Environmental Protection Report

IMPACT ASSESSMENT OF ACIDIC AND METALLIFEROUS POLLUTION IN THE FOWLEY STREAM

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NRA
National Rivers Authority
South West Region

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EXETER

This investigation and report was undertaken by staff of the Freshwater Investigation Team.

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TECHNICAL REPORT No FWI/92/003

SUMMARY

A study was carried out during September 1991 to assess the cause and impact of acidic and metalliferous pollution in the Fowley Stream. The study is part of an overall project to identify and control intermittent acidic and metalliferous discharges in the River Okement Catchment.

The source of poor water quality in the Fowley Stream was traced to a land drainage ditch. Land drainage has allowed the oxygenation of pyrites in the soils which leads to the leaching of acidic and metalliferous water particularly during the first flush of rainfall at the break of a period of drought.

The principal impact of the land drainage ditch on water quality in the West Okement River during rainfall was to increase iron concentrations up to 42,600 ug/l compared to concentrations upstream of the confluence (Environmental Quality Standard = 1,000 ug/l). The impact on other metal concentrations in the West Okement River was masked by poor water quality upstream thought to result from discharges from Meldon Quarry.

Acidic and metal pollution in the Fowley Stream is comparable to similar pollution recorded in the Brightley Stream. Metal concentrations other than iron were probably not as high in the Fowley Stream as those detected in the Brightley Stream because of the absence of mineral sulphides other than pyrites.

It is recommended that the contents of this report are discussed with the landowner to secure quality improvements. Possible options include, filling the land drains and ditch or creating a reed bed in the land drainage ditch.

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Aerial Photograph of the Fowley Catchment.

Iron ochre deposits in the land drainage ditch.

Land drain entering the land drainage ditch.

CONTENTS.

IMPACT ASSESSMENT OF ACIDIC AND METALLIFEROUS POLLUTION IN THE FOWLEY STREAM.

1. INTRODUCTION.

The 'Acid Waters Project' in the River Okement Catchment has identified acidic and metalliferous pollution occurring in the Fowley Stream (Ref.1).

This study sets out to:

1. to assess the cause of acid and metalliferous pollution in the Fowley Stream.

2. to assess the impact on water quality in the West Okement River.

2. STUDY AREA.

The Fowley Stream flows for 1.8 km before entering the West Okement River downstream of Meldon Quarry in the River Torridge catchment (see Fig. 1). Manor House Stream (1.1 km) is a tributary of the Fowley Stream.

The Fowley Catchment covers an area 1.8 km^2. Land use is dominated by permanent pasture under the ownership of Hughslade Farm. A large hotel complex is located at the source of Manor House Stream. A disused mine shaft is shown on OS maps at the top of the Fowley Stream. No licensed discharges or abstractions exist in the catchment.

The catchment is underlain by the sands and shales of the Crackington Formation. Crystallised pyrites (FeS_2) is the principal mineral present in the Crackington Formation. Mineral sulphides such as chalcopyrite ($CuFeS_2$) are not thought to be present (pers. comm G. Nichols). However, metals such as copper, nickel and zinc are present in the geology since they can proxy for iron in pyrites. The geology is therefore quite different to that underlying the Brightley Stream catchment where serious acidic and metalliferous pollution has previously been identified (Ref. 2).

2.1. River Quality Objectives.

The Fowley Stream has not been assigned a specific River Quality Objective (RQO), but it does discharge into the West Okement River, which has a RQO of National Water Council (NWC) Class 1A.

2.2. River Uses.

The National Rivers Authority - South West (NRA-SW) have continued to use the following use-related Environmental Quality Objectives for the West Okement River which were adopted in 1986:

* Protection of Aesthetic Quality
* Protection of Direct Abstraction for Potable Supply
* Protection of Salmonid Fish

* Protection of Other Aquatic Life/Dependent Organisms
* Protection of Livestock Watering
* Protection of Irrigation of Crops

The Environmental Quality Standards (EQS's) applicable for the Fowley Stream and the West Okement River were equal to the strictest use-related standards (see Table 1).

TABLE 1. EQS's applicable in this report.

Determinand	EQS (in ug/l)		EC Directive
pH	6.0	(5%ile)	Freshwater Fish
Total Zinc	30*	(95%ile)	" "
Dissolved Nickel	50	(annual mean)	" "
Dissolved Copper	5*	(95%ile)	" "
Total Cadmium	5	(95%ile)	Surface Water Abstraction
Total Iron	1000	(annual mean)	Dangerous substances
Dissolved Aluminium	100	(95%ile)	Tentative EQS adopted by NRA-SW

* <50mg/l hardness

Dissolved concentrations of zinc and cadmium were compared with the EQS's for these metals although they specify total concentrations. The limits of detection for zinc and cadmium (total concentrations) had been set too high and were above the EQS's due to a mistake in the coding of the samples for analysis.

