Documentation for Delisting Middle Creek Tazewell County, Virginia

Prepared By

MapTech Inc.,
Blacksburg, VA
for

Virginia Department of Mines, Minerals, and Energy, and
Virginia Department of Environmental Quality

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Introduction

Middle Creek is located in Tazewell County, Virginia, just northwest of the town of Cedar Bluff. An assessment of the benthic macroinvertebrate community in Middle Creek was conducted by VADEQ. The results of this study led to Middle Creek being placed on the Commonwealth of Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report because of violations of the General Standard (benthic). The applicable state standard (Virginia State Law 9VAC25-260-20) specifies that all state waters shall be free of substances, which are inimical or harmful to aquatic life. The Rapid Bioassessment Protocol II (RBP) was used to assess compliance with state law.

The impaired stream segment has a length of 11.01 miles, and extends from its headwaters to its confluence with Clinch River in Cedar Bluff. The land area of the Middle Creek watershed is approximately 7,179 acres, with forest as the primary landuse. Approximate proportions of specific landuses as of 1995 were 96% forest, 1% agriculture, less than 1% water/wetlands, less than 1% urban/industrial development, 1% transitional, and 1% (approximately 70 acres) permitted for mining operations.

Water Quality Assessment

The VADEQ has only one monitoring station in the watershed and it is located at river mile 0.20 near Middle Creek's confluence with the Clinch River. Benthic and field data are collected at this monitoring station. Middle Creek was initially placed on the Virginia 1998 Section 303(d) Total Maximum Daily Load Priority List and Report for violations of the General Standard (benthic) based on monitoring performed on 21 May 1996 at station 6BMID000.20 (Figure 2.1). A sample from a healthy site typically has at least 100 organisms (personal communication with VADEQ-SWRO, March 8, 2004). In cases where significantly less than 100 organisms are found, RBP II is not calculated. The impaired rating was necessary for Middle Creek because only 28 organisms were collected. Middle Creek remained on the Virginia 2002 Section 303(d) Report on Impaired Waters and on the Virginia 2004 305(b)/303(d) Water Quality Integrated Report for not supporting the aquatic life use. On July 31 and November 17, 2003 follow up biological monitoring was done at station 6BMID00.20 and on both occasions no impairment was found. This provides justification for delisting Middle Creek.

Benthic impairments have two general causes: input of pollutants to streams and alteration of habitat in either the stream or the watershed. Habitat assessment for Middle Creek was analyzed using habitat scores recorded by VADEQ biologists at VADEQ monitoring station 6BMID000.20.

Water quality data from 17 sites monitored by private coal mining companies in Middle Creek were supplied by DMME for assessment. The majority of this data was collected between October 1995 and September 1999.

Stressor Identification

The General Standard does not identify the stressor(s) (*e.g.*, pollutants) that are harmful to aquatic life. In order to assess the potential impact of water quality on the macroinvertebrate population in Middle Creek a suitable watershed was selected for comparison. The McClure River is a fourth order stream in the same ecoregion and there are mining related land uses in the watershed. Recent biological monitoring at VADEQ station 6AMCR000.55 indicates a healthy macroinvertebrate population. Therefore, for water quality parameters without established standards or screening levels, the 90^{th} percentile for the parameters available from the McClure River (6AMCR000.20) was used to evaluate the water quality data in this stressor analysis.

Reclamation

Comprehensive environmental regulations requiring technology based conservation measures for the coal mining industry were not established in Virginia until the United States Department of the Interior granted the state primacy over the Surface Mine Control and Reclamation Act (SMCRA) in 1981. At that time, decades-old mining operations were underway throughout southwestern Virginia's coalfields including Middle Creek. There existed some older abandoned mined lands in Middle Creek, but most of the mined areas were incorporated into state issued mining and reclamation permits during the early 1980s. These permits contained requirements for drainage plans, materials handling, regrading, revegetation, and pollution control. Also, the permits required operators to provide a performance bond to insure that the mine sites would be reclaimed to an acceptable post mining land use.

Regulated, permitted, and routinely inspected mining operations were conducted in the watershed from 1983 until 1999. During this period, sediment control and land management practices were required and utilized at the mines. Improvements in stream water chemistry were noted. A compliance evaluation inspection by DMLR of all the active coal operations in Middle Creek was concluded in September 1996.

The mined land reclamation activities administered by DMLR in Middle Creek included best management practices and conservation measures typical of reclamation throughout the coalfields; removal of equipment and structures, regrading of the land to original contours, revegetation, and establishment of a designed post mining land use. In Middle Creek, all sites were reclaimed as unmanaged forestlands.

Conclusion

Following the results of VADEQ's recent benthic monitoring, DMLR initiated additional chemical testing. The results from the first several samples show an average specific conductance of 263 (? mhos/cm). This indicates that the reclamation work was successful in improving water quality in Middle Creek. It also confirms the findings in the stressor identification that further reductions in conductivity and total dissolved solids from the 1990s values would return the stream to a non-impaired status.

Based upon the fact that extensive reclamation work has been completed and both the benthic and chemical data indicate improvement in Middle Creek, the stream meets all of the EPA's requirements for delisting.

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1. INTRODUCTION

1.1 Background

EPA's document, Guidance for Water Quality-Based Decisions: The TMDL Process (USEPA, 1999) states:

> *According to Section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs .*
>
> *. . . A TMDL, or total maximum daily load, is a tool for implementing State water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

According to the 1998 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1998), Middle Creek was listed as impaired. Virginia Department of Environmental Quality (VADEQ) identified Middle Creek as being impaired with regard to the General Standard (benthic). Middle Creek carries an agency watershed ID of VAS-P03R. Since being listed as impaired Middle Creek has shown considerable improvement. Follow up biomonitoring was performed on July 31 and November 17, 2003 and both results indicated that it was not impaired. Two consecutive surveys indicating no impairment satisfies EPA's requirements for delisting. Therefore the remainder of this process will focus on delisting Middle Creek.

Middle Creek is a second order stream, in the Central Appalachian Ridges and Valleys ecoregion located in Tazewell County (Figure 1.1). It has a length of 11.01 miles, and flows into the Clinch River at Cedar Bluff, VA. The Clinch River is part of the Tennessee/Big Sandy River Drainage Basin, and drains via the Mississippi River to the Gulf of Mexico. The entire stream length was considered impaired prior to the most recent benthic survey results.

The watershed consists primarily of steep sloped forested hillside. Less than five percent of the land is developed as residential, urban, and agricultural with most of the development located along the creek at the lower end of the watershed. The local geology can be described as layers of gently dipping sedimentary rocks interspersed with several above drainage coal seams. The watershed has had a considerable amount of coal mining activity in it over the past five decades. Coal mining activities principally included underground extraction, coal processing and coal haulage. At the present time there are no active mines (the last active mine ceased production in 1999) and post-mining activity is proceeding under the supervision of the Virginia Department of Mines, Minerals and Energy's Division of Mined Land Reclamation (DMLR). The land area of the Middle Creek Watershed is approximately 7,179 acres, with forest as the primary landuse (Figure 1.2). Approximate proportions of specific landuses as of 1995 were 96% forest, 1% agriculture, less than 1% water/wetlands, less than 1% urban/industrial development, 1% transitional, less than 1% quarries, strip mines or gravel pits, and 1% (approximately 70 acres) permitted for mining operations. There are no VPDES permitted facilities in the watershed.

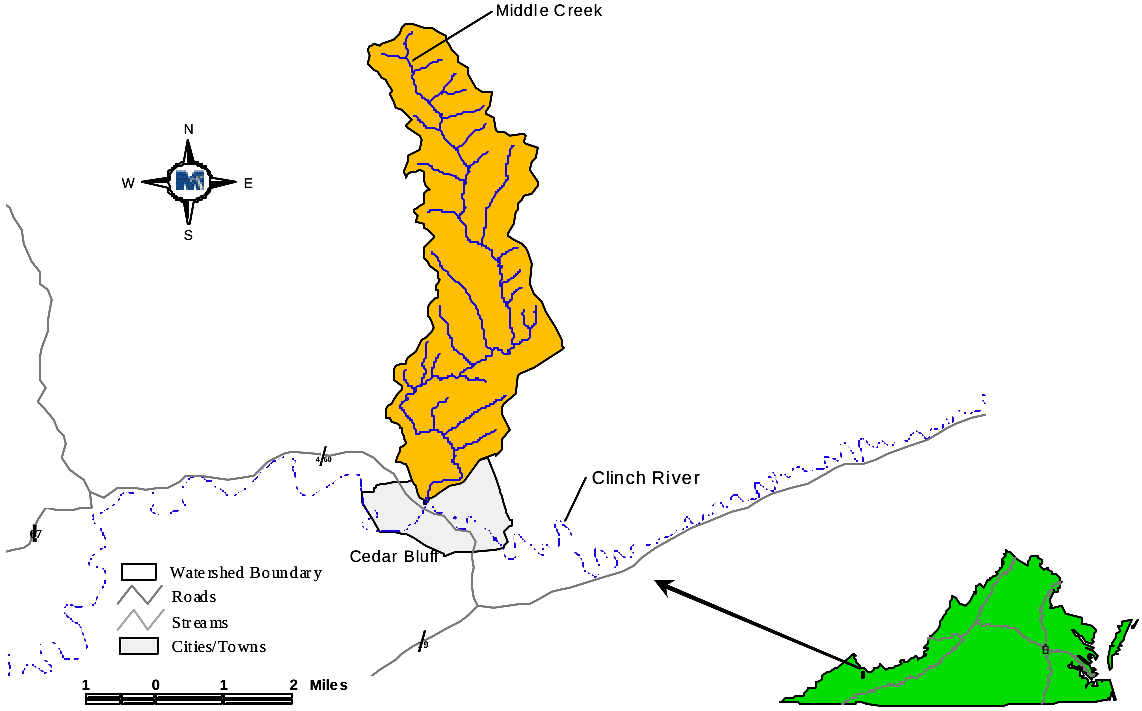

Figure 1.1 Location of the Middle Creek Watershed.

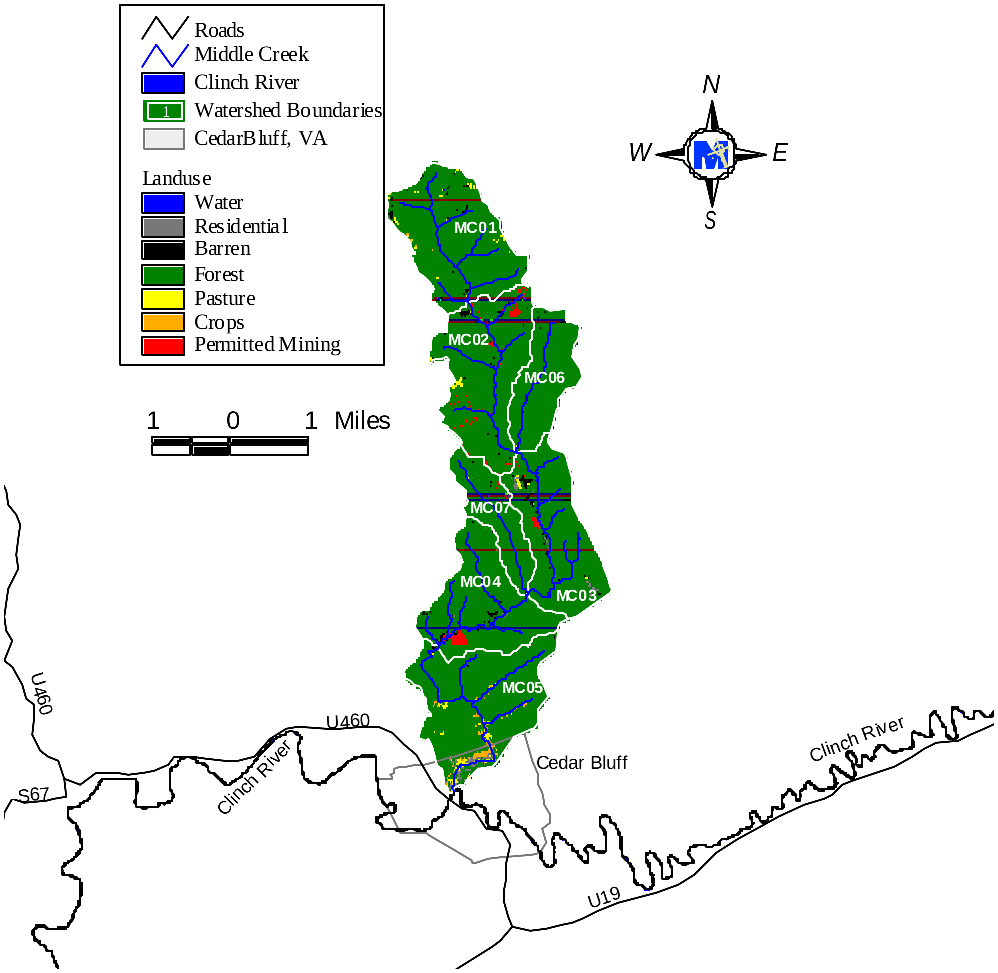

Figure 1.2 Landuses in the Middle Creek watershed.

The National Land Cover Data (NLCD) produced cooperatively between USGS and EPA was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital landuse coverage was developed identifying up to 21 possible landuse types. Classification, interpretation, and verification of the land cover dataset involved several data sources (when available) including: aerial photography;

soils data; population and housing density data; state or regional land cover data sets; USGS landuse and land cover (LUDA) data; 3-arc-second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data. Approximate acreages for each land use are given in Table 1.1.

Table 1.1 Landuse and area of Middle Creek.

Landuse	Acreage
Barren	74
Commercial	18
Forest	6,887
Residential	35
Pasture	59
Permitted Mining	70
Row Crop	34
Water	1.5
Wetlands	0.22
Total	7,179

1.2 Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

Virginia state law 9VAC25-260-10 (Designation of uses) indicates:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

1.3 Applicable Criterion for Benthic Impairment

Additionally, Virginia state law 9VAC25-260-20 defines the **General Standard** as:

> *A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

The General Standard is implemented by VADEQ through application of the Rapid Bioassessment Protocol II (RBP II). Using the RBP II, the health of the benthic macroinvertebrate community is typically assessed through measurement of 8 biometrics (Table 1.2), which measure different aspects of the community's overall health. Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. It is this bioassessment that is the endpoint for General Standard (benthic) impaired TMDLs.

Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.,* non-impaired, moderately impaired, or severely impaired).

Table 1.2 Components of the RBP II Assessment

Biometric	Benthic Health [1]
Taxa Richness	?
Modified Family Biotic Index	?
Scraper to Filtering Collector Ratio	?
EPT / Chironomid Ratio	?
% Contribution of Dominant Family	?
EPT Index	?
Community Loss Index	?
Shredder to Total Ratio	?

[1] An upward arrow indicates a positive response in benthic health when the associated biometric increases.

2. WATER QUALITY ASSESSMENT

2.1 Benthic Assessment

The VADEQ has only one monitoring station in the watershed and it is located at river mile 0.20 near Middle Creek's confluence with the Clinch River. Benthic and field data are collected at this monitoring station. Middle Creek was initially placed on the Virginia 1998 Section 303(d) Total Maximum Daily Load Priority List and Report for violations of the General Standard (benthic) based on monitoring performed on 21 May 1996 at station 6BMID000.20 (Figure 2.1). A sample from a healthy site typically has at least 100 organisms (personal communication with VADEQ-SWRO, March 8, 2004). In cases where significantly less than 100 organisms are found, RBP II is not calculated. The impaired rating was necessary for Middle Creek because only 28 organisms were collected. Middle Creek remained on the Virginia 2002 Section 303(d) Report on Impaired Waters and on the Virginia 2004 305(b)/303(d) Water Quality Integrated Report for not supporting the aquatic life use. On July 31 and November 17, 2003 follow up biological monitoring was done at station 6BMID00.20 and on both occasions no impairment was found. This provides justification for delisting Middle Creek.

Tables 2.1 and 2.2 show the individual RBP II metrics for Middle Creek, and the reference station that was used in 2003.

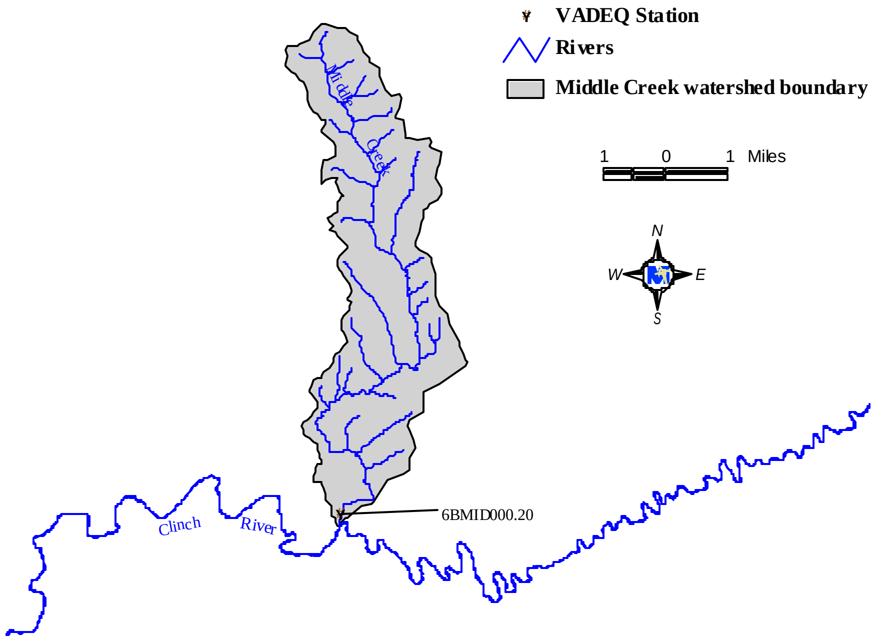

Figure 2.1 Location of VADEQ in-stream water quality monitoring station in the Middle Creek watershed.

Table 2.1 RBP II biological monitoring data for station 6BMID000.20 July 31, 2003.

RBP II	**Reference Site MFH045.83**			**6BMID000.20**		
Metric	**Value**	**Ratio**	**Score**	**Metric**	**Ratio**	**Score**
Taxa Richness	15	100	6	16	107	6
MFBI	4.65	100	6	4.39	106	6
SC/CF	1.36	100	6	0.68	50	4
EPT/Chi Abund	2.59	100	6	9.86	381	6
% Dominant	26.17	26	4	22.94	23	4
EPT Index	7	100	6	7	100	6
Comm. Loss Index	0	0	6	0.19	0	6
SH/Tot	0.02	100	6	0.07	393	6
Biological Condition Score			46			44
% of Reference			100			95.65%
Assessment			Reference			No Impairment

Table 2.2 RBP II biological monitoring data for station 6BMID000.20 November 17, 2003.

RBP II	Reference Site: MFH045.83			6BMID000.20		
Metric	**Value**	**Ratio**	**Score**	**Metric**	**Ratio**	**Score**
Taxa Richness	11	100	6	14	127	6
MFBI	4.69	100	6	4.38	107	6
SC/CF	0.5	100	6	0.52	105	6
EPT/Chi Abund	12.29	100	6	10.5	85	6
% Dominant	43.52	44	0	35.11	35	2
EPT Index	8	100	6	6	75	2
Comm. Loss Index	0	0	6	0.21	0	6
SH/Tot	0.03	100	6	0.18	651	6
Biological Condition Score			42			40
% of Reference			100			95.24%
Assessment			Reference			No impairment

2.2 Habitat Assessment

Benthic impairments have two general causes: input of pollutants to streams and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.*, by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.*, due to landuse changes in the watershed such as increasing the area of impervious surfaces). Habitat assessment for Middle Creek included an analysis of habitat scores recorded by VADEQ biologists.

2.2.1 Habitat assessment at biological monitoring stations

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of nine individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 2.3.

Table 2.3 Classification of habitat metrics based on score.

Metric Score	Combined Score	Classification
16-20	151-200	Optimal
11-15	101-150	Suboptimal
6-10	51-100	Marginal
0-5	0-50	Poor

The habitat scores from the VADEQ benthic surveys are summarized in Table 2.4. Poor habitat does not appear to be a significant problem in Middle Creek.

Table 2.4 Habitat scores for VADEQ benthic surveys in 1996 and 2003 at VADEQ monitoring station 6BMID00020.

	Date		
Habitat Assessment	5/21/1996	7/31/2003	11/17/2003
Alteration	18	13	15
Banks	16	14	14
Bank – Vegetation	18	10	10
Embeddedness	9	11	9
Flow	19	16	18
Riffle	14	13	16
Riparian – Vegetation	7	9	13
Sediment	8	12	11
Substrate	13	12	14
Velocity	13	10	10
Total	135	120	130

2.3 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream monitoring data throughout the Middle Creek Watershed. Sources of data and pertinent results are discussed.

2.3.1 Inventory of Water Quality Monitoring Data

Middle Creek has been monitored to support mine permit applications, mine permit compliance, and assessment by the Virginia Department of Mines, Minerals, and Energy (DMME).

2.3.1.1 Mine Permit Application/Compliance Monitoring

Data from 17 sites monitored by private coal mining companies in the area were supplied by DMME. It is important to note that the majority of this data was collected between October

1995 and September 1999. There were still active mining permits at this time but mining operations had ceased. Only a few scattered samples have been collected between September 1999 and the present. Scatter graphs for each parameter at all 17 monitoring stations can be found in Appendix A. Twelve of the 17 monitoring stations had at least nine data points and were on the main stem of Middle Creek (Figure 2.2 and Table 2.5). Nine data points were selected as a cutoff for statistical accuracy and to ensure all seasons were represented. The data from these stations were used in the stressor identification in Chapter 3.

Each station included in the DMME permit-monitoring database has been assigned unique monitoring point identification (MPID) number. Figure 2.2 shows the locations of the DMME monitoring sites. Table 2.5 relates the MPIDs to the river mile on Middle Creek, as well as the permit numbers and data record.

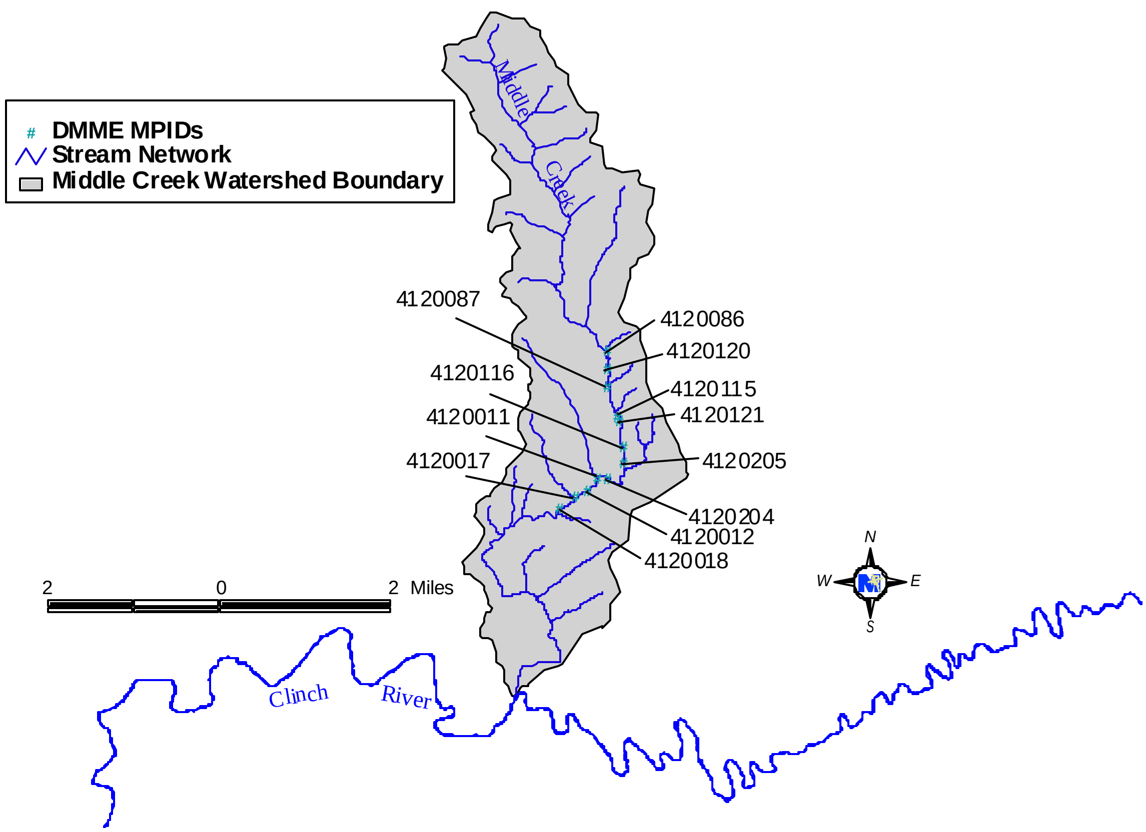

Figure 2.2 The locations of DMME monitoring stations in the Middle Creek watershed.

Table 2.5 Monitoring stations on Middle Creek from data supplied by DMME.

MPID	River Mile	Permit	Data Record
4120018	3.67	1201017	4/1996-9/1999
4120017	3.89	1201017	4/1996-9/1999
4120012	4.05	1201019	7/1996-9/1999
4120011	4.25	1201019	7/1996-9/1999
4120204	4.42	1301421	10/1995-9/1999
4120205	4.86	1301421	10/1995-9/1999
4120116	5.04	1201260	5/1996-9/1999
4120121	5.36	1201022	1/1996-9/1999
4120115	5.44	1201260	5/1996-9/1999
4120087	5.78	1201021	1/1996-9/1999
4120120	5.99	1201022	10/1995-9/1999
4120086	6.20	1201021	1/1996-9/1999

Tables 2.6 through 2.17 show summaries of the water quality data collected at each of the 12 in-stream monitoring locations. Various personnel representing both the coal mining industry and consultants hired by mining companies performed sampling. Sample timing varied based on the mine permit that the sample was intended to support. Abbreviations used in these tables include: TDS (Total Dissolved Solids), Fe (Total Iron), Mn (Total Manganese), and TSS (Total Suspended Solids). All flow values that contributed to these summaries were estimated.

Table 2.6 In-stream Water Quality Data for MPID 4120018 (4/96—9/99).

MPID 4120018	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	206	175	470	75	97	37
Ph	7.5	7.6	8.4	6.0	0.6	39
FE (mg/L)	0.48	0.38	2.7	0.10	0.4	38
MN (mg/L)	0.1	0.1	0.1	0.1	0	22
TSS (mg/L)	11.5	5.0	59	4.0	13.0	39
ALKALINITY (mg/L)	91	90	190	24	45.5	39
CONDUCTIVITY (µmhos/cm)	451	450	820	190	153	39
TDS (mg/L)	374	319	1240	168	218	39
SULFATE (mg/L)	132	94	542	27	101	39

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.7 In-stream Water Quality Data for MPID 4120017 (4/96—9/99).

MPID 4120017	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	180	175	430	75	79	41
pH	7.9	7.7	20.0	6.2	2.0	42
FE (mg/L)	0.40	0.30	3.4	0.10	0.50	41
MN (mg/L)	0.12	0.10	0.50	0.10	0.08	25
TSS (mg/L)	17.0	5.5	316	4.0	48.7	42
ALKALINITY (mg/L)	197	93	4423	26.0	670	42
CONDUCTIVITY (µmhos/cm)	436	428	720	180	148	41
TDS (mg/L)	322	317	954	121	148	42
SULFATE (mg/L)	110	92	275	17.0	62	42

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.8 In-stream Water Quality Data for MPID 4120012 (7/96—9/99).

MPID 4120012	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	179	160	430	75	83	37
pH	7.6	7.65	8.4	6.5	0.48	38
FE (mg/L)	21.7	0.30	435	0.10	90	37
MN (mg/L)	0.10	0.10	0.10	0.10	0.00	23
TSS (mg/L)	10.2	6.5	77	4.0	12.4	38
ALKALINITY (mg/L)	95.9	93	205	26.0	49.2	38
CONDUCTIVITY (µmhos/cm)	435	428.5	680	180	150	38
TDS (mg/L)	325	317	954	140	149	38
SULFATE (mg/L)	108	92	268	33.0	58	38

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.9 In-stream Water Quality Data for MPID 4120011 (7/96—9/99).

MPID 4120011	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	160	150	390	70	75	39
pH	7.6	7.7	8.3	6.1	0.54	39
FE (mg/L)	0.39	0.35	1.1	0.10	0.20	38
MN (mg/L)	0.10	0.10	0.10	0.10	0	23
TSS (mg/L)	12.7	6.0	142	4.0	23.8	39
ALKALINITY (mg/L)	98	88	204	30.0	48.5	39
CONDUCTIVITY (µmhos/cm)	440	420	690	180	148	39
TDS (mg/L)	375	299	1731	136	322	39
SULFATE (mg/L)	108	96	225	16.0	57.0	38

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.10 In-stream Water Quality Data for MPID 4120204 (10/95—9/99).

MPID 4120204	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	130	130	320	40	61	44
pH	7.5	7.5	11.0	6.4	0.71	45
FE (mg/L)	0.50	0.40	1.8	0.15	0.30	45
MN (mg/L)	0.17	0.10	1.00	0.10	0	36
TSS (mg/L)	9.3	6.0	29	4.0	6.7	45
ALKALINITY (mg/L)	100	101	371	23.0	64.8	44
CONDUCTIVITY (µmhos/cm)	445	440	730	160	157	45
TDS (mg/L)	321	312	721	126	132	45
SULFATE (mg/L)	116	102	320	11.0	74	45

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.11 In-stream Water Quality Data for MPID 4120205 (10/95—9/99).

MPID 4120205	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	147	142.5	350	50	65	42
pH	7.4	7.4	8.2	6.5	0.48	45
FE (mg/L)	0.68	0.50	7.5	0.15	1.09	45
MN (mg/L)	0.18	0.10	0.60	0.10	0.11	37
TSS (mg/L)	8.8	6.0	27.0	4.0	6.4	45
ALKALINITY (mg/L)	95	91	209	23.0	53	45
CONDUCTIVITY (µmhos/cm)	485	430	2000	180	284	45
TDS (mg/L)	316	304	635	111	127	45
SULFATE (mg/L)	117	99	364	20.0	72	45

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.12 In-stream Water Quality Data for MPID 4120116 (5/96—9/99).

MPID 4120116	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	133	130	320	50	61	39
pH	7.5	7.5	8.2	6.4	0.50	39
FE (mg/L)	0.51	0.40	1.8	0.15	0.31	39
MN (mg/L)	0.15	0.10	0.40	0.10	0.08	31
TSS (mg/L)	9.2	6.0	29.0	4.0	6.7	39
ALKALINITY (mg/L)	103	102	371	23.0	67	39
CONDUCTIVITY (µmhos/cm)	440	420	730	160	163	39
TDS (mg/L)	319	312	721	126	134	39
SULFATE (mg/L)	115	102	320	11.0	75	39

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.13 In-stream Water Quality Data for MPID 4120121 (1/96—9/99).

MPID 4120121	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	175	120	2000	35.0	294	47
pH	7.5	7.6	8.4	6.2	0.59	47
FE (mg/L)	0.47	0.40	2.7	0.10	0.41	46
MN (mg/L)	0.10	0.10	0.10	0.10	0.00	29
TSS (mg/L)	9.5	6.0	53	4.0	10.1	47
ALKALINITY (mg/L)	81	71	182	6.0	58	47
CONDUCTIVITY (µmhos/cm)	363	340	710	70	165	47
TDS (mg/L)	233	219	467	50	115	46
SULFATE (mg/L)	85	74	278	13.0	52	47

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.14 In-stream Water Quality Data for MPID 4120115 (5/96—9/99).

MPID 4120115	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	150	123.3	1305	35.0	193	41
pH	7.5	7.7	8.3	6.2	0.60	42
FE (mg/L)	0.49	0.40	2.7	0.20	0.42	42
MN (mg/L)	0.10	0.10	0.13	0.10	0.01	29
TSS (mg/L)	9.3	6.0	53	4.0	9.1	42
ALKALINITY (mg/L)	88	85.5	193.3	14.0	58	42
CONDUCTIVITY (µmhos/cm)	384	385.5	710	150	158	42
TDS (mg/L)	255	250.5	467	78	116	42
SULFATE (mg/L)	92	83	278	25.0	52	42

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.15 In-stream Water Quality Data for MPID 4120087 (1/96—9/99).

MPID 4120087	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	96	95	250	15	53	45
pH	7.7	7.6	18.0	6.0	1.7	45
FE (mg/L)	0.32	0.30	0.7	0.10	0.17	41
MN (mg/L)	0.10	0.10	0.20	0.10	0.02	21
TSS (mg/L)	8.6	4.0	34.0	4.0	7.9	45
ALKALINITY (mg/L)	88	56	242	10.0	77	45
CONDUCTIVITY (µmhos/cm)	275	224	650	68	161	45
TDS (mg/L)	192	144	506	33	126	45
SULFATE (mg/L)	36	33	73	11.0	17.1	45

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.16 In-stream Water Quality Data for MPID 4120120 (10/95—9/99).

MPID 4120120	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	92	90	250	15	53	49
pH	7.3	7.4	8.3	5.9	0.69	50
FE (mg/L)	1.45	0.30	53	0.10	7.77	46
MN (mg/L)	0.10	0.10	0.20	0.10	0.02	22
TSS (mg/L)	7.7	4.0	32	4.0	6.7	50
ALKALINITY (mg/L)	91	67.5	242	10.0	77	50
CONDUCTIVITY (µmhos/cm)	282	260	620	68	154	50
TDS (mg/L)	195	150.5	506	33.0	122	50
SULFATE (mg/L)	39.4	33.5	124	11.0	21.5	50

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.17 In-stream Water Quality Data for MPID 4120086 (1/96—9/99).

MPID 4120086	Mean	Median	Max	Min	SD[1]	N[2]
FLOW (gpm)	84	90	200	15.0	46	41
pH	7.6	7.8	8.7	5.9	0.65	44
FE (mg/L)	0.33	0.30	0.9	0.10	0.19	43
MN (mg/L)	0.10	0.10	0.10	0.10	0.00	20
TSS (mg/L)	9.9	4.0	98	4.0	15.4	44
ALKALINITY (mg/L)	82	45.5	242	8.0	77	44
CONDUCTIVITY (µmhos/cm)	245	204	600	65	154	44
TDS (mg/L)	164	130	402	22	103	44
SULFATE (mg/L)	32.9	30.5	87	6.0	16.8	44

[1]SD: standard deviation, [2]N: number of sample measurements

3. STRESSOR IDENTIFICATION

There are no water quality standards or recommended screening levels for some of the water quality parameters in the state of Virginia. In order to assess the potential impact of water quality on the macroinvertebrate population in Middle Creek a suitable watershed for comparison was selected. The McClure River is a fourth order stream in the same ecoregion and there are mining related land uses in the watershed. Recent biological monitoring at VADEQ station 6AMCR000.55 indicates a healthy macroinvertebrate population. Therefore, for water quality parameters without established standards or screening levels, the 90th percentile for the parameters available from the McClure River (6AMCR000.20) was used to evaluate the water quality data in this stressor analysis. When a parameter exceeded the 90th percentile more than 10% of the time it was considered excessive and a scatter graph is shown for the parameter at that monitoring site. Depending on the habitat and benthic metrics as well as additional chemical evidence, a parameter with excessive values may be considered a possible or probable stressor. In addition, summary graphs depicting the median values for a parameter at each monitoring site are also shown (monitoring sites are ordered from downstream to upstream). Table 3.1 shows the 90th percentile values used as screening values from the McClure River (6AMCR000.20) data. Scatter graphs for all of the parameters evaluated at each DMME permitted monitoring site are shown in Appendix A. Monitoring sites with less than nine values were not used in the Stressor Identification unless there were extreme values reported. Scatter graphs for the sites with small datasets are also shown in Appendix A. The presence of nine values was selected as a cut off in order to avoid assessing stations that weren't sampled during different seasons and flow regimes of the year.

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not but they usually don't provide enough information to determine the cause(s) of the impairment. The process outlined in EPA's Stressor Identification Guidance Document (USEPA, 2000) was used to separately identify the most probable stressor(s) for Middle Creek. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Landuse data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. The list of potential stressors is: conductivity, sulfate, total dissolved solids, pH, metals, and sediment.

Table 3.1 McClure River (6AMCR000.20) 90th percentile screening values.

Parameter	90th Percentile
Conductivity (?mho/cm)	800
Total dissolved solids (mg/L)	525
Total suspended solids, (mg/L)	25
Sulfate (mg/L)	150
Alkalinity (mg/L)	200
Total iron (mg/L)	1.45
Total manganese (mg/L)	0.10*

*0.1 mg/L was used because this value represents the minimum detection value in the majority of the available data.

3.1 Metals

In data submitted by DMME, total iron and total manganese were collected at all the sites on Middle Creek. Median total iron concentrations were low and did not exceed 0.5 mg/l (Figure 3.1). However, there were two spikes: one at MPID 4120012, river mile 4.05 (435 mg/L) and one at MPID 4120120, river mile 5.99 (53 mg/L). The 90th percentile total iron value of 1.5 mg/L was not exceeded in more than 10% of the samples collected at any of the DMME monitoring sites. A review of the available literature suggests that the main problem for aquatic life caused by iron occurred when persistently high values precipitated out and covered up habitat and/or smothered organisms. This does not appear to be the case in Middle Creek.

Total manganese concentrations were also relatively low. The 90th percentile value (0.10 mg/L) was exceeded by more than 10% of the values at three of the eight monitoring stations (Figures 3.2 through 3.4). Median total manganese concentrations did not exceed 0.1 mg/L (Figure 3.5). There was one spike of 1.0 mg/L at MPID 4120204 at river mile 4.05. Baetidae, a family of Mayflies, is extremely sensitive to metal pollutants and during a study of Middle Creek in 2001 and 2002, Baetidae were found throughout Middle Creek. This suggests that metal contamination is not a significant factor affecting the benthic community (Merricks, 2003). Therefore, metals are not considered a significant stressor in Middle Creek.

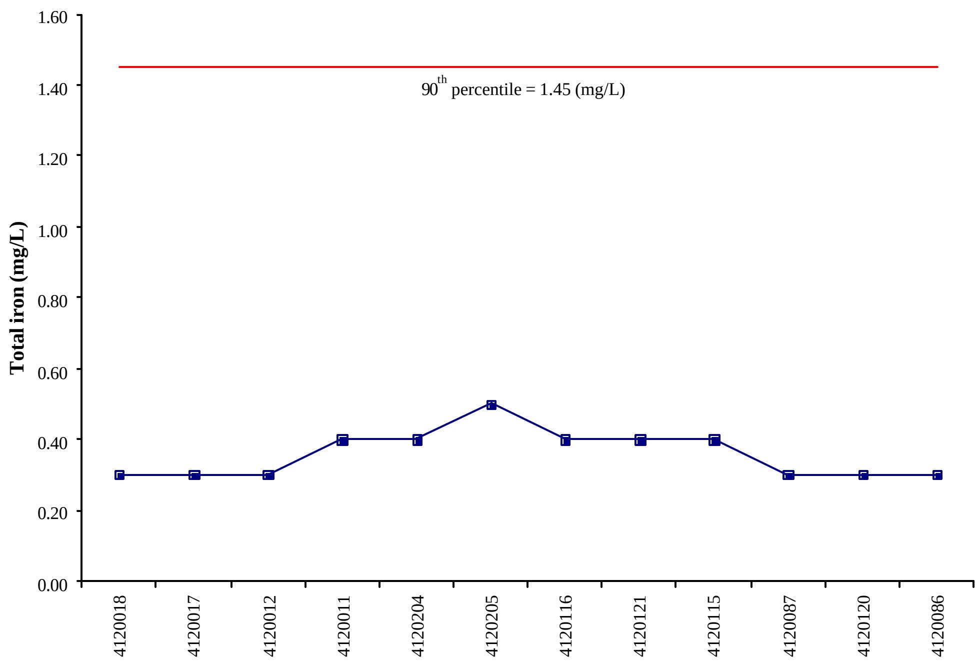

Figure 3.1 Median total iron concentrations at DMME monitoring sites in Middle Creek.

