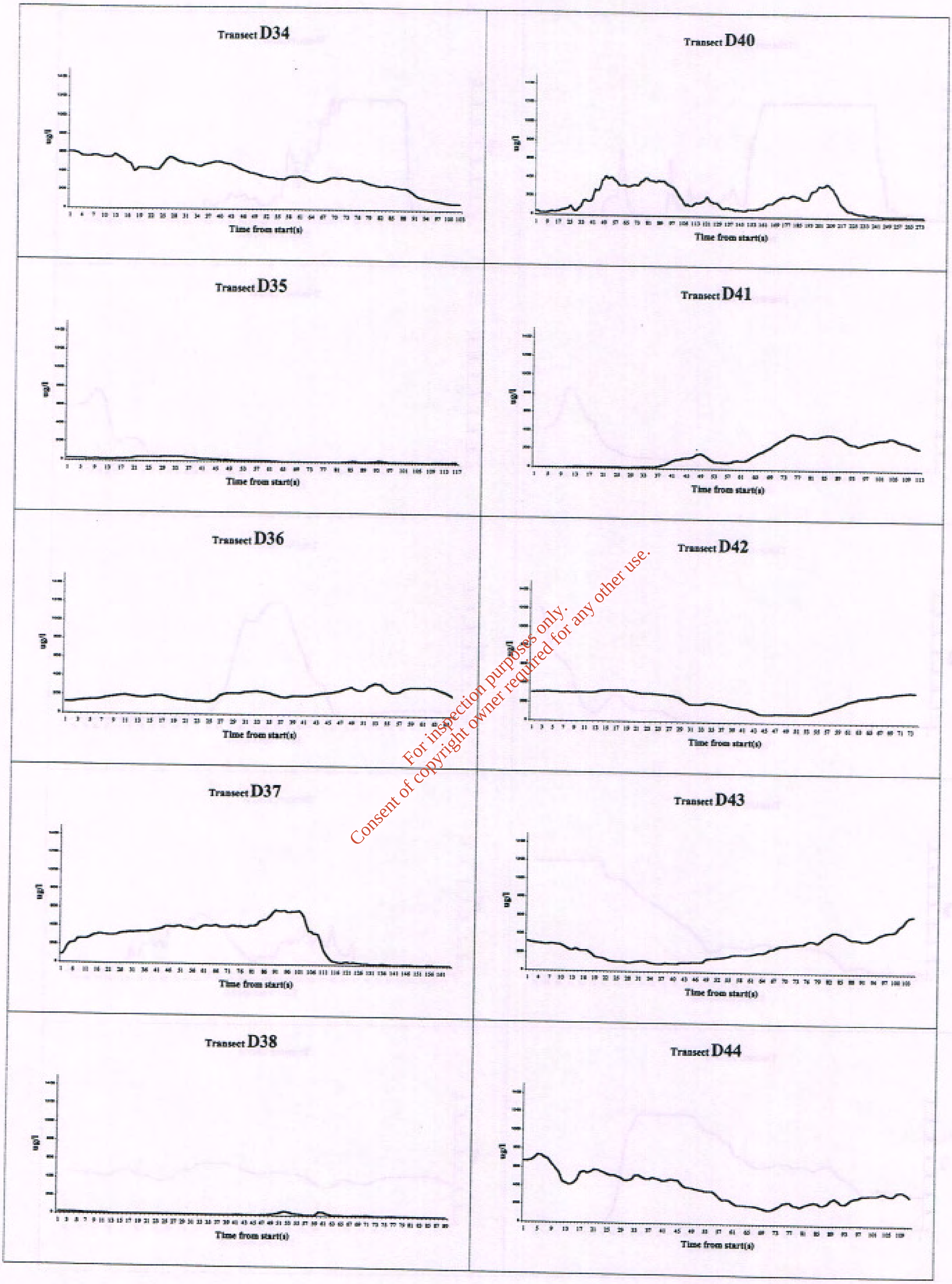


Figure 6. Continued

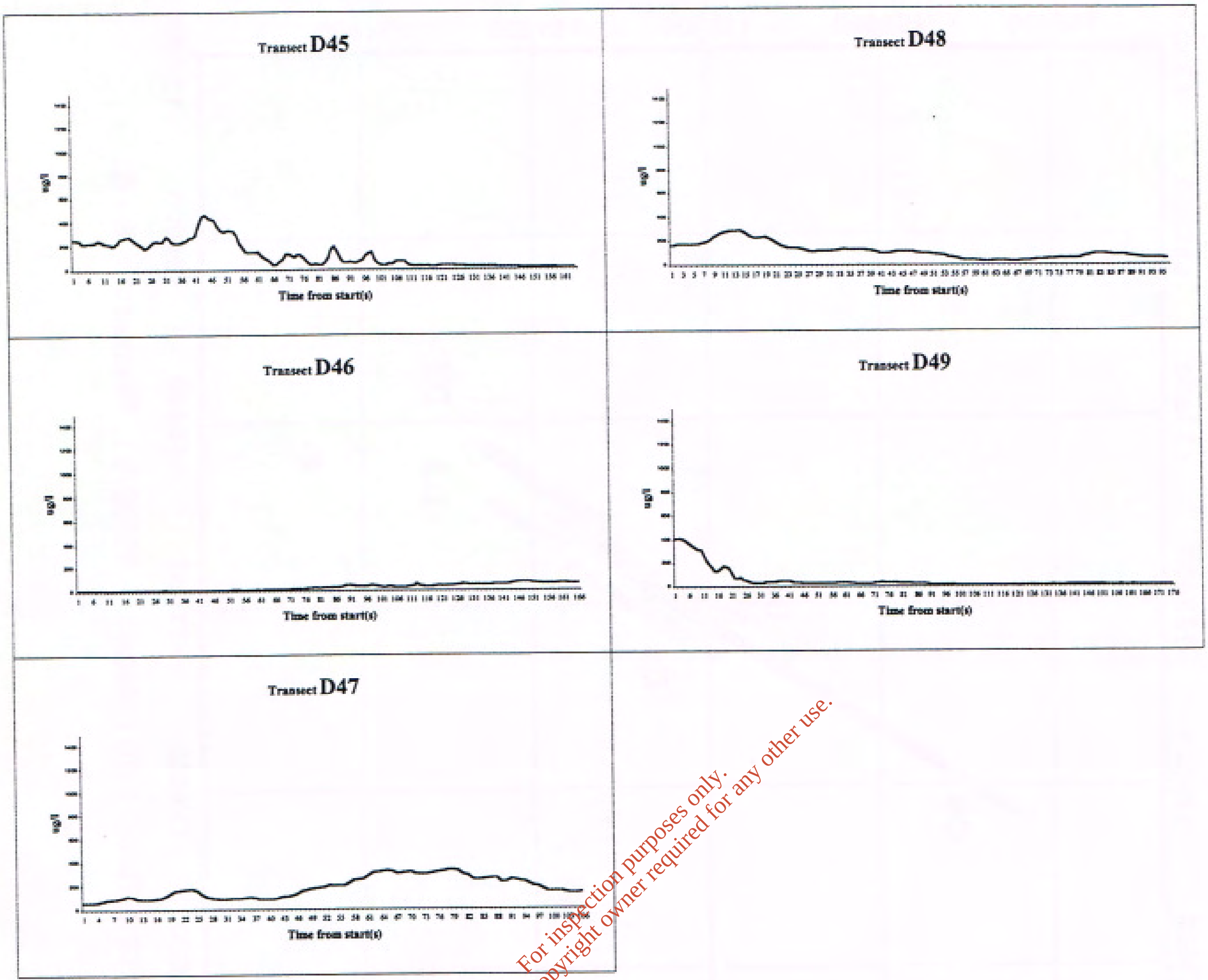


Figure 6. Continued

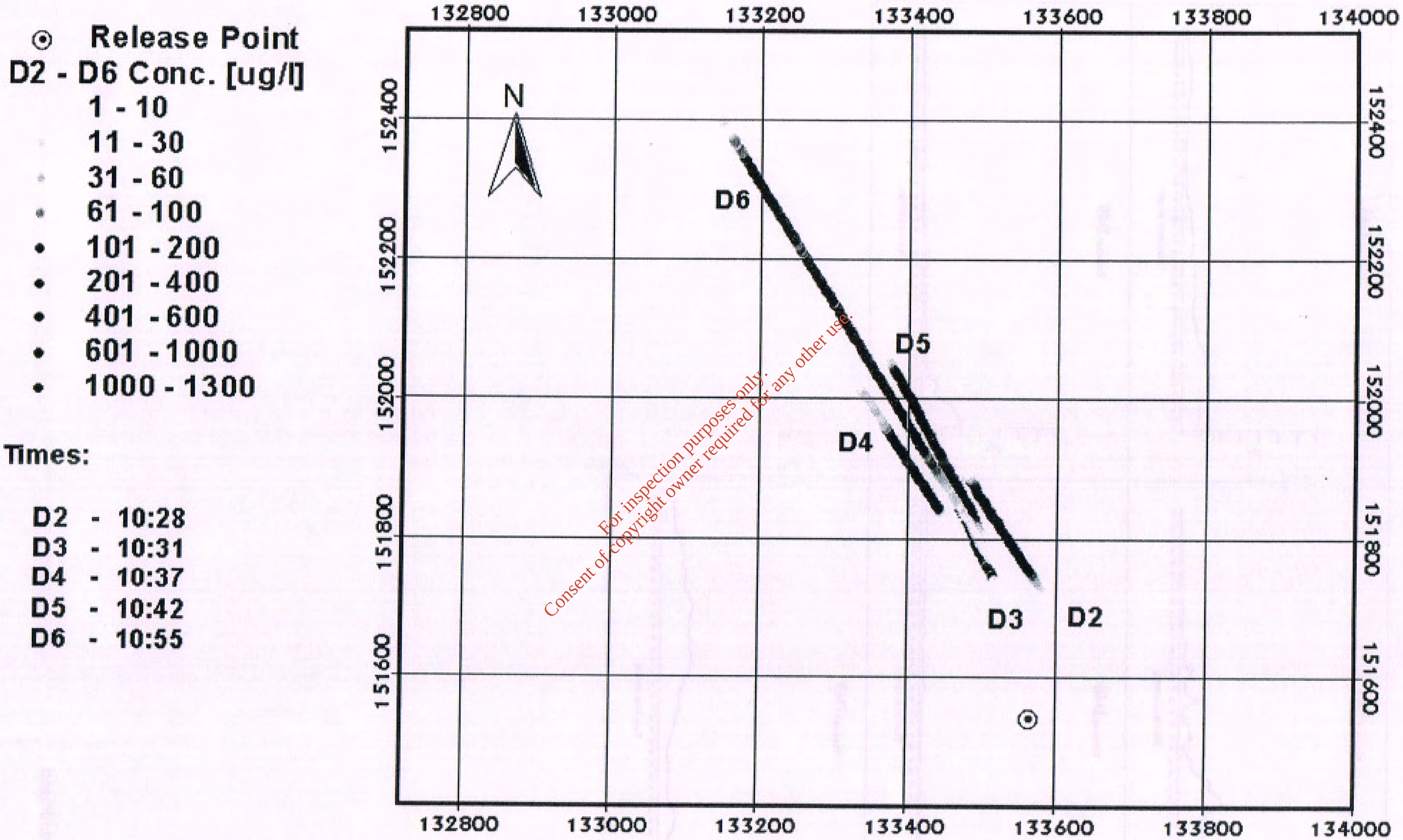