3. METHODS.

Biological and chemical surveys were carried out to identify the cause and impact of the metalliferous problems in the Fowley Stream.

3.1. Cause of metalliferous pollution.

Following a visual site assessment, 10 sites were chosen for investigation (see Figure 1).

Manual spot water samples were taken on 13 September 1991 at these 10 sites and analysed for total and dissolved metals, pH and hardness. Samples taken for dissolved metal analysis were filtered on site. pH, temperature and dissolved oxygen were recorded in situ with WTW OXI 196 and pH 196 meters.

An aquatic macroinvertebrate survey was carried out on 11 September 1991 and consisted of a 1 minute kick sample in a riffle area of the site with riverside examination, followed by a further 2 minute kick sample, which was combined with the 1 minute sample giving the 3 minute sample for laboratory sorting and identification.

3.2. Impact of metalliferous pollution.

Heavy rainfall following a drought in the West Okement River has previously caused episodic pollution resulting in fish kills.

Therefore the chemical survey was repeated on 28 September 1991 during the first high flows following a period of drought in order to assess the likely maximum impact. Four repeat chemical surveys, involving sites 1, 2, 3 and 6, were undertaken on 28 and 29 September 1991 to characterise the nature and impact of the pollution over the rainfall event.

A biological sample (1 minute kick) was taken in the Fowley Stream at site 6 after the rainfall event on 30 September 1991. The sample was examined in the field to assess mortality and any gross changes in abundance or diversity compared to the initial baseline survey. A further field sample was taken on 15 October 1991 to assess change over a longer period of time. If significant differences had been found then more detailed biological assessment would have been undertaken.

A pHOX 47 Series pH meter was installed within the Fowley Stream at site 6 at the start of the high-flow survey.

4. RESULTS.

4.1. Cause of metalliferous pollution.

The visual site assessment indicated a land drainage ditch to be the most likely source of metal and acid pollution in the Fowley Stream.

Chemical surveys.

During low flows slightly higher concentrations of nickel, zinc and iron were recorded downstream of the ditch (site 5) compared with concentrations upstream (site 4). However, these concentrations were within the respective EQS's (see Table 2).

During rainfall on 28 September 1991 pH fell rapidly to below pH 4 in the Fowley Stream and to pH 4.3 in the West Okement River (see Figure 3). High concentrations of zinc (530 ug/l), nickel (150 ug/l), copper (48 ug/l), cadmium (9.2 ug/l), iron (32,600 ug/l) and aluminium (7,100 ug/l), and low pH (pH 3.4) were identified in the land drainage ditch (sites 8 and 9). Significant increases in these metal concentrations to above EQS's (except cadmium) occurred in the Fowley Stream downstream of the ditch (site 5) (see Table 2).

EQS's for pH, zinc, iron and aluminium were also marginally exceeded upstream of the ditch.

Biological surveys.

Twenty macroinvertebrate taxa were present upstream of the land drainage ditch in the Fowley Stream (site 4)(see Figure 2). Mollusca, which are known to be sensitive to acidic and metalliferous pollution, were present in significant numbers at this site. Ephemeroptera and Trichoptera were notably absent (see Appendix I).

Fewer macroinvertebrate taxa were found in the Fowley Stream downstream of the ditch (sites 5, 6 and 7) compared to upstream (site 4). Mollusca were scarce (see Figure 2).

Aquatic macroinvertebrate samples collected from the Manor House Stream had a diverse community structure with a total of 35 taxa, including Ephemeroptera, Trichoptera and Mollusca (see Appendix 1 and Figure 2). Manor House Stream enters the Fowley Stream downstream of the land drains and so has been used as a control (site 10).

4.2. Impact of the acidic and metalliferous pollution

During the first flush of the high-flow survey (i.e. between 08.00 and 09.00 hrs on 28 September 1991) there was a significant increase in iron concentration in the Fowley Stream and in the West Okement River downstream of the Fowley Stream confluence (see Table 3). Increases in concentrations of other metals occurred in the Fowley Stream as rainfall progressed. However, the impact on the West Okement River could not be assessed because EQS's were already exceeded upstream of the Fowley Stream confluence making the contribution from the Fowley Stream difficult to assess. No change in pH was detected up and downstream of the Fowley confluence in the West Okement River.

Metal concentrations in the West Okement River upstream of Meldon Quarry were significantly lower than downstream (see Table 3). The impact of Meldon Quarry has been investigated and reported separately (Ref 1).

No deterioration in the number of macroinvertebrate taxa occurred in the West Okement River downstream of the Fowley Stream confluence (see Appendix 1 and Figure 2). However there was a significant reduction in the number of taxa in the West Okement River downstream of Meldon Quarry compared to upstream suggesting only invertebrates tolerant to this type of pollution were typically able to survive at this site.