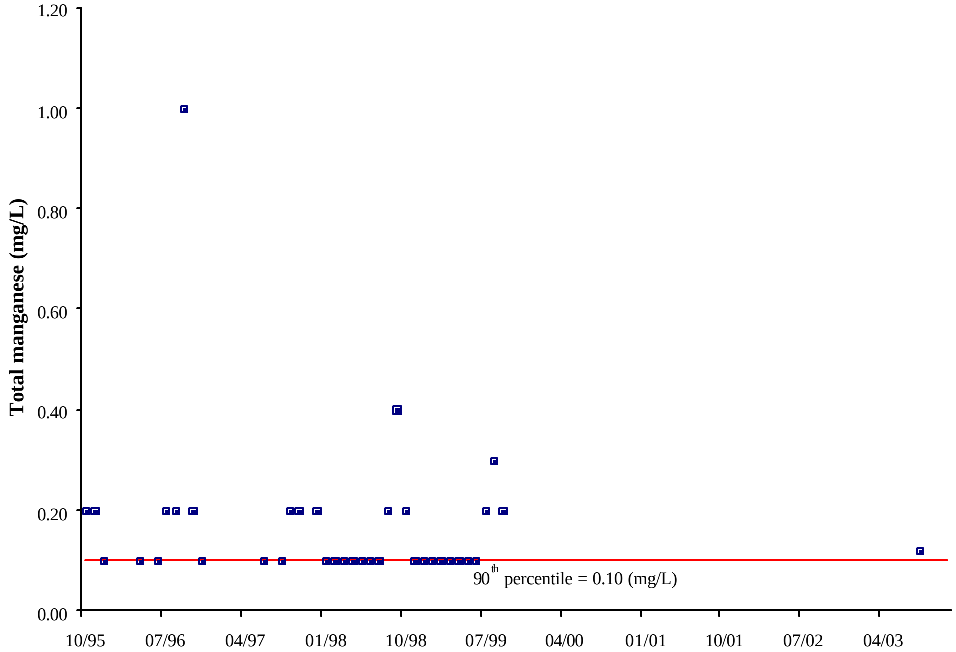

Figure 3.2 Total manganese concentrations at MPID 4120204.

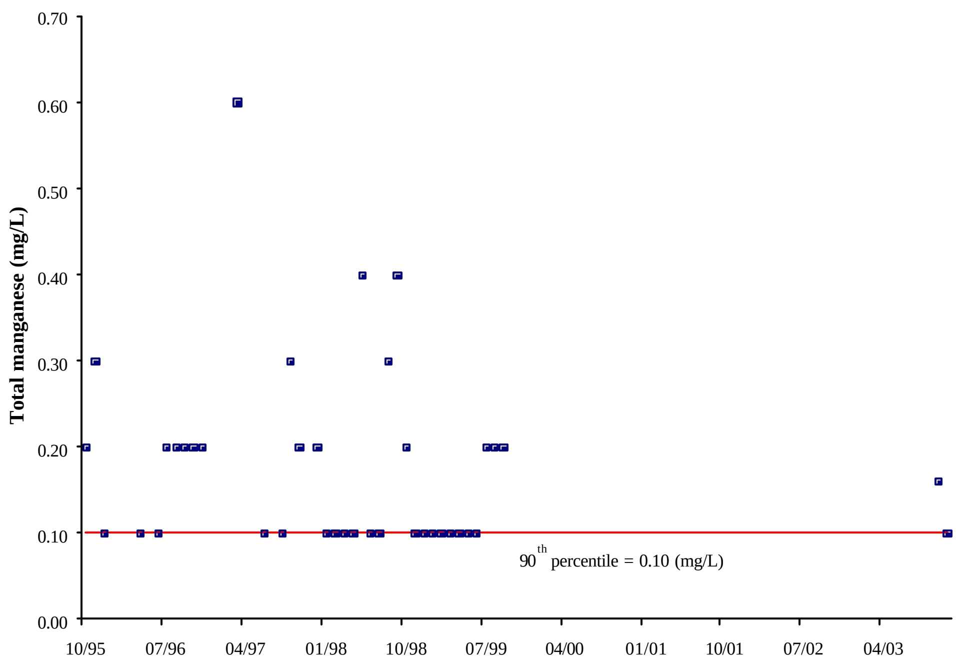

Figure 3.3 Total manganese concentrations at MPID 4120205.

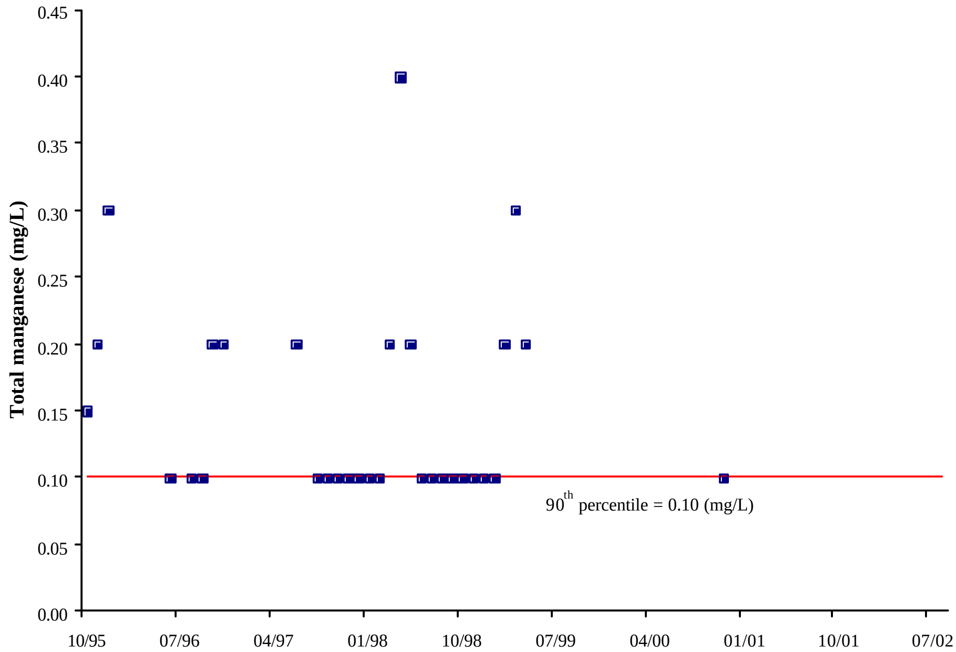

Figure 3.4 Total manganese concentrations at MPID 4120116.

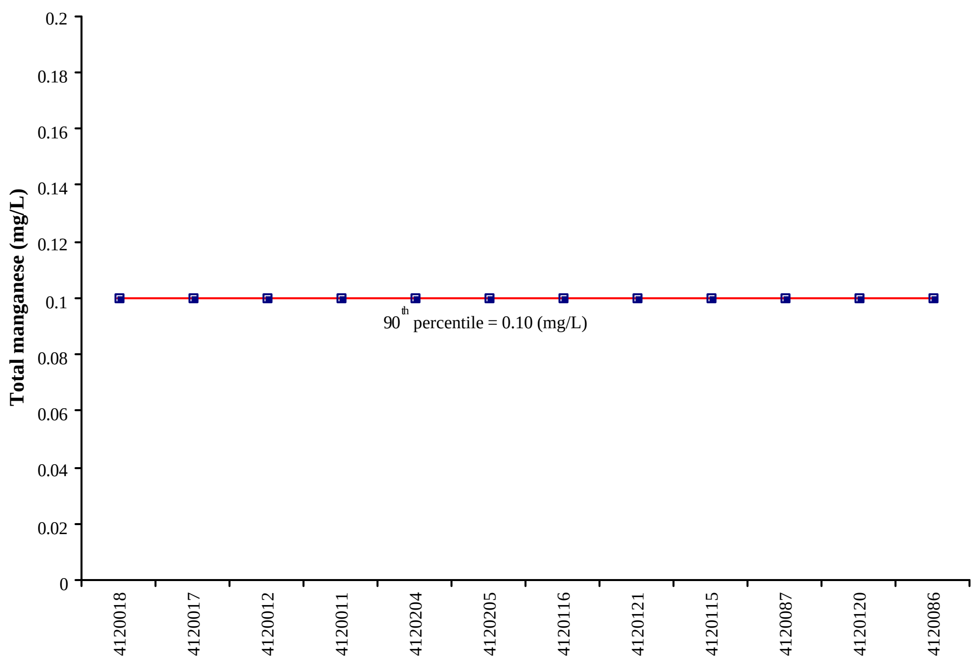

Figure 3.5 Median total manganese concentrations at DMME sites in Middle Creek.

3.2 pH

Field pH values ranged from 5.95 and 5.9 at MPID 4120120 and 4120086, respectively, to 11.0 at MPID 4120204. Occasional values just below the minimum standard of 6.0 are not considered stressful to the aquatic community. However, occasional values as high as 11.0 can be stressful to benthic organisms. The pH of 11.0 was recorded at river mile 4.42 in the area were the benthic life was the most impacted. Median pH values ranged from 7.2 to 7.85 (Figure 3.6). Alkalinity values ranged from 6 mg/L to 4,423 mg/L. The maximum value was measured at monitoring site 4120017, river mile 3.89. Median alkalinity values ranged from 26 mg/L to 104 mg/L. Based on the occasional high pH and alkalinity values, pH is considered a possible stressor.

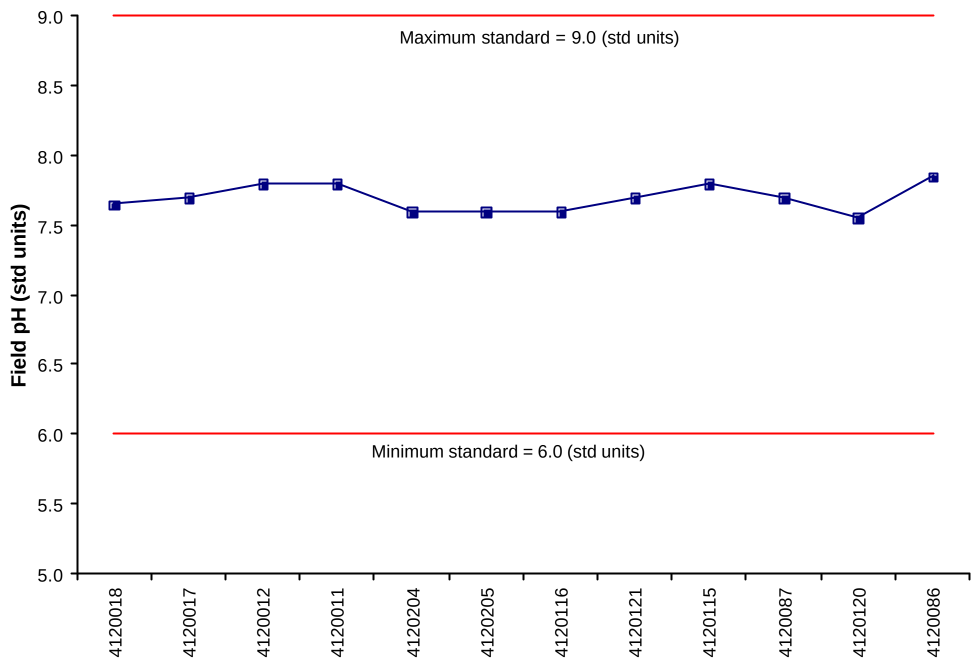

Figure 3.6 Median field pH values at DMME sites in Middle Creek.

3.3 Sediment

Habitat scores in Middle Creek were determined by VADEQ in 1996 and 2003. The habitat metrics most related to sediment deposition are embeddedness and sediment. The 1996 VADEQ benthic survey at 6BMID000.20 found scores for embeddedness and sediment in the marginal range (nine and eight, respectively). Surveys by VADEQ in July 2003 found much improved conditions. VADEQ performed an additional survey in November 2003 and the embeddedness score slipped back into the marginal category with a rating of nine. Total suspended solids (TSS) data submitted by DMME showed median scores were within an acceptable range of 4 mg/L – 8 mg/L. The EPA notes that TSS values in flowing streams as high as 25 mg/L are acceptable (EPA 1986). However, there were occasional spikes and the highest was 316 mg/L at monitoring site 4120017, river mile 3.89. Only MPID 4120018 at river mile 3.67 exceeded the 90th percentile value of 25 (mg/L) in more than 10% of the samples collected (Figure 3.7). Median TSS concentrations for every station are shown in Figure 3.8. Based on the habitat scores and TSS concentrations, sediment is considered a possible stressor.

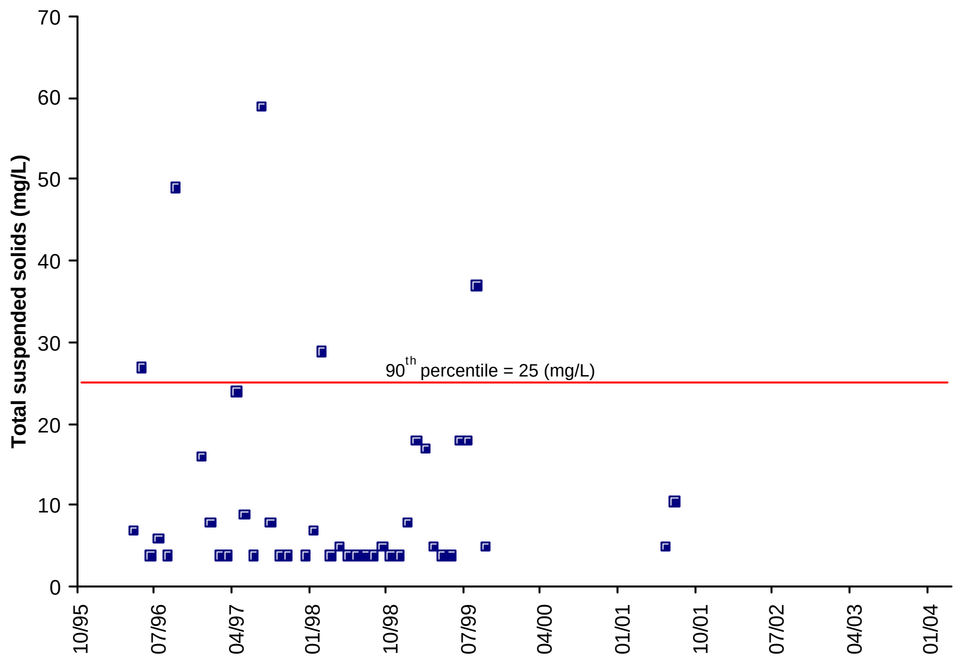

Figure 3.7 TSS concentrations at MPID 4120018.

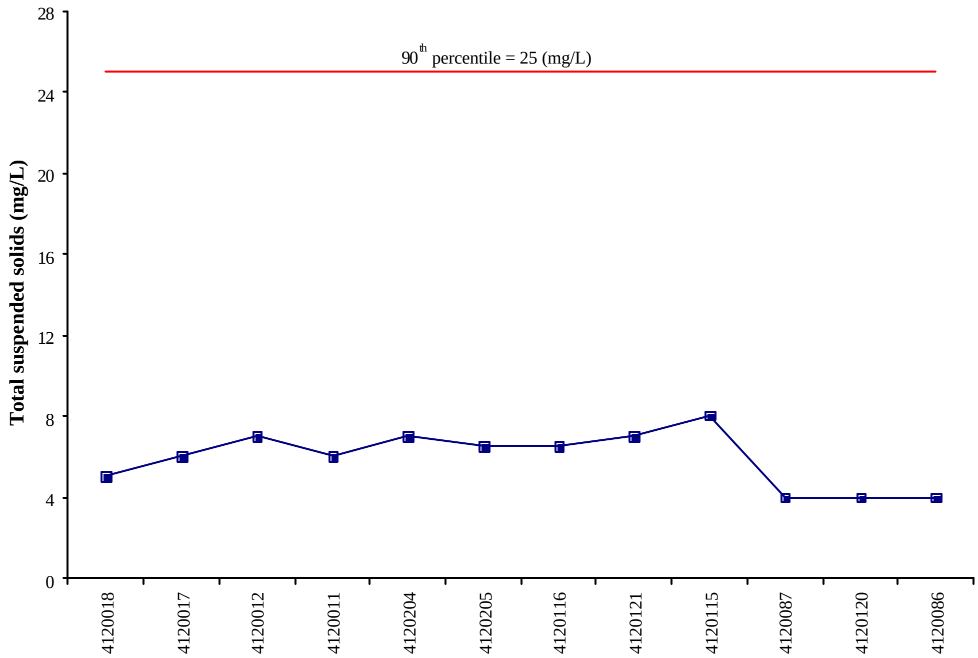

Figure 3.8 Median TSS concentrations at DMME monitoring sites in Middle Creek.

3.4 Sulfate

Sulfate concentrations were very high in Middle Creek. Eight of the 12 DMME monitoring sites exceeded the 90th percentile value of 150 (mg/L) in more than 10% of the samples collected (Figure 3.9 through 3.16). Median sulfate concentrations were below 150 (mg/L) at every monitoring site (Figure 3.17). There is no current criterion available for sulfate, and literature reviews do not specify levels that are harmful to aquatic life. A number of studies note that sulfate is a reliable indicator of mining activity and it is often linked to depressed benthic health but it has not been shown to actually cause a reduction in the health of benthic communities. Therefore, sulfate can be considered a possible stressor.

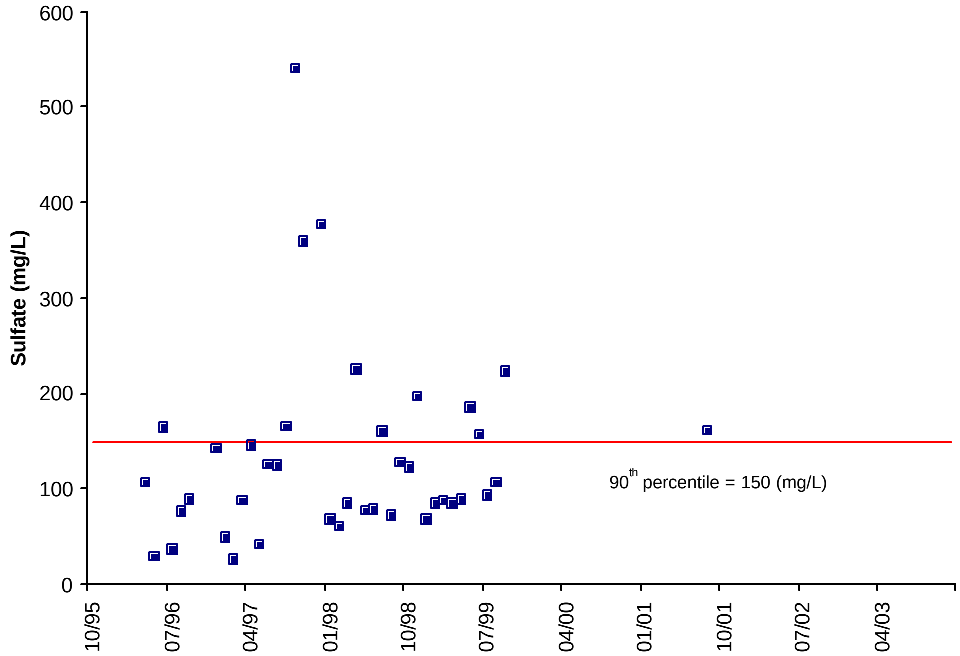

Figure 3.9 Sulfate concentrations at MPID 4120018.

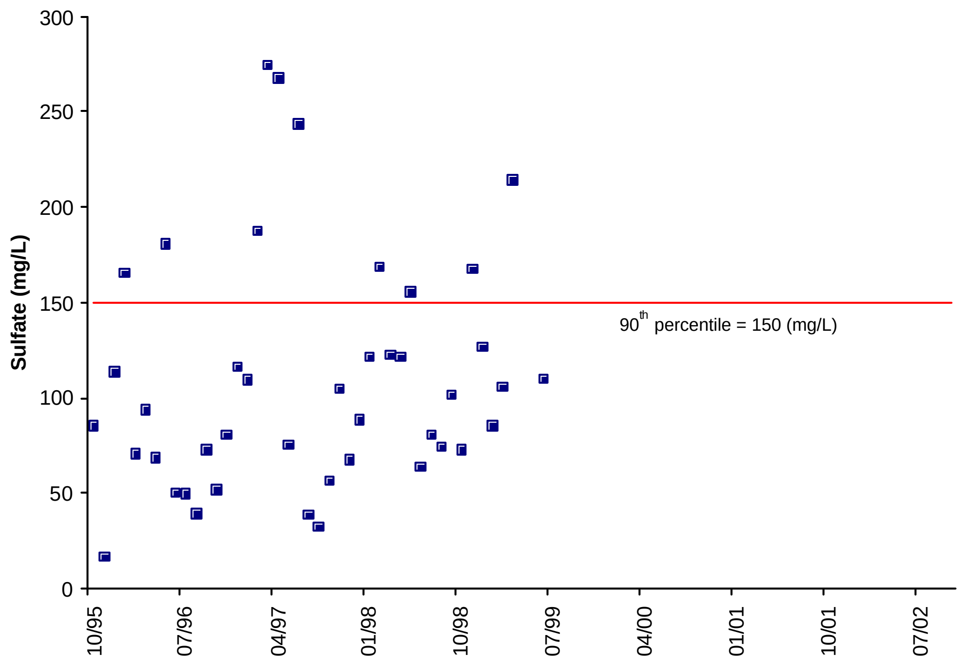

Figure 3.10 Sulfate concentrations at MPID 4120017.

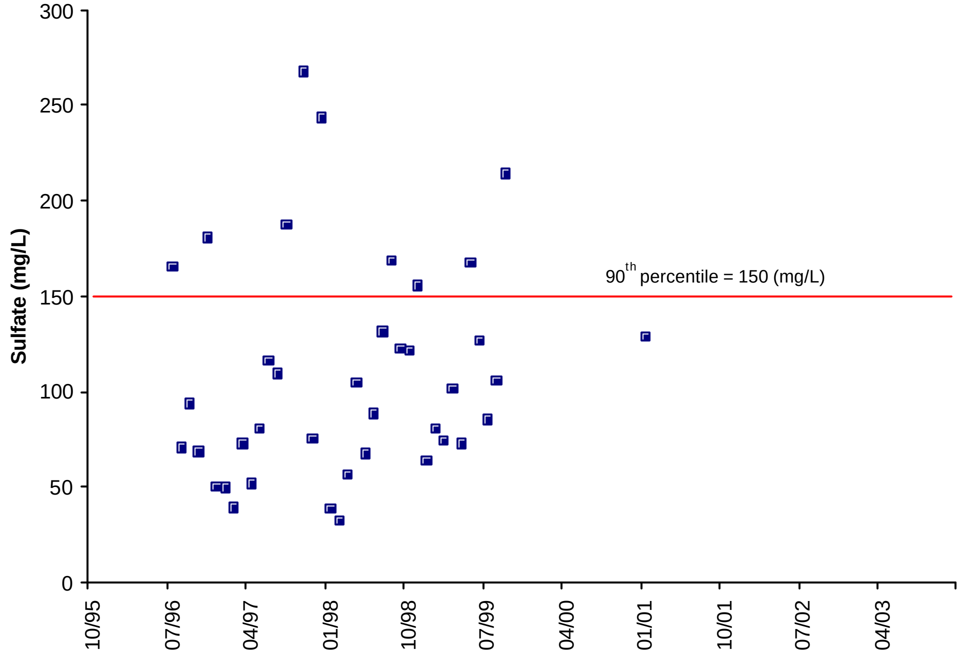

Figure 3.11 Sulfate concentrations at MPID 4120012.

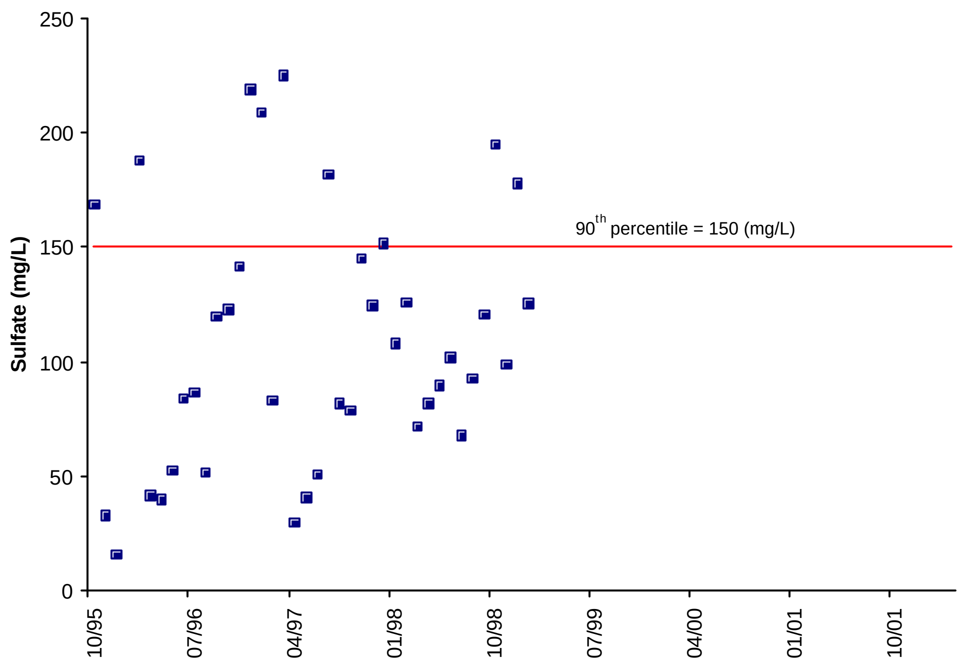

Figure 3.12 Sulfate concentrations at MPID 4120011.

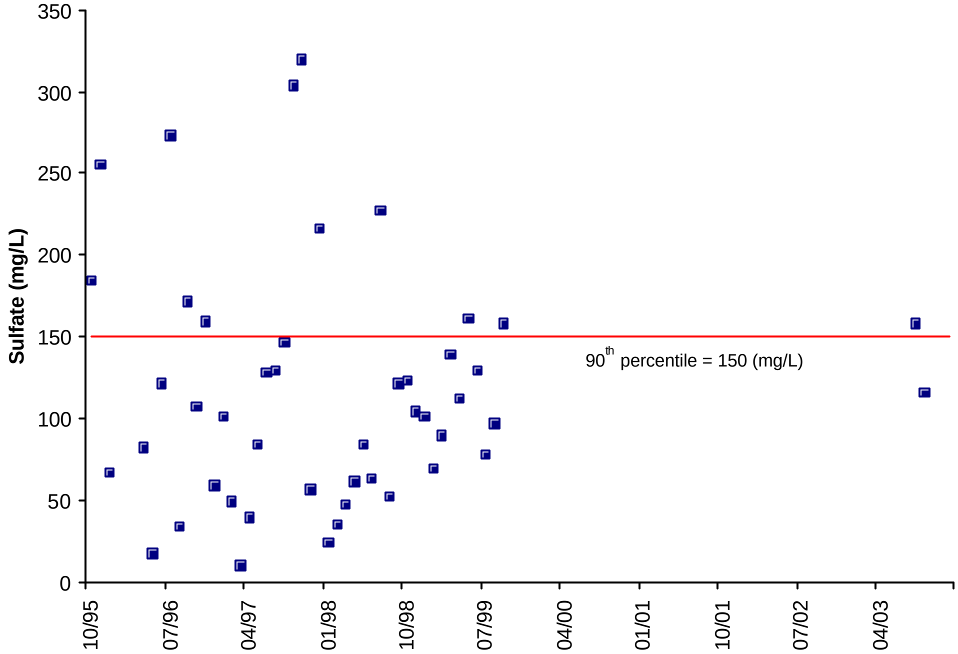

Figure 3.13 Sulfate concentrations at MPID 4120204.

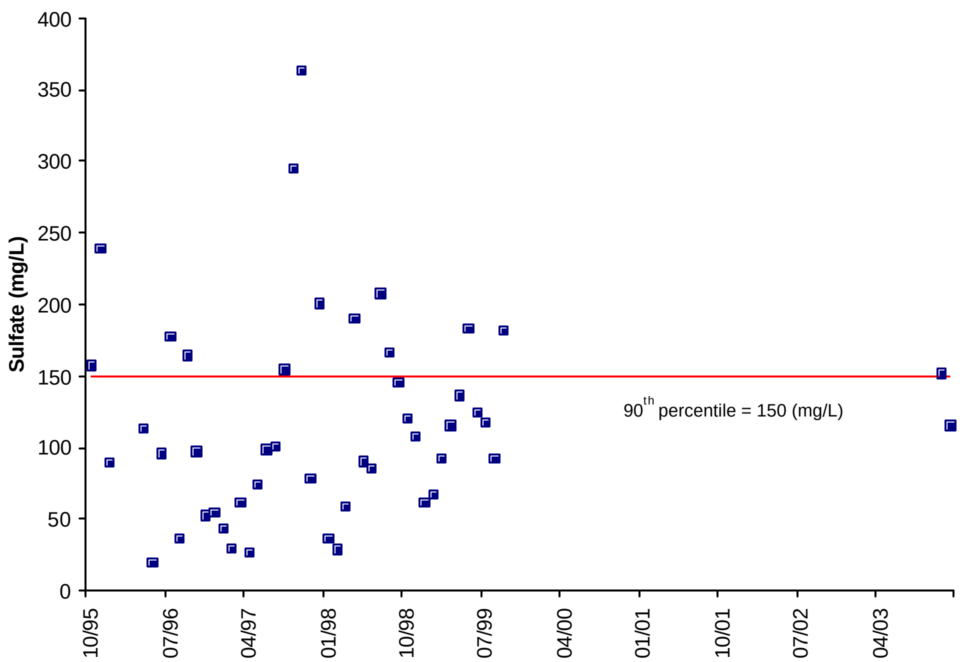

Figure 3.14 Sulfate concentrations at MPID 4120205.

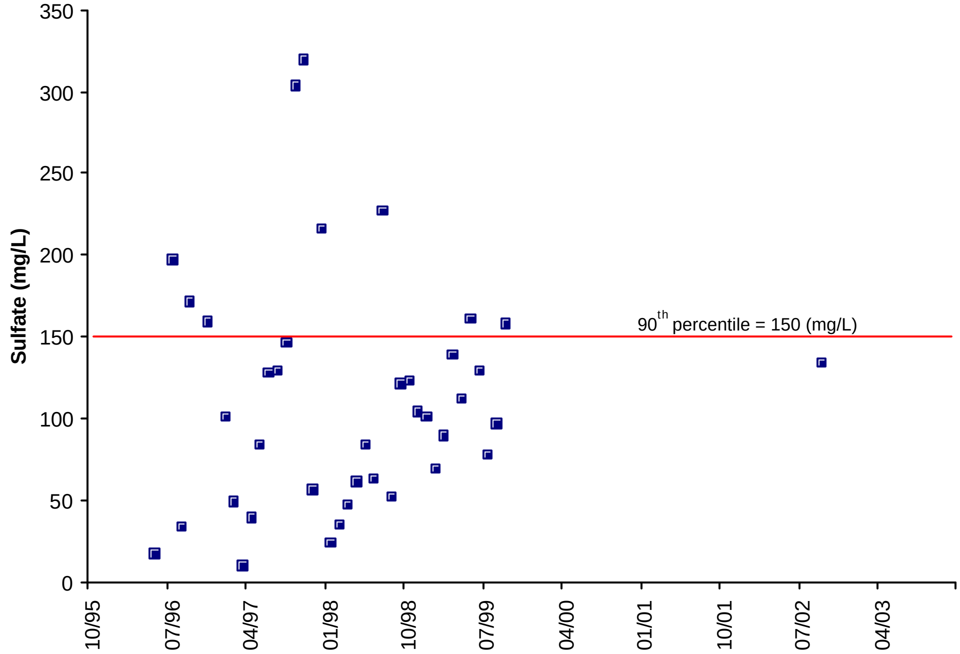

Figure 3.15 Sulfate concentrations at MPID 4120116.

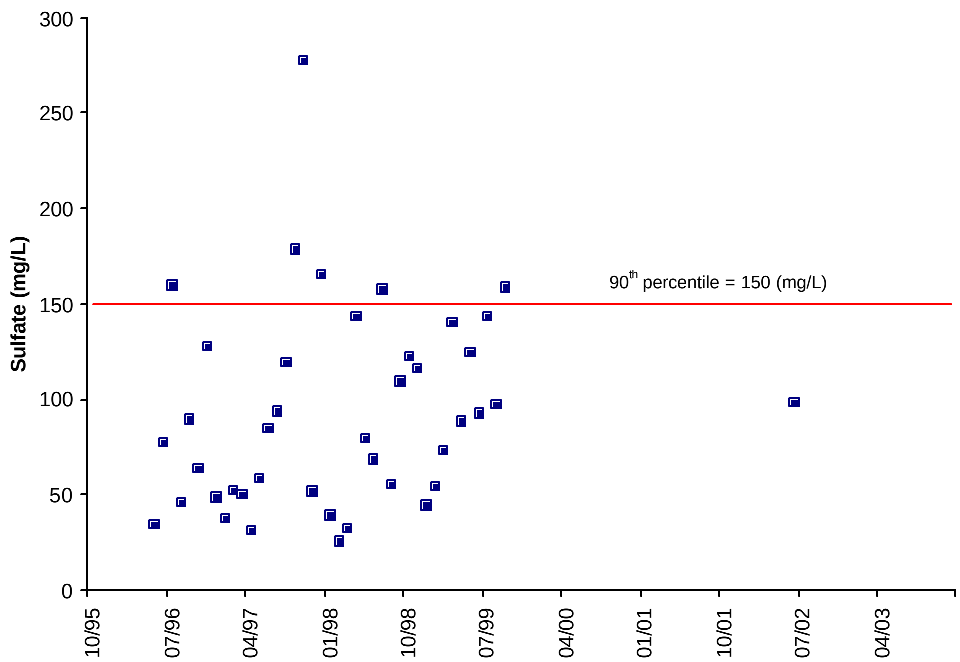

Figure 3.16 Sulfate concentrations at MPID 4120115.

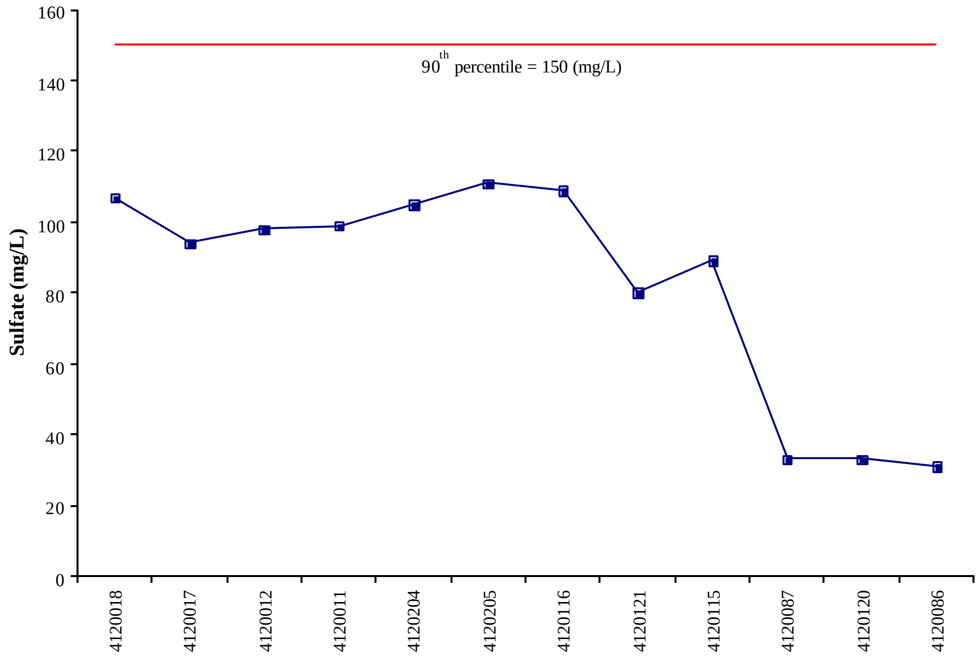

Figure 3.17 Median sulfate concentrations at DMME monitoring sites in Middle Creek.

3.5 Conductivity/Total dissolved solids

High conductivity values have been linked to poor benthic health (Merricks, 2003) and elevated conductivity is common with land disturbance and mine drainages. In the data provided by DMME no monitoring site exceeded the 90th percentile value for conductivity of 800 (? mhos/cm) in more than 10% of the samples collected. Median values are shown in Figure 3.18. Two MPIDs, 4120018 and 4120205 (river miles 3.67 and 4.86), had one value greater than or equal to 800 (? mhos/cm). Because Middle Creek had high conductivity values at two monitoring sites, conductivity was considered a possible stressor.

Electrical conductivity is a measure of the ability of solution to carry a current, which depends on the concentration of ionized substances dissolved in the water. The ionized substances are dissolved salts, which primarily consist of calcium, magnesium, potassium, sodium, bicarbonate, chlorides and sulfates. Total dissolved solids (TDS) consist primarily of dissolved salts plus dissolved metals, minerals and organic matter. This is why conductivity and TDS are often significantly correlated.

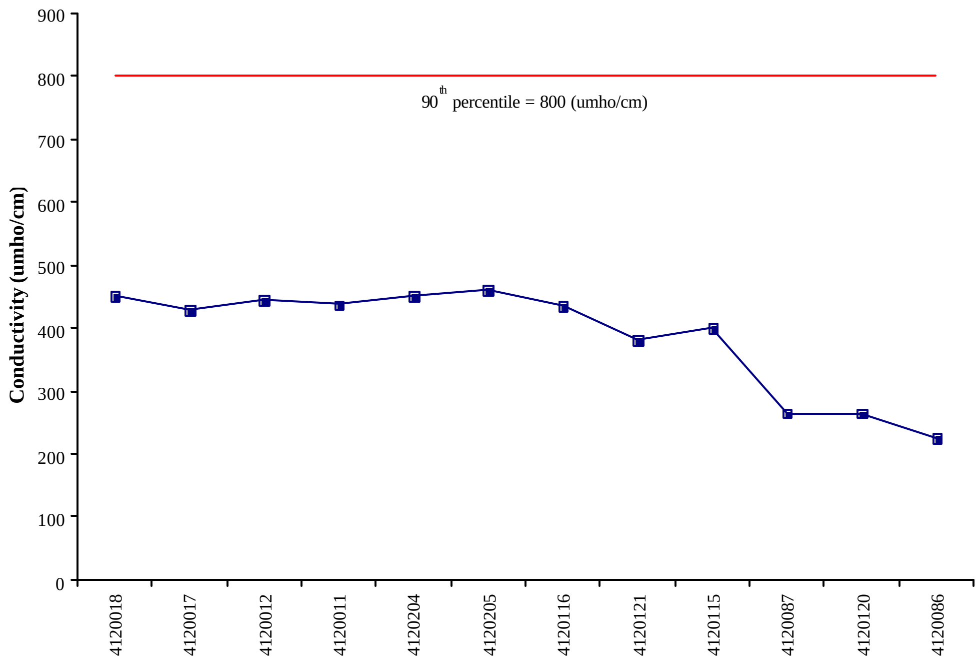

Figure 3.18 Median conductivity values at DMME monitoring sites in Middle Creek.

Elevated TDS have been linked to depressed benthic communities and are also an indicator of mining activity. While there is no specific water quality criterion for the protection of aquatic life large swings in TDS concentrations can be harmful to aquatic organisms because the density of water determines the flow of water into and out of an organism's cells (KanCRN 2004). TDS concentrations did not exceed the 90th percentile value of 525 mg/L for TDS in more than 10% of the samples at any of the DMME monitoring sites. However, MPIDs 4120011 and 4120018 each had two values exceed 1,000 mg/L. The maximum concentration recorded was 1,731 mg/L at MPID 4120011. Based upon the fact that Middle Creek had TDS concentrations exceeding 1000 mg/L at two monitoring sites, TDS is considered a possible stressor.

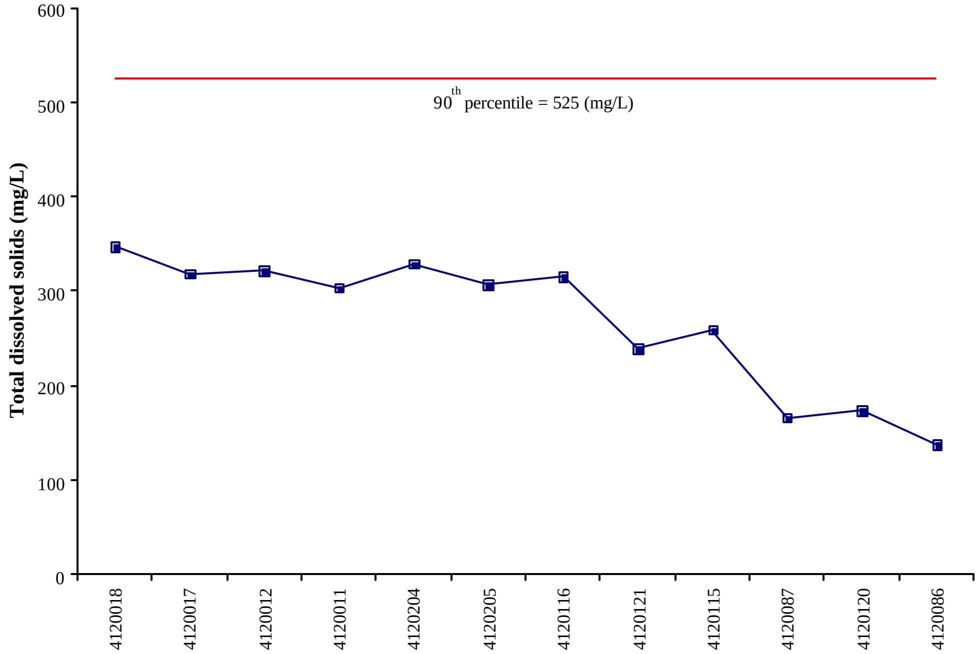

Figure 3.19 Median TDS concentrations in Middle Creek.