Figure 7(a): River Deel dye study, spring flood tide release - 05/09/01. Transects 2 - 6.

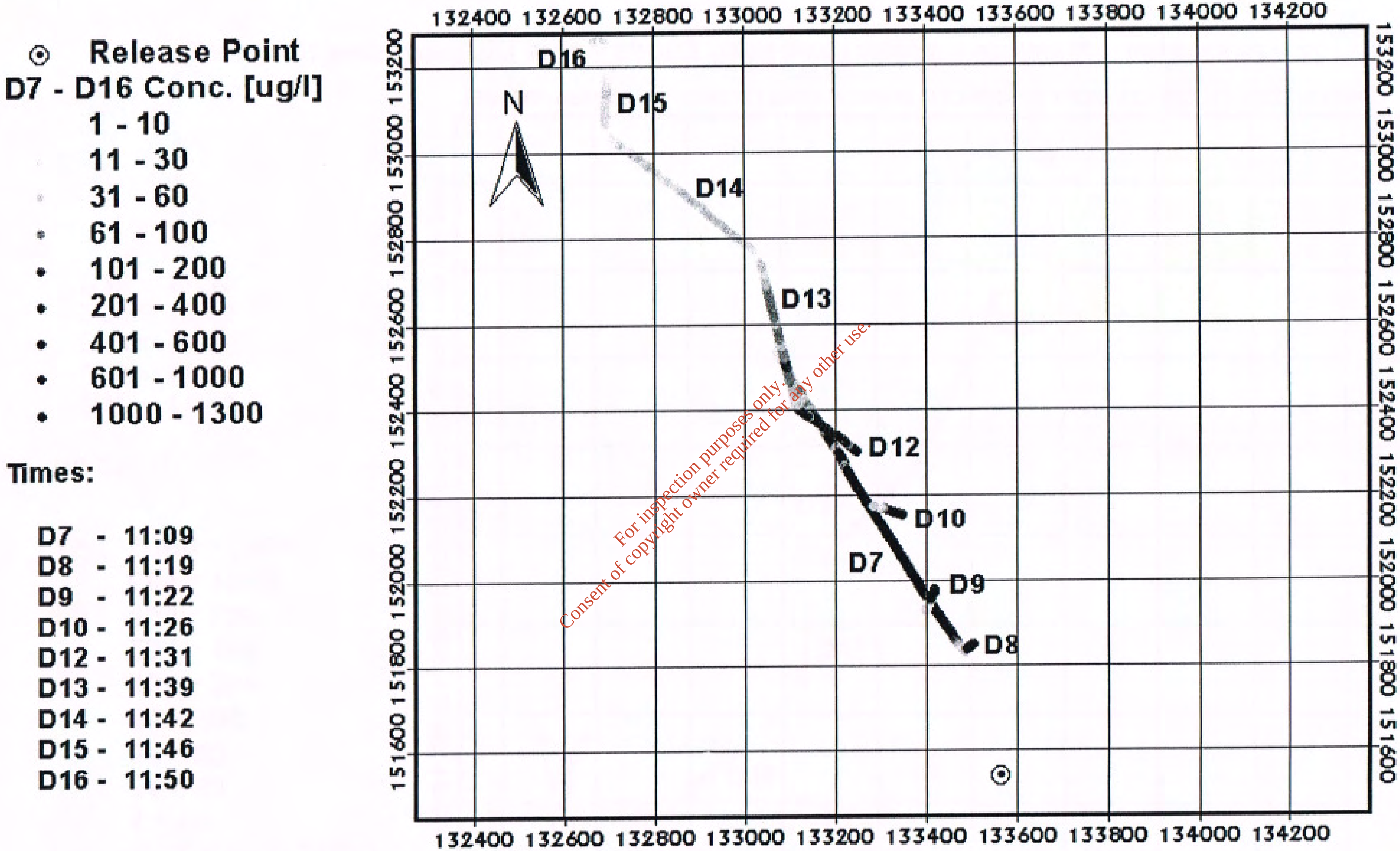


Figure 7(b): River Deel dye study, spring flood tide release - 05/09/01. Transects 7 - 16.