When site 6 was visited after the rainfall event, no invertebrate mortalities were found immediately after the rainfall event on 30 September 1991 or on 15 October 1991 (see Table 4).

5. DISCUSSION.

Aquatic invertebrate and chemical surveys have shown a land drainage ditch to be the principal cause of acidic and metalliferous pollution in the Fowley Stream.

The major impact of the land drainage ditch on water quality in the West Okement River was to significantly increase iron concentrations (up to 42,600 ug/l) downstream of the Fowley Stream confluence. The impact of the land drainage ditch on other metal concentrations in the West Okement River was masked by poor water quality upstream from Meldon Quarry.

The land drainage ditch had similar iron concentrations and pH when compared to those recorded in the Brightley Stream during the break of the 1989 drought (see Table 5). Other metal concentrations in the ditch were not as high as those found in the Brightley Stream (Ref 2).

Table 5. Water quality at Brightley Mill on the Brightley Stream 18 September 1989 and in the land drainage ditch in the Fowley Stream catchment 28 September 1991.

Determinand (ug/l)	Brightley Stream	Fowley Ditch
pH	3.4	3.4
Total copper	1,420	200
Total zinc	6,300	300
Total iron	21,300	32,600
Total nickel	3,700	200
Total cadmium	25	<20
Dissolved aluminium	38,400	7,100

Land drainage improvements in the Fowley Stream catchment has allowed the bacterial oxygenation of pyrites in the soil. Contaminated water gains access to the stream via the ditch and land drains entering the ditch. Water quality is particularly poor during the first flush at the break of a drought. A similar process occurs in the Brightley Stream catchment.

Metalliferous pollution in the Fowley Stream is not as serious as pollution identified in the Brightley Stream because of the absence of mineral sulphides other than pyrites in the soils of the Fowley Stream Catchment. The oxidation of pyrites would account for the very high iron contamination in the Fowley Stream.

No significant change was recorded in the macroinvertebrate fauna in the Fowley Stream after the high rainfall event nor was there a significant reduction in the numbers present. This is surprising as other work has recorded up to 25% macroinvertebrate mortality at aluminium concentrations of 280 ug/l and pH 4.3 (Ref 3). Macroinvertebrates present in Fowley Stream may be acclimated to acidic pollution and can tolerate short-term events. It is also possible that less toxic species of aluminium were present in the Fowley Stream (e.g. organo-aluminium complexes).

No fish mortalities were detected in the Fowley Stream.

Slight acidic and metalliferous pollution was detected in the Fowley Stream upstream of the ditch. Similar conditions were also present in the West Okement River upstream of Meldon Quarry Okement River illustrating the 'natural' acid drainage that occurs in the West Okement River catchment.

The slightly restricted macroinvertebrate fauna identified in the Fowley Stream at site 4, upstream of the entry of the land drainage ditch compared to the Manor House Stream, could be due to the high levels of silt on the river bed. The origin of this silt is unknown.

Future Control Methods:

The NRA could accept intermittent failure of EQS's. However, this would be contrary to NRA-SW policy to maintain and improve water quality.

The land drain or the ditch are consentable discharges, and if the discharge is to continue then it should be controlled in order to fulfil the requirements of the Water Resources Act 1991- Part III Section 85.1. A number of options have been considered in order to avoid future pollution and include;

1. Block/break the land drains and fill in the land drainage ditch.

   - This would impede the flow of contaminated water to the Fowley Stream.

2. Add limestone chippings to the identified land drain.

   - Limestone chippings would precipitate metals and increase pH, however, the accumulation of an iron hydroxide coating on the chippings reduces their effectiveness.

3. Create a reed bed in the land drain ditch.

   - Past experience with the Wigney Stream (Ref. 1) has demonstrated that wetlands remove metals and increase pH due to a variety of processes (see Fig. 4).

6. CONCLUSIONS.

1. A land drainage ditch in the Fowley Stream catchment was shown to increase significantly metal concentrations and decrease pH in the Fowley Stream and as such was causing a significant impact on water quality in the Fowley Stream.

2. The land drainage ditch was found to discharge water of a low pH and high metal concentrations to the Fowley Stream.

3. Discharges from the land drainage ditch were shown to cause a three-fold increase in iron concentrations in the West Okement River compared to the concentrations upstream of the confluence (up to 42,600 ug/l in the West Okement River downstream of Fowley Stream). The impact on other metal concentrations in the West Okement River was masked by poor water quality upstream from Meldon Quarry.

4. A decline in the number of taxa and in the abundance of Mollusca was found downstream of the ditch although no further deterioration was detected following the rainfall event.

5. The cause of poor water quality is likely to be the bacterial oxidation of pyrites in the soils, as a result of land drainage improvements.

6. Acidic and iron pollution in the Fowley Stream is comparable to pollution identified in the Brightley Stream.

7. Acidic and metalliferous pollution resulting from the land drainage ditch should be controlled.

7. RECOMMENDATIONS.

1. The contents of this report should be discussed with the owner of Hughslade Farm with an objective to secure quality improvements.