4. RECLAMATION

Comprehensive environmental regulations requiring technology based conservation measures for the coal mining industry were not established in Virginia until the United States Department of the Interior granted the state primacy over the Surface Mine Control and Reclamation Act (SMCRA) in 1981. At that time, decades-old mining operations were underway throughout southwestern Virginia's coalfields including Middle Creek. There existed some older abandoned mined lands in Middle Creek, but most of the mined areas were incorporated into state issued mining and reclamation permits during the early 1980s. These permits contained requirements for drainage plans, materials handling, regrading, revegetation, and pollution control. Also, the permits required operators to provide a performance bond to insure that the mine sites would be reclaimed to an acceptable post mining land use.

Unfortunately, adverse environmental impacts to Middle Creek from pre-law mining had already occurred by the time SMCRA primacy was granted. In December 1981, approximately 200 acres of the watershed was disturbed by active mining. Coalmine refuse was being disposed along the stream and its tributaries without adequate environmental and engineering safeguards. Precipitation events washed suspended and dissolved solids into the stream from the mine sites. Releases of black water were noted by representatives of Virginia's Division of Mined Land Reclamation (DMLR) and an average of specific conductivity values for samples collected from the stream in December 1981 was relatively high at 660 (?mhos/cm).

Regulated, permitted, and routinely inspected mining operations were conducted in the watershed from 1983 until 1999. During this period, sediment control and land management practices were required and utilized at the mines. Improvements in stream water chemistry were noted. A compliance evaluation inspection by DMLR of all the active coal operations in Middle Creek was conducted in September 1996. Specific conductivity values for the stream at the same general location as the December 1981 measurements averaged 416 (?mhos/cm) for the period of July through September 1996.

Through the 1990's, Covenant Coal Corporation (Covenant) operated the mines in Middle Creek. Their last facility, the coal processing plant, was idled in 1999. Covenant's operations in Middle Creek included the Middle Seaboard No. 3 mine, the Middle Creek Energy mine, the Greasy Creek No. 3 mine, the Sawmill Hollow refuse area, the Middle Creek fill No. 5 and Middle Creek Coal Preparation Plant. These facilities totaled 243.92 permitted acres. The general location of these facilities, along with the two permitted two discharge points from underground mining that are currently discharging into Middle Creek are shown in Figure 4.1. After Covenant closed their last operation in Middle Creek, the company did not complete reclamation of the mine sites. As a result of Covenant's failure to reclaim permitted areas, DMLR initiated enforcement actions that led to the company's forfeiture of the performance bonds in August 2000. After bond forfeiture, DMLR administered the reclamation of the sites through a settlement agreement with Clarendon National Insurance Company – the bonding agent.

The mined land reclamation activities administered by DMLR in Middle Creek included best management practices and conservation measures typical of reclamation throughout the coalfields; removal of equipment and structures, regrading of the land to original contours, revegetation, and establishment of a designed post mining land use. In Middle Creek, all sites were reclaimed as unmanaged forestlands. Following is a site specific description for the reclamation of the Covenant sites.

Reclamation of the Middle Seaboard No. 3 mine consisted of dewatering and removing an existing pond concurrent with establishment of erosion and sediment control for the project. The mine portal was closed and covered. The primary construction and reclamation activities at the site, based on cost and time, were site preparation, excavation, grading, and revegetation. Erosion and sediment were controlled during reclamation with the placement of silt fencing and straw bales. Revegetation included seeding, mulching, and tree planting based on an approved plan to establish forested lands compatible with the surroundings. Once the regraded areas were stabilized and vegetation established, fencing and straw bales were removed.

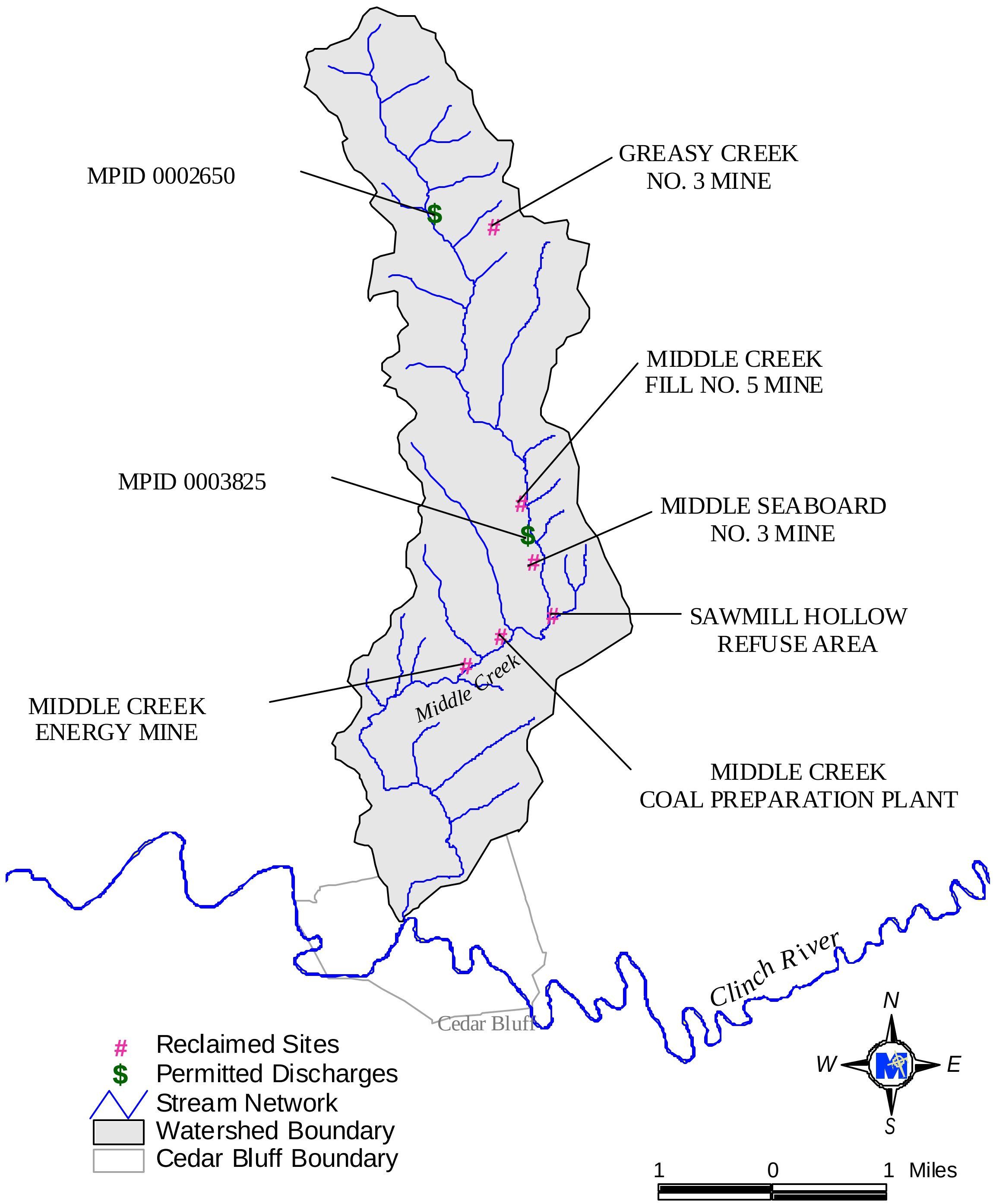

Figure 4.1 General location of reclaimed mined land in the Middle Creek watershed.

The Middle Creek Energy mine was a smaller site than the Seaboard mine and required no excavation work nor mine portal closure. The primary construction and reclamation activities at the site were road maintenance, regrading, and revegetation. Four basins were removed and a ground water monitoring well sealed.

Reclamation of the Sawmill Hollow Refuse area was more elaborate. The first phases were to grade and cover the upper terrace of the refuse fill. This immediately provided reductions to the sedimentation and mineralization of Middle Creek. The whole refuse area was covered with a twelve inch layer of topsoil. Clean water diversions were retained around the fill area. There were some chemicals located on this permit area and they were collected and returned to the company where purchased. The site was revegetated with trees planted during the first planting season that followed the fill coverage.

The Preparation Plant was dismantled and removed, along with other structures and debris, from the site. Once all the structures on the site were dismantled and removed, all coal related material was cleaned up and hauled from the site. Prior to the disposal of the material, it was tested and determined not to be toxic. After the plant facilities were removed, reclamation at the site consisted primarily of the elimination of existing highwalls, via regrading and revegetation, and the restoration of the stream channel.

Fill 5 and the Greasy Creek mine were reclaimed in the same manner as the other four sites and all mined land reclamation was completed by June 2002. The cost of all the reclamation and restoration efforts in Middle Creek exceeded $400,000 and most of the work was performed by a contractor for the insurance company; Matco Contracting. The reclamation work was inspected by DMLR and Appalachian Technical Services, a contracted engineering firm.

DMLR has initiated chemical monitoring at two stations in Middle Creek – one near the mouth of the stream at VADEQ's benthic macroinvertebrate monitoring station and one near the location of the 1981 and 1996 chemical measurements mentioned earlier in this narrative. The initial samples collected from Middle Creek averaged 263 (?mhos/cm) for specific conductivity. The reclamation of the historical mining sites in Middle Creek should further reduce the level of solids contributed to the stream from these sites. Solids reductions will result in continued improvement in the biological health of the stream.

5. CONCLUSION

Middle Creek was listed as impaired for benthics on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report. The cause of the impairment was identified by VADEQ as resource extraction. Coal mining was conducted in the upper portions of the watershed from the 1950s through the 1990s. In addition there existed some older abandoned mines.

Comprehensive environmental regulations were not established in Virginia until 1981. Prior to the new regulations coal mine refuse was disposed of along Middle Creek and it's tributaries with no protection allowing large quantities of suspended and dissolved solids to be washed into the stream during precipitation events. Water quality monitoring by the mining permit holders indicated an average specific conductance of 600 (? mhos/cm) in 1981. The new regulations required sediment control and land management practices and by 1996 average specific conductance values were 416 (? mhos/cm). The last coal processing plant was idled in 1999 and the company that owned it forfeited its performance bonds. DMLR quickly began contracting reclamation work. Reclamation consisted of best management practices and conservation measures for coalfields; removal of equipment and structures, regrading to the original contours and revegetation. Reclamation work was completed in 2002 at a total cost of $400,000 and 244 acres of mined land were reclaimed.

Development of a TMDL for the benthic impairment was started in early 2004. The initial analysis, using instream chemistry data from DMLR collected between 1995 and 1999, indicated a borderline condition but noted that the stream could benefit from further reductions in conductivity and total dissolved solids. Two consecutive benthic surveys in July and November of 2003 show that the stream has fully recovered and meets the EPA's requirements for removal from the 303(d) list.

Following the results of VADEQ's recent benthic monitoring DMME initiated additional chemical testing. The results from the first several samples show an average specific conductance of 263 (? mhos/cm). This indicates that the reclamation work was successful in improving water quality in Middle Creek. It also confirms the findings in the stressor identification that further reductions in conductivity and total dissolved solids from the 1990s values would return the stream to a non-impaired status.

Based upon the fact that extensive reclamation work has been completed, the chemical data indicates improvement and the two most recent benthic surveys show no impairment in Middle Creek and the stream meets all of the EPA's requirements for delisting.

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APPENDIX A

Instream water quality data

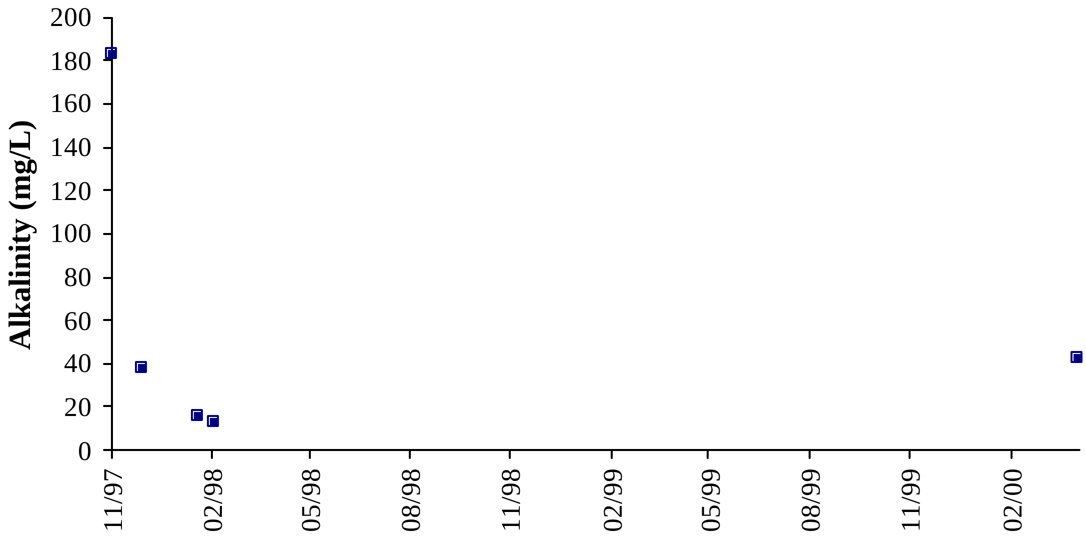

Figure A.1 Alkalinity concentrations at DMME permitted site 01988.

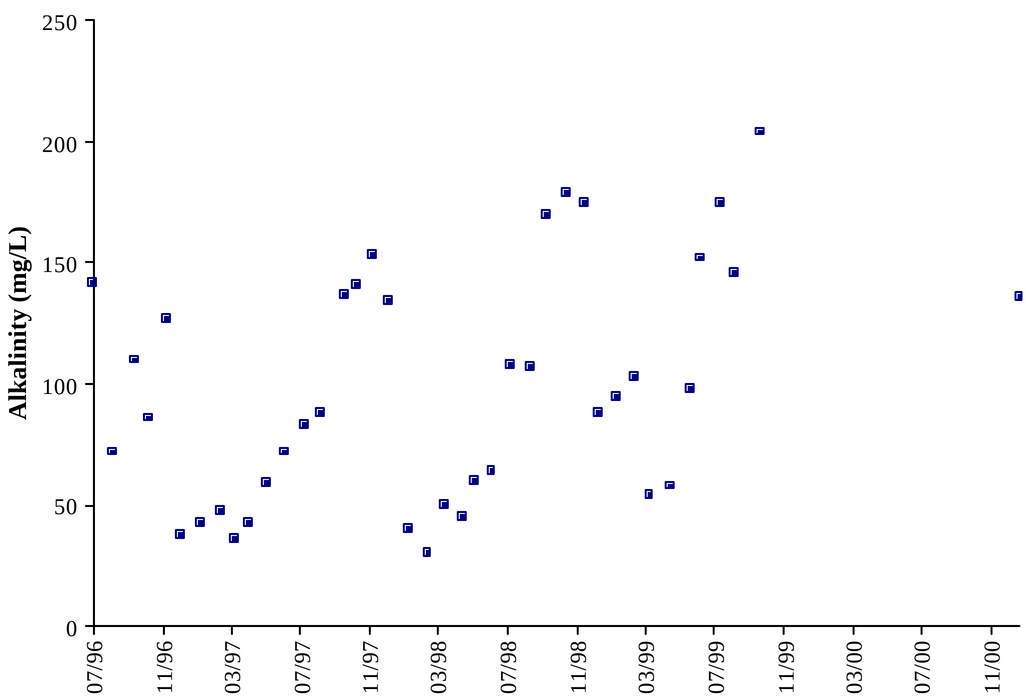

Figure A.2 Alkalinity concentrations at DMME permitted site 4120011.

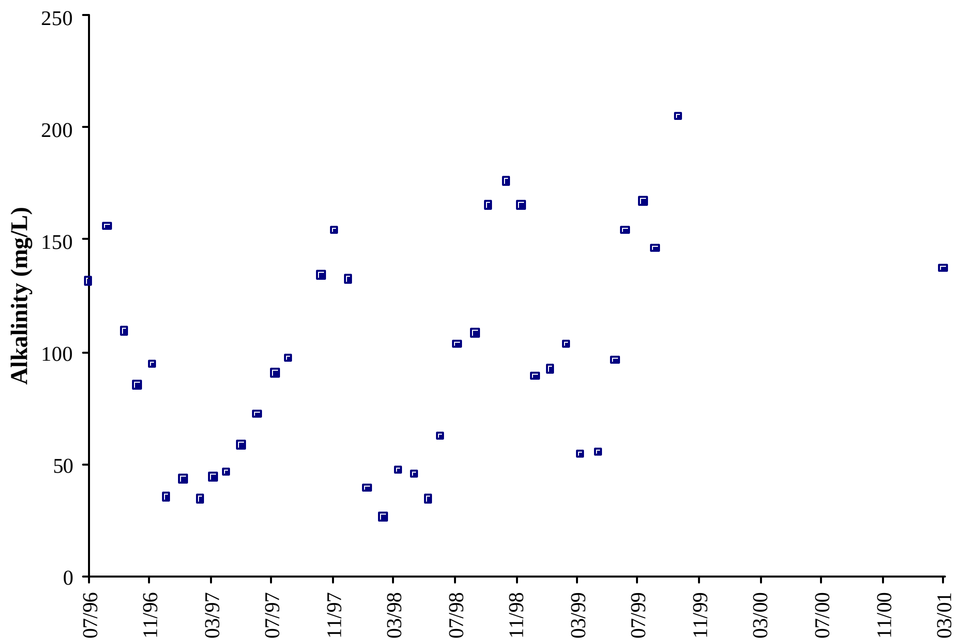

Figure A.3 Alkalinity concentrations at DMME permitted site 4120012.

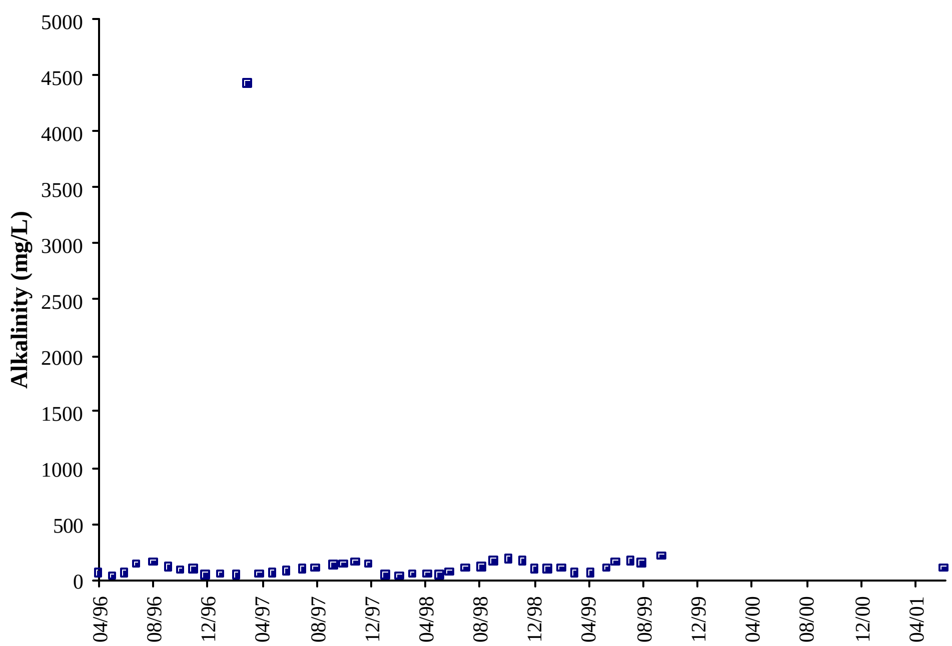

Figure A.4 Alkalinity concentrations at DMME permitted site 4120017.

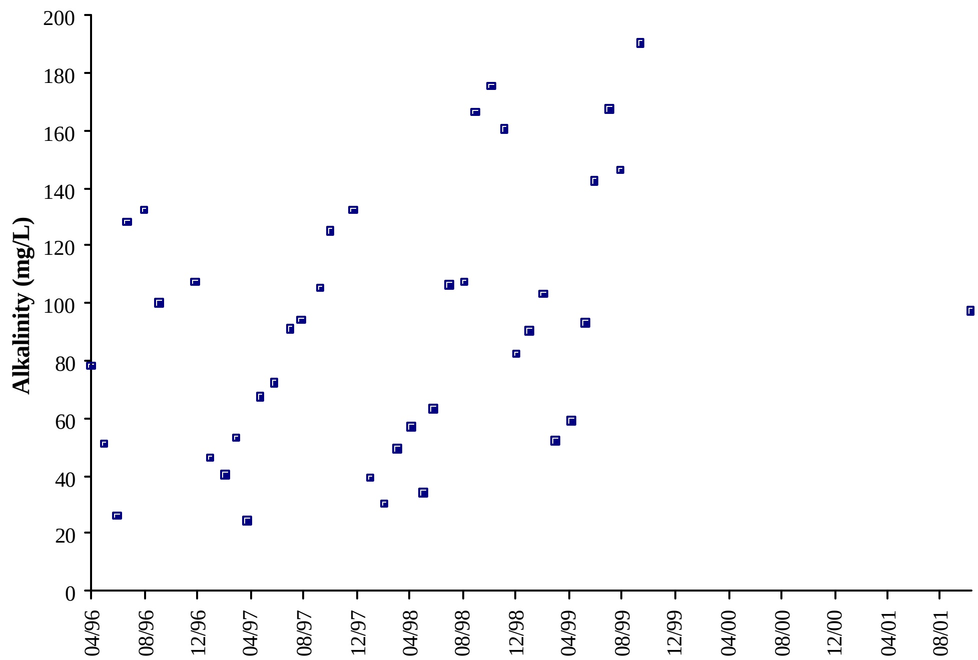

Figure A.5 Alkalinity concentrations at DMME permitted site 4120018.

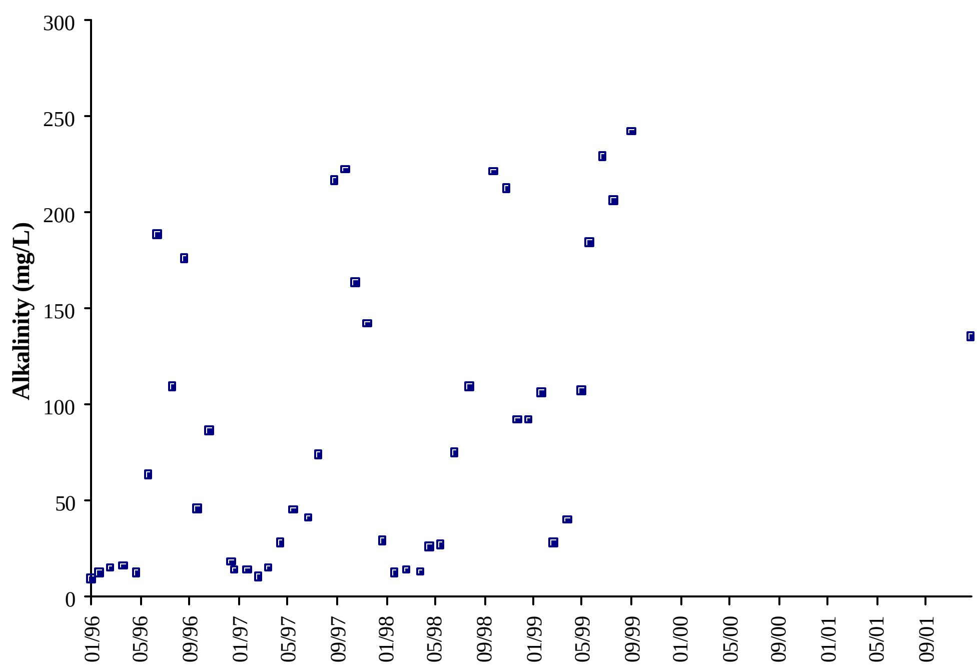

Figure A.6 Alkalinity concentrations at DMME permitted site 4120086.

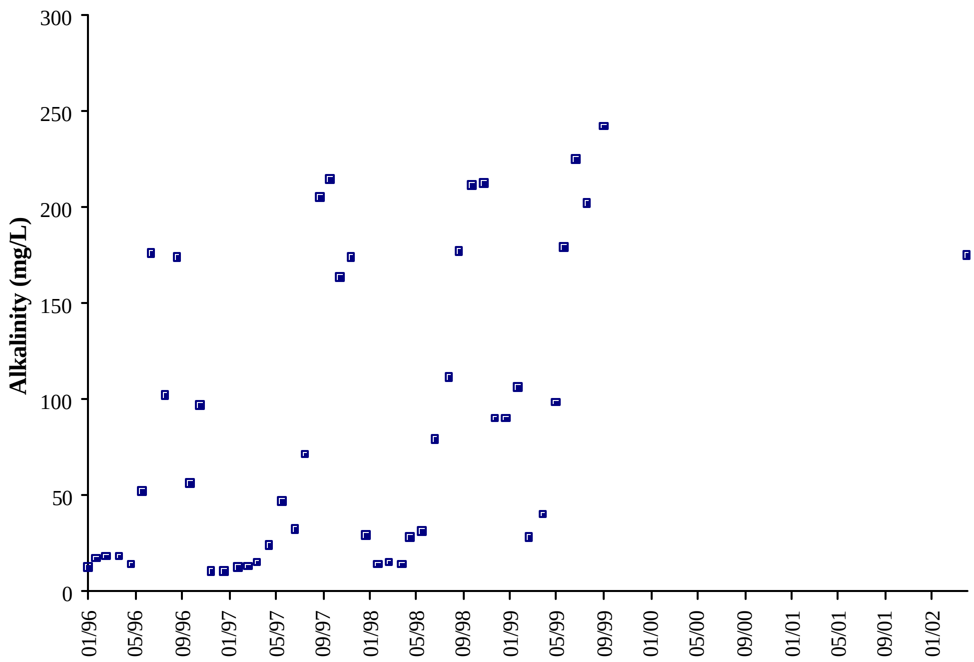

Figure A.7 Alkalinity concentrations at DMME permitted site 4120087.

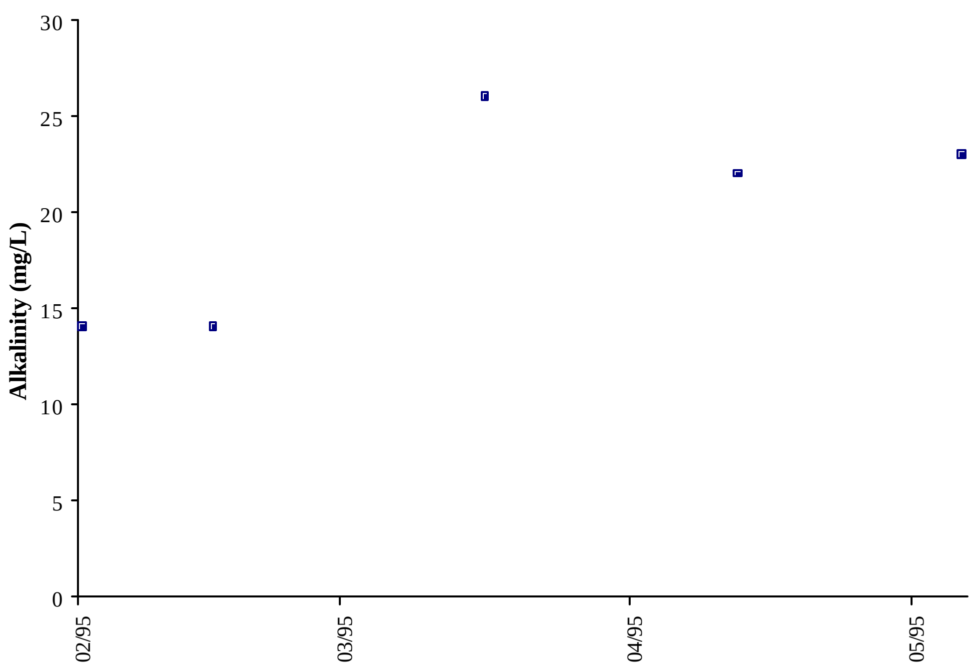

Figure A.8 Alkalinity concentrations at DMME permitted site 4120099.

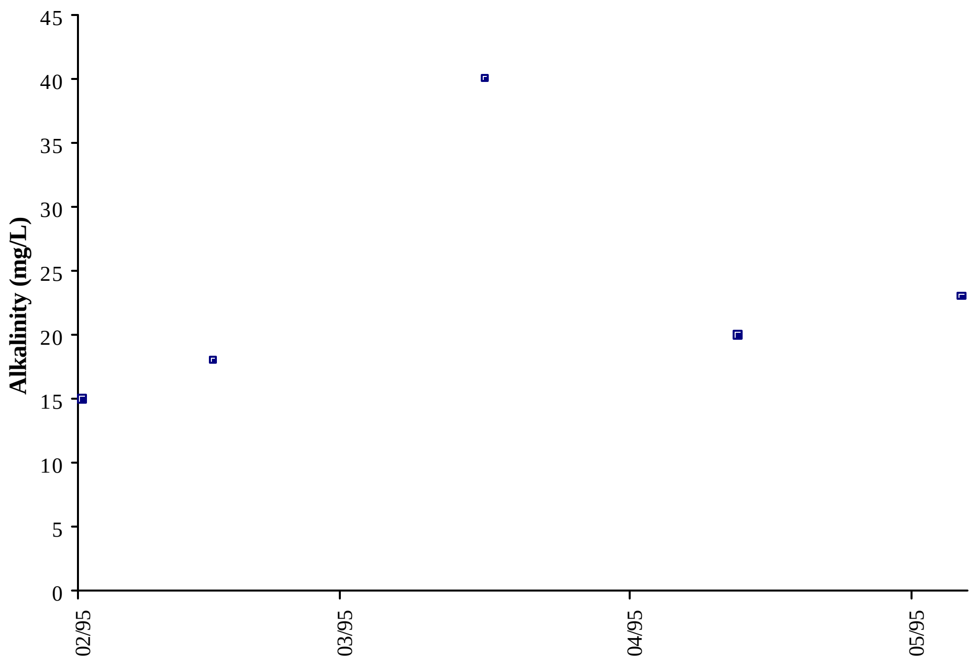

Figure A.9 Alkalinity concentrations at DMME permitted site 4120100.

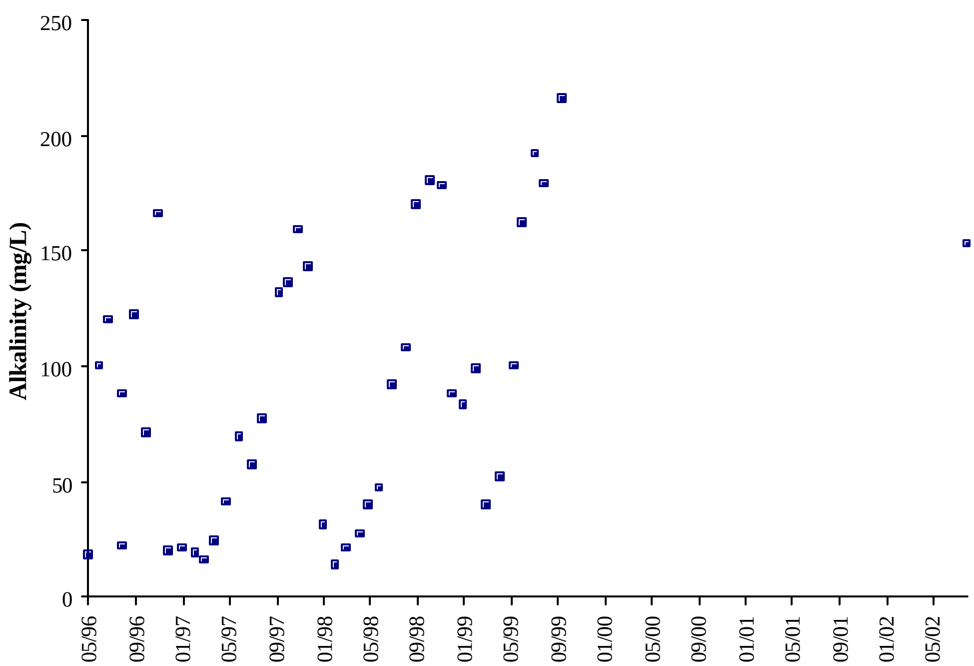

Figure A.10 Alkalinity concentrations at DMME permitted site 4120115.

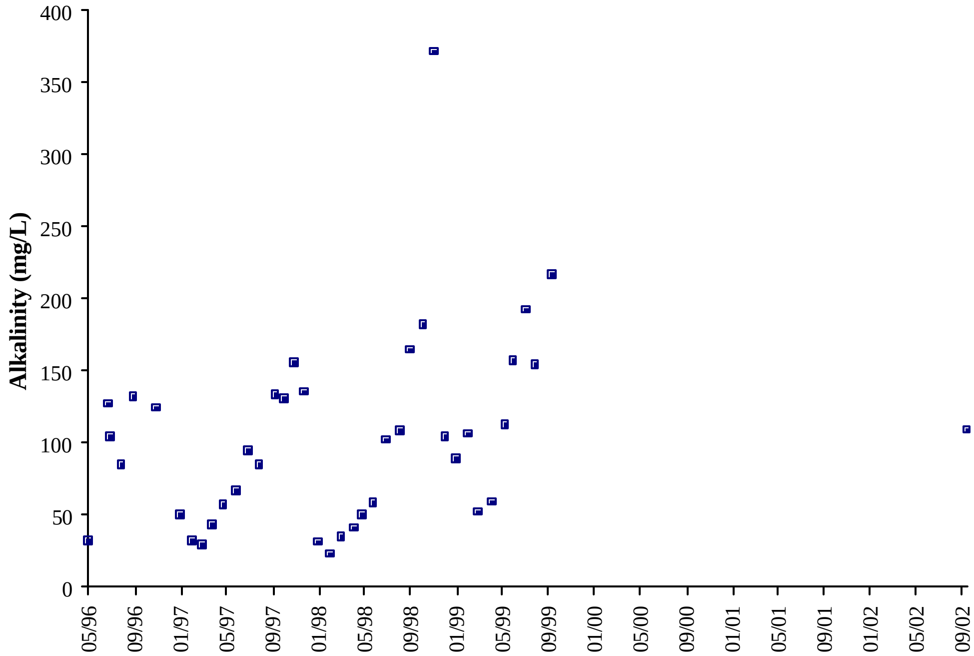

Figure A.11 Alkalinity concentrations at DMME permitted site 4120116.

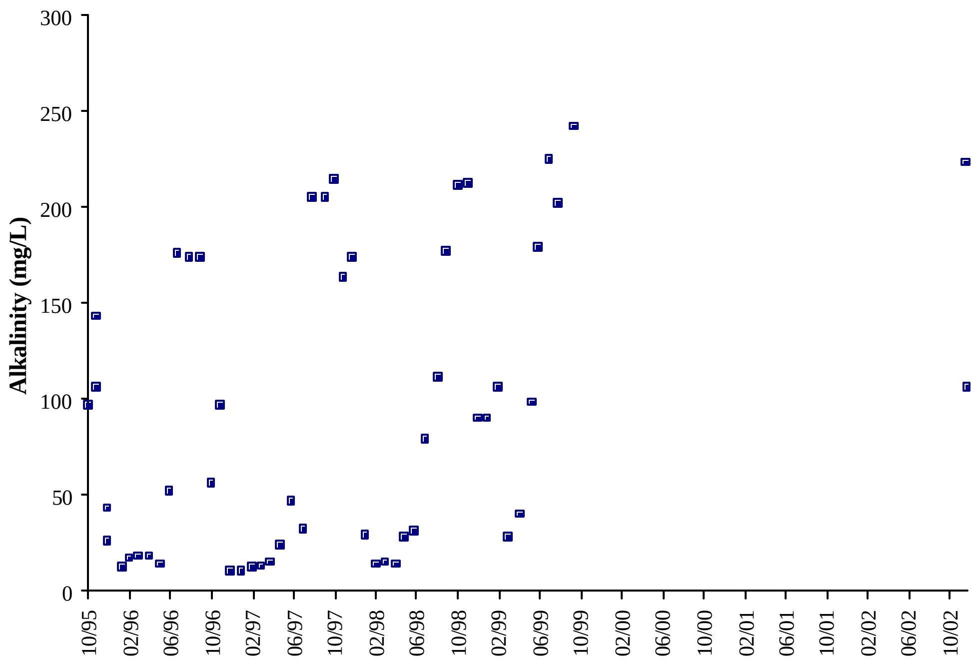

Figure A.12 Alkalinity concentrations at DMME permitted site 4120120.

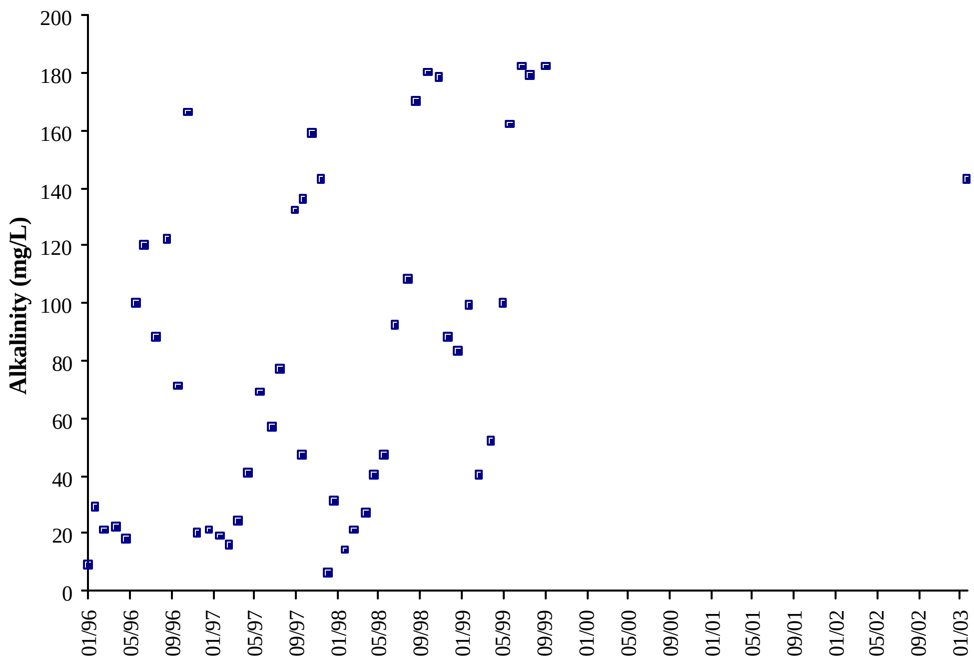

Figure A.13 Alkalinity concentrations at DMME permitted site 4120121.

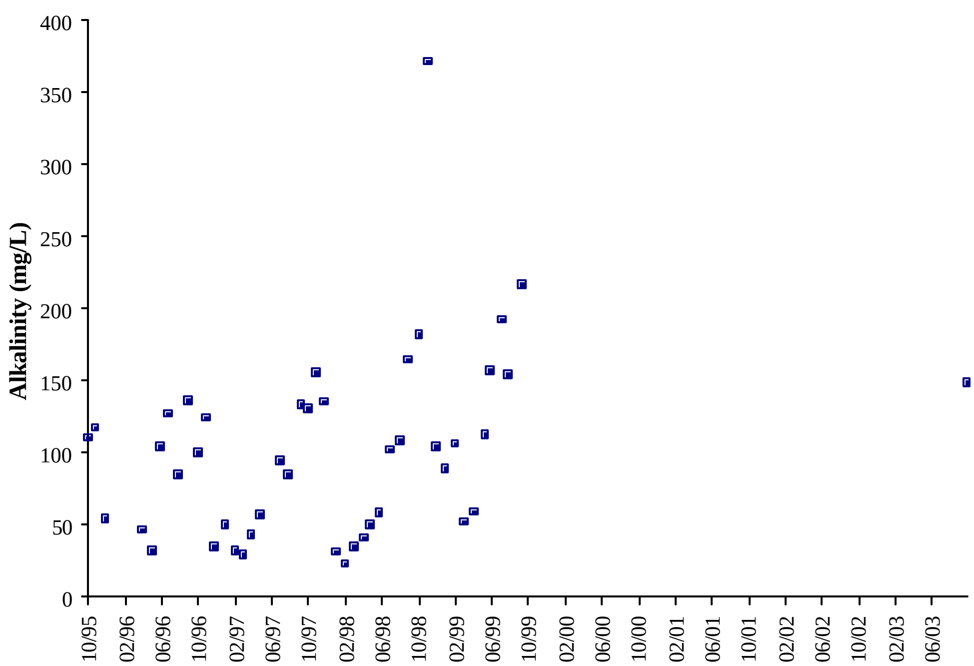

Figure A.14 Alkalinity concentrations at DMME permitted site 4120204.