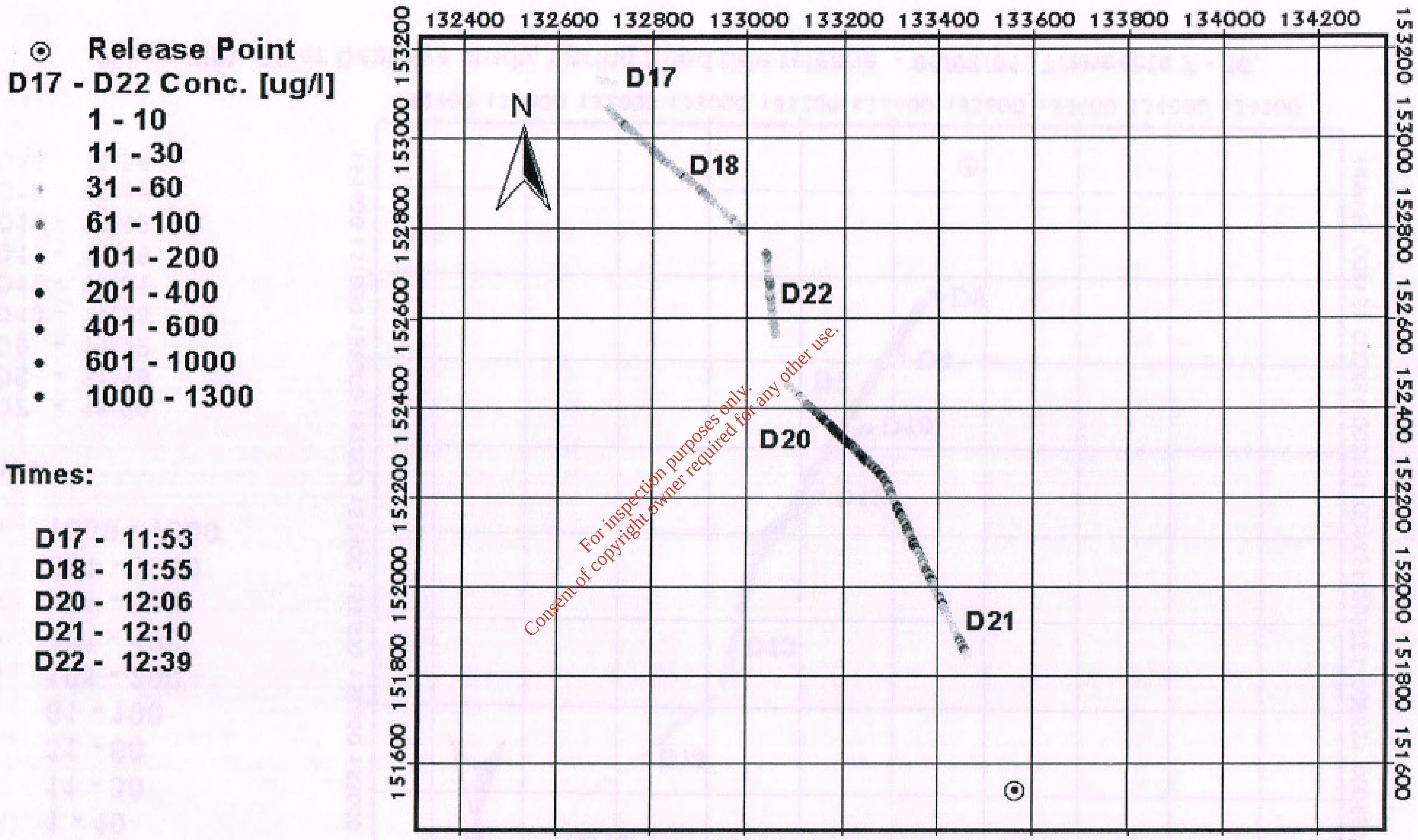


Figure 7(c): River Deel dye study, spring flood tide release - 05/09/01. Transects 17 - 22.