   - Action by Pollution Officer (East)/Freshwater Officer.

8. REFERENCES.

1. SMITH, RP. (1991). Impact Assessment of Meldon Quarry on Water Quality in the West Okement River. (FWI/91/002)

2. SMITH, RP. (1991). Pollution Control of Acidic Water in the Brightley Stream. (FWI/91/001)

FIGURE 1. Map of the West Okement Catchment.

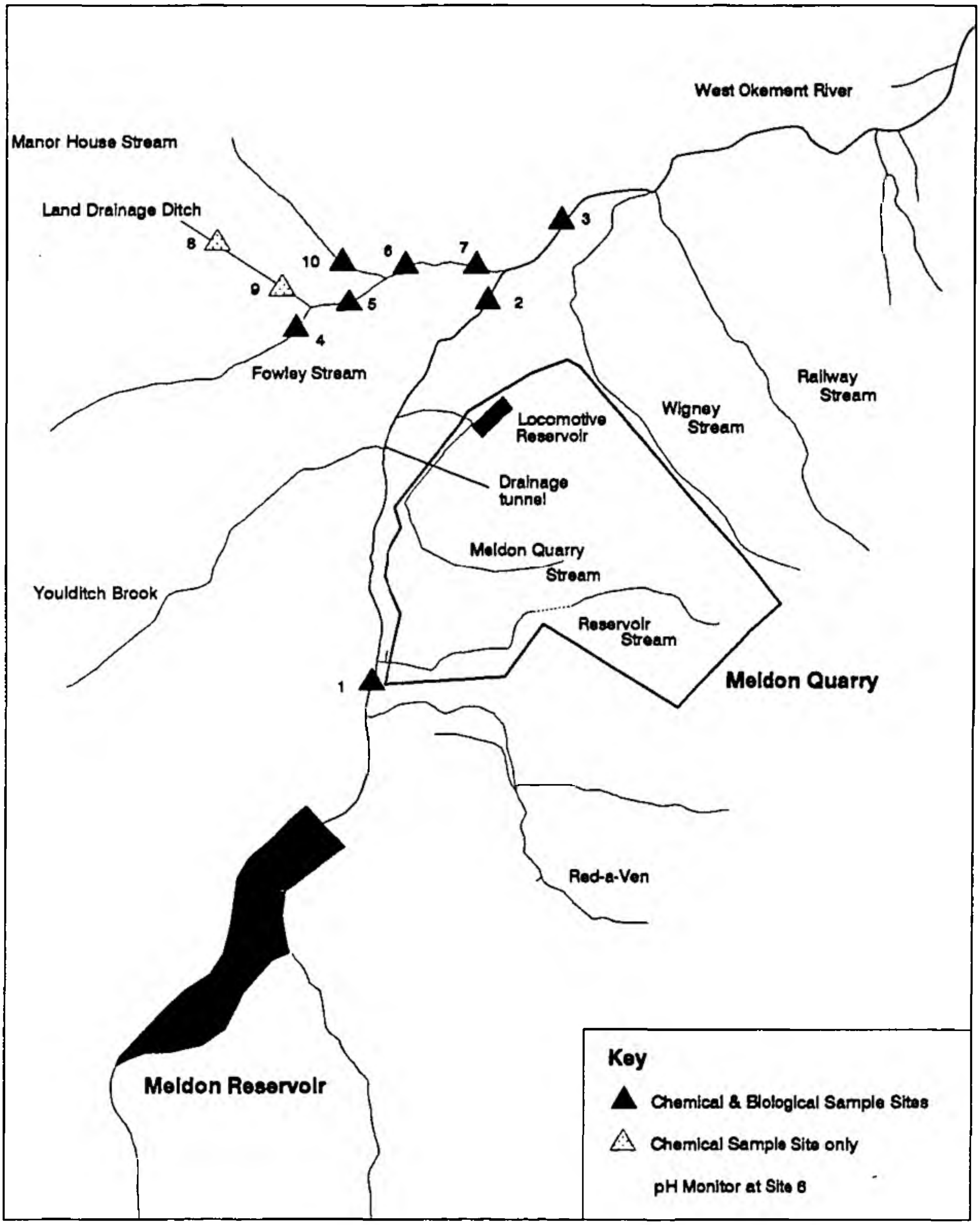

FIGURE 2. Total Number of Macroinvertebrate Taxa and number of Mollusca in the West Okement Catchment 11 September 1991.