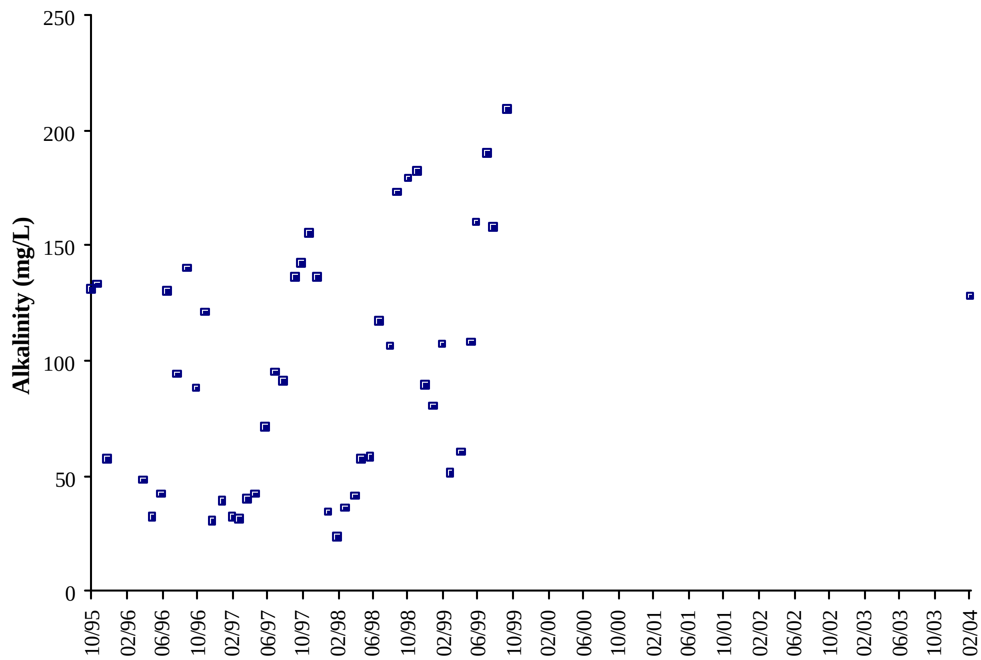

Figure A.15 Alkalinity concentrations at DMME permitted site 4120205.

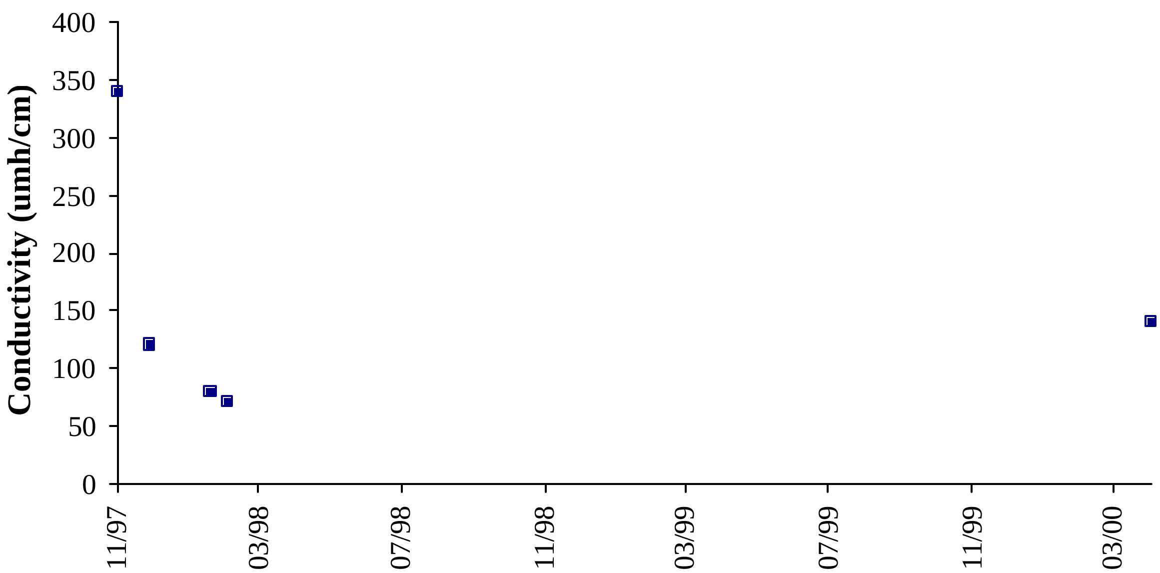

Figure A.16 Conductivity values at DMME permitted site 01988.

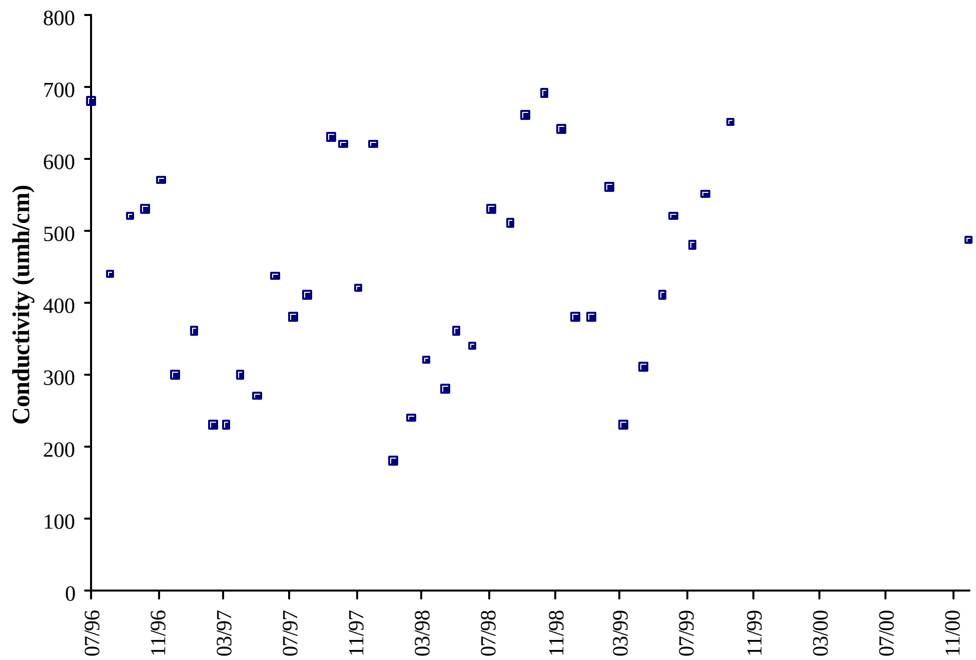

Figure A.17 Conductivity values at DMME permitted site 4120011.

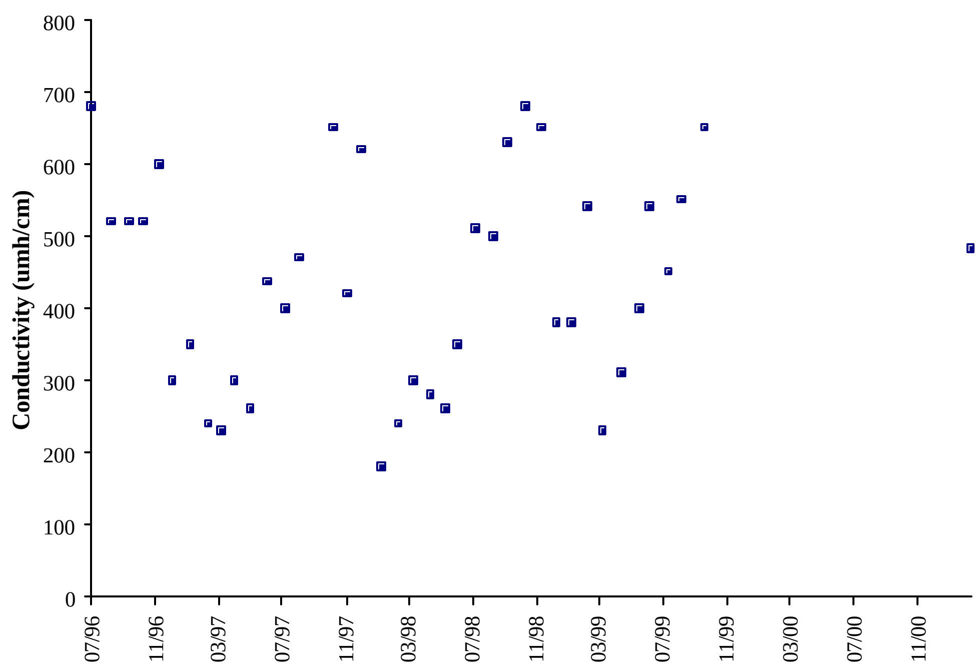

Figure A.18 Conductivity values at DMME permitted site 4120012.

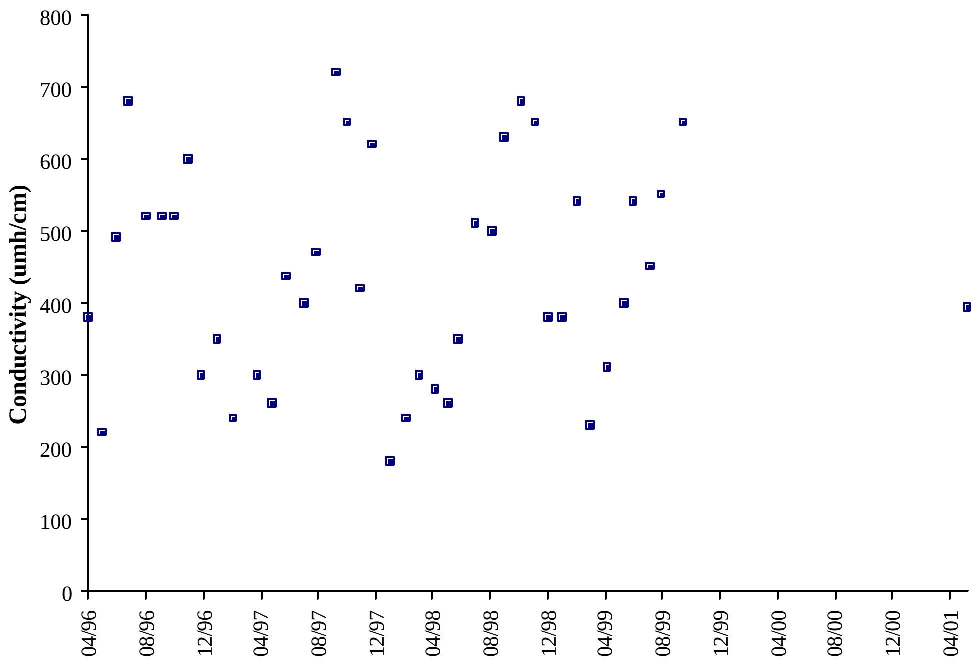

Figure A.19 Conductivity values at DMME permitted site 4120017.

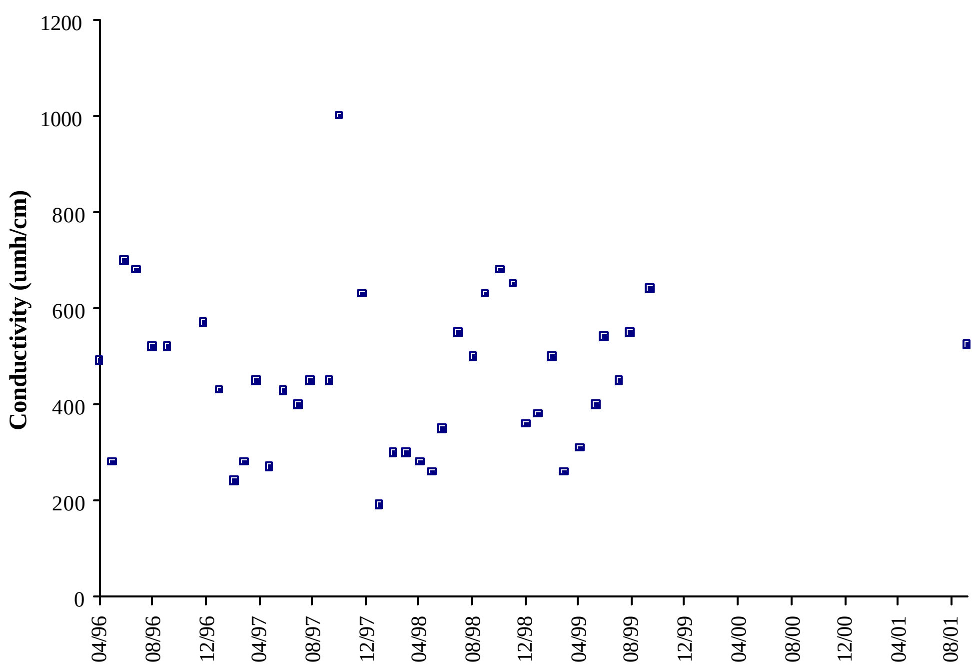

Figure A.20 Conductivity values at DMME permitted site 4120018.

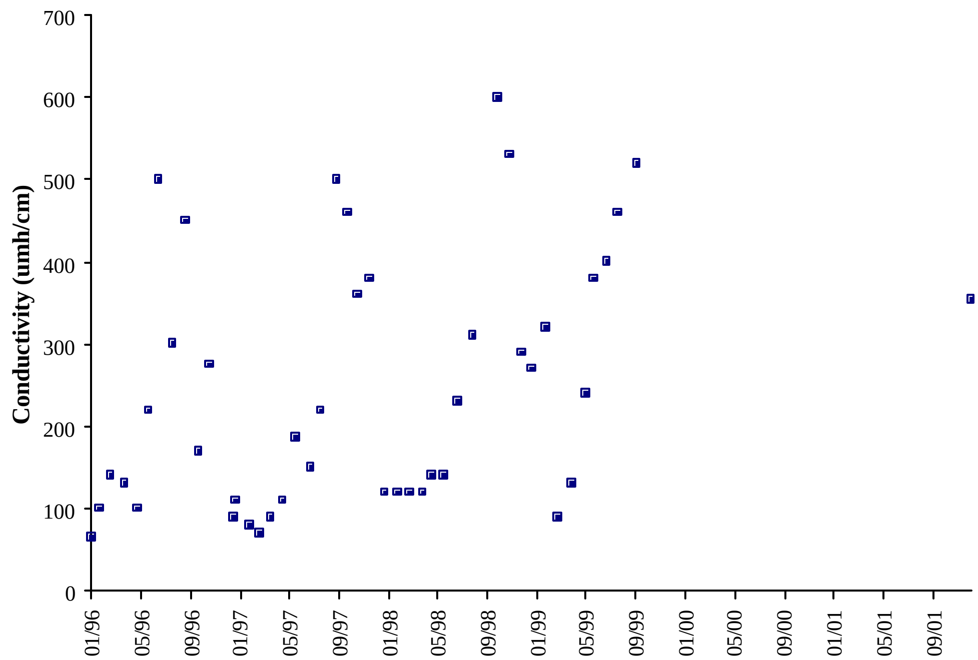

Figure A.21 Conductivity values at DMME permitted site 4120086.

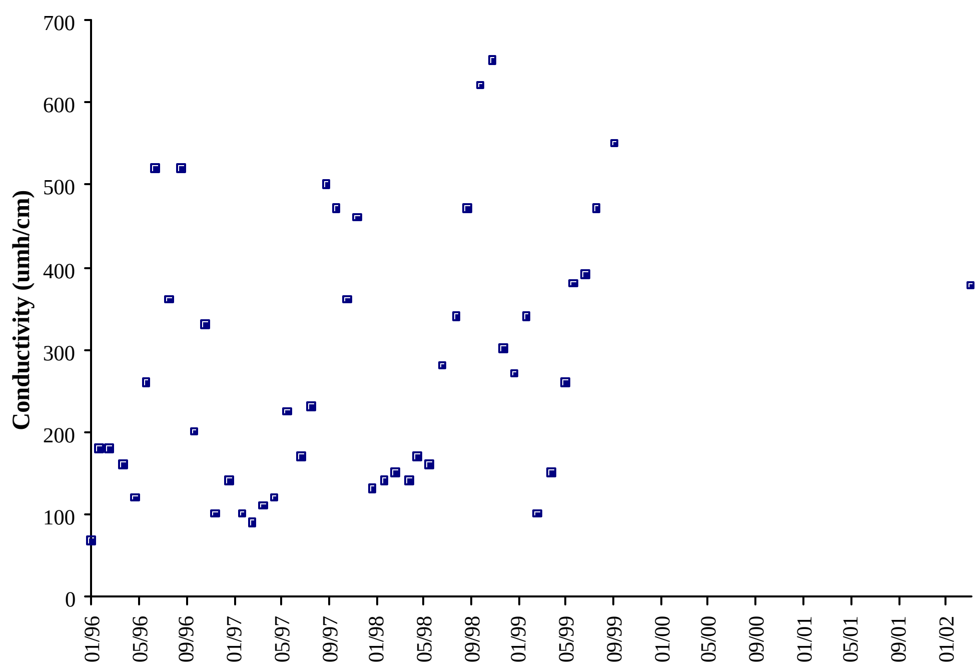

Figure A.22 Conductivity values at DMME permitted site 4120087.

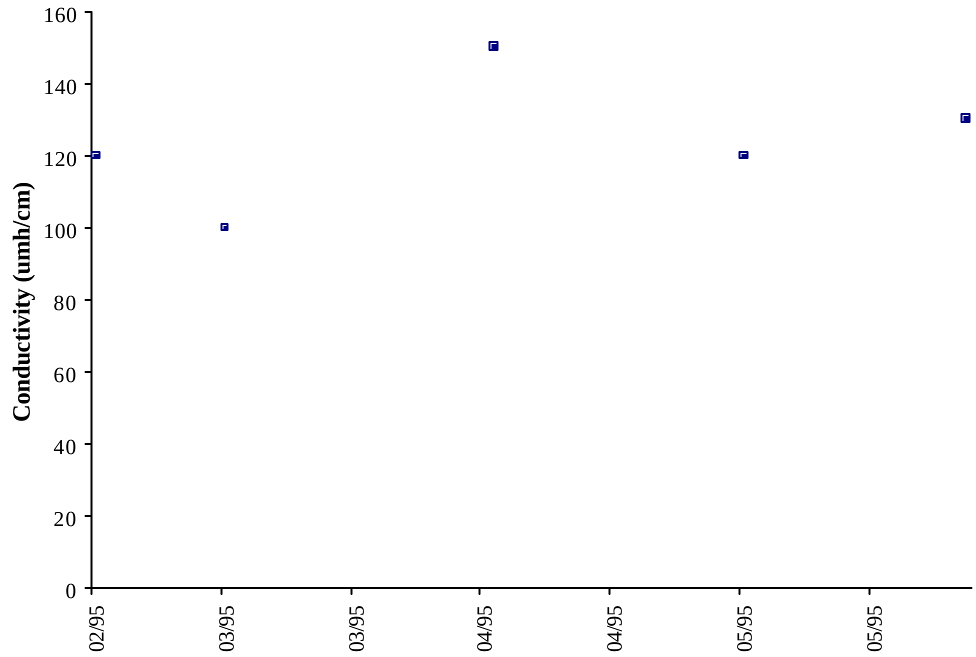

Figure A.23 Conductivity values at DMME permitted site 4120099.

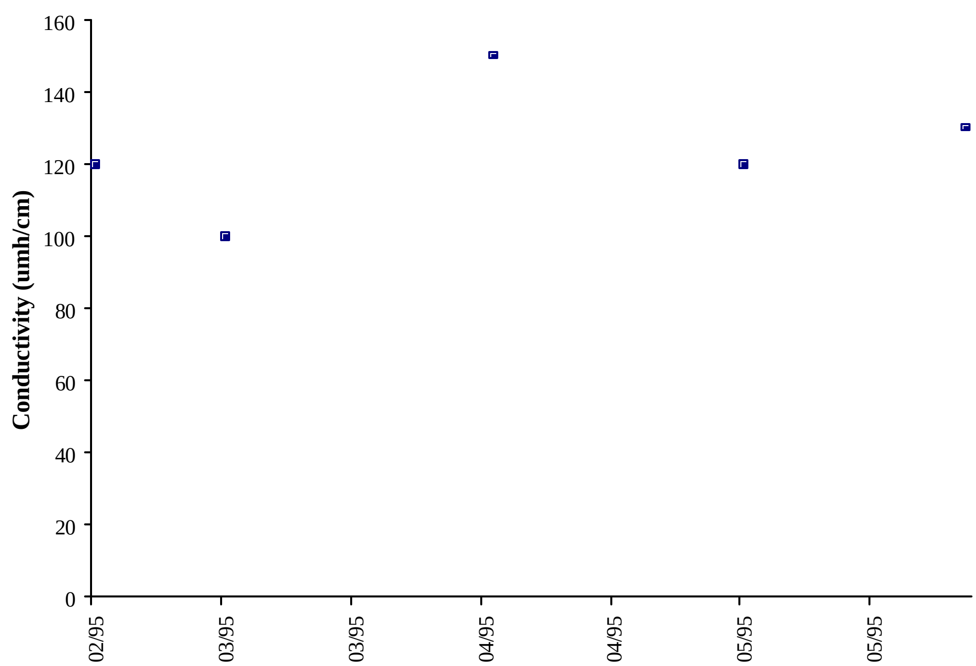

Figure A.24 Conductivity values at DMME permitted site 4120100.

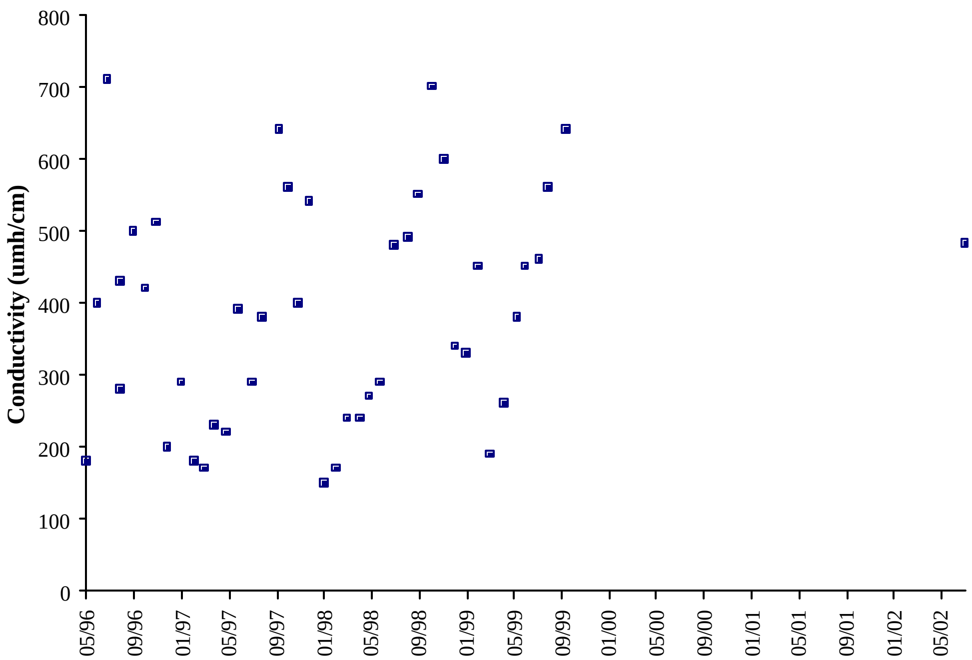

Figure A.25 Conductivity values at DMME permitted site 4120115.

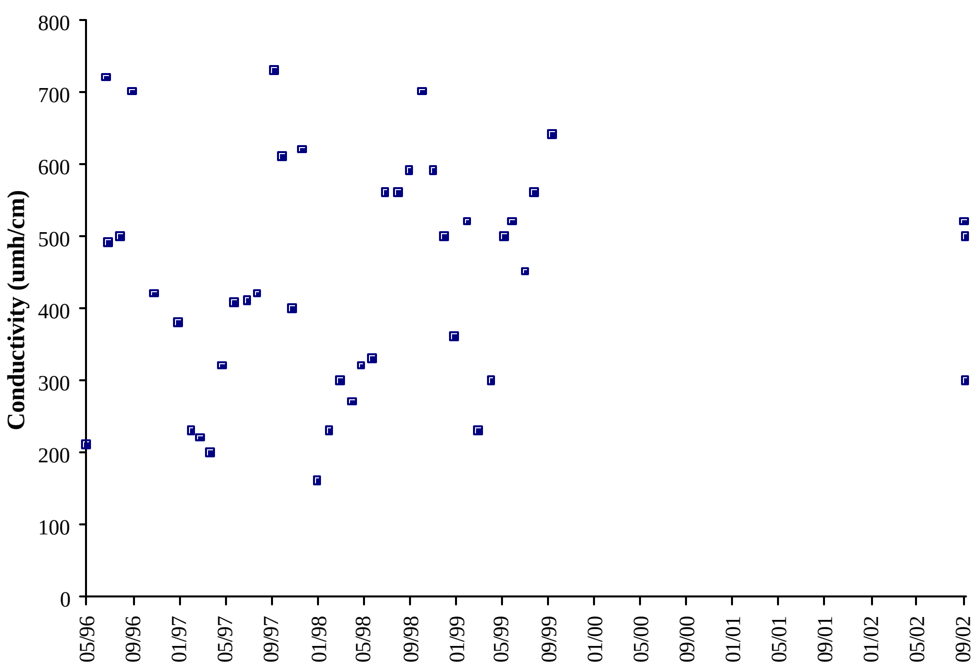

Figure A.26 Conductivity values at DMME permitted site 4120116.

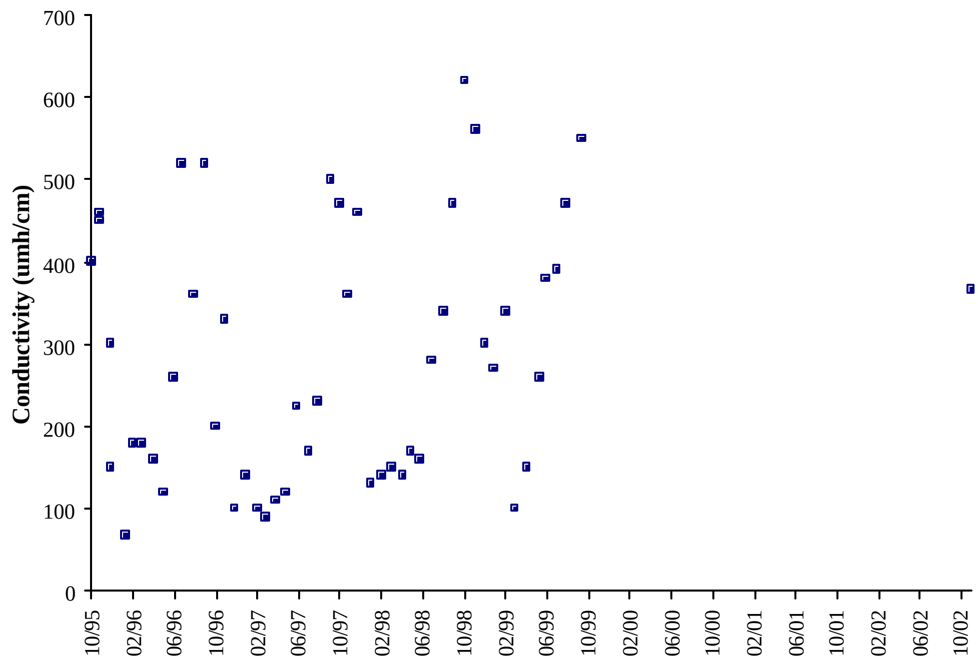

Figure A.27 Conductivity values at DMME permitted site 4120120.

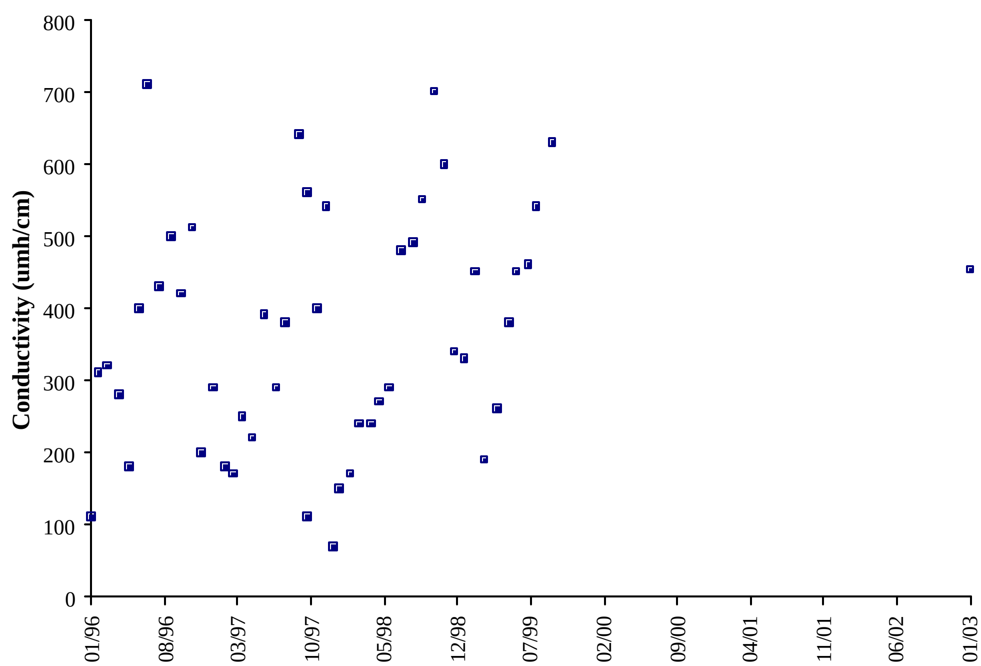

Figure A.28 Conductivity values at DMME permitted site 4120121.

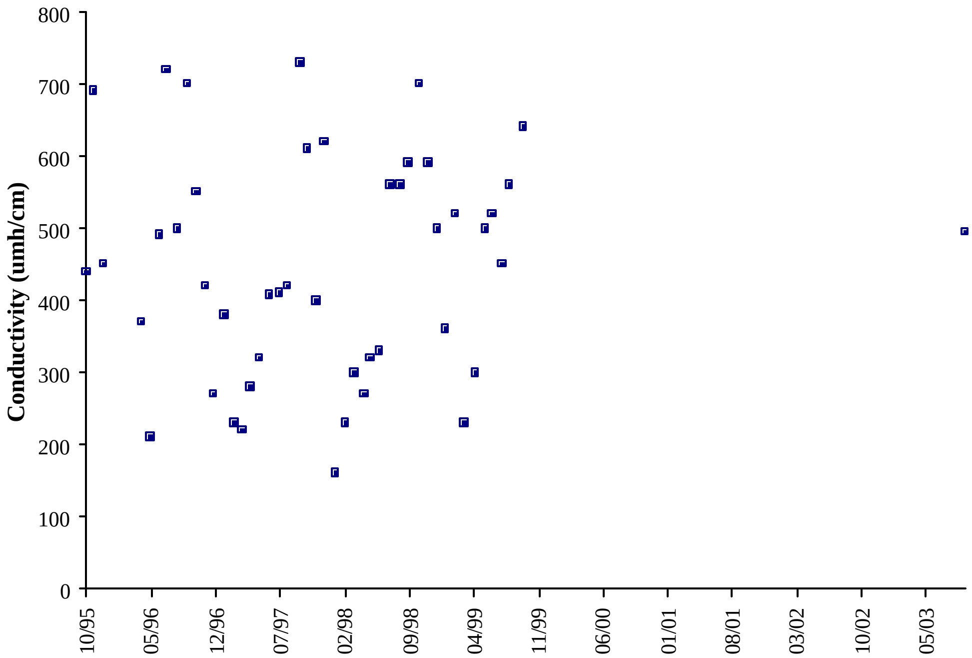

Figure A.29 Conductivity values at DMME permitted site 4120204.

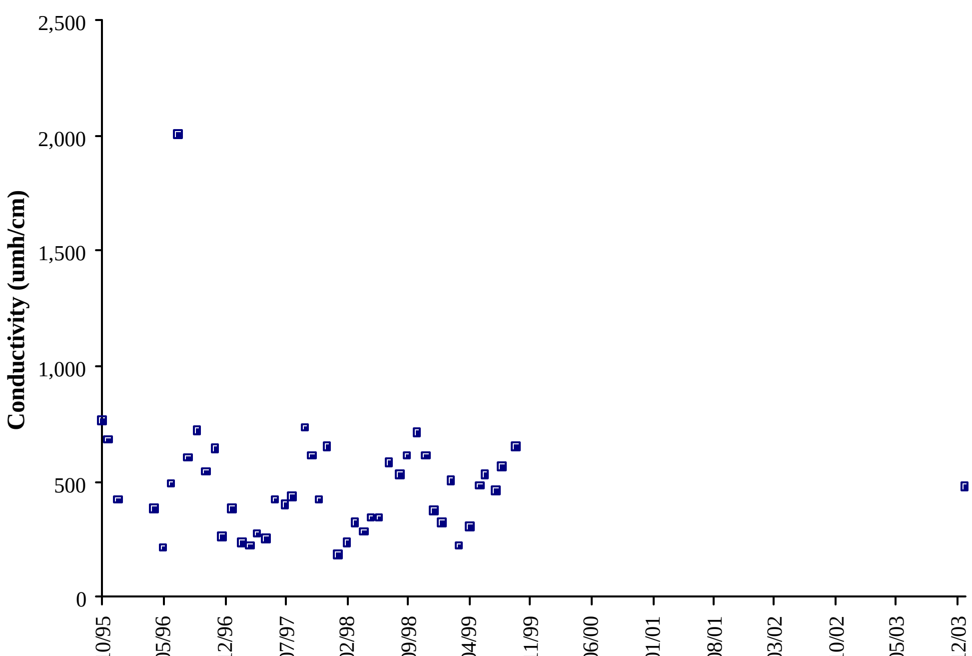

Figure A.30 Conductivity values at DMME permitted site 4120205.

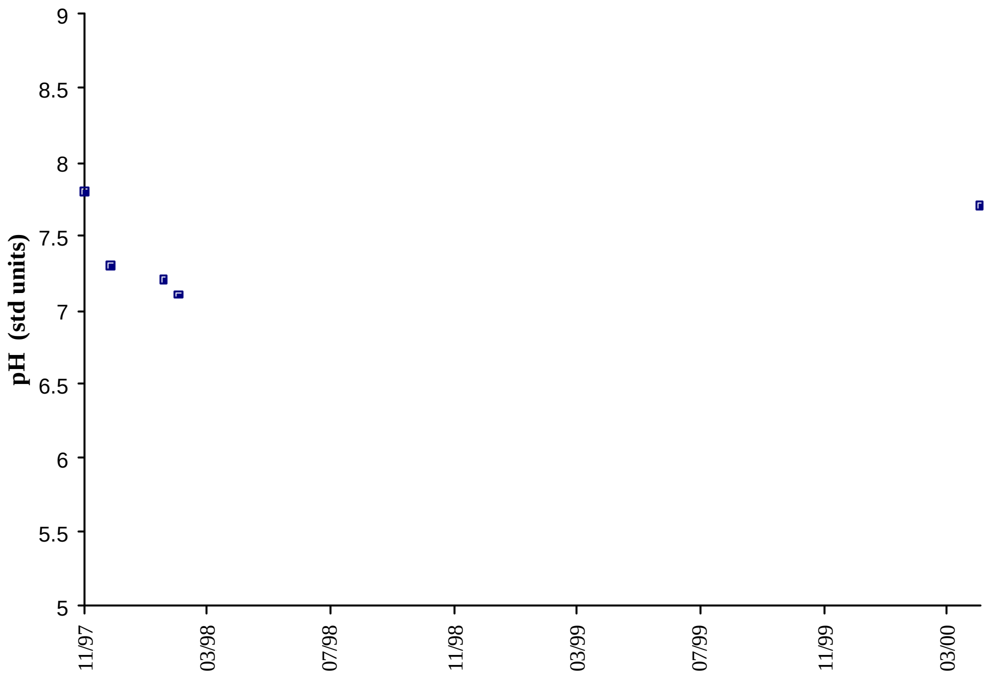

Figure A.31 Field pH values at DMME permitted site 0001988.

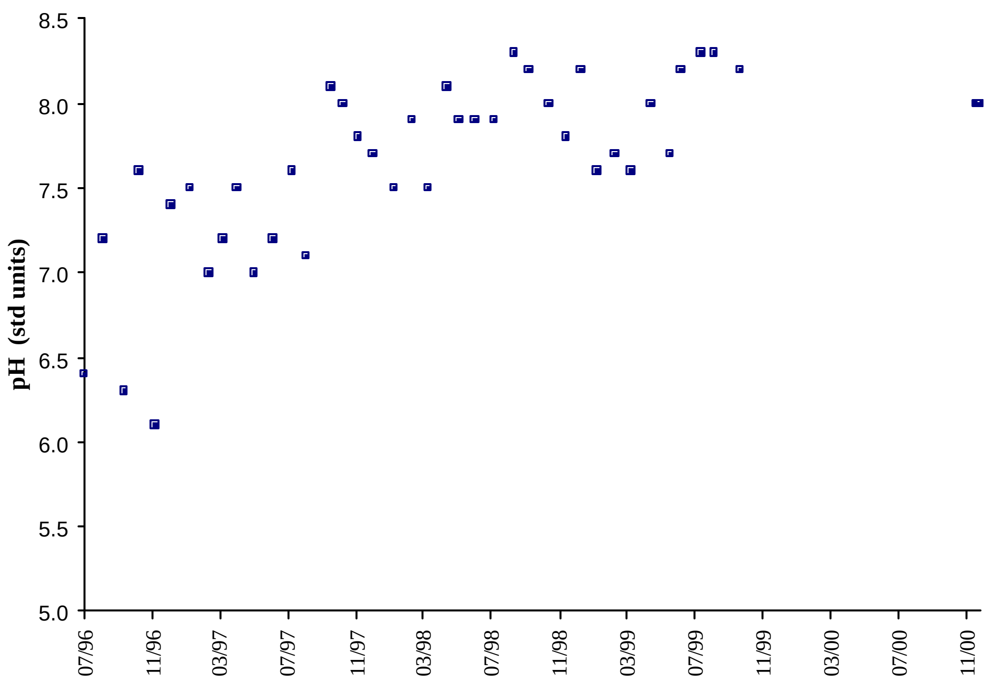

Figure A.32 Field pH values at DMME permitted site 4120011.

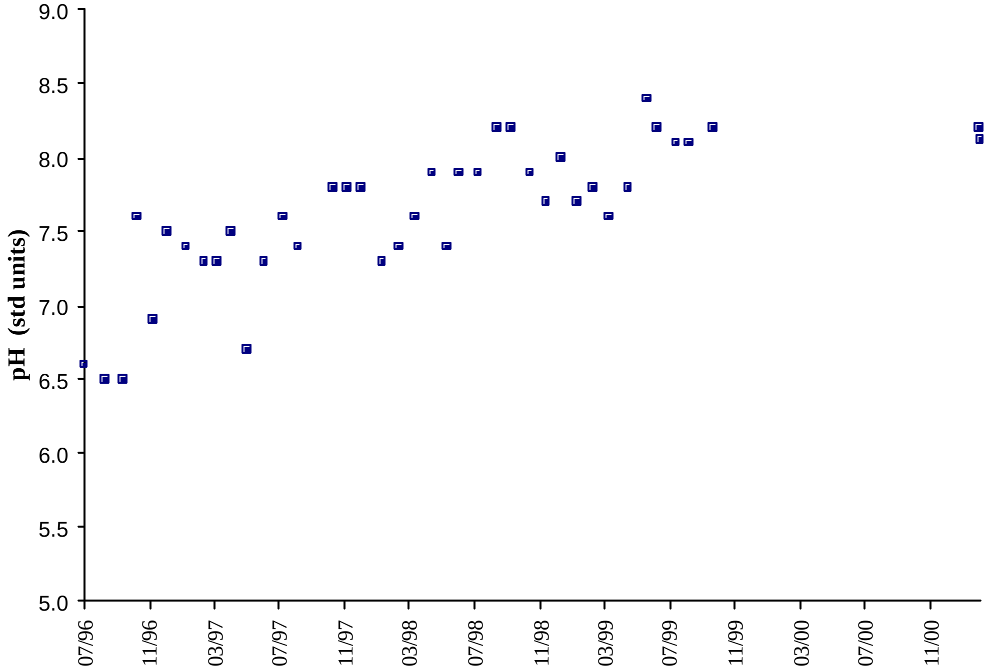

Figure A.33 Field pH values at DMME permitted site 4120012.