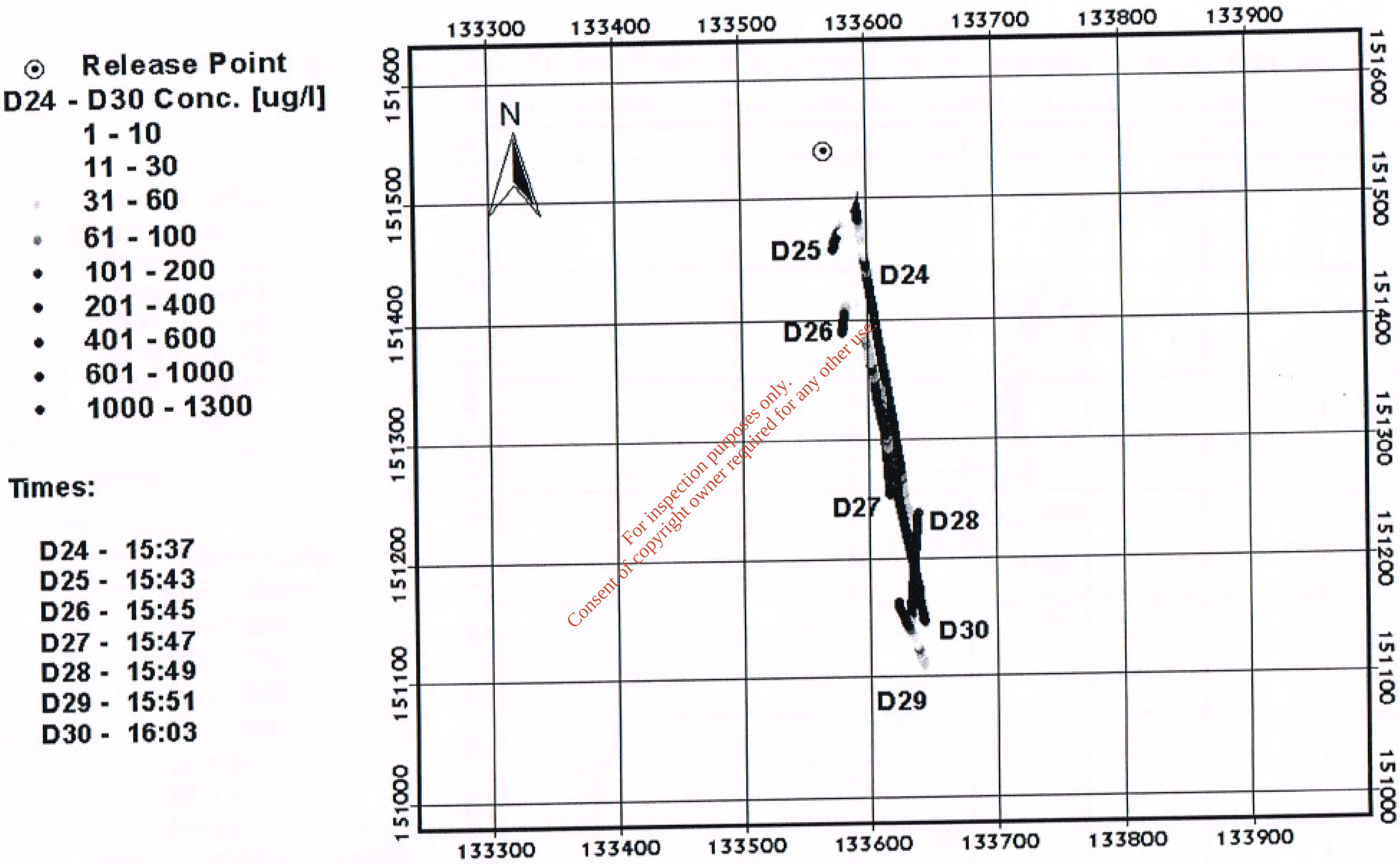


Figure 7(d): River Deel dye study, spring ebb tide release - 05/09/01. Transects 24 - 30.

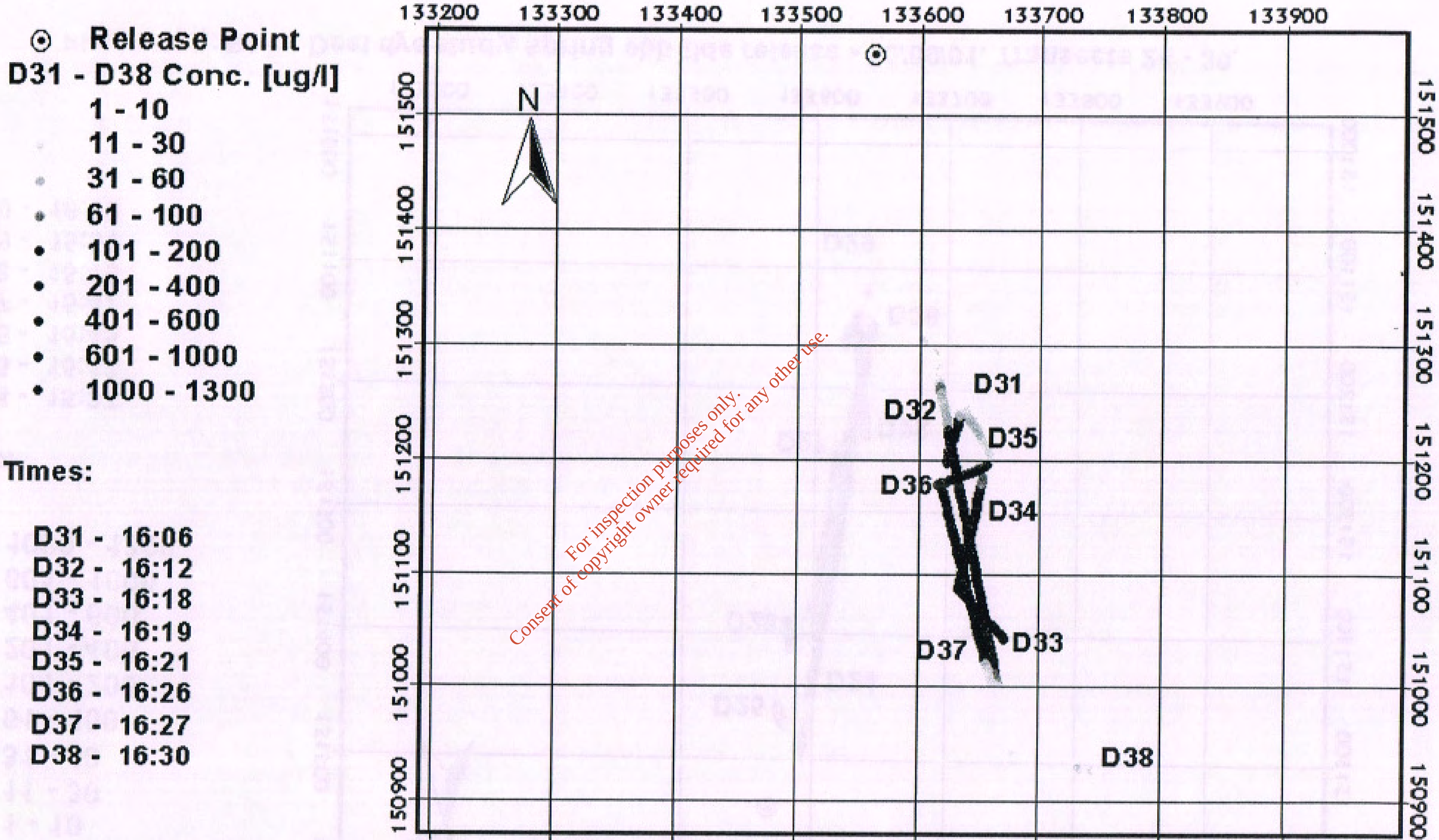


Figure 7(e): River Deel dye study, spring ebb tide release - 05/09/01. Transects 31 - 38.