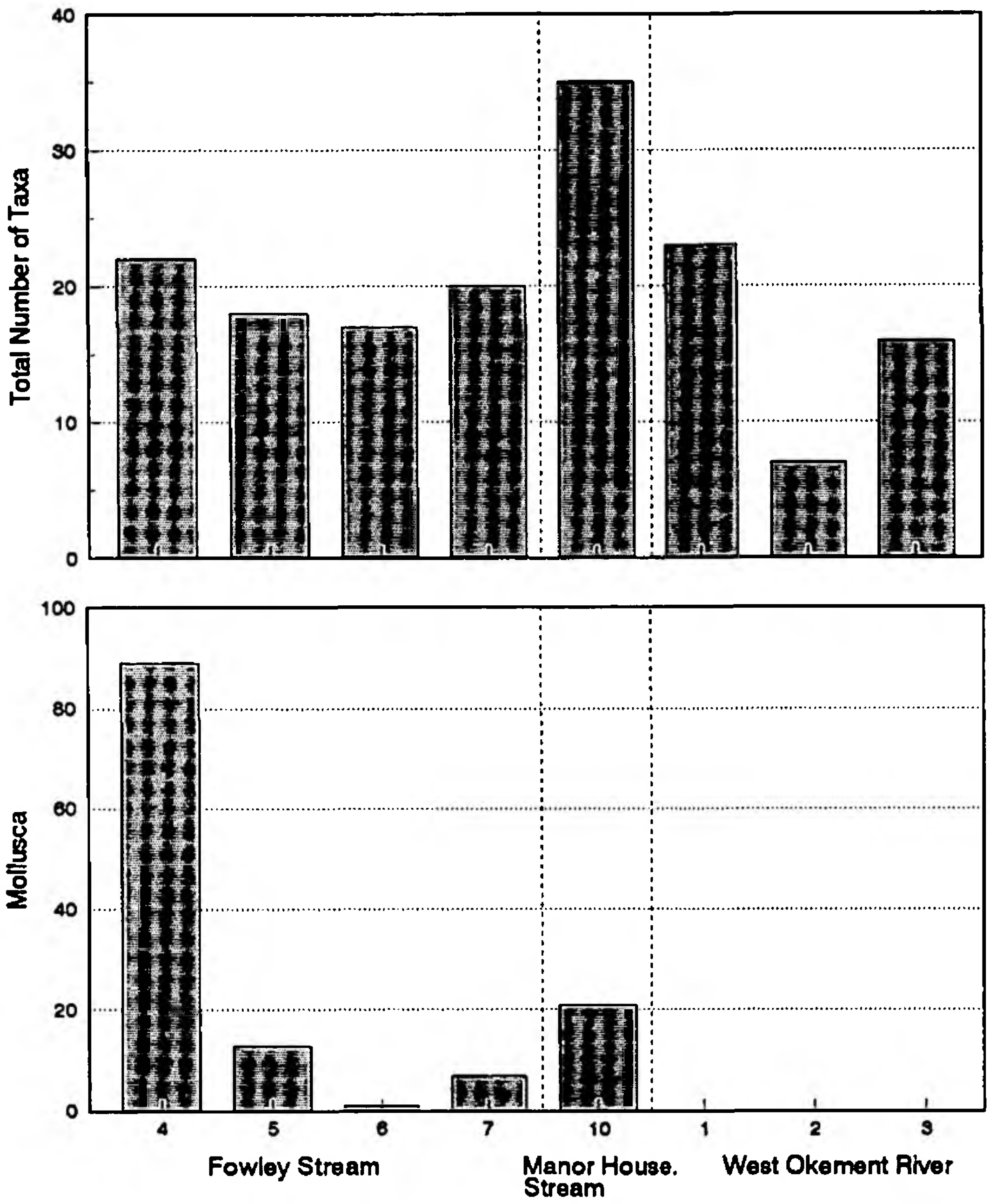

FIGURE 3. pH & Rainfall Recorded in the West Okement Catchment.