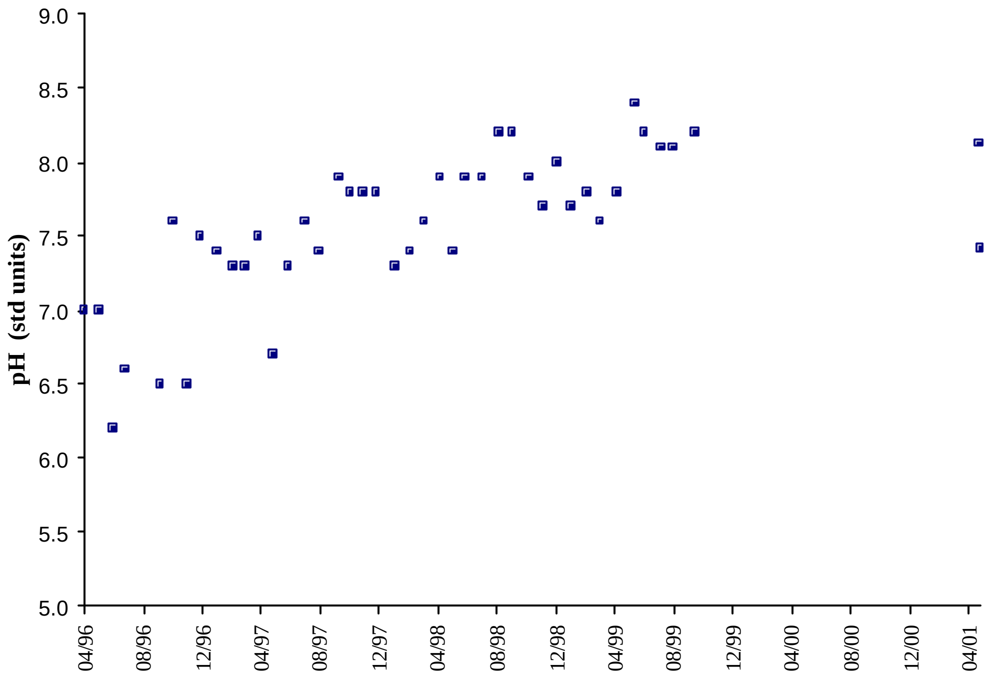

Figure A.34 Field pH values at DMME permitted site 4120017.

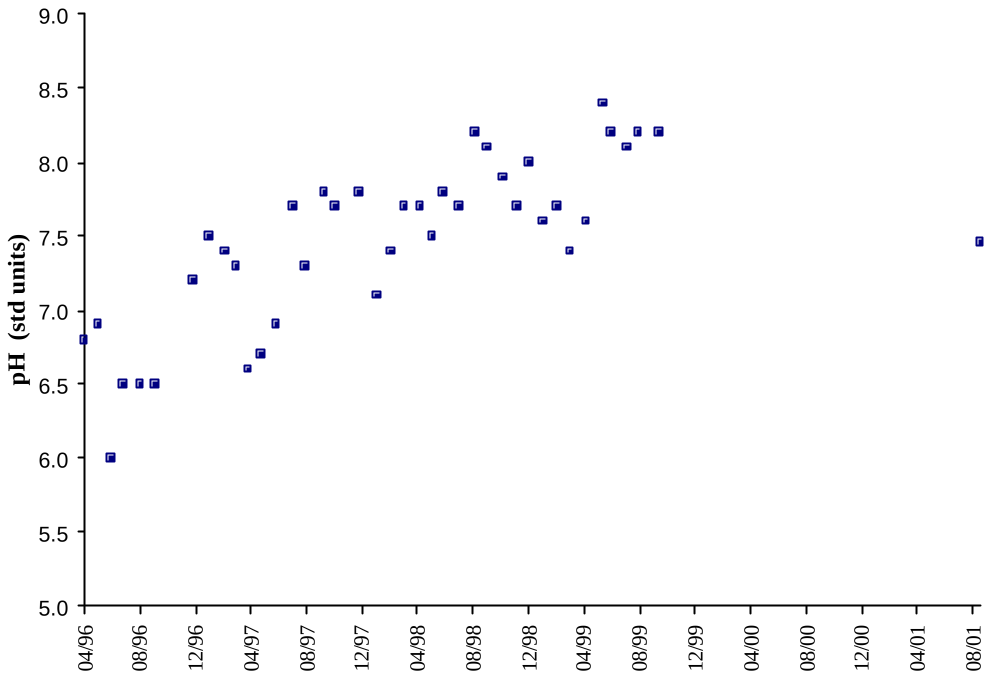

Figure A.35 Field pH values at DMME permitted site 4120018.

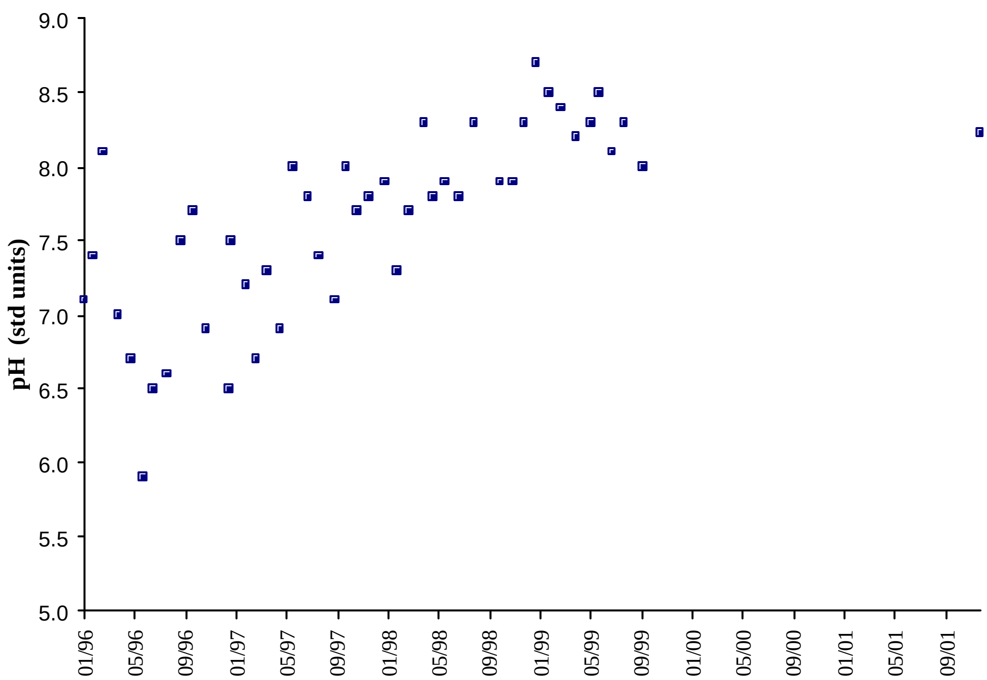

Figure A.36 Field pH values at DMME permitted site 4120086.

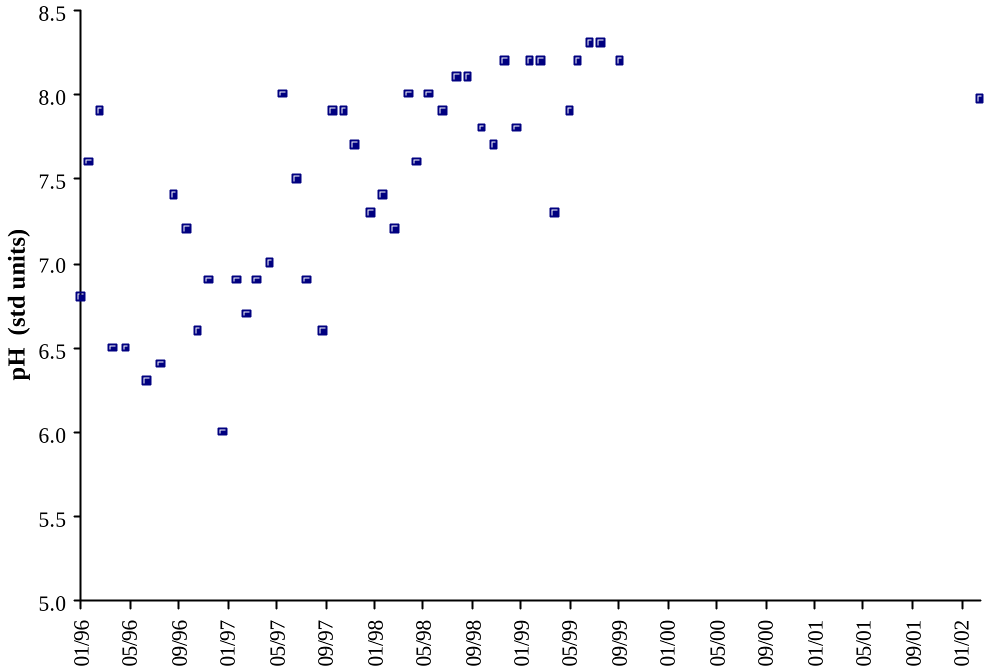

Figure A.37 Field pH values at DMME permitted site 4120087.

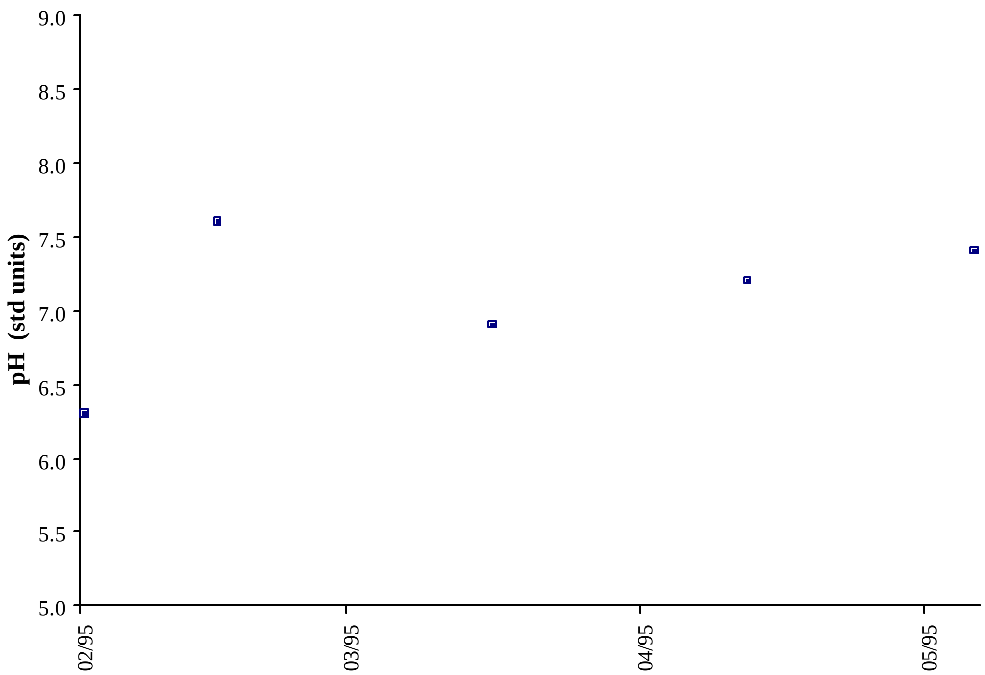

Figure A.38 Field pH values at DMME permitted site 4120099.

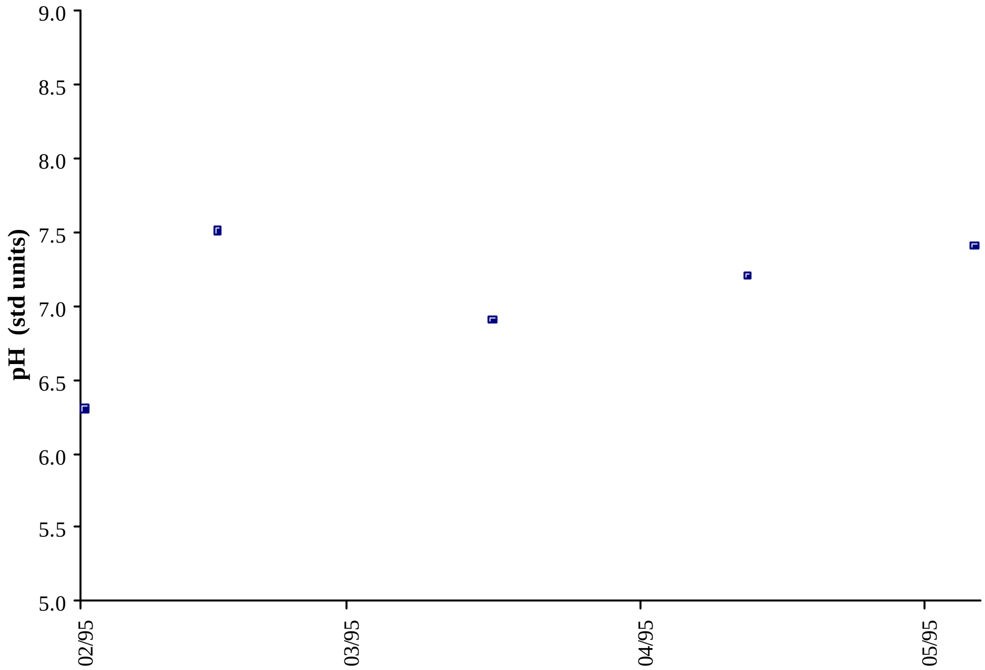

Figure A.39 Field pH values at DMME permitted site 4120100.

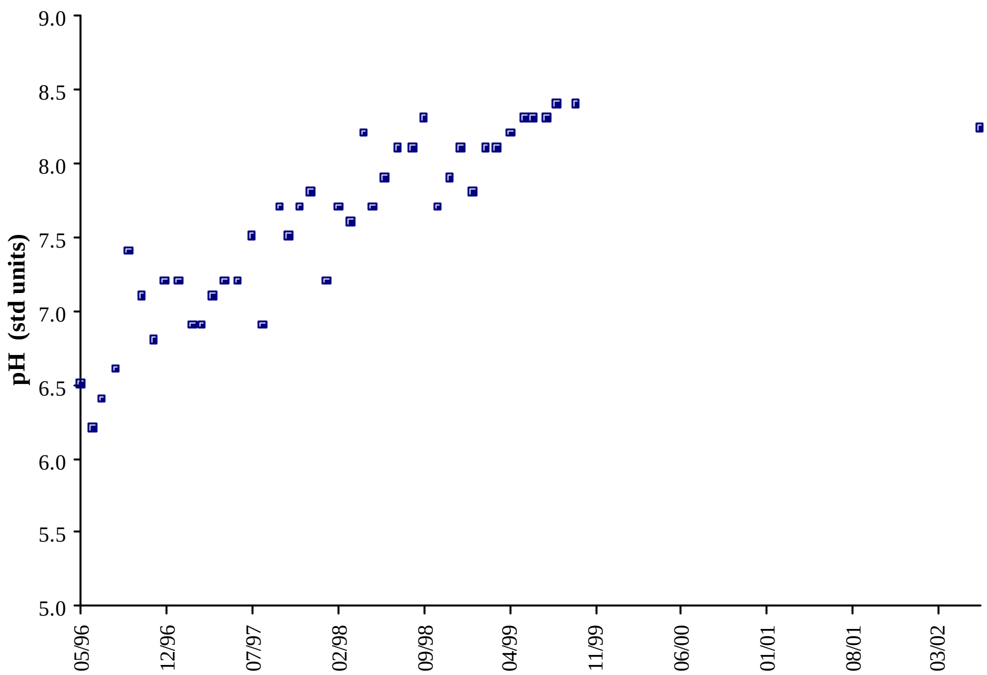

Figure A.40 Field pH values at DMME permitted site 4120115.

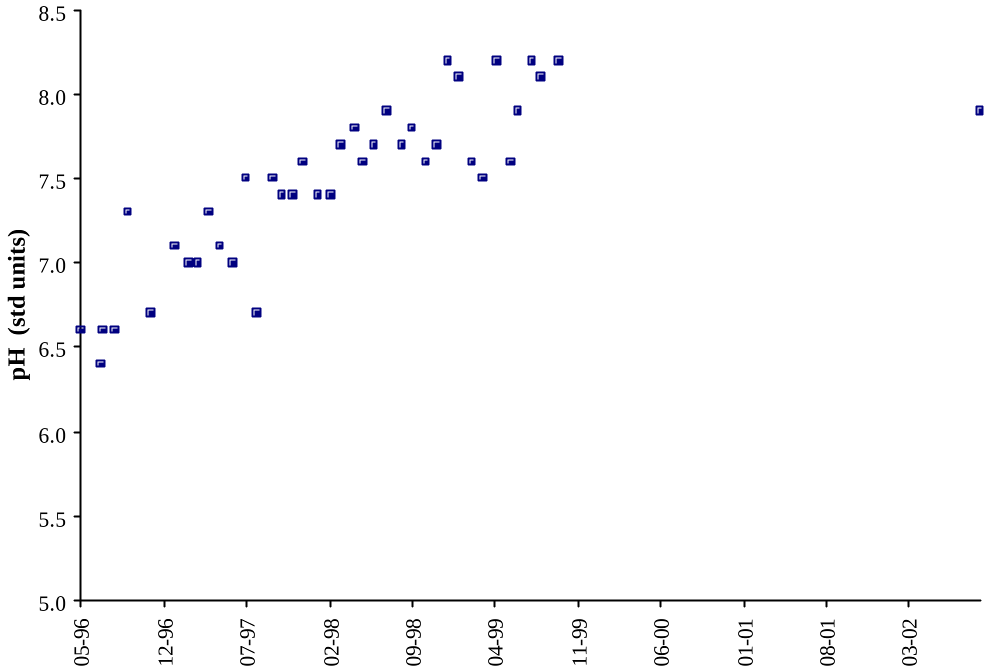

Figure A.41 Field pH values at DMME permitted site 4120116.

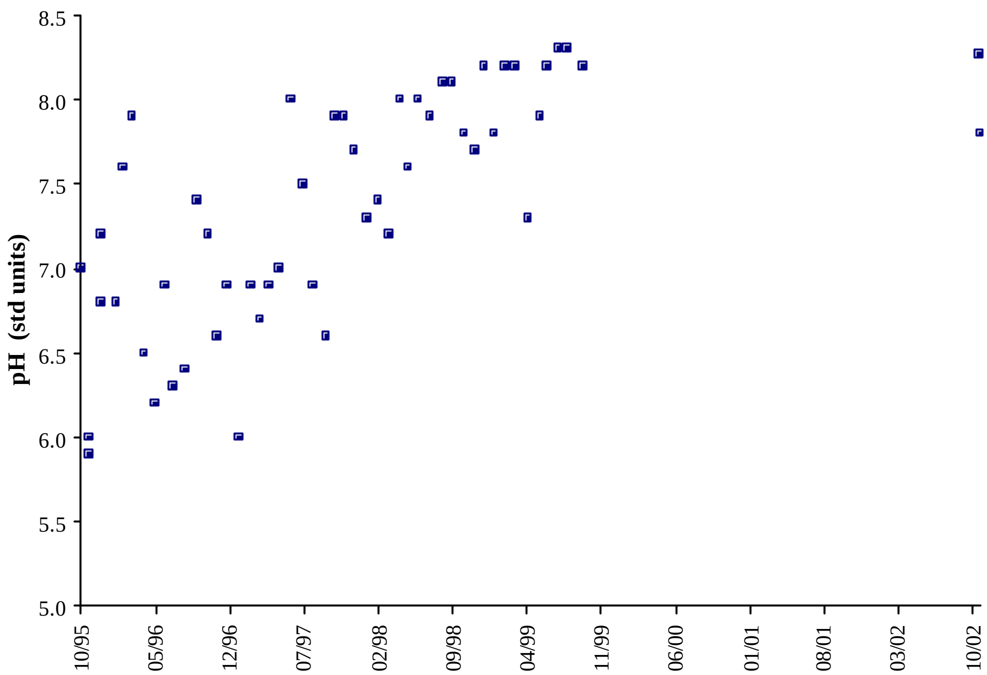

Figure A.42 Field pH values at DMME permitted site 4120120.

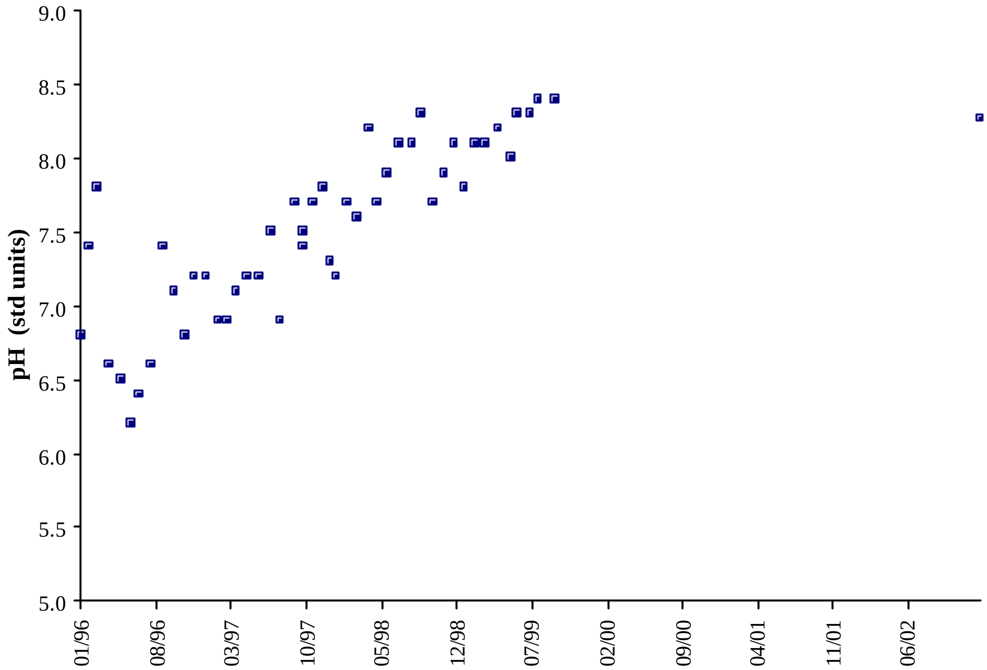

Figure A.43 Field pH values at DMME permitted site 4120121.

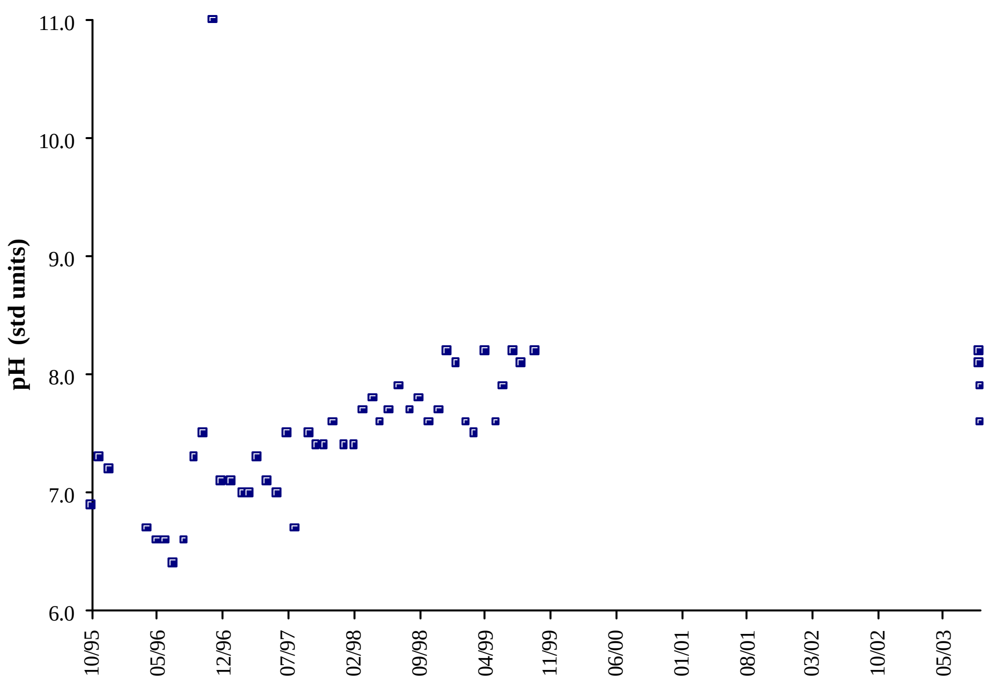

Figure A.44 Field pH values at DMME permitted site 4120204.

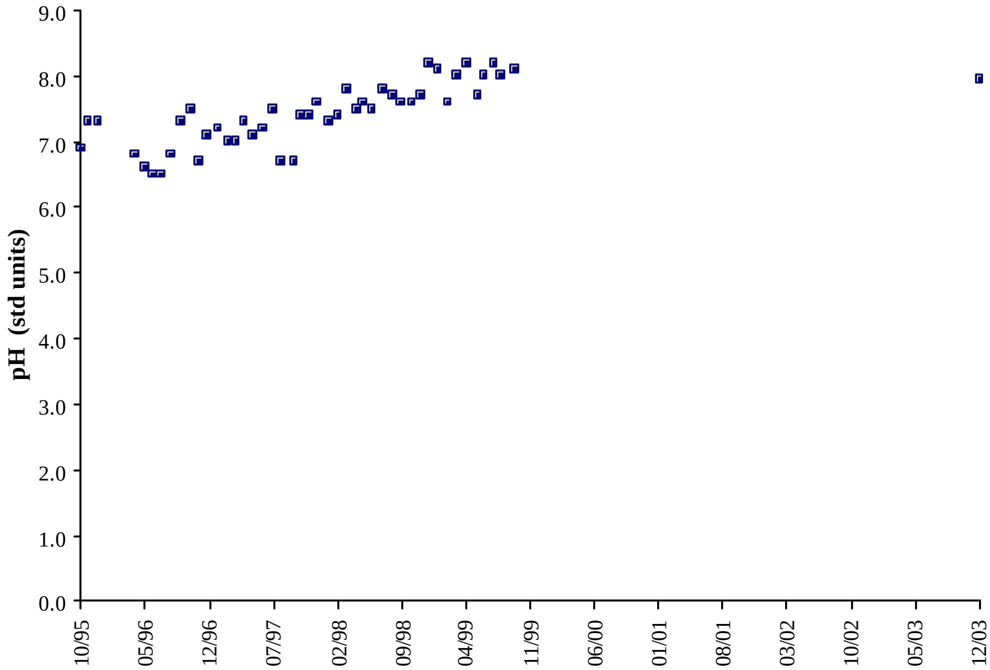

Figure A.45 Field pH values at DMME permitted site 4120205.

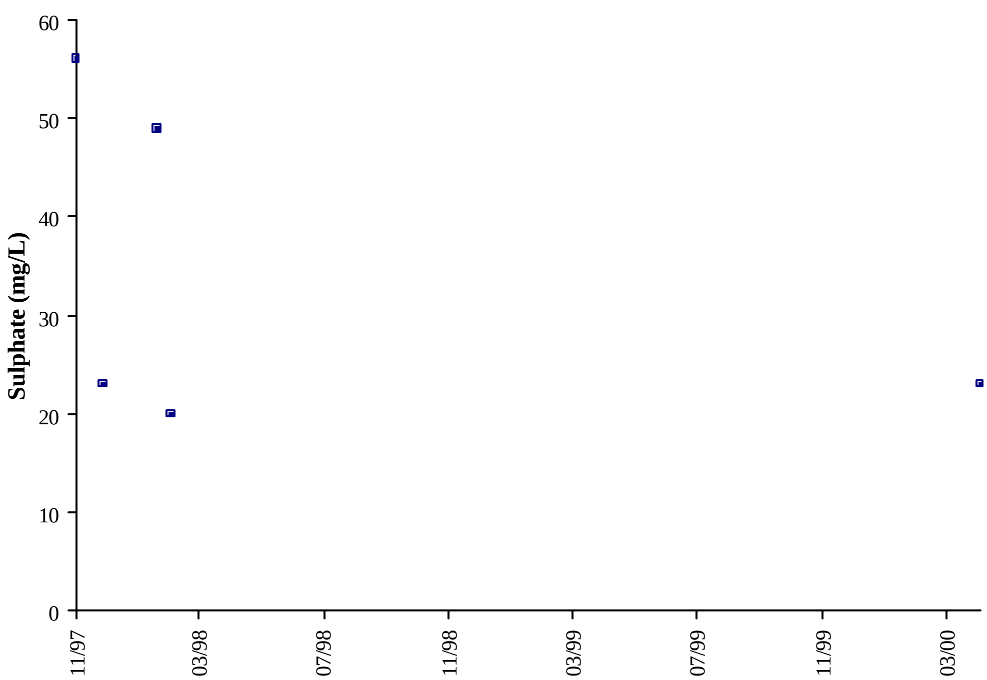

Figure A.46 Sulphate concentrations at DMME permitted site 0001988.

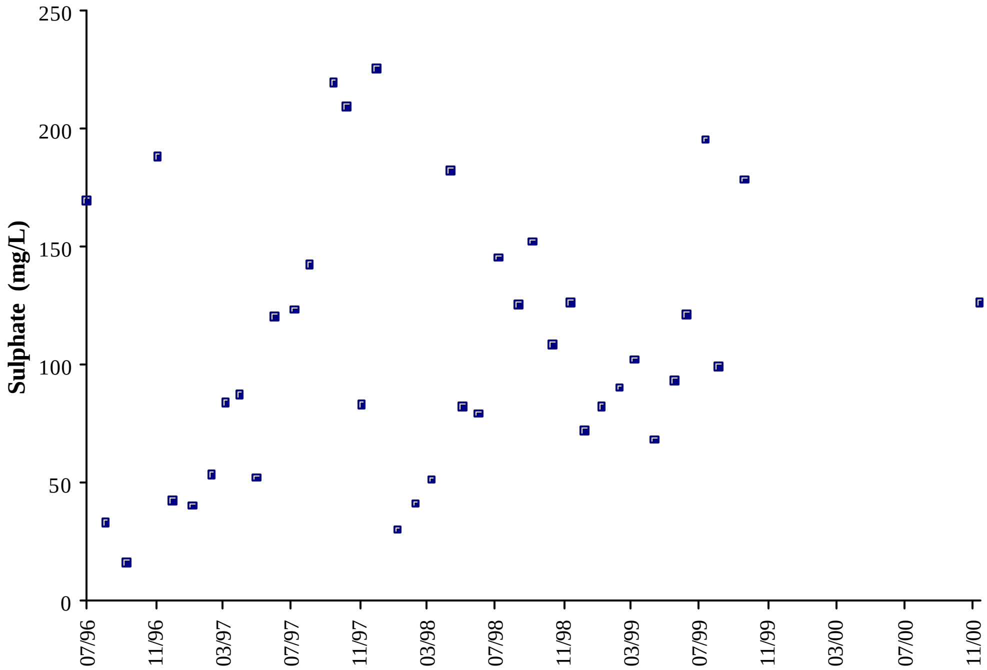

Figure A.47 Sulphate concentrations at DMME permitted site 4120011.

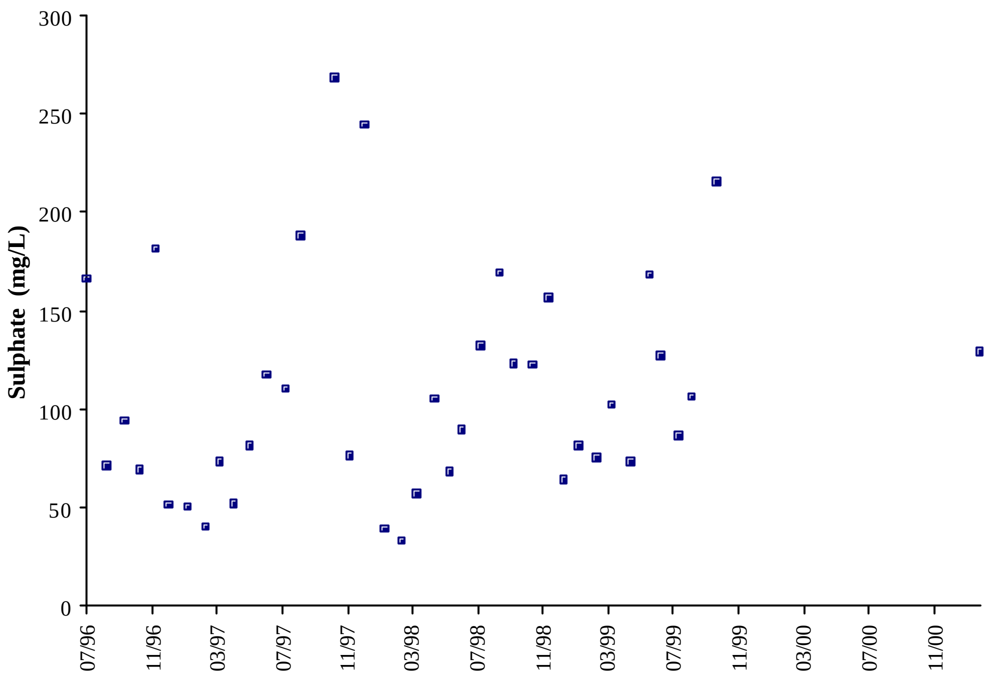

Figure A.48 Sulphate concentrations at DMME permitted site 4120012.

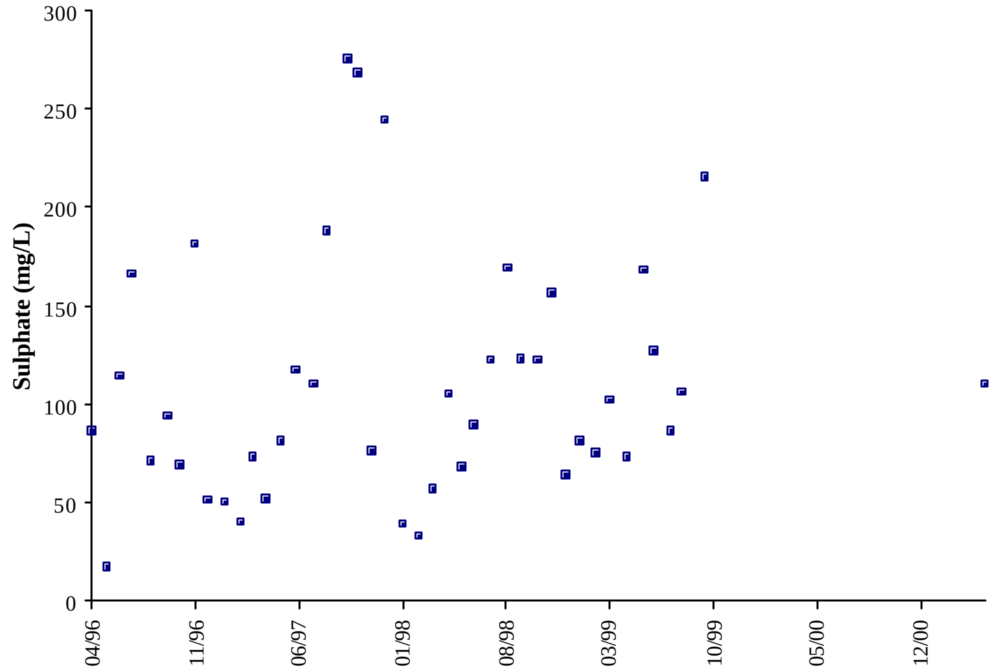

Figure A.49 Sulphate concentrations at DMME permitted site 4120017.

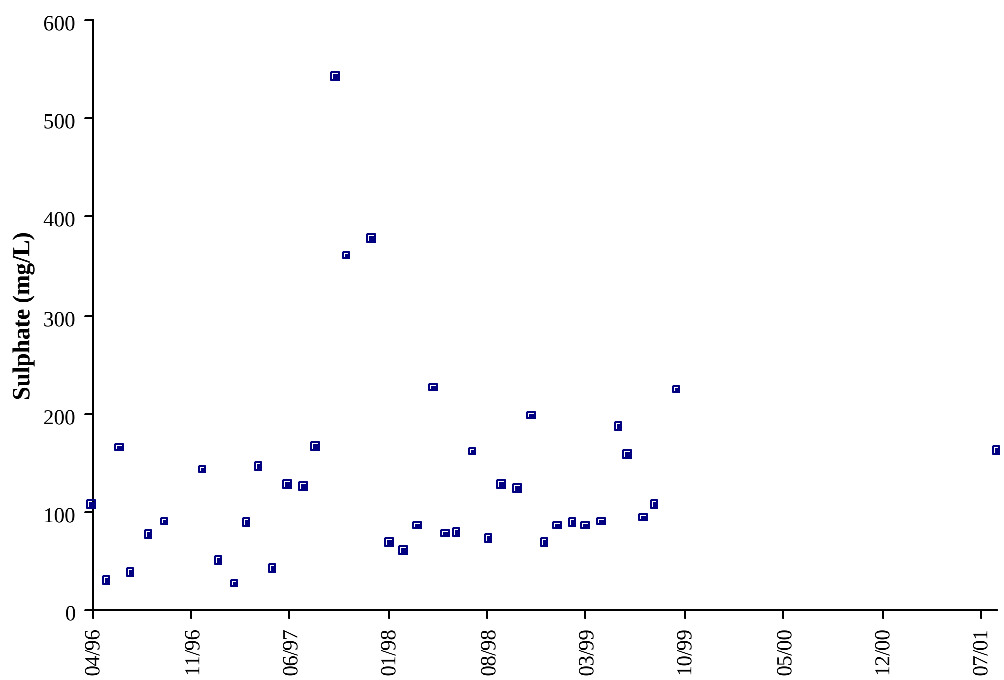

Figure A.50 Sulphate concentrations at DMME permitted site 4120018.

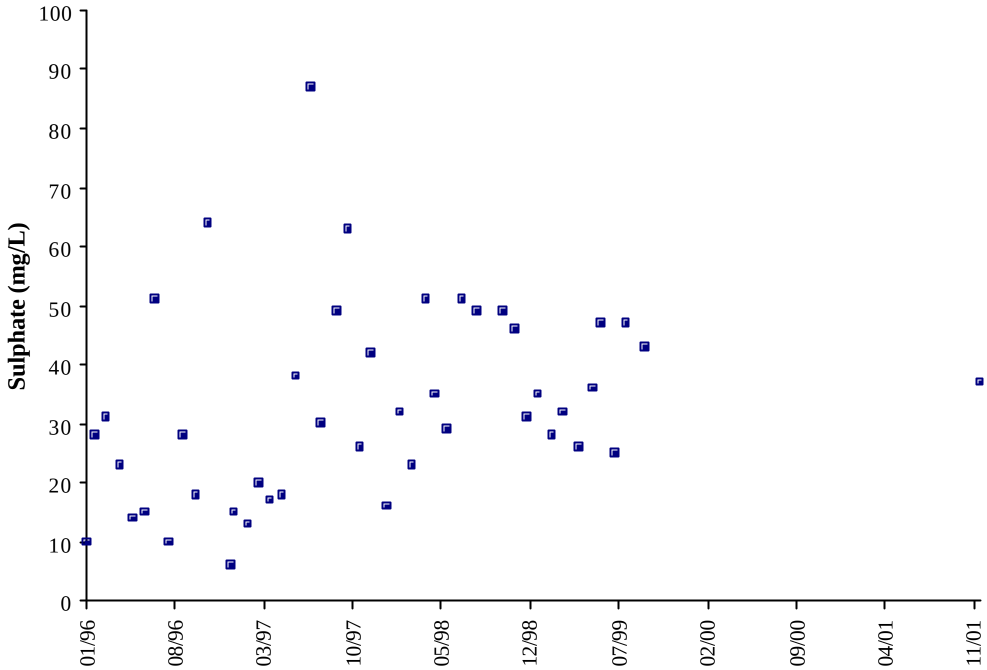

Figure A.51 Sulphate concentrations at DMME permitted site 4120086.