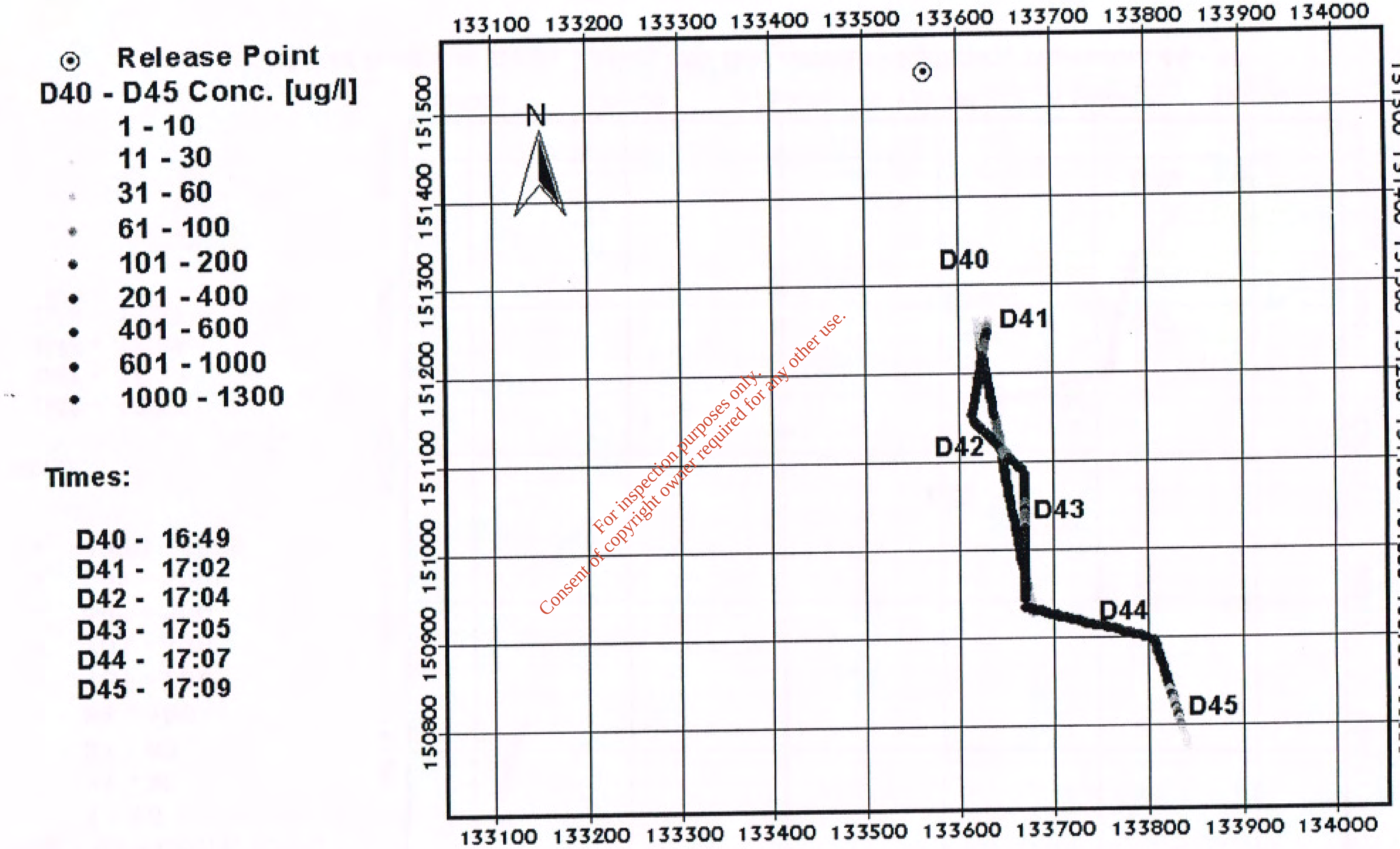


Figure 7(f): River Deel dye study, spring ebb tide release - 05/09/01. Transects 40 - 45.

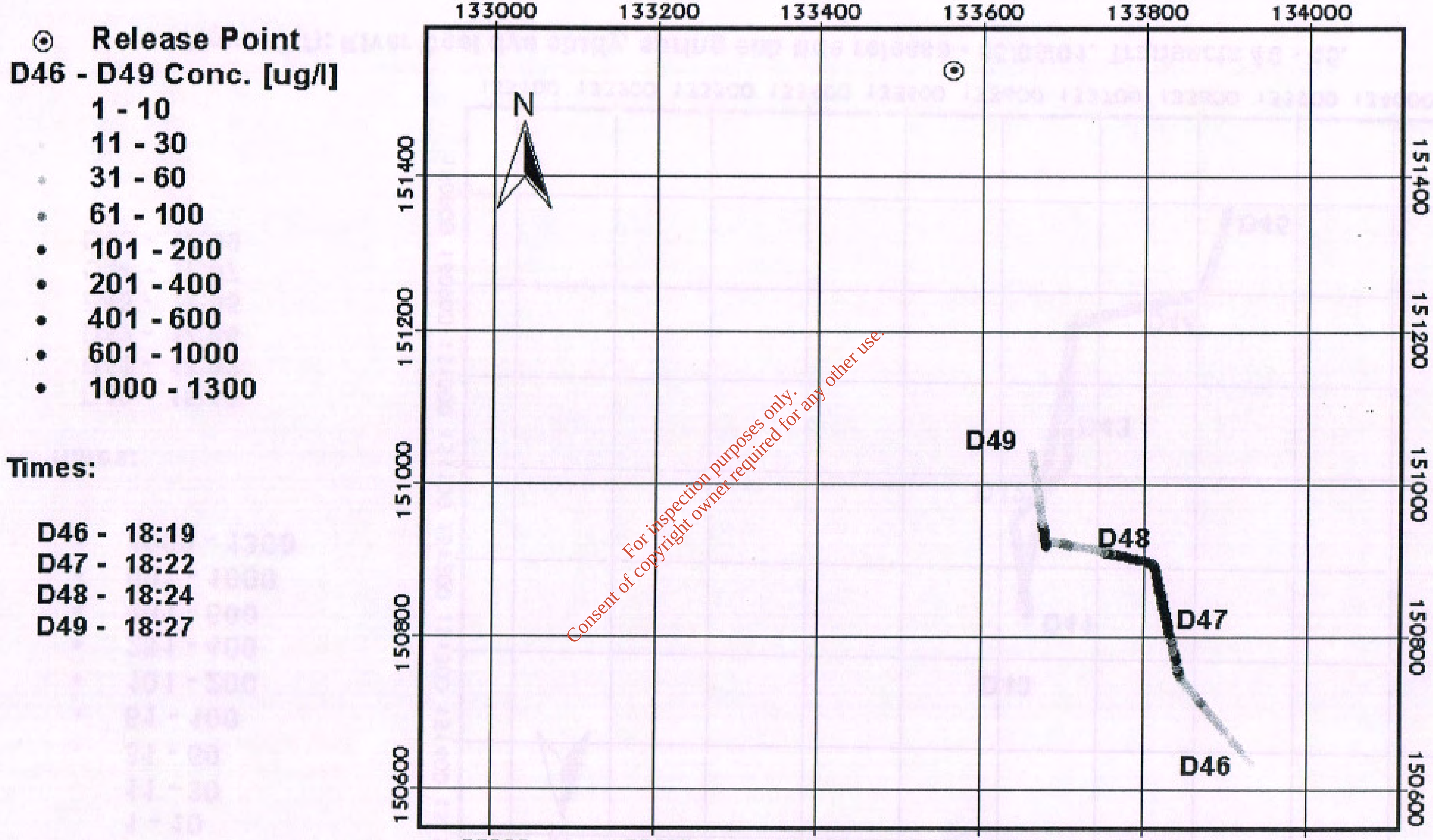


Figure 7(g): River Deel dye study, spring ebb tide release - 05/09/01. Transects 46 - 49.