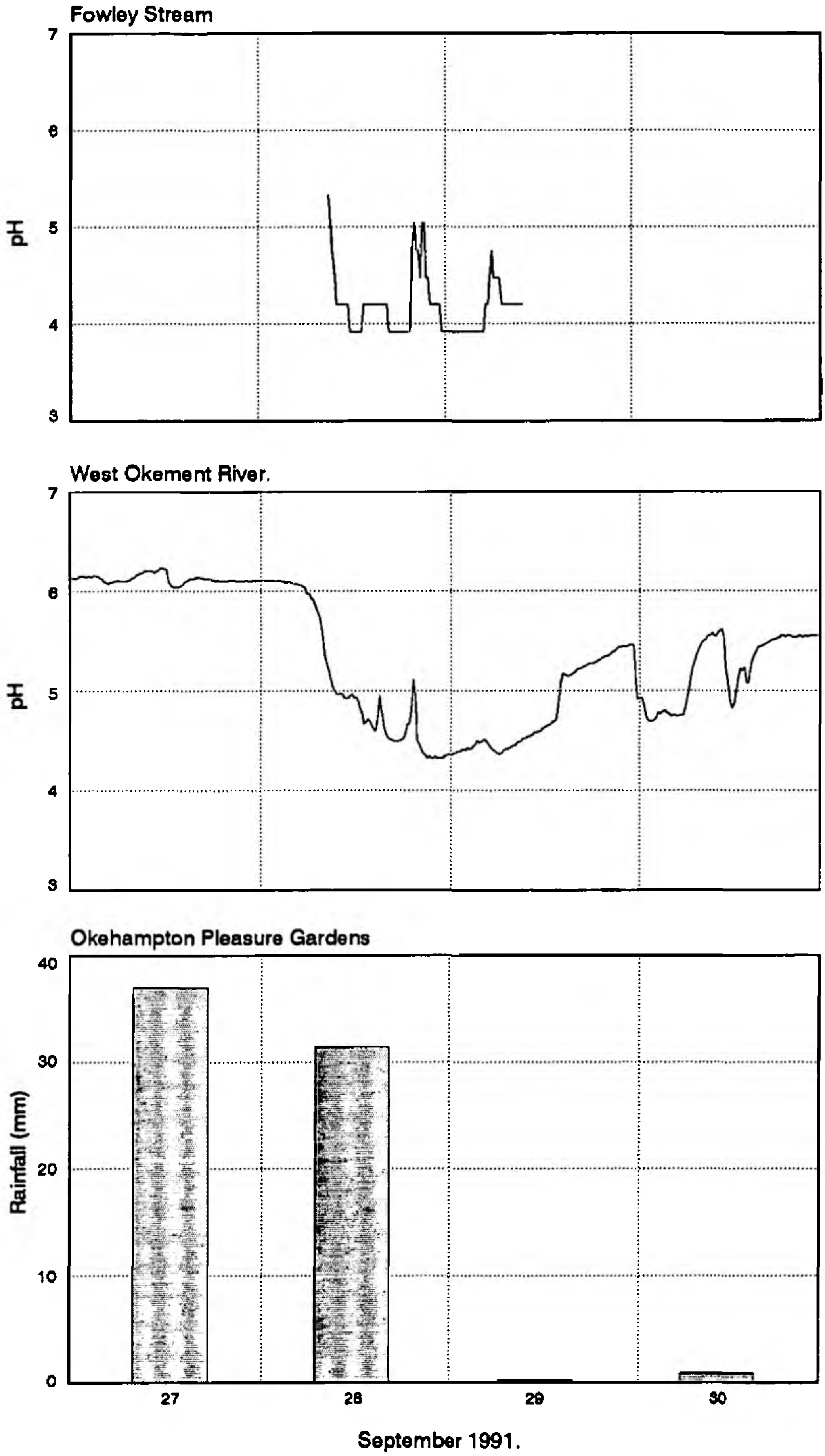

TABLE 2. Water quality in the Fowley Stream and West Okement River.

13 September 1991, Baseline Survey.

Site	pH	Diss Zinc	Diss. Nickel	Diss. Copper	Diss. Cadmium	Total Iron	Diss. Alumin.
West Okement River							
1. U/S Meldon Quarry	6.8	33	< 1	1	<0.0002	1,040	100
2. U/S Fowley Stream	6.9	35	5	2	<0.0002	1,600	90
3. D/S Fowley Stream	6.9	33	4	2	<0.0002	510	50
Fowley Stream							
4. U/S Ditch	7.2	7	2	2	<0.0002	200	150
5. U/S Manor House Stream	6.7	37	5	2	<0.0002	610	60
6. D/S Manor House Stream	7.2	31	4	2	<0.0002	730	50
7. Prior to W. Okement River	6.8	39	6	2	<0.0002	1,750	110
Land Drainage Ditch							
8. Prior To Fowley Stream	3.8	33	12	2	0.0004	770	310
9. Land Drain	6.5	38	5	2	<0.0002	810	110
Manor House Stream							
10. U/S Fowley Stream	7.5	30	4	3	<0.0002	430	50

28 September 1991, High Flow Survey.

Site	pH	Diss Zinc	Diss. Nickel	Diss. Copper	Diss Cadmium	Total Iron	Diss. Alumin.
West Okement River							
1. U/S Meldon Quarry	6.2	21	2	5	<0.02	8,100	500
2. U/S Fowley Stream	6.2	120	39	5	0.4	12,800	180
3. D/S Fowley Stream	6.1	122	15	8	0.7	42,600	250
Fowley Stream							
4. U/S Ditch	5.6	150	22	5	2.1	7,200	190
5. U/S Manor House Stream	4.2	270	58	20	4.2	187100	2,300
6. D/S Manor House Stream	5.9	112	40	5	0.4	12000	180
7. Prior to W. Okement River	-	-	-	-	-	-	-
Land Drainage Ditch							
8. Prior To Fowley Stream	3.4	530	150	48	9.2	32,600	7,100
9. Land drain	3.5	400	110	36	7.7	14,400	5,500
Manor House Stream							
10. U/S Fowley Stream	7.0	47	5	9	0.2	8,400	130

N.B. Concentrations in ug/l

TABLE 3. Repeated Water Quality Surveys on the West Okement River During the Rainfall Event on 28 & 29 September 1991.