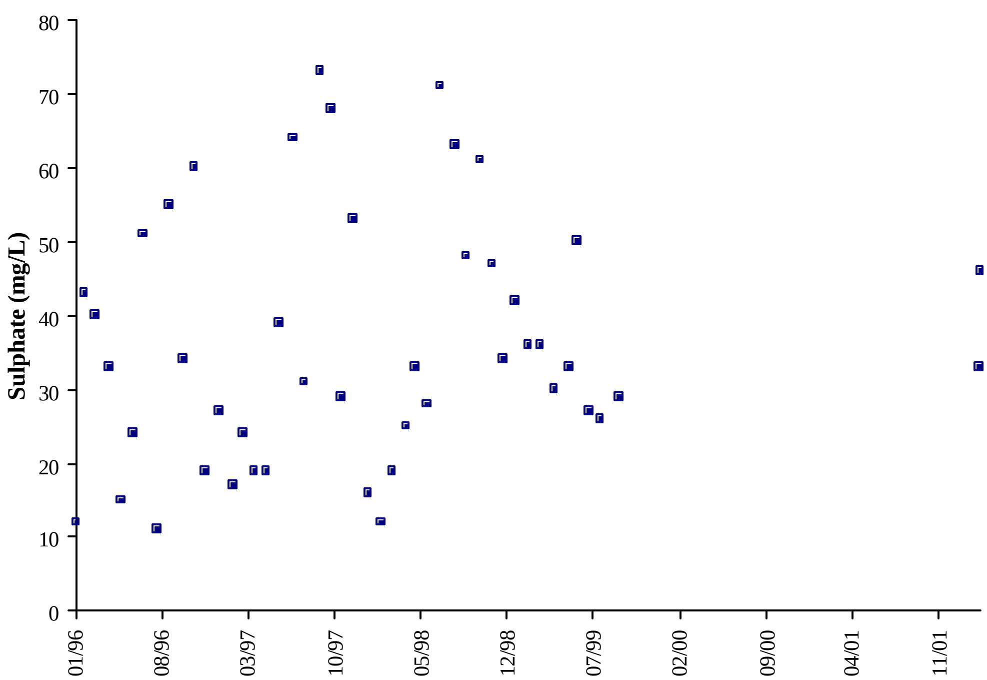

Figure A.52 Sulphate concentrations at DMME permitted site 4120087.

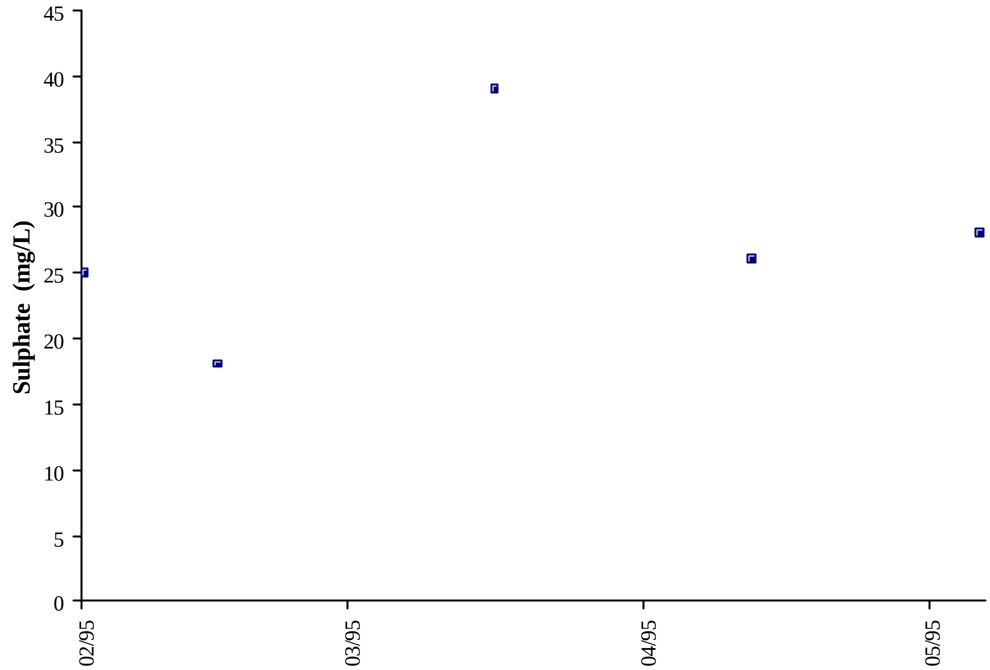

Figure A.53 Sulphate concentrations at DMME permitted site 4120099.

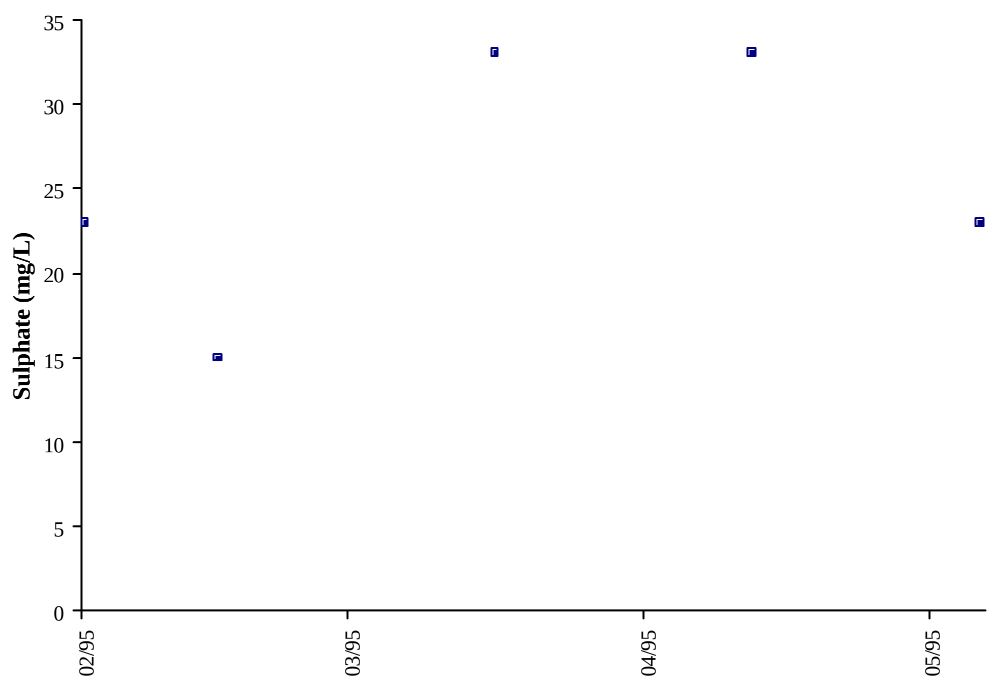

Figure A.54 Sulphate concentrations at DMME permitted site 4120100.

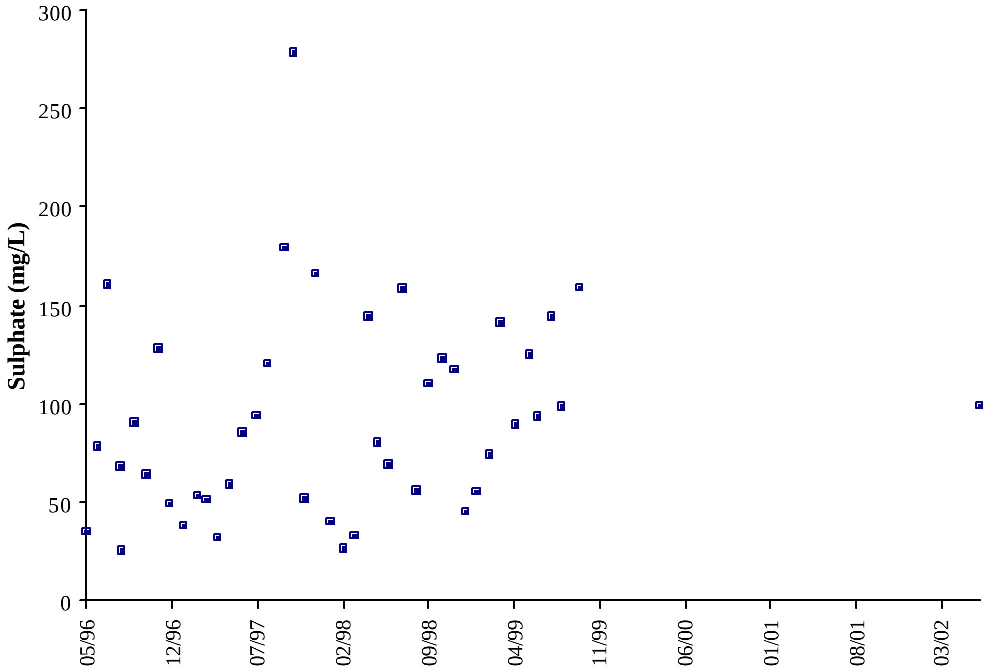

Figure A.55 Sulphate concentrations at DMME permitted site 4120115.

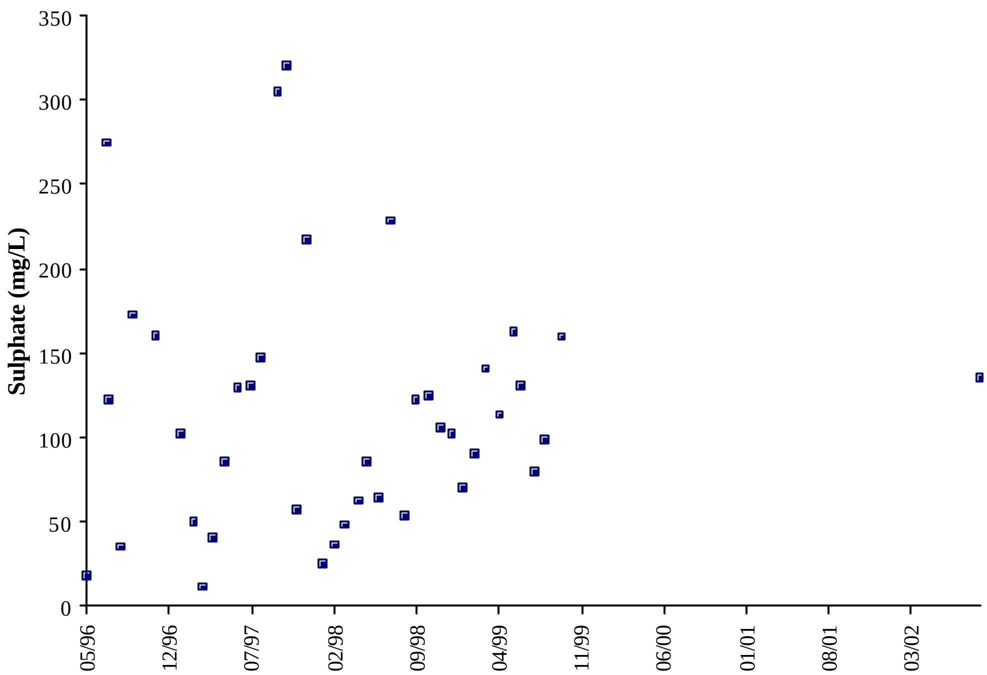

Figure A.56 Sulphate concentrations at DMME permitted site 4120116.

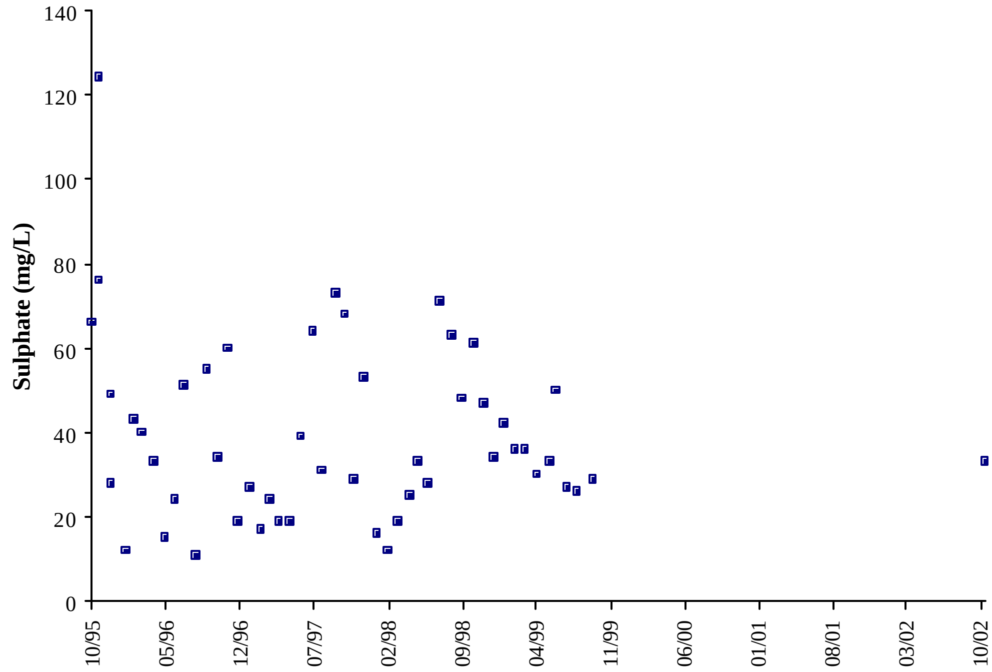

Figure A.57 Sulphate concentrations at DMME permitted site 4120120.

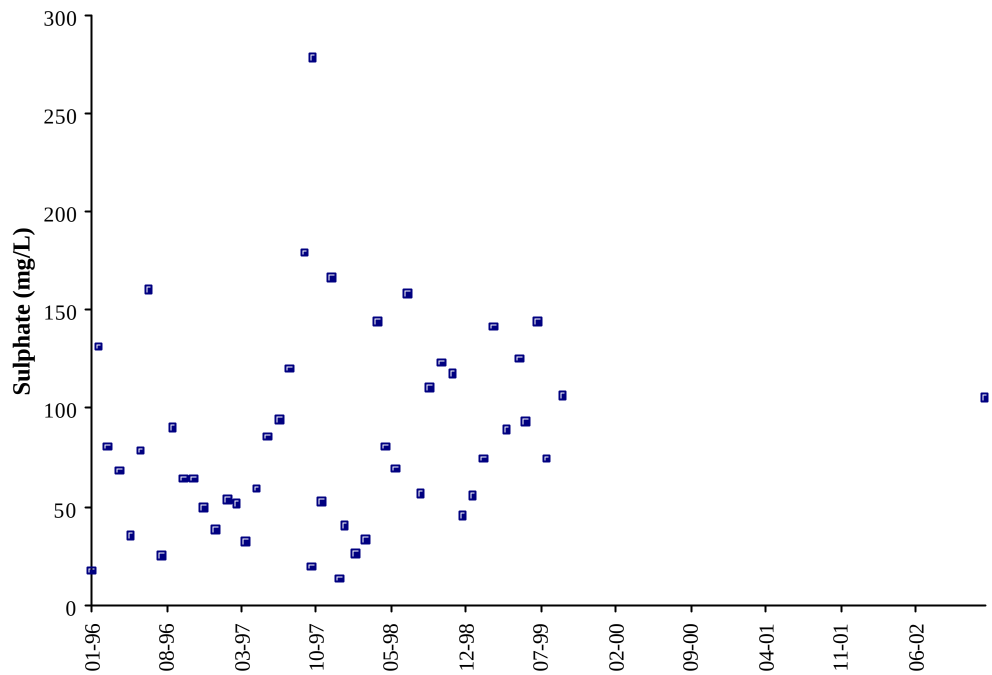

Figure A.58 Sulphate concentrations at DMME permitted site 4120121.

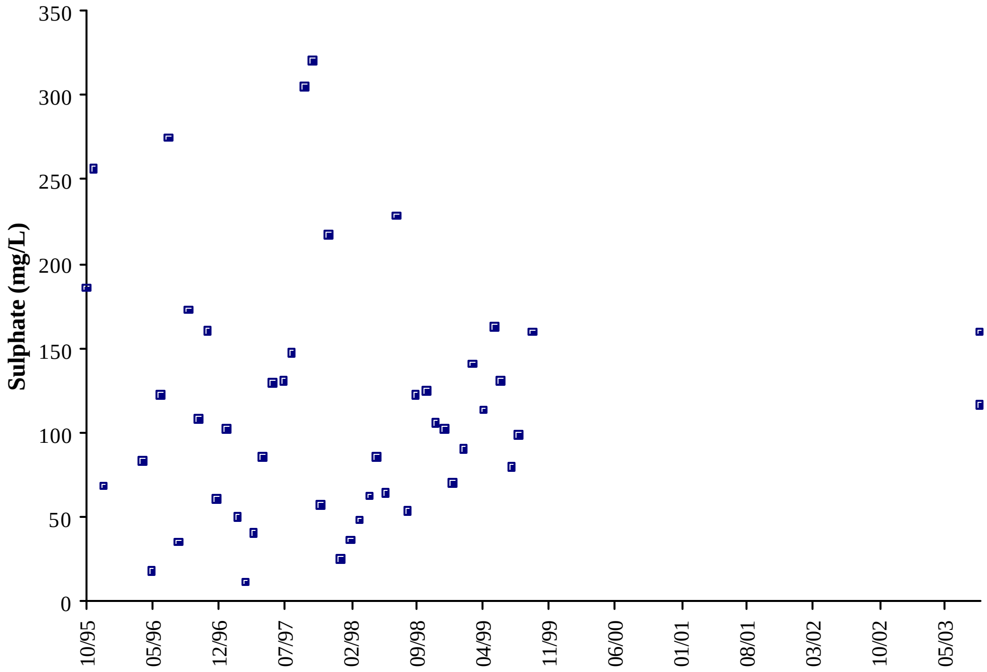

Figure A.59 Sulphate concentrations at DMME permitted site 4120204.

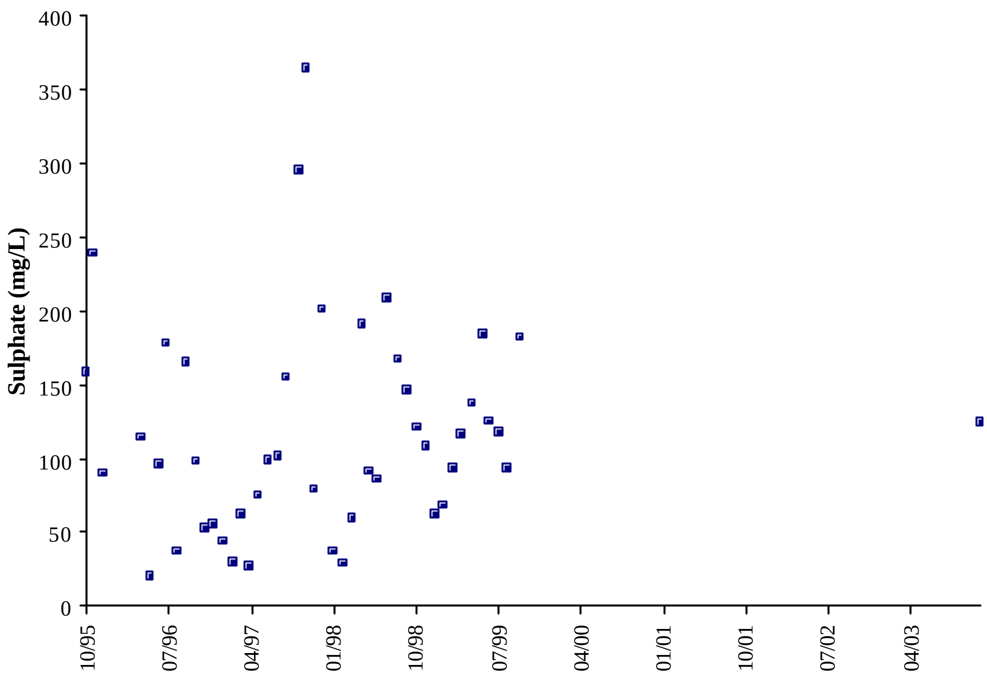

Figure A.60 Sulphate concentrations at DMME permitted site 4120205.

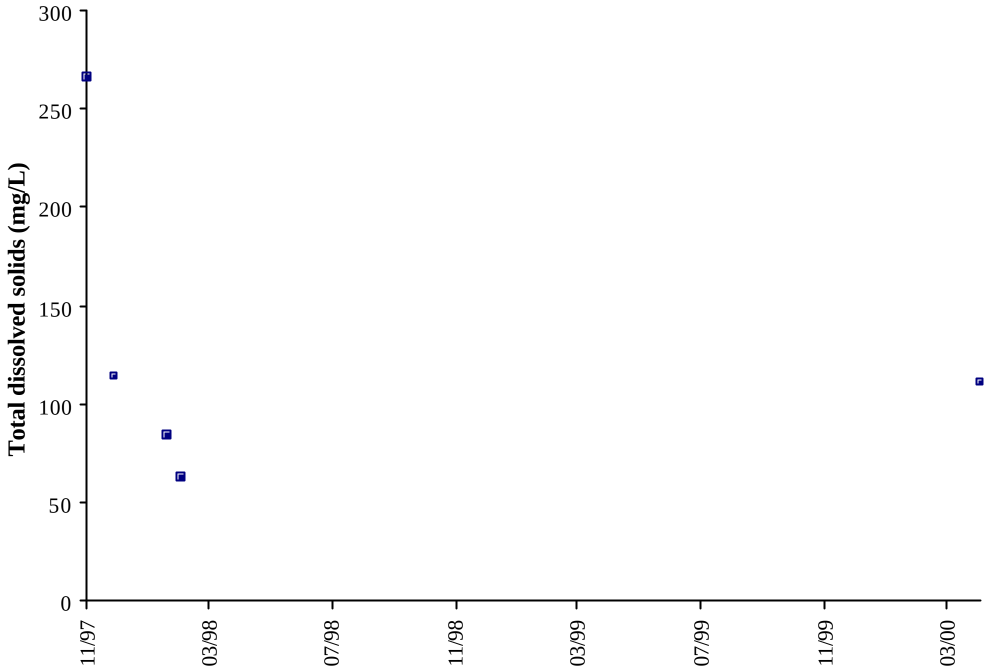

Figure A.61 TDS concentrations at DMME permitted site 0001988.

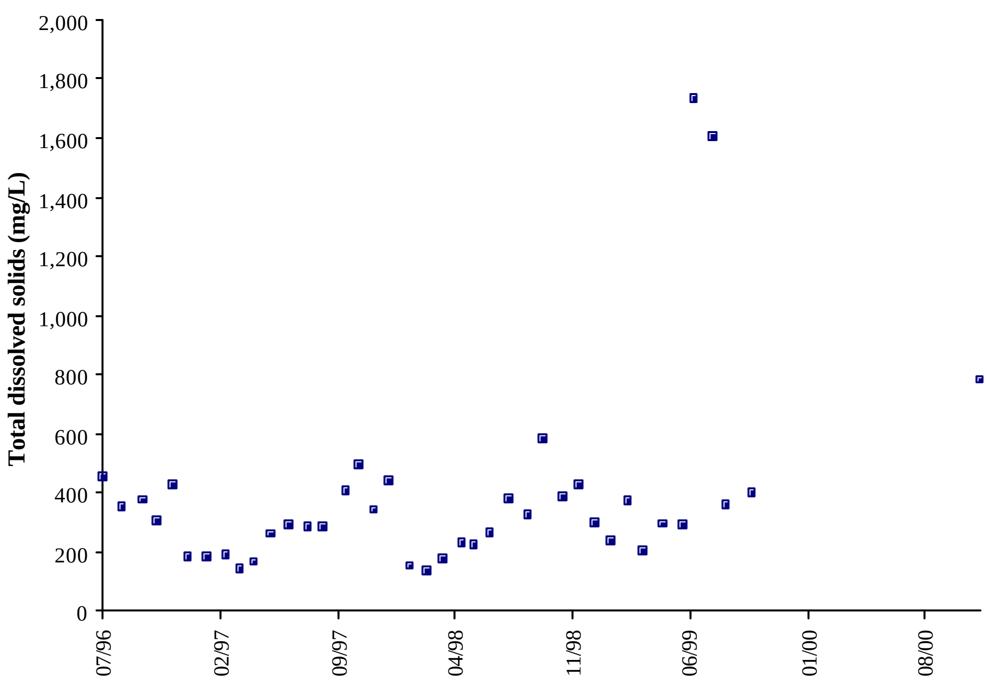

Figure A.62 TDS concentrations at DMME permitted site 4120011.

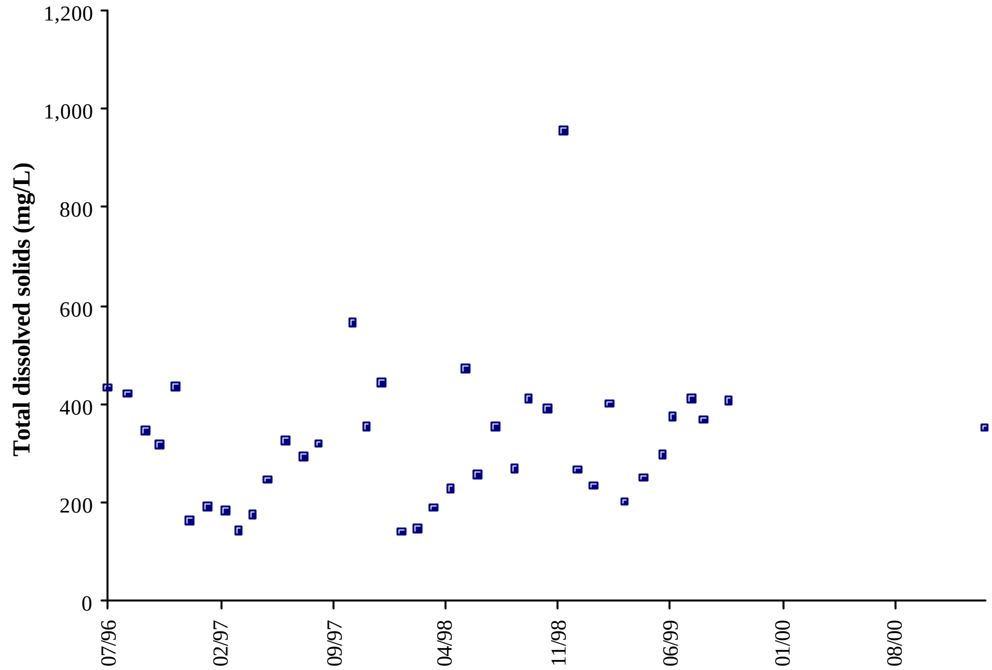

Figure A.63 TDS concentrations at DMME permitted site 4120012.

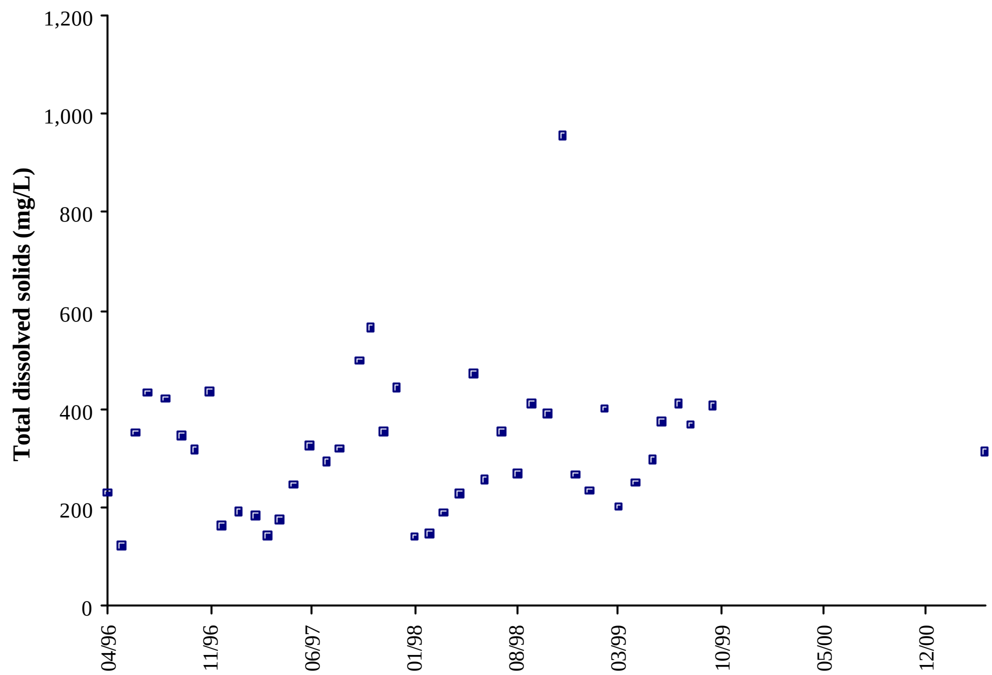

Figure A.64 TDS concentrations at DMME permitted site 4120017.

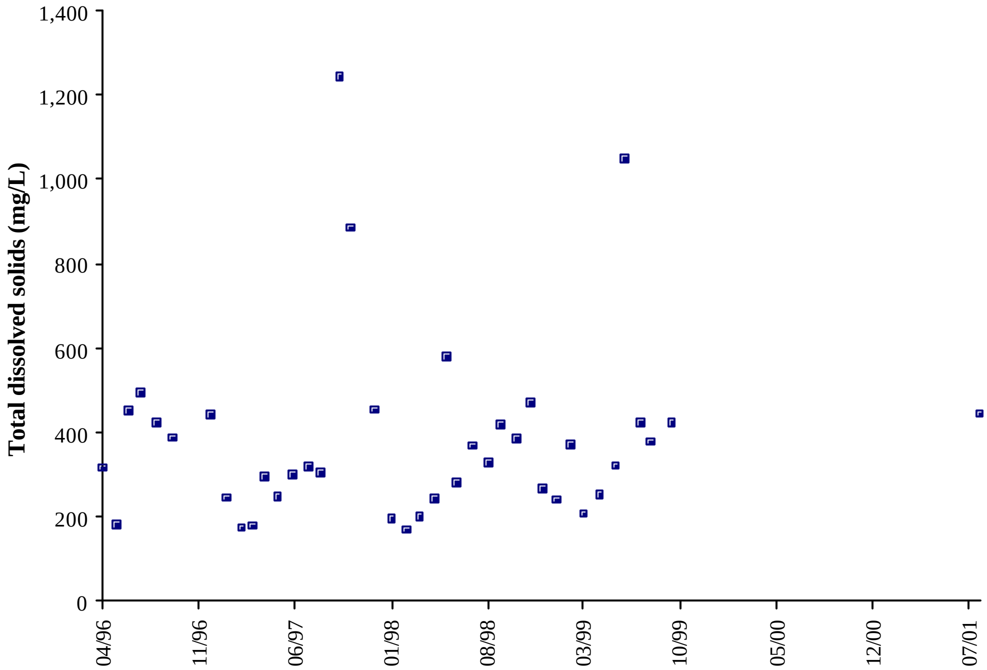

Figure A.65 TDS concentrations at DMME permitted site 4120018.

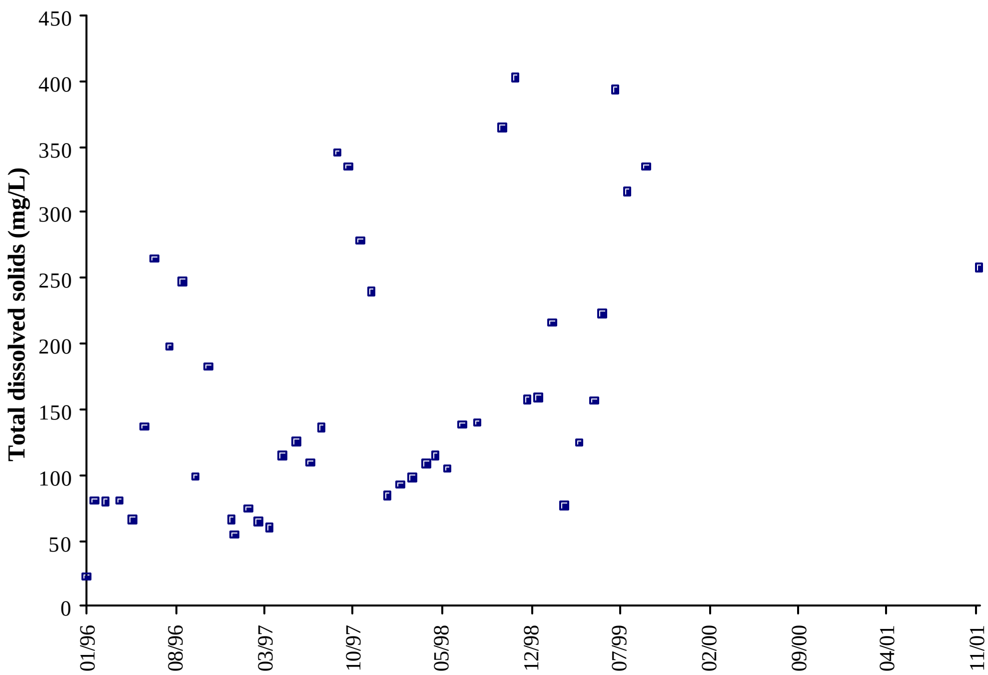

Figure A.66 TDS concentrations at DMME permitted site 4120086.

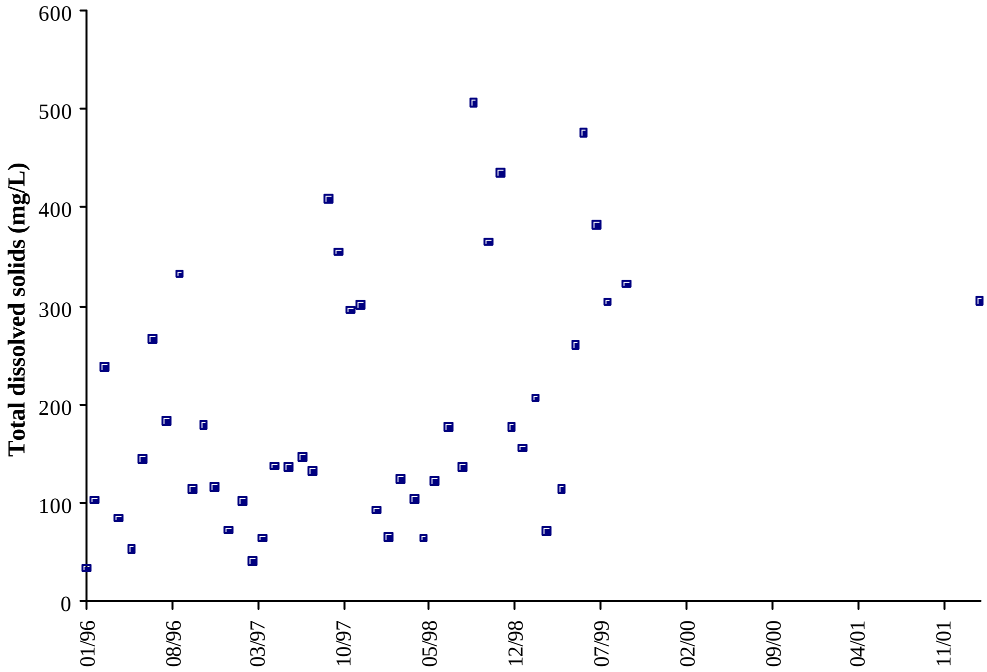

Figure A.67 TDS concentrations at DMME permitted site 4120087.

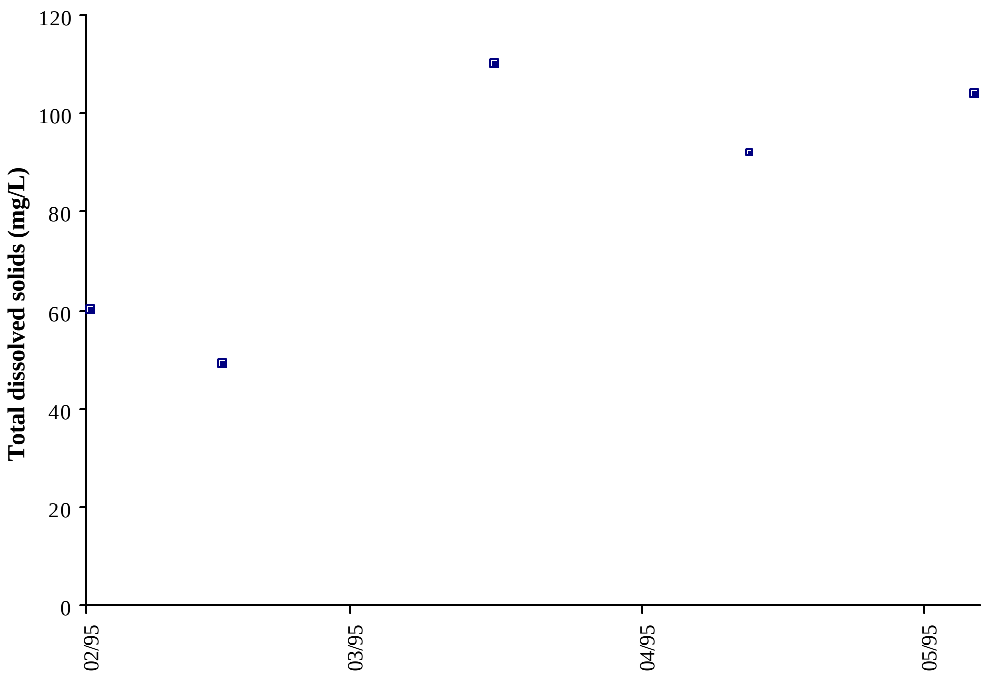

Figure A.68 TDS concentrations at DMME permitted site 4120099.

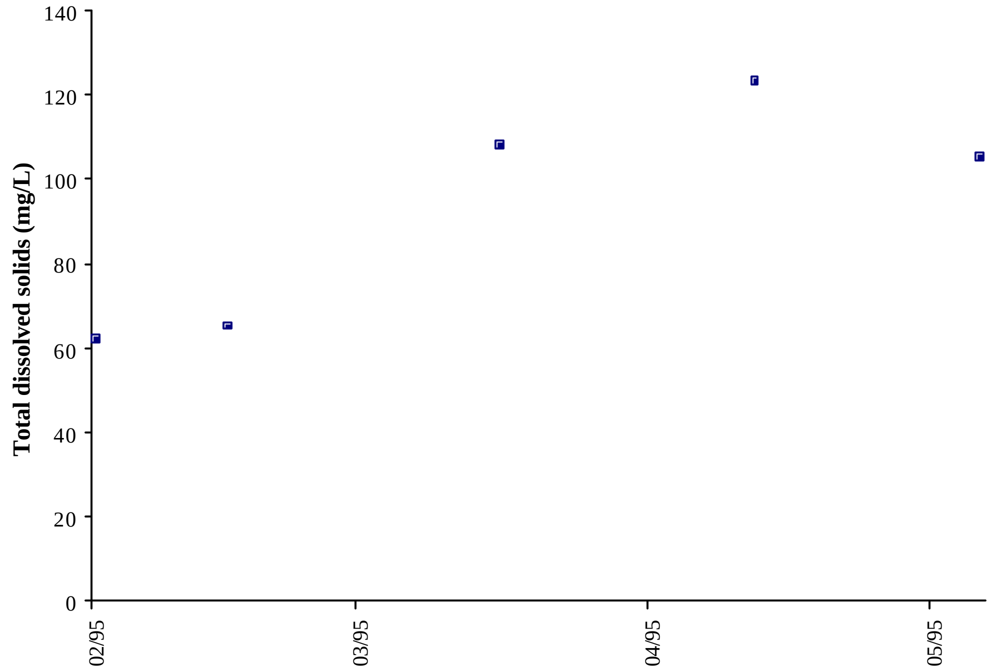

Figure A.69 TDS concentrations at DMME permitted site 4120100.