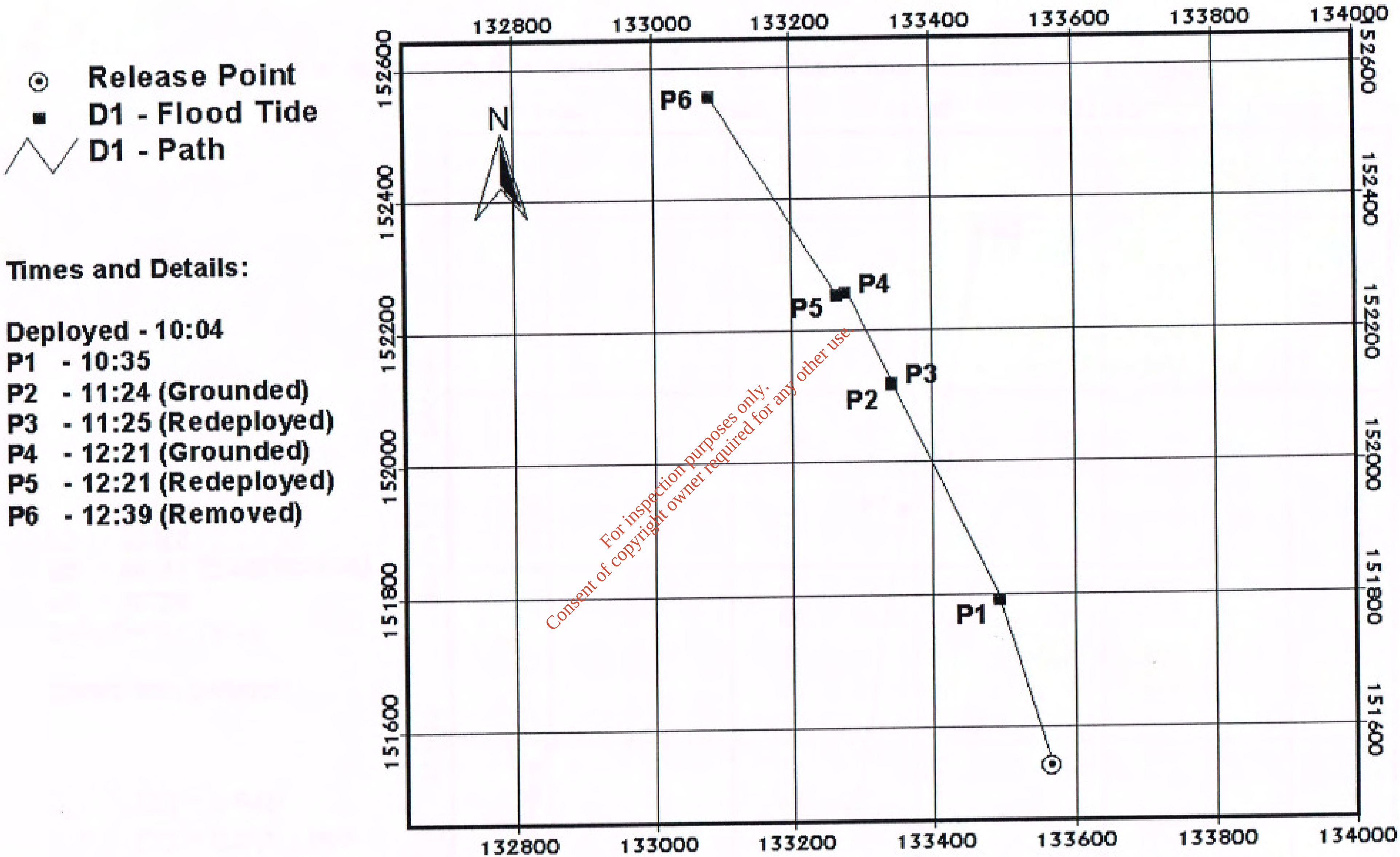
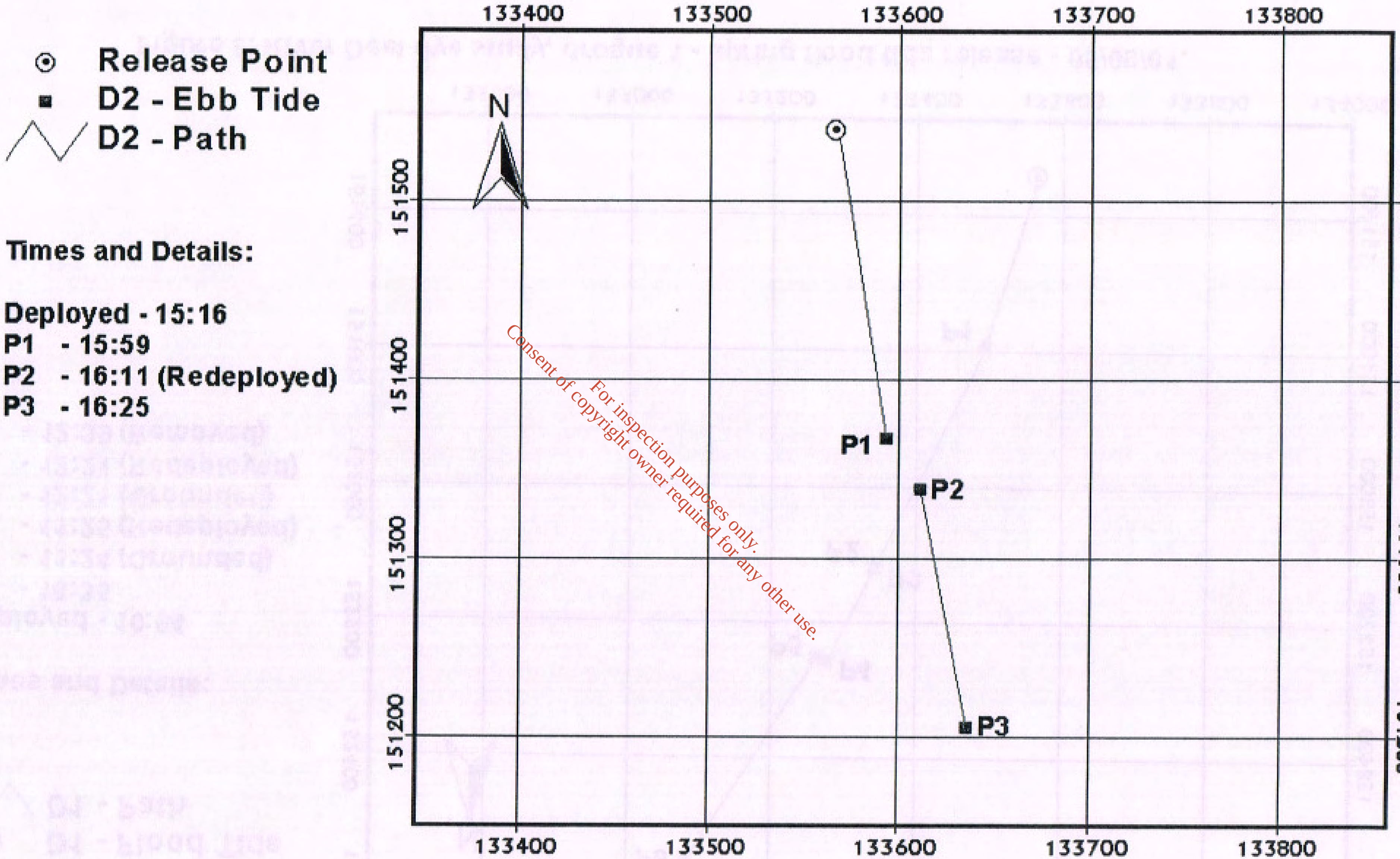


Figure 8: River Deel dye study, drogue 1 - spring flood tide release - 05/09/01.



Times and Details:

Deployed - 15:16
P1 - 15:59
P2 - 16:11 (Redeployed)
P3 - 16:25

Figure 9: River Deel dye study, drogue 2 - spring ebb tide release - 05/09/01.