SITE	Time	pH	Diss. Zinc	Diss. Nickel	Diss. Copper	Diss. Cadmium	Total Iron	Diss. Alumin.
West Okement River 28 Sept. 1991								
1. U/S Meldon Quarry	08.09	6.2	21	2	5	<0.02	8,100	500
2. U/S Fowley Stream	09.04	6.2	120	39	5	0.4	12,800	180
3. D/S Fowley Stream	08.47	6.1	122	15	8	0.7	42,600	250
Fowley Stream								
6. D/S Manor House Stream	09.10	5.9	112	40	5	0.4	12,000	180
West Okement River 28 Sept. 1991								
1. U/S Meldon Quarry	11.15	5.7	44	1	4	0.2	1,100	330
2. U/S Fowley Stream	11.40	5.6	146	60	10	0.5	1,800	540
3. D/S Fowley Stream	11.46	5.9	137	61	10	0.7	1,500	560
Fowley Stream								
6. D/S Manor House Stream	12.05	4.7	193	54	15	3.1	5,600	1,600
West Okement River 28 Sept. 1991								
1. U/S Meldon Quarry	12.40	5.7	61	3	20	0.2	700	360
2. U/S Fowley Stream	12.55	5.6	180	86	20	0.7	1,300	730
3. D/S Fowley Stream	13.02	5.8	177	85	17	0.7	1,300	720
Fowley Stream								
6. D/S Manor House Stream	13.20	4.6	201	44	21	3.2	7,000	1,500
West Okement River 29 Spet. 1991								
1. U/S Meldon Quarry	09.40	5.6	35	1	4	<0.2	290	310
2. U/S Fowley Stream	10.00	5.1	181	98	16	0.8	600	840
3. D/S Fowley Stream	10.10	5.1	179	98	15	0.8	660	840
Fowley Stream								
6. D/S Manor House Stream	10.30	4.5	175	42	17	3.3	4,850	4,400
West Okement River 29 Spet. 1991								
1. U/S Meldon Quarry	15.00	6.2	39	< 1	1	0.4	1,440	130
2. U/S Fowley Stream	14.06	5.2	260	160	18	1.3	2,000	380
3. D/S Fowley Stream	13.40	5.2	290	170	21	1.4	1,550	440
Fowley Stream								
6. D/S Manor House Stream	12.30	4.9	142	27	9	1.8	2,610	920

All concentrations in ug/l

TABLE 4. Macroinvertebrate Abundance in the Fowley Stream at Site 6 Before and After the Rainfall Event.

DATE SAMPLED	11 September	30 September	15 October
EPHEMEROPTERA			
BAETIDAE	A	A	A
HEPTAGENIDAE	A	B	A
LEPTOPHLEBIDAE	A	A	A
ODONATA			
CORDULAGASTERIDAE		A	
PLECOPTERA			
CHLOROPERLIDAE		A	
LEUCTRIDAE		A	A
NEMOURIDAE	A	A	B
PERLIDAE			
PERLODIDAE		A	
HEMIPTERA			
HYDROMETRIDAE			
VELIIDAE	A	A	
MEGALOPTERA		A	
SIALIDAE			A
TRICHOPTERA			
HYDROPSYCHIDAE		A	
PHILOPOTOMATIDAE		A	
RHYACOPHILIDAE	A	A	A
POLYCENTROPIDAE	A	A	
SERICOSTOMATIDAE	A	A	A
DIPTERA			
ATHERICIDAE			
CERATAPOGONIDAE		A	A
CHIRONOMIDAE	A	A	A
EMPIDIDAE			
DIXIDAE	A		
SIMULIDAE	A	A	A
TIPULIDAE	A	A	A
COLEOPTERA			
DYTISCIDAE		A	A
ELMIDAE		A	
HYDRAENIDAE	A	A	
HYDROPHILIDAE			
CRUSTACEA			
OSTRACODA	A		
CHELICERATA			
ACARI			
MOLLUSCA			
HYDROBIDAE			
PLANORBIDAE			
SPHAERIDAE			
OLIGOCHAETA	B	C	C
PLATYHELMINTHIDAE			
PLANARIDAE			

A=1–9, B=9–99, C=100–999

APPENDIX I. Abundance of Macroinvertebrate Taxa in the West Okement River Catchment 11 September 1991.