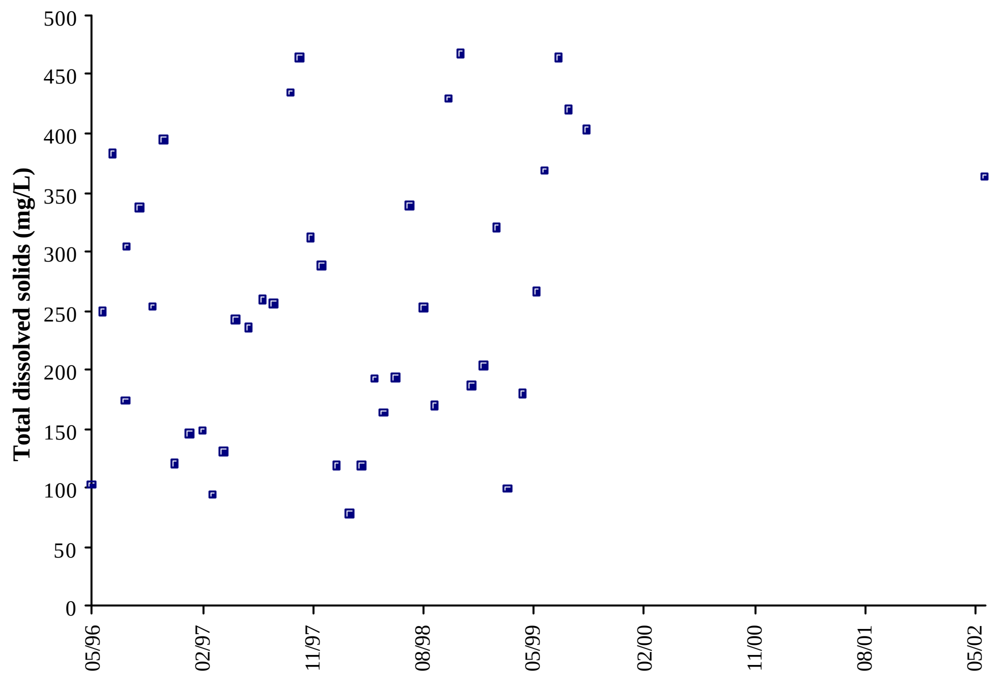

Figure A.70 TDS concentrations at DMME permitted site 4120115.

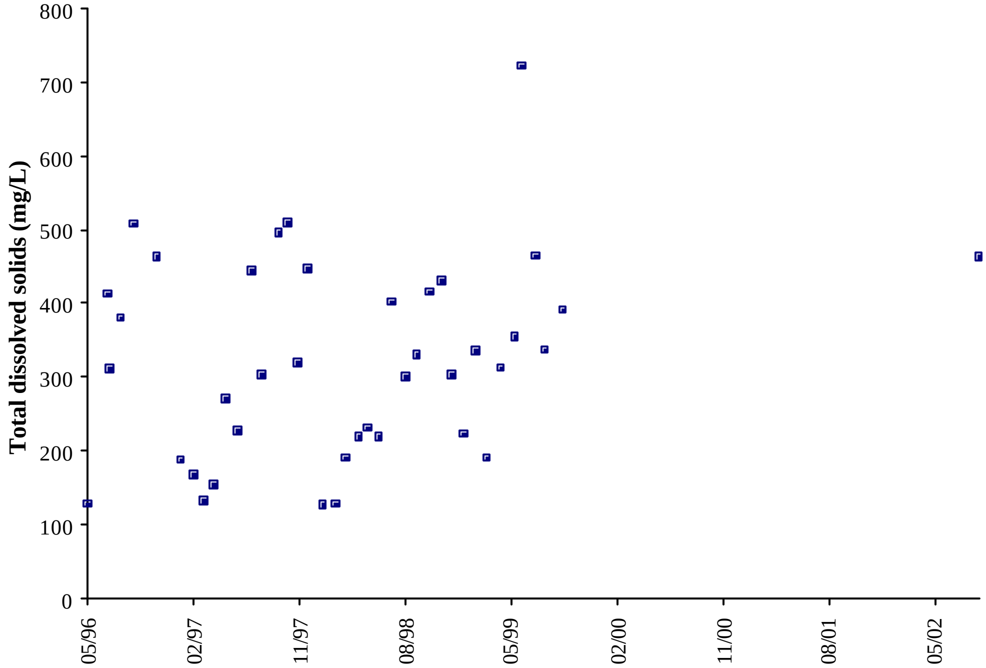

Figure A.71 TDS concentrations at DMME permitted site 4120116.

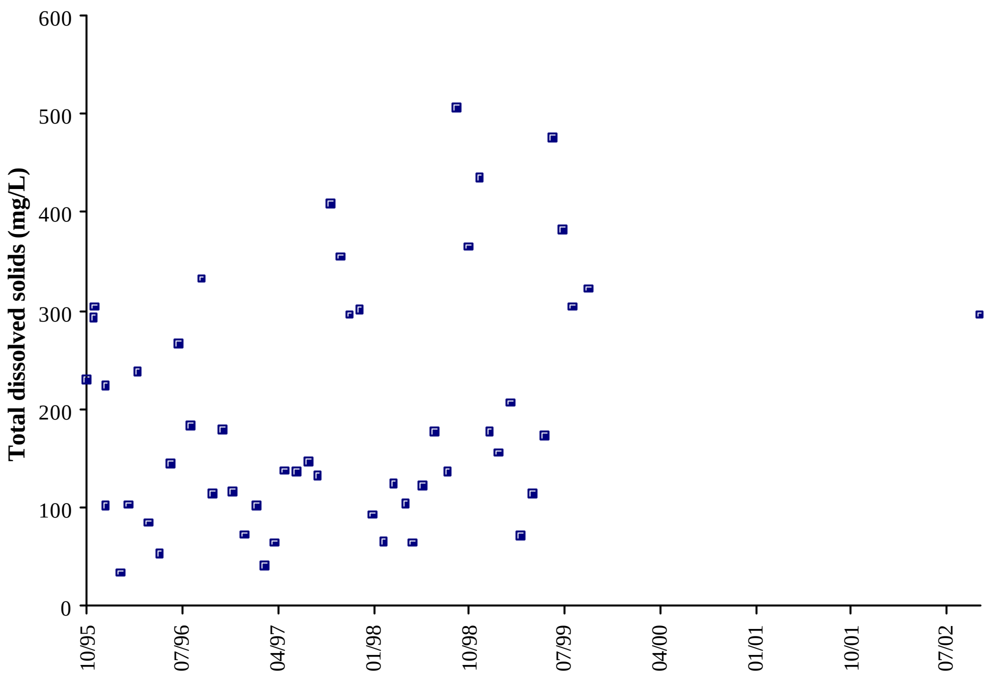

Figure A.72 TDS concentrations at DMME permitted site 4120120.

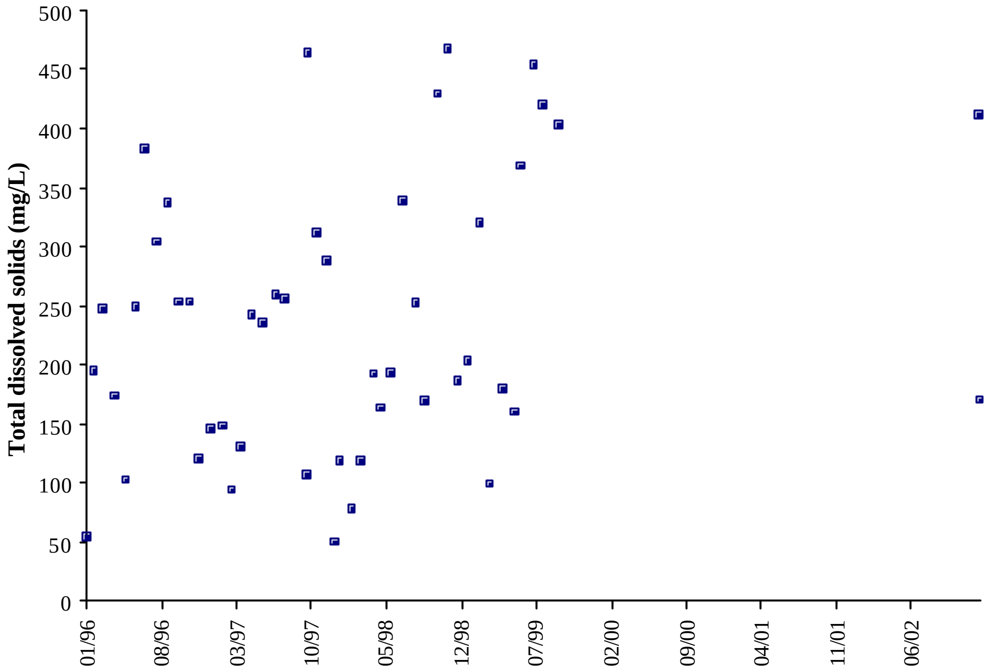

Figure A.73 TDS concentrations at DMME permitted site 4120121.

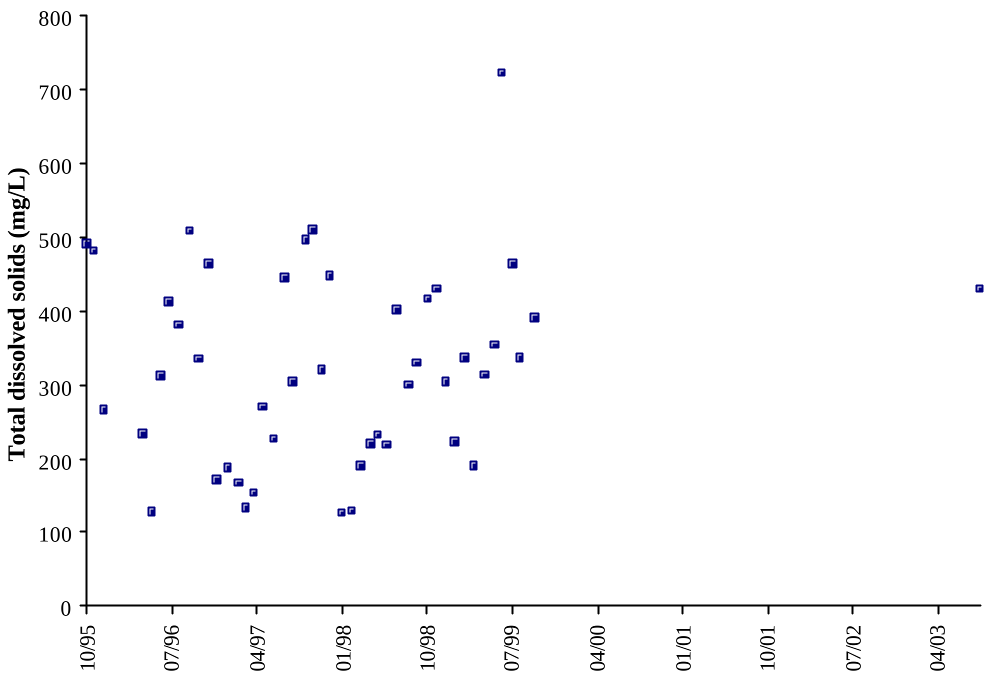

Figure A.74 TDS concentrations at DMME permitted site 4120204.

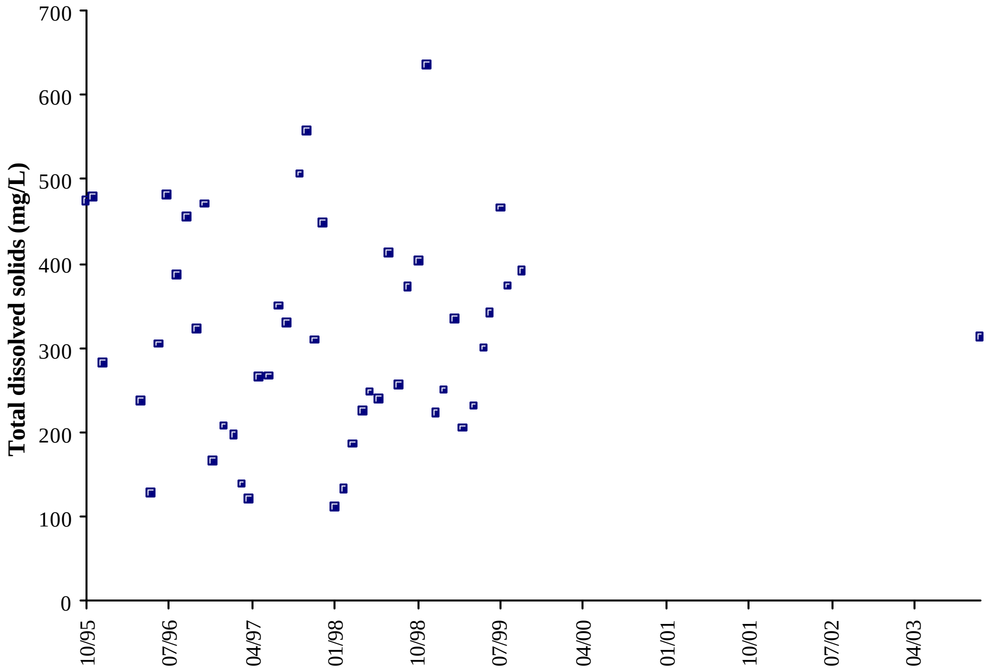

Figure A.75 TDS concentrations at DMME permitted site 4120205.

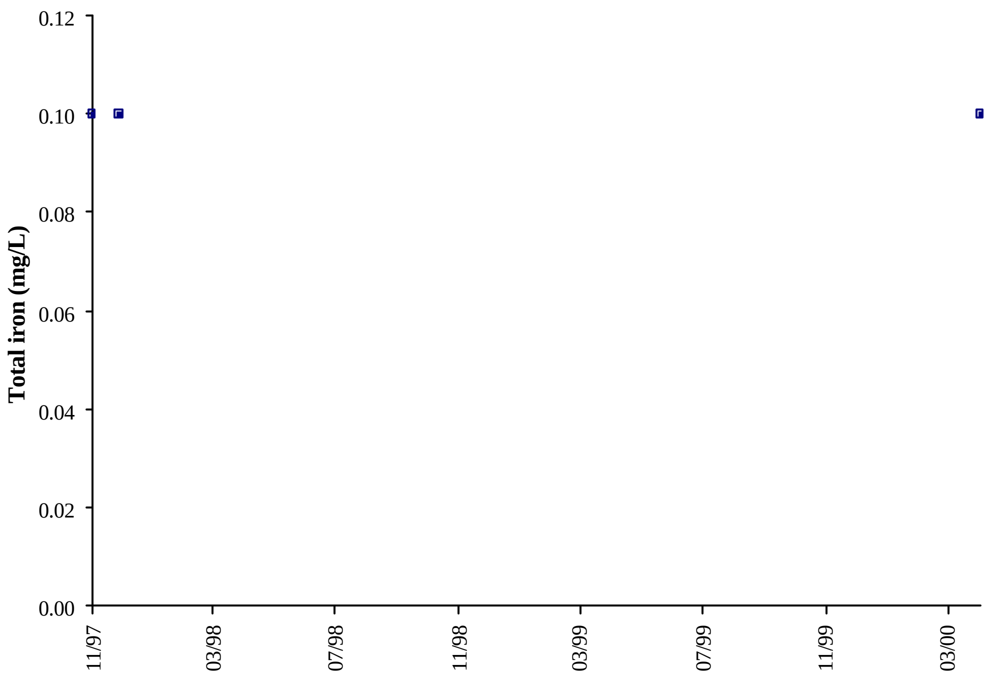

Figure A.76 Total iron concentrations at DMME permitted site 0001988.

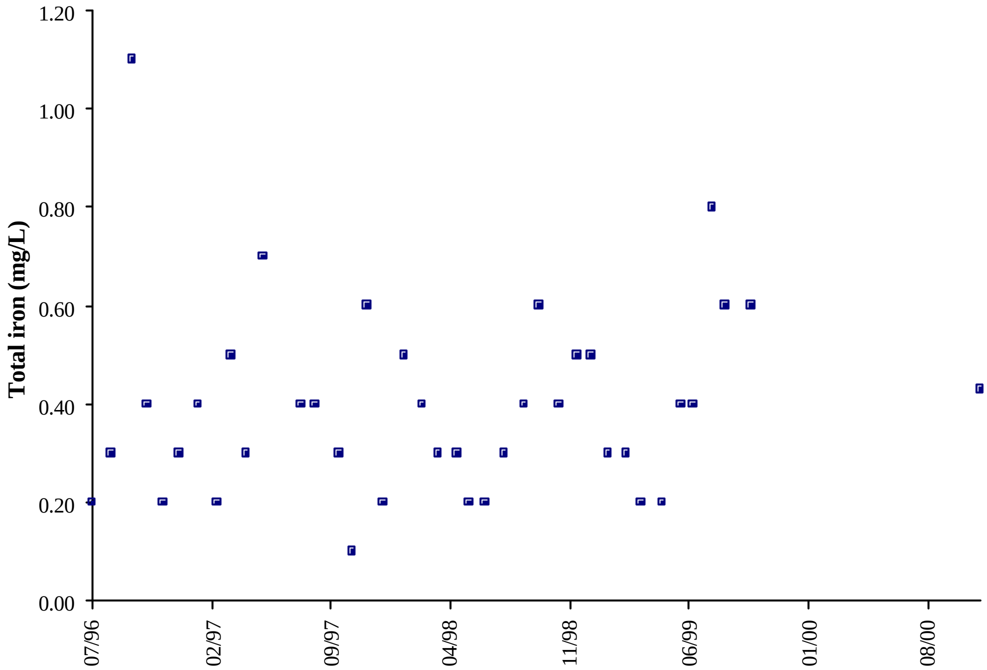

Figure A.77 Total iron concentrations at DMME permitted site 4120011.

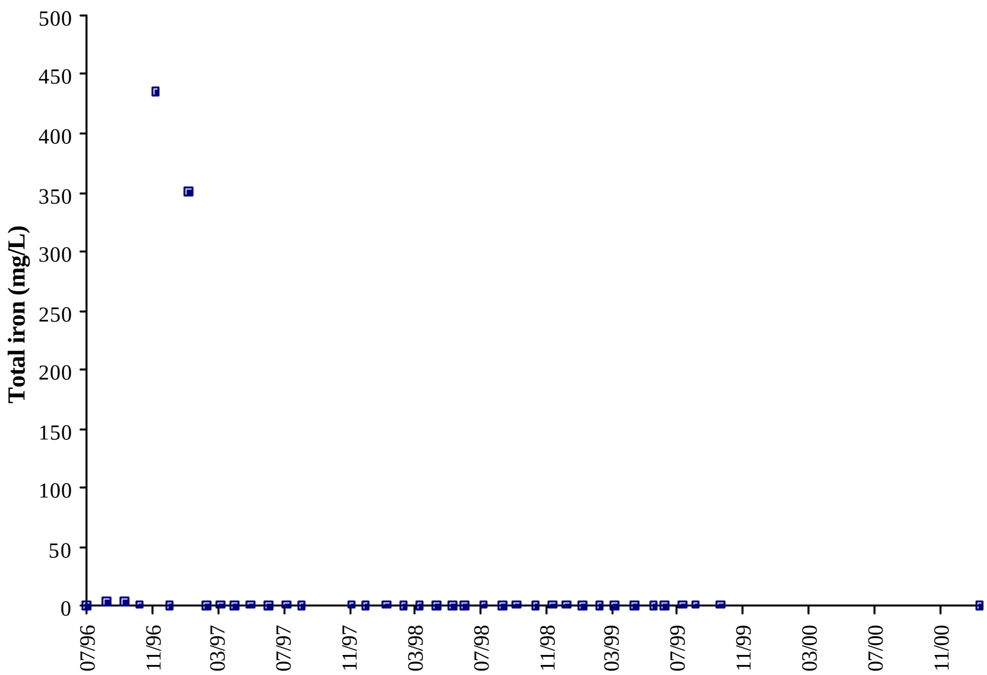

Figure A.78 Total iron concentrations at DMME permitted site 4120012.

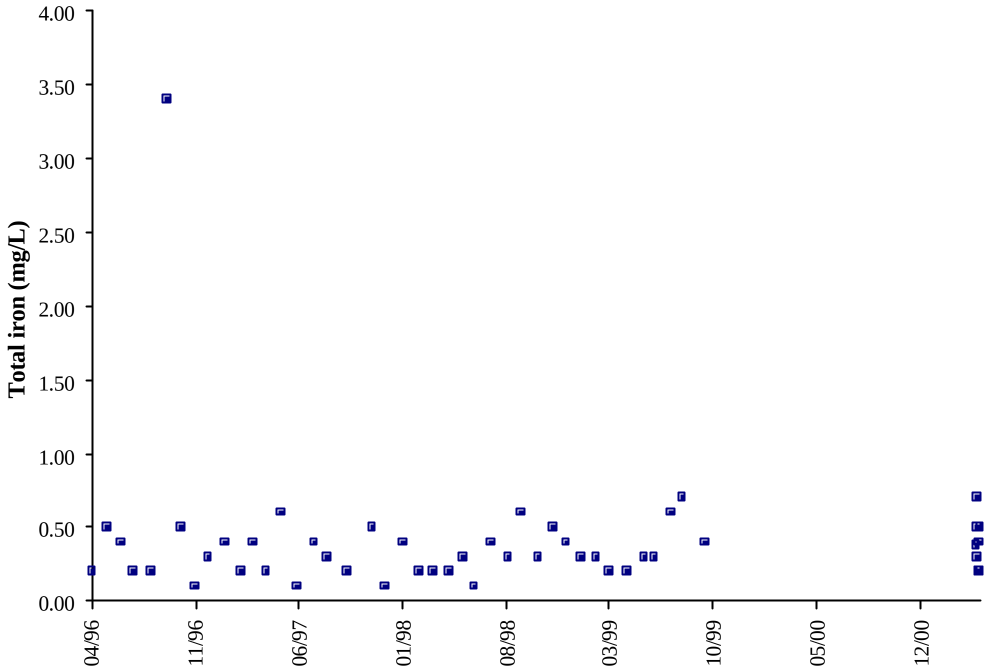

Figure A.79 Total iron concentrations at DMME permitted site 4120017.

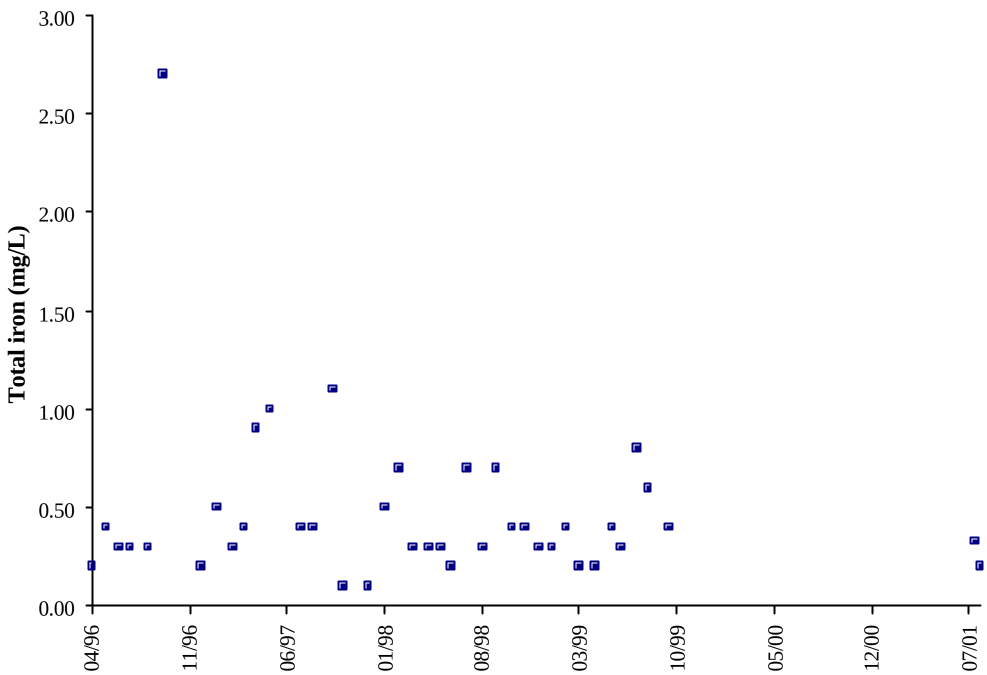

Figure A.80 Total iron concentrations at DMME permitted site 4120018.

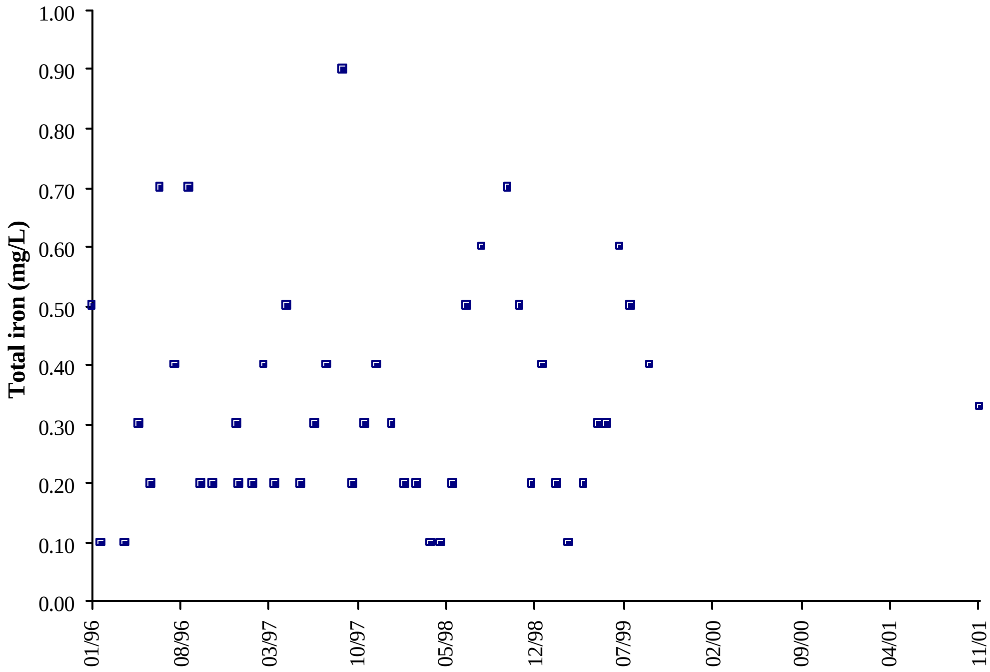

Figure A.81 Total iron concentrations at DMME permitted site 4120086.

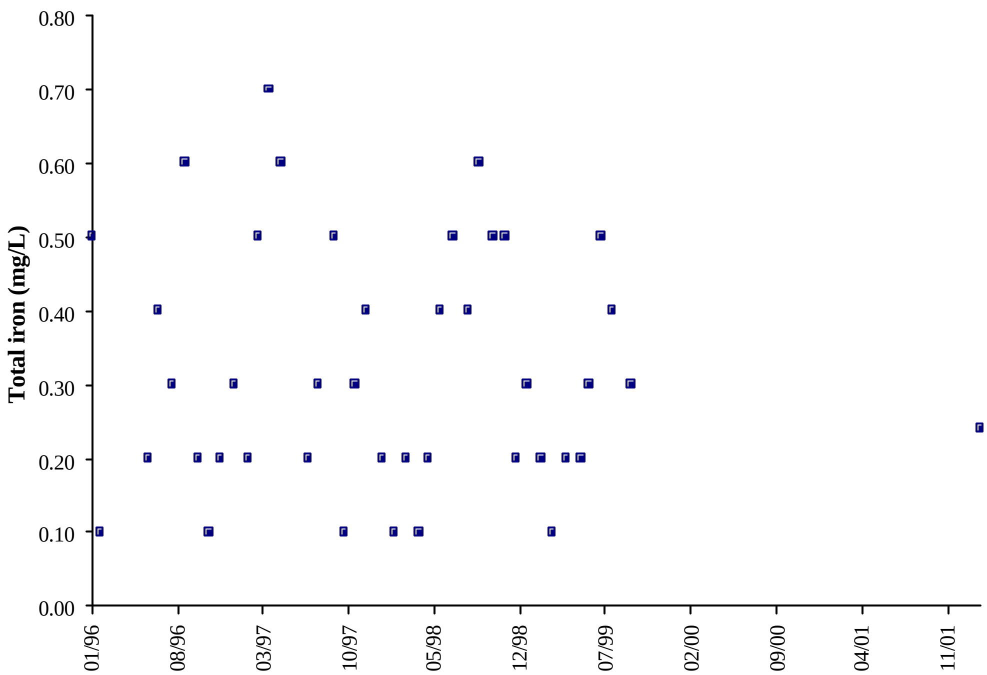

Figure A.82 Total iron concentrations at DMME permitted site 4120087.

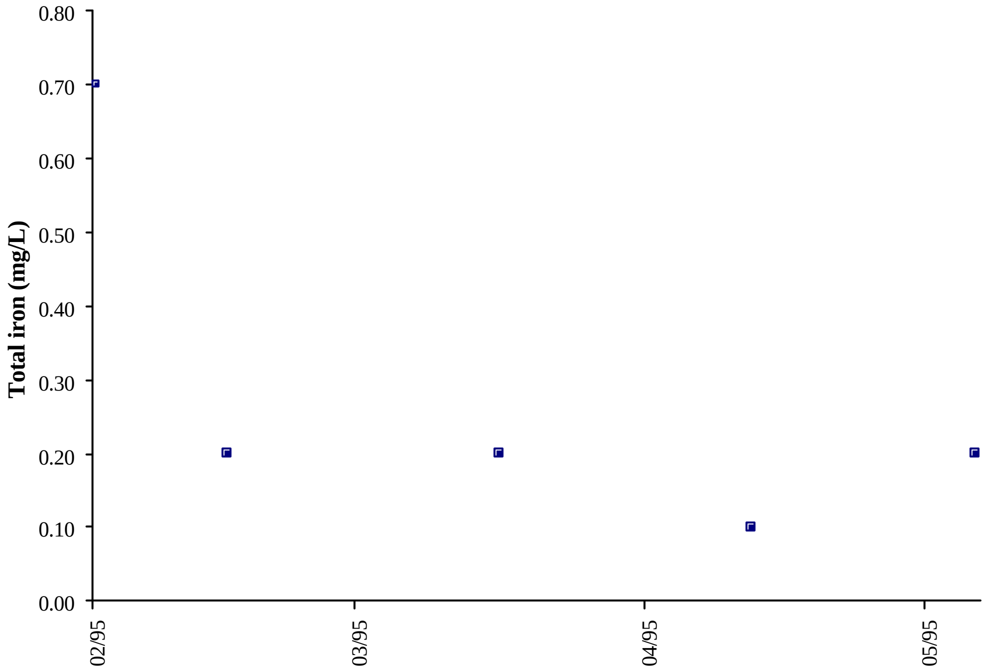

Figure A.83 Total iron concentrations at DMME permitted site 4120099.

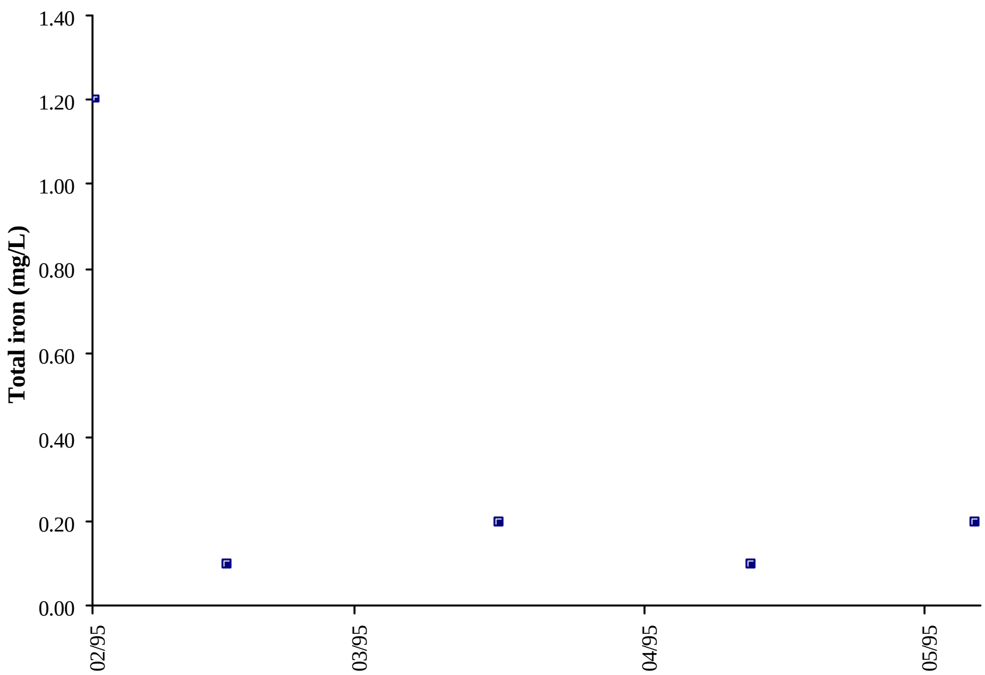

Figure A.84 Total iron concentrations at DMME permitted site 4120100.

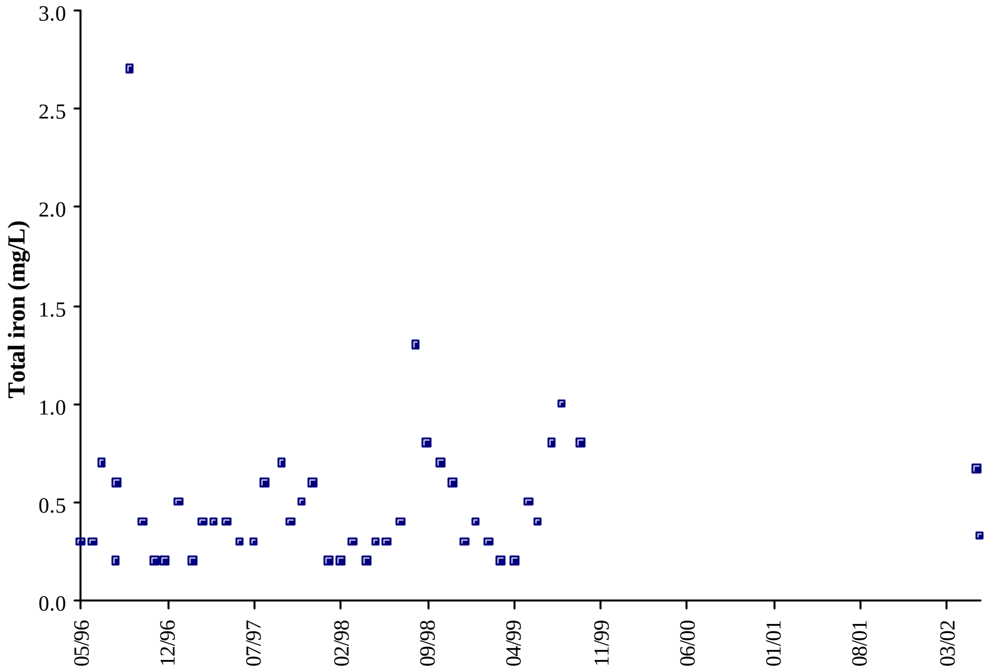

Figure A.85 Total iron concentrations at DMME permitted site 4120115.

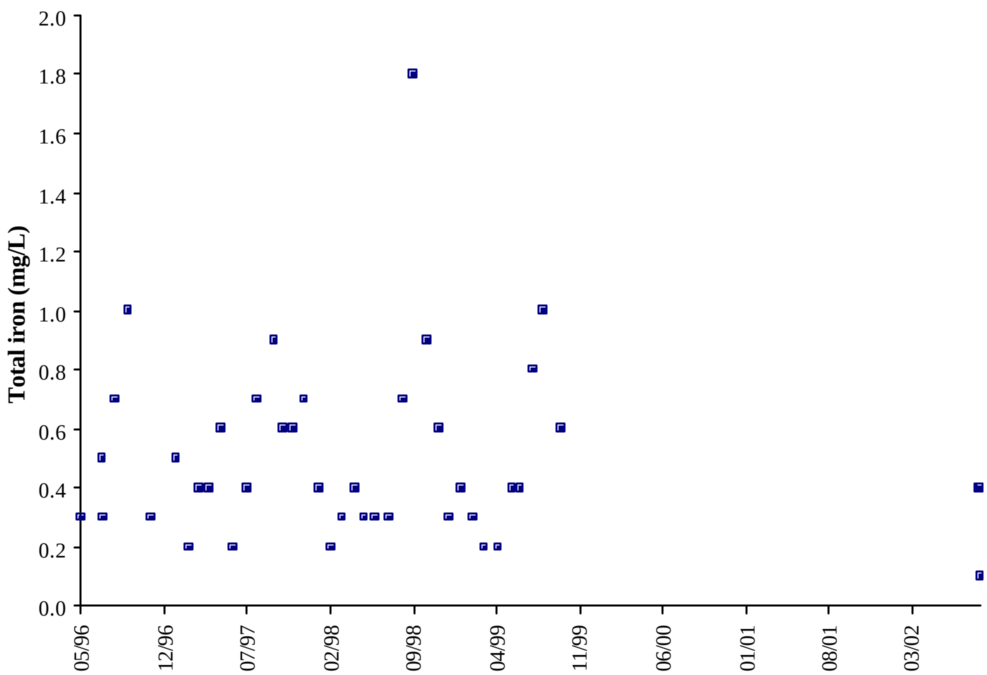

Figure A.86 Total iron concentrations at DMME permitted site 4120116.

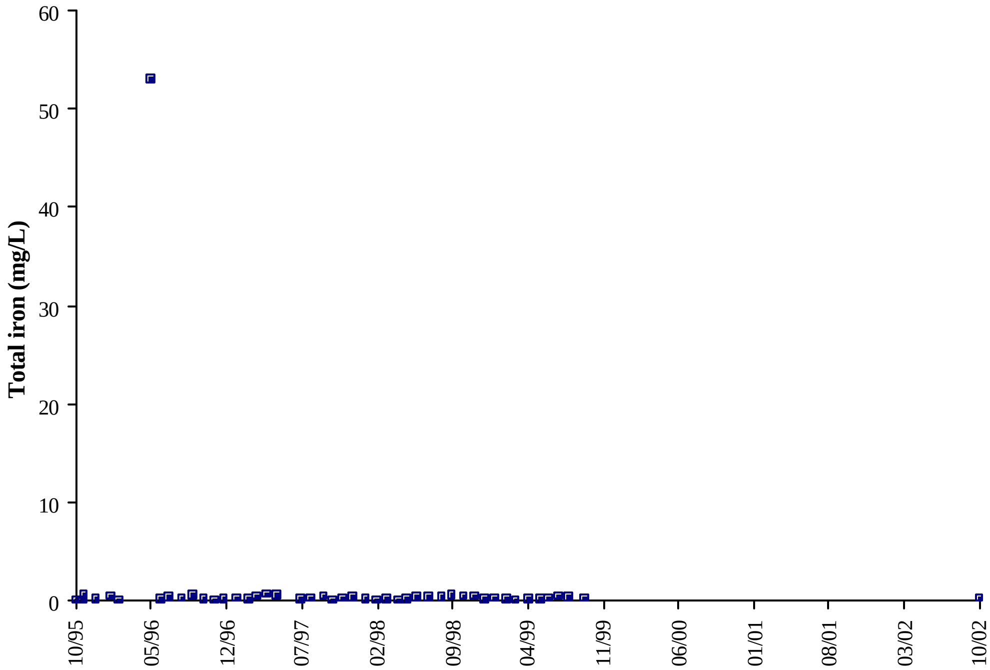

Figure A.87 Total iron concentrations at DMME permitted site 4120120.

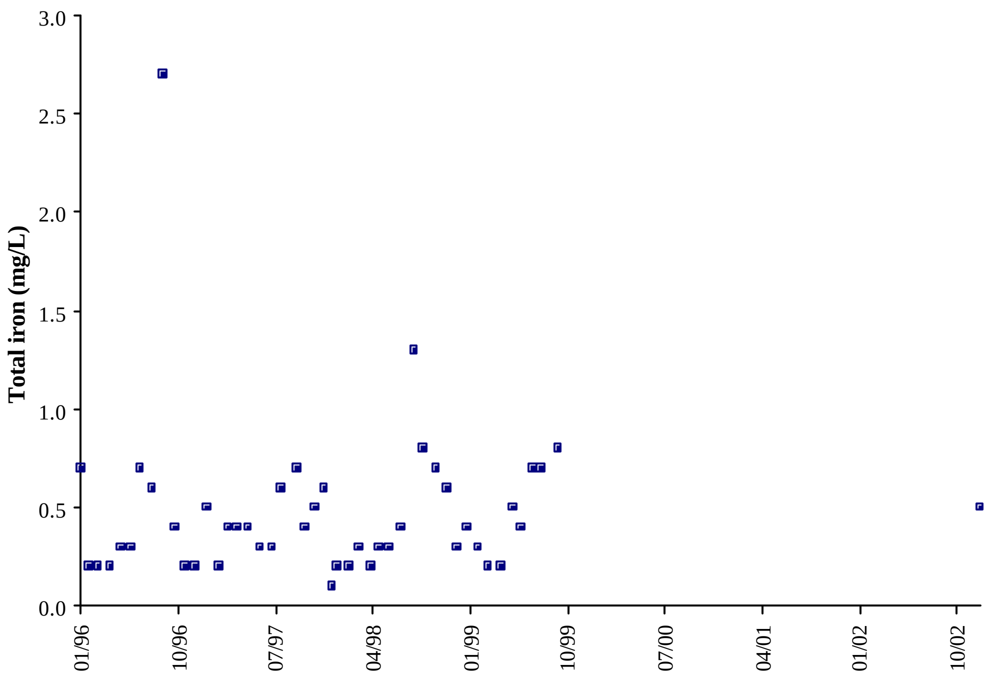

Figure A.88 Total iron concentrations at DMME permitted site 4120121.