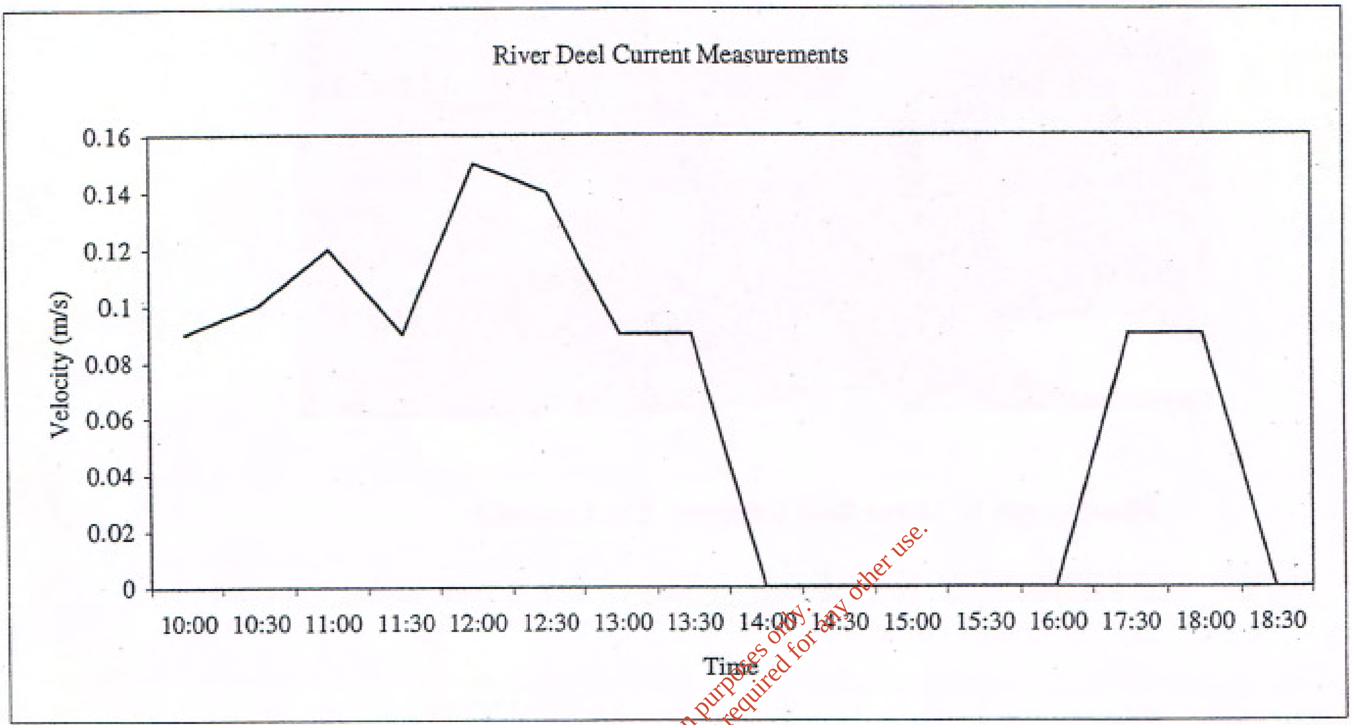
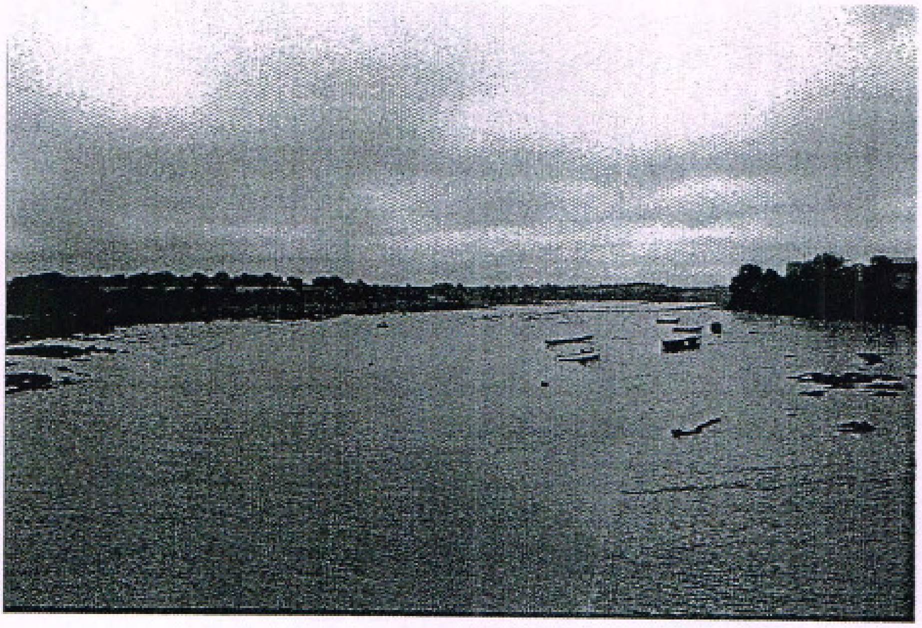
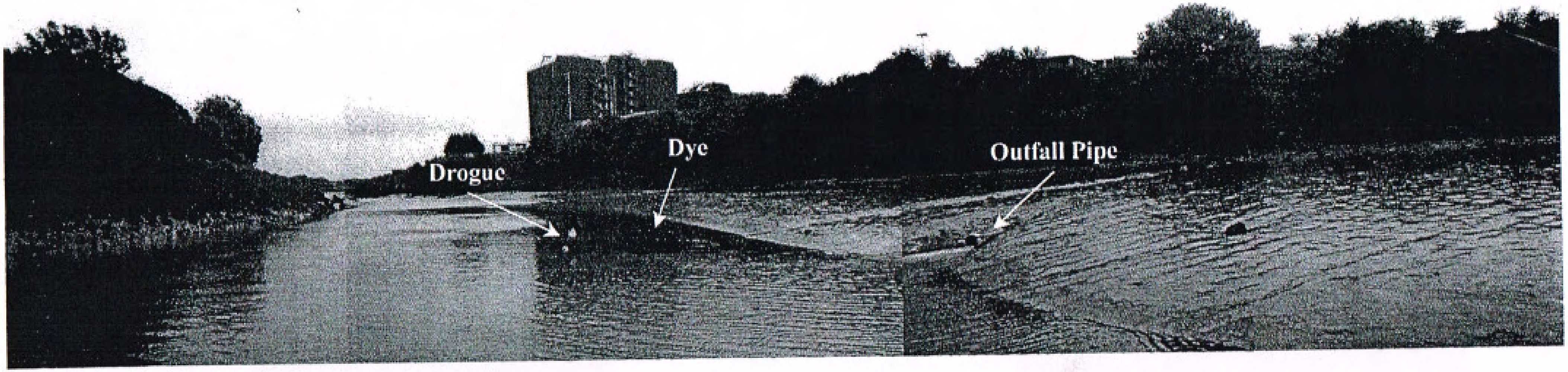


Figure 10. Current measurements recorded in the River Deel Estuary, 5-9-01.