SITE NUMBER	1	2	3	4	5	6	7	10
EPHEMEROPTERA								
BAETIDAE								
Baetis muticus								9
Baetis rhodani	29		2			3	1	13
Baetis sp.	15	1	4					
EPHEMERIDAE								
Ephemera sp.								2
HEPTAGENIDAE								
Ecdyonurus sp.	2					6	2	66
LEPTOPHLEBIDAE								2
ODONATA								
CORDULAGASTERIDAE								
Cordulagaster boltoni					1			3
PLECOPTERA								
CHLOROPERLIDAE								
Siphonoperla torrentum								1
LEUCTRIDAE								
Leuctra fusca	1	10	25		3	1		64
Leuctra hippopus			3					
Leuctra sp.	2		1			1		
NEMOURIDAE								
Nemourella picteti				15	10	6	20	
Protonemura meyeri	2		6					
Nemoura sp.				11	32	14	11	6
PERLIDAE								
Dinocras cephalotes	1							
PERLODIDAE								
Isoperla grammatica	2		1					
HEMIPTERA								
VELIDAE								
Velia sp.				2	1	1	1	2
MEGALOPTERA								

SITE NUMBER	1	2	3	4	5	6	7	10
SIALIDAE								
Sialis fulignosa							1	3
TRICHOPTERA								
HYDROPSYCHIDAE								
Hydropsyche siltali	4	1						3
HYDROPTILIDAE								
Oxythyra sp.	4							
LIMNEPHLIDAE								
Chaetopteri:								2
Limnephlidae					1			2
POLYCENTROPIDAE								
Plectronemiocnemia conspersa					5	4	5	
Plectrocnemia geniculata	1							
Plectrocnemia sp.	2		1					
RHYACOPHILIDAE								
Rhyacophila dorsalis	3	2	5			5	4	5
SERICOSTOMATIDAE								
Sericostoma personatum	1		1		4	3		25
DIPTERA								
CERATAPOGONIDAE								1
CHIRONOMIDAE	51	4	25	71	46	16	21	43
DIXIDAE								
Dixa sp.					1		3	5
EMPIDIDAE								
Chelifera sp.				23				
Wiedmannia sp.	10	1	5	4				1
MUSCIDAE							2	
PSYCHODIDAE								
Pericoma sp.				2				
SIMULIDAE								
Simulium sp.	13		2	20		1	57	24
TIPULIDAE								
Dicranota sp.		1		6		1	3	10
Tipula sp.			1	2				2

SITE NUMBER	1	2	3	4	5	6	7	10
COLEOPTERA								
DYTISCIDAE								
Oreodytes sanmarkii				3			1	2
Agabus guttatus								1
Agabus sp.					9			2
Hydroporus sp.					1			
ELMIDAE								
Elmis aenea	4		2	1			1	6
Limnius volkmari	3			1		2	2	3
Oulimnius tuberculatus	1							1
GYRINIDAE								
Orectochilus sp.	2				1			
HYDRAENIDAE								
Limnibius trunculata				1				
HYDROPHILIDAE								
Helophorus brevipalpus								1
SCIRTIDAE								
Elodes sp.				4	1	4	1	2
CRUSTACEA								
ASELLIDAE				1				
Asellus sp.								
CHELICERATA								
ACARI				3				1
MOLLUSCA								
ANCYLIDAE								
Ancylus fluviatilus				11			5	20
HYDROBIIDAE								
Potomopyrgus jenkinsi				66	3			
LYMNAEIDAE								
Lymnea truncata				1				
SPHAERIDAE								
Psidium sp.				11	10	1	2	1
OLIGOCHAETA	11		1	13	40	30	35	17
HIRUDINEA								

SITE NUMBER	1	2	3	4	5	6	7	10
GLOSSIPHONIDAE								
Glossiphona complanata					1			6
PLANARIDAE								
Polycelis felina	2							
NUMBER OF TAXA	23	7	16	22	18	17	20	35
NUMBER OF INDIVIDUALS	166	20	85	272	170	99	178	356
PHYSICAL PARAMETERS								
FLOW (SECOND/METRES)	1.6			<0.4	<0.4	<0.4	<0.4	<0.4
TURBIDITY	MOD	MOD	MOD	CLEAR	SLGT	SLGT	SLGT	CLEAR
WATER COLOUR	BROWN	BROWN	BROWN	NONE	BROWN	BROWN	BROWN	NONE
SHADE (%)	25	25	25	70	80	70	80	20
SUBSTRATE (%)								
ROCK PAVEMENT								
BOULDERS (>256mm)	35	60	70				40	
COBBLES (64–256mm)	60	40	30	10	10	20	20	20
PEBBLES (16–64mm)	5			30	40	50	30	30
GRAVEL (2–16mm)				20	10	10	10	20
SAND				10	10	10		20
SILT				30	30	10		10
CLAY								
FLORA								
MACROPHYTE COVER (%)	1							
BRYOPHYTE COVER (%)							10	
ALGAE COVER (%)	80	80	80					
OCHRE					30			