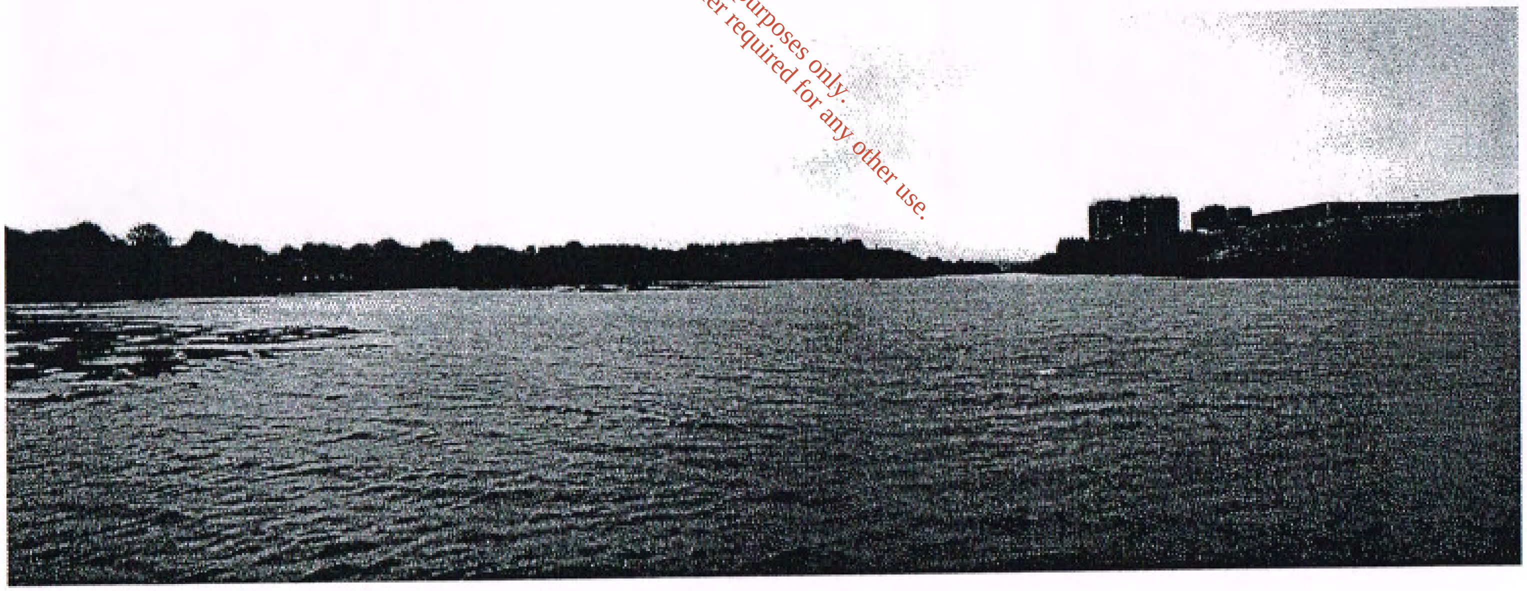
Photograph 1. River Deel Estuary, Co. Limerick



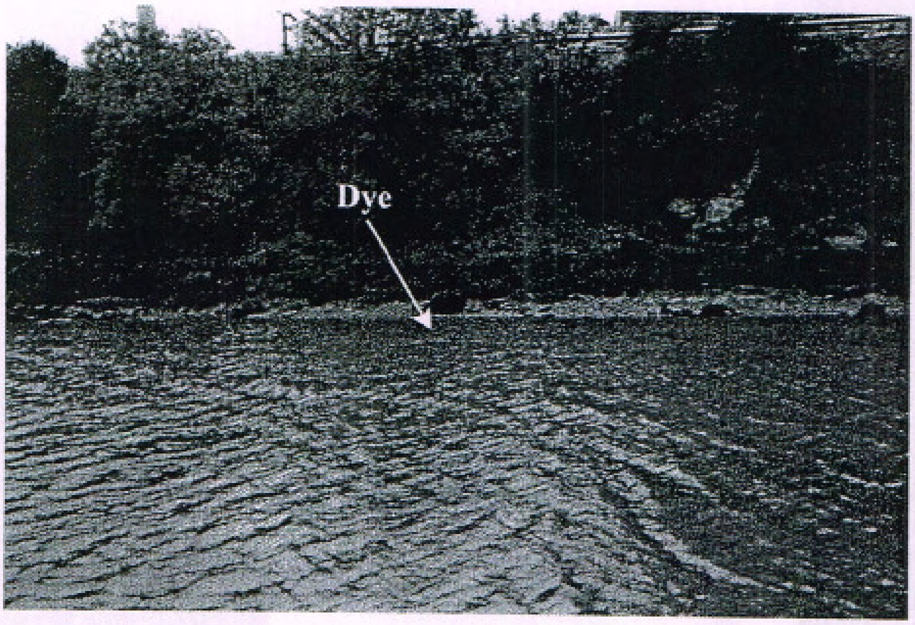
Photograph 2. River Deel Estuary, Co. Limerick



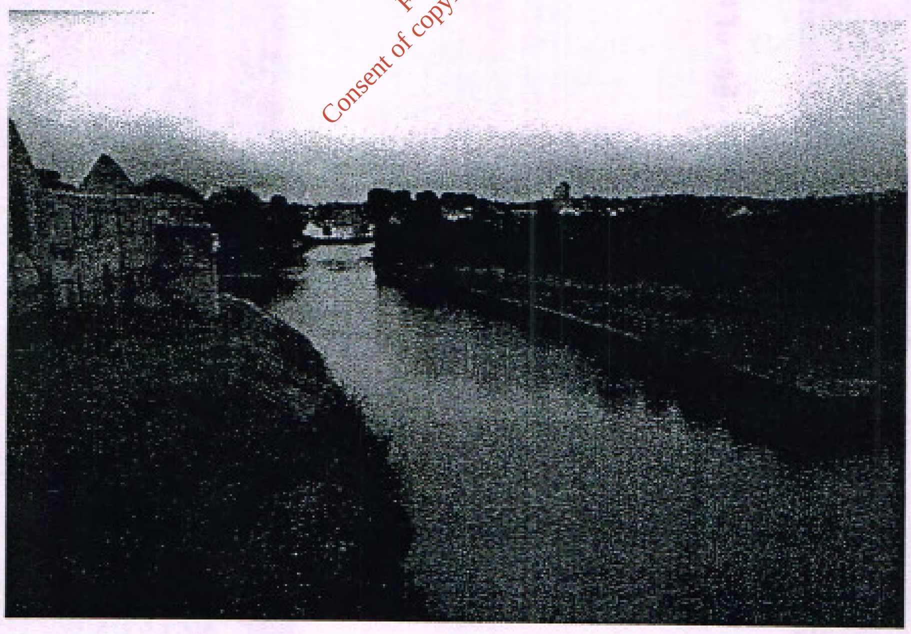
Photograph 3. Wide angle shot of the outfall location and Deel Estuary looking south



Photograph 4. Deel estuary, looking towards the Wyeth Plant, shortly after high water.



Photograph 5. Dye movement in Deel Estuary..



Photograph 6. Asketon, river Deel, Co Limerick

Appendix E – Estuary Salinity Levels

57 Deel Estuary

	Summary S	Salinity	Temp (°C)	pH	Secchi (m)	DO sat. (%	DO (mg/l)	BOD (mg/l)	TON (mg/l)	NH_3 (mg/l)	DIN (mg/l)	MRP (µg/l)	Chl. a (µg/l)
Winter	MINIMUM	0.29	4.34	8.0	0.2	87.3	9.7	< 2	0.51	0.01	0.540	6	0.2
	MEDIAN	0.41	7.50	8.1	0.2	101.0	11.2	< 2	2.26	0.04	2.310	25	1.9
	MAXIMUM	20.22	9.90	8.3	0.2	111.7	11.9	2.0	2.95	0.12	2.955	46	4.2
	No. of sam	*14*	*17*	*17*	*2*	*17*	*9*	*11*	*17*	*17*	*17*	*17*	*8*
Summer	MINIMUM	< 0.10	11.83	7.9	0.5	84.7	7.1	< 2	0.11	0.01	0.130	2	0.2
	MEDIAN	3.20	16.11	8.1	0.7	100.1	9.3	< 2	0.97	0.03	1.010	75	2.5
	MAXIMUM	27.01	18.90	8.6	1.3	153.5	15.2	7.0	1.96	0.20	1.970	190	30.8
	No. of sam	*39*	*41*	*40*	*6*	*41*	*30*	*19*	*40*	*40*	*40*	*40*	*36*