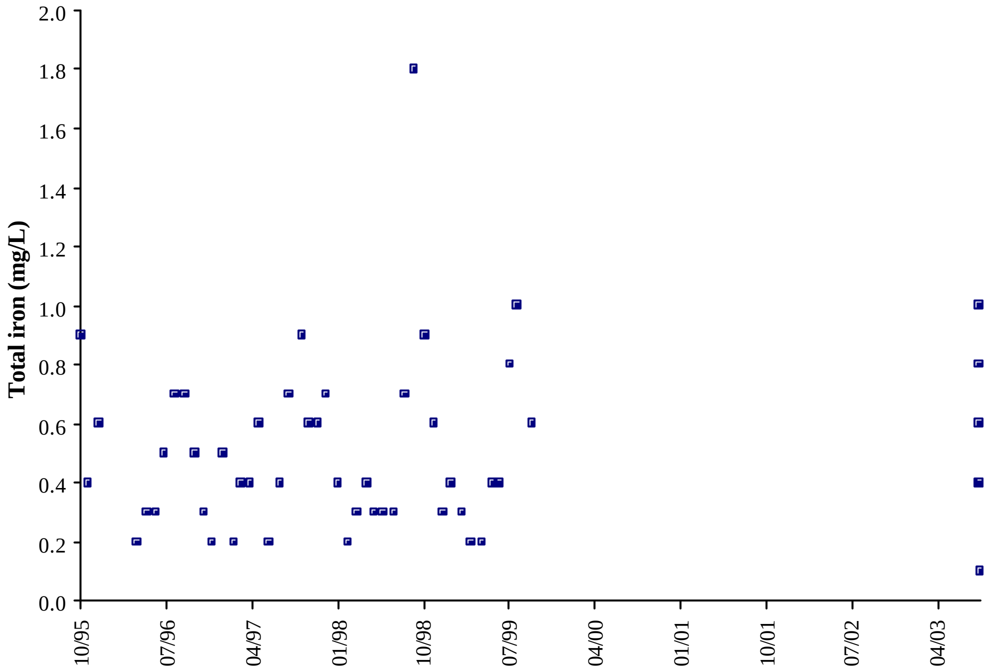

Figure A.89 Total iron concentrations at DMME permitted site 4120204.

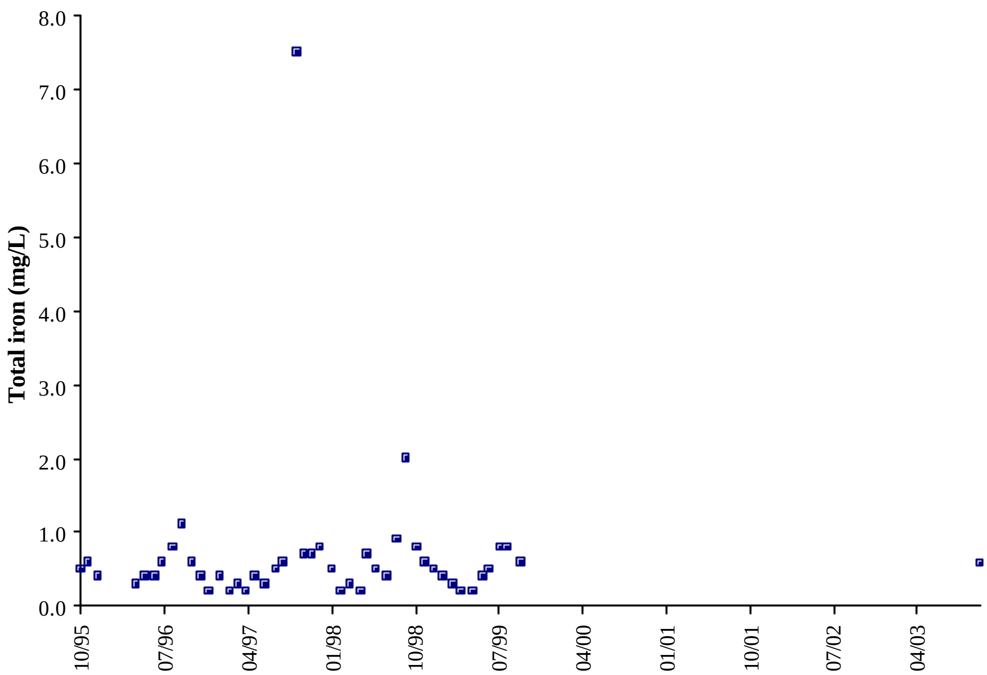

Figure A.90 Total iron concentrations at DMME permitted site 4120205.

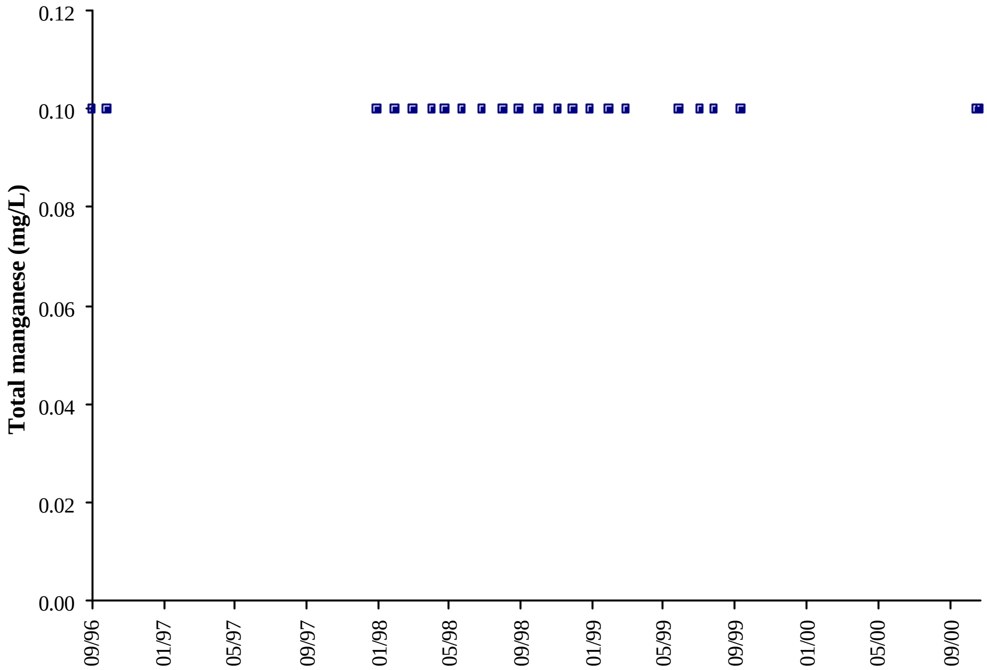

Figure A.91 Total manganese concentrations at DMME permitted site 4120011.

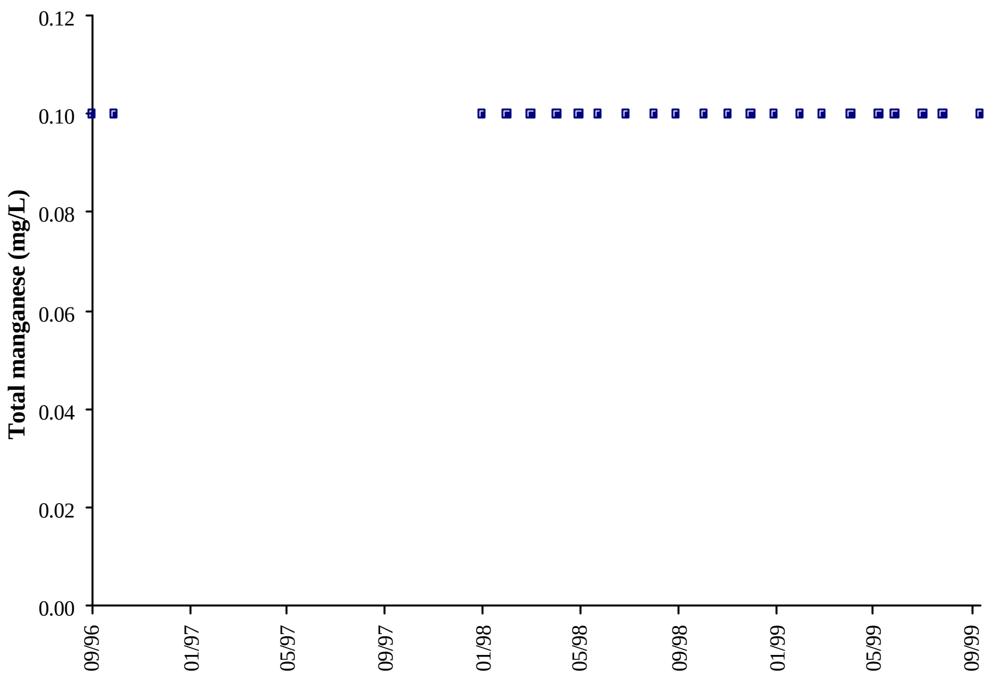

Figure A.92 Total manganese concentrations at DMME permitted site 4120012.

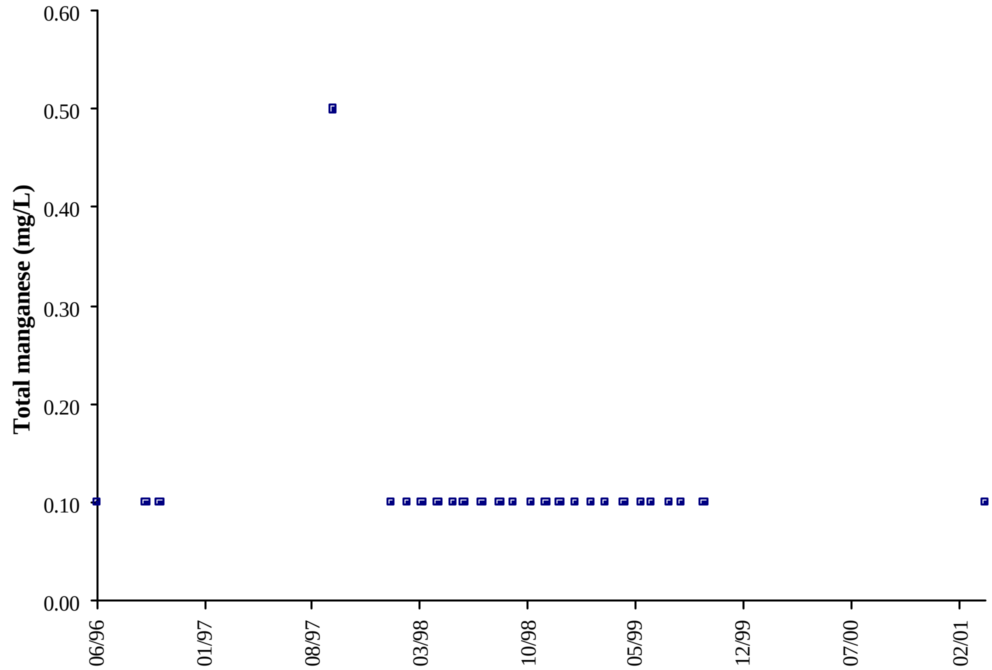

Figure A.93 Total manganese concentrations at DMME permitted site 4120017.

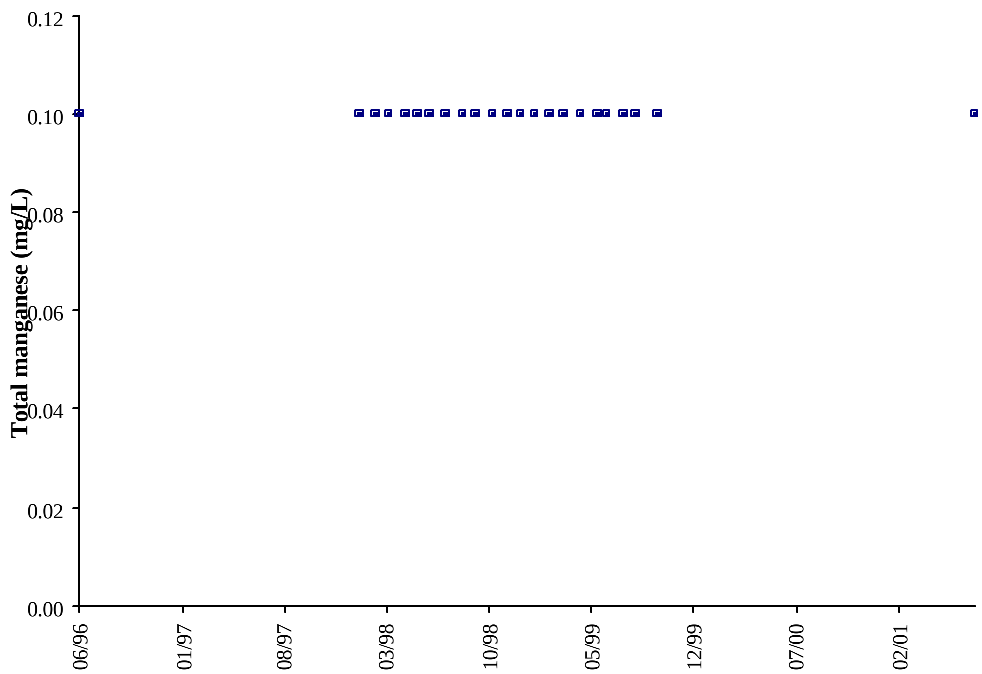

Figure A.94 Total manganese concentrations at DMME permitted site 4120018.

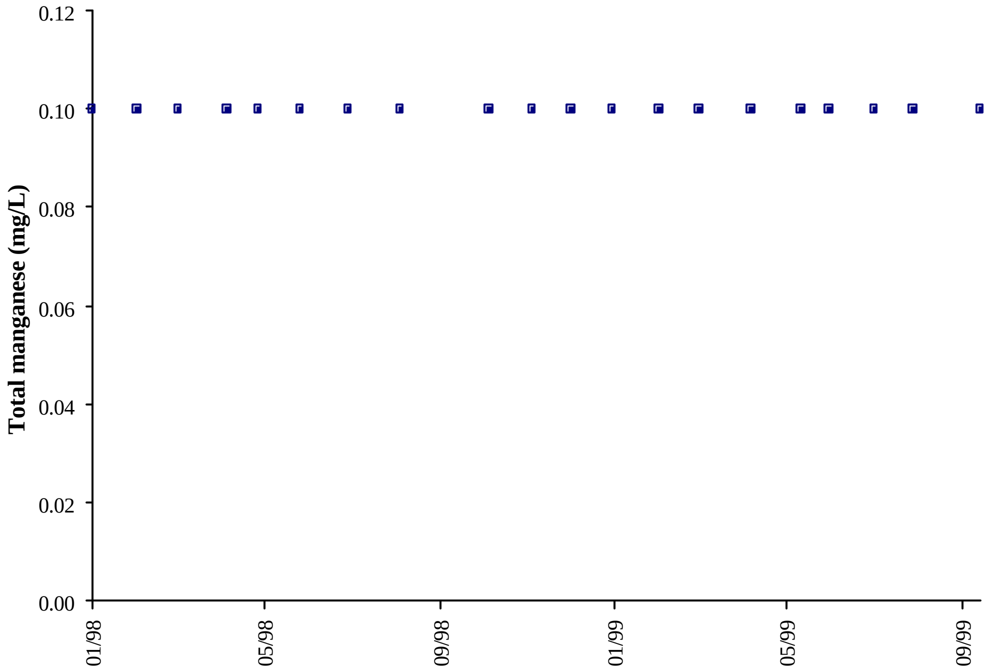

Figure A.95 Total manganese concentrations at DMME permitted site 4120086.

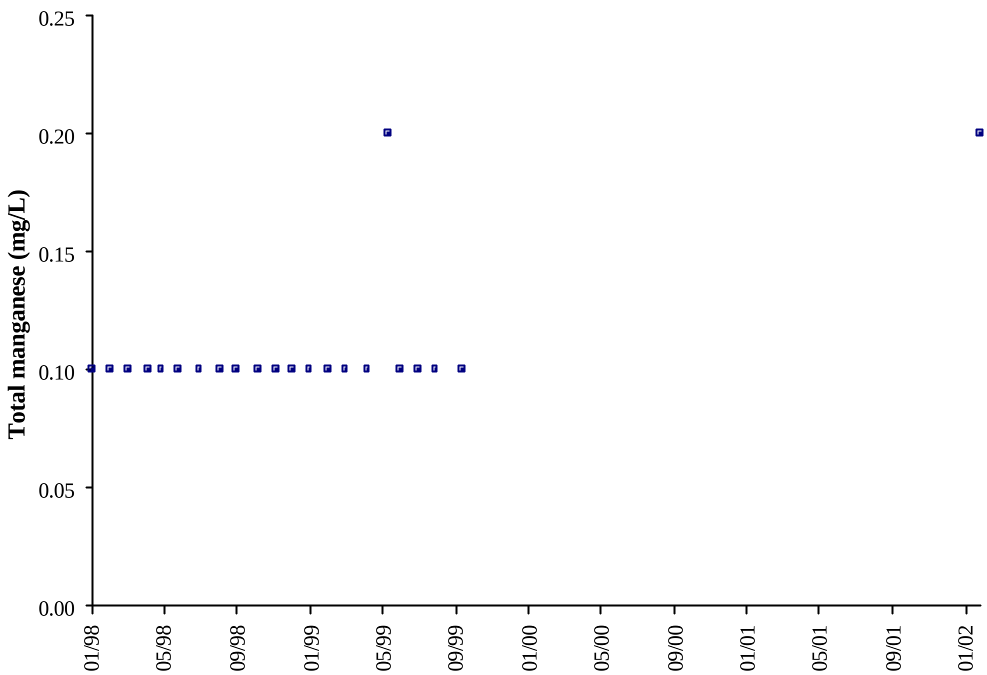

Figure A.96 Total manganese concentrations at DMME permitted site 4120087.

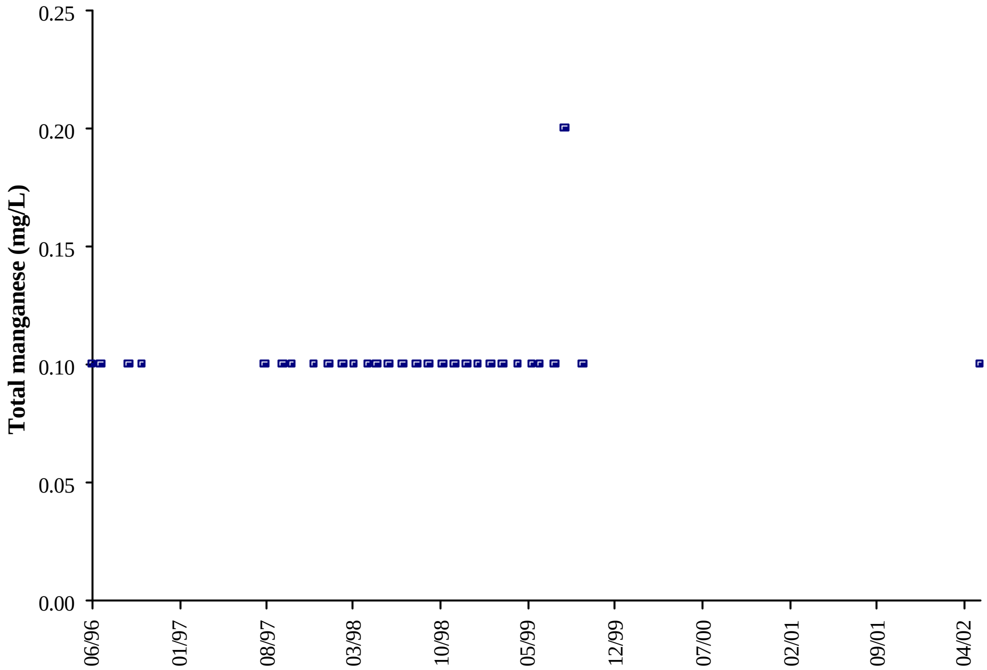

Figure A.97 Total manganese concentrations at DMME permitted site 4120115.

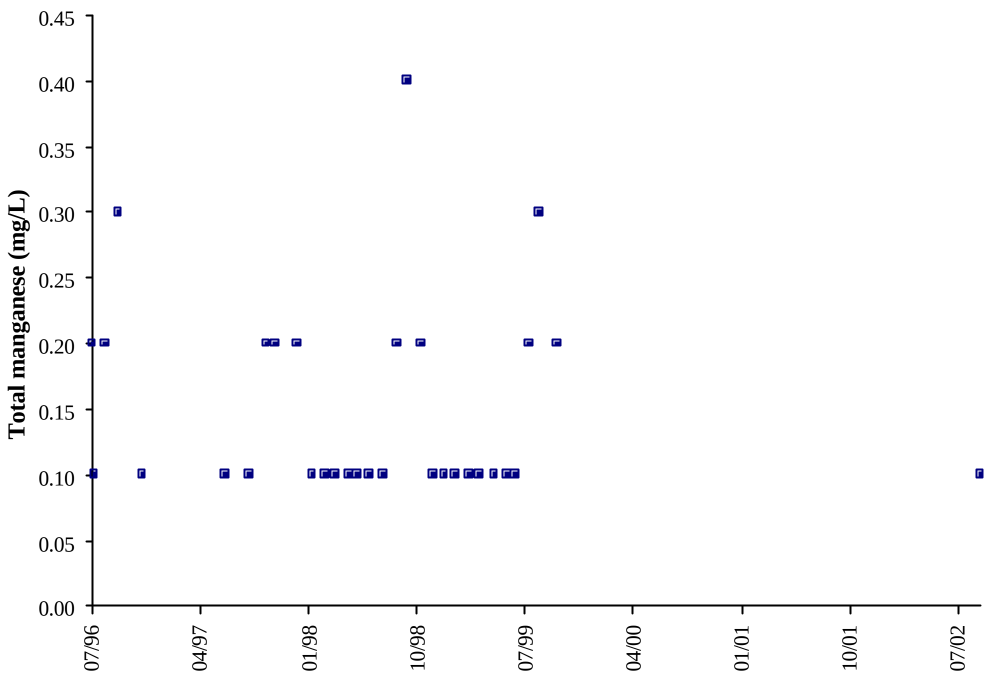

Figure A.98 Total manganese concentrations at DMME permitted site 4120116.

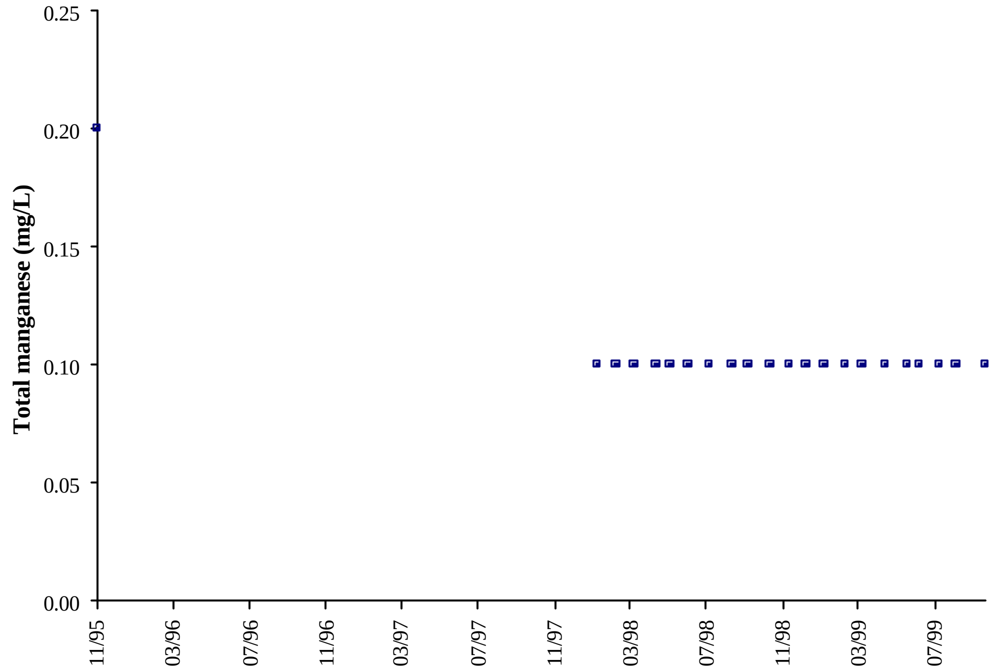

Figure A.99 Total manganese concentrations at DMME permitted site 4120120.

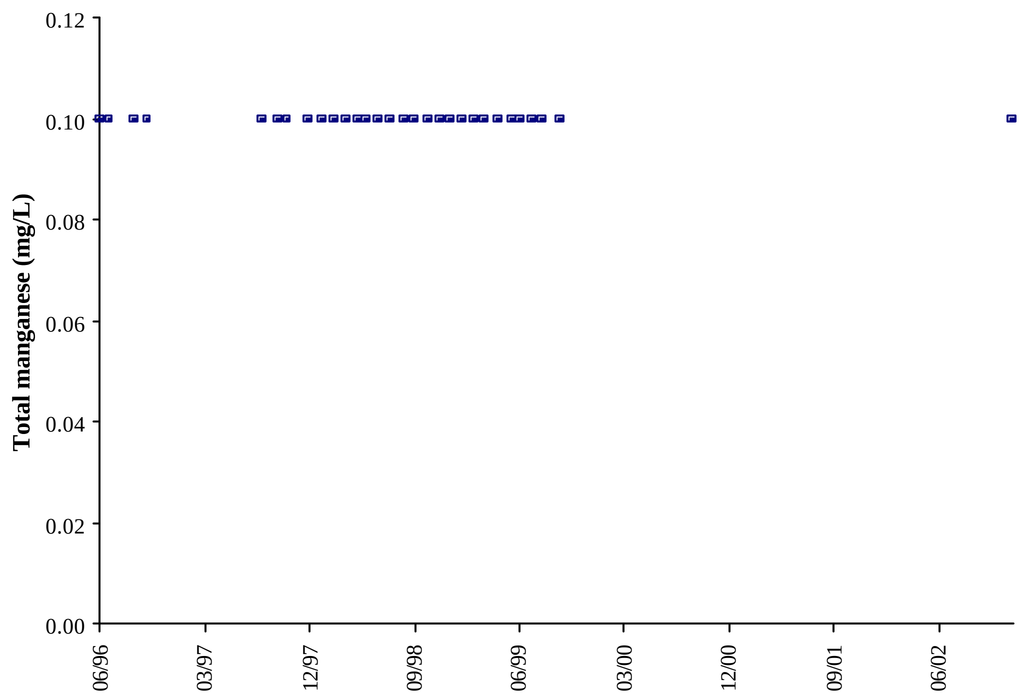

Figure A.100 Total manganese concentrations at DMME permitted site 4120121.

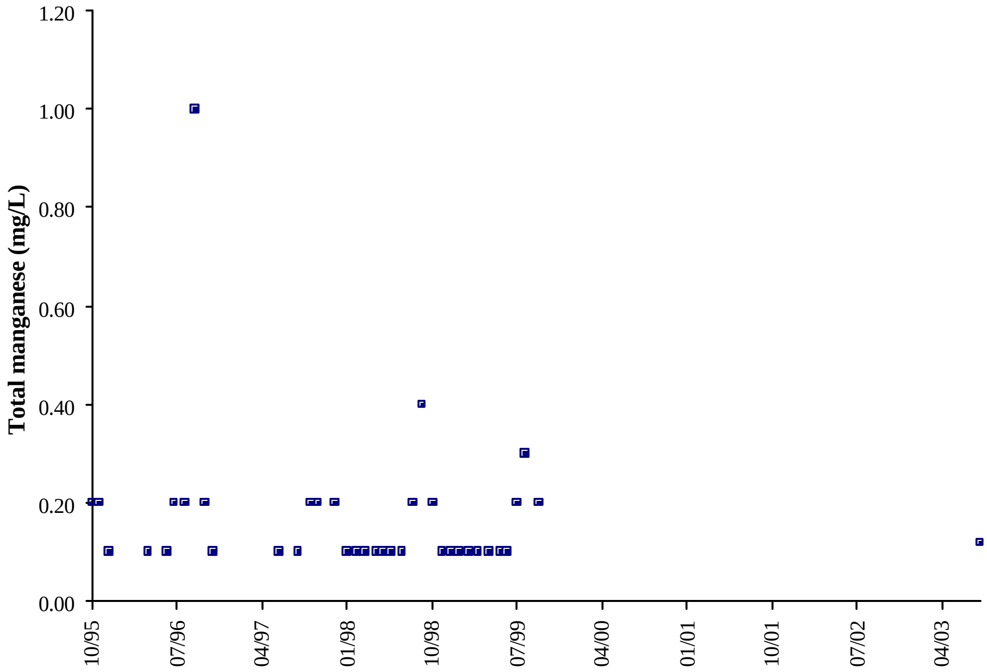

Figure A.101 Total manganese concentrations at DMME permitted site 4120204.

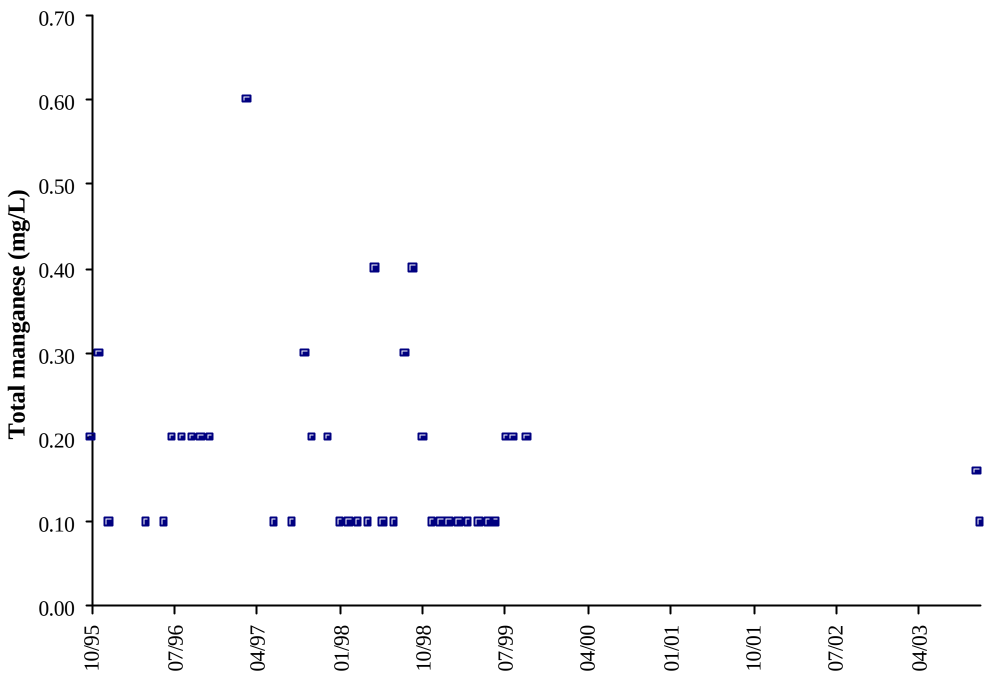

Figure A.102 Total manganese concentrations at DMME permitted site 4120205.

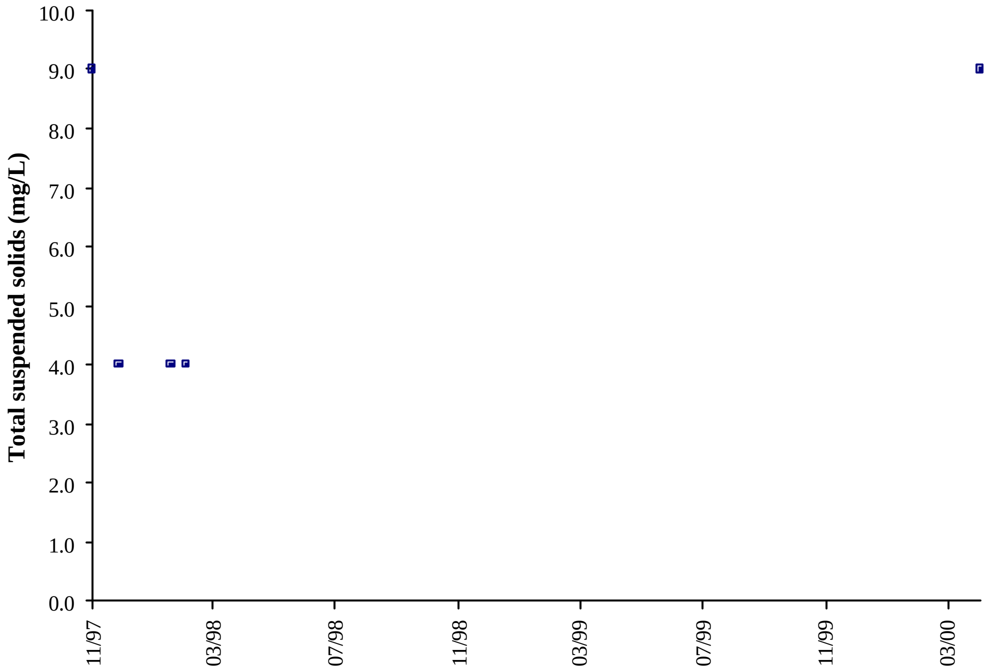

Figure A.103 TSS concentrations at DMME permitted site 0001988.

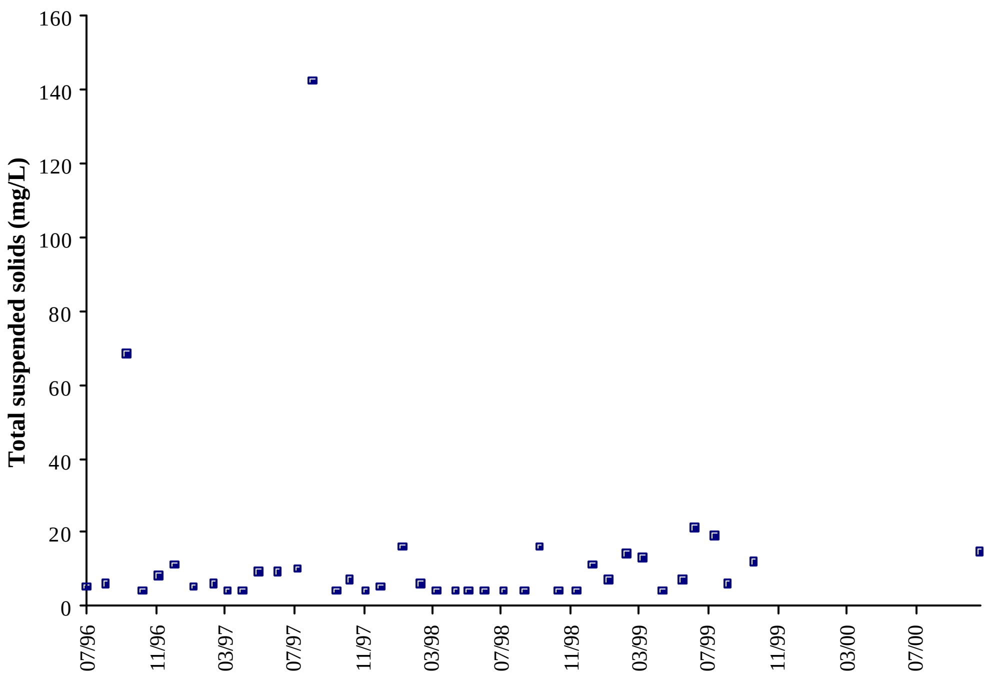

Figure A.104 TSS concentrations at DMME permitted site 4120011.

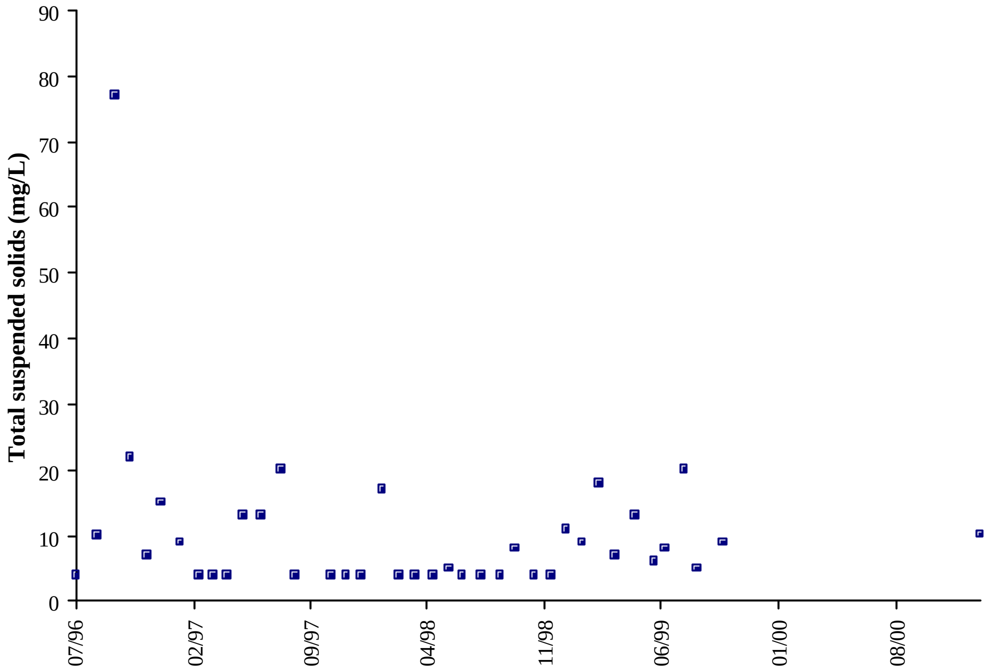

Figure A.105 TSS concentrations at DMME permitted site 4120012.

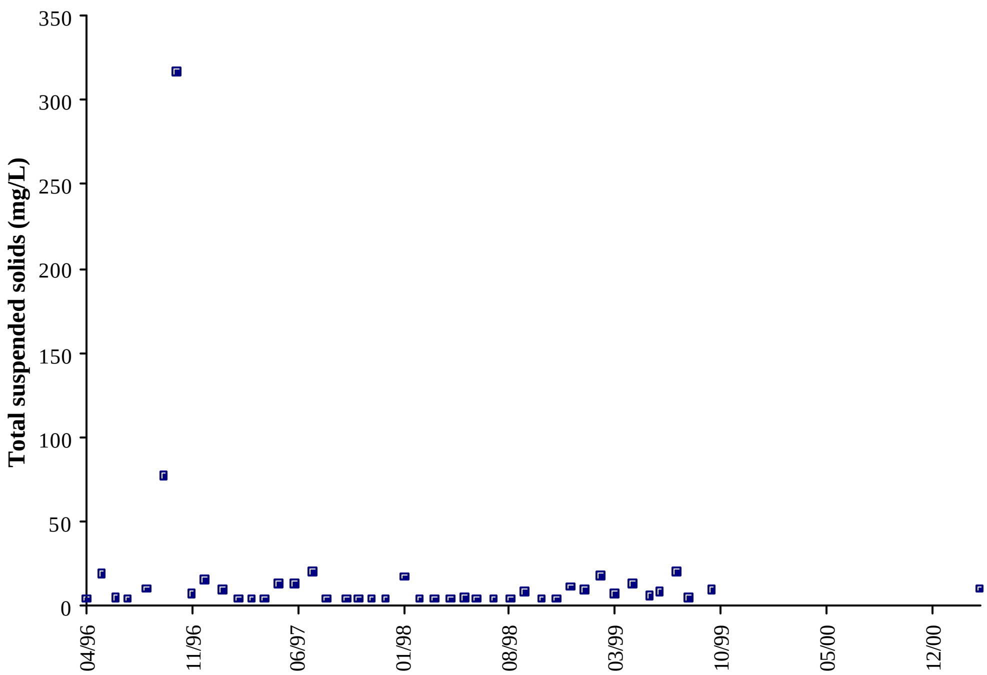

Figure A.106 TSS concentrations at DMME permitted site 4120017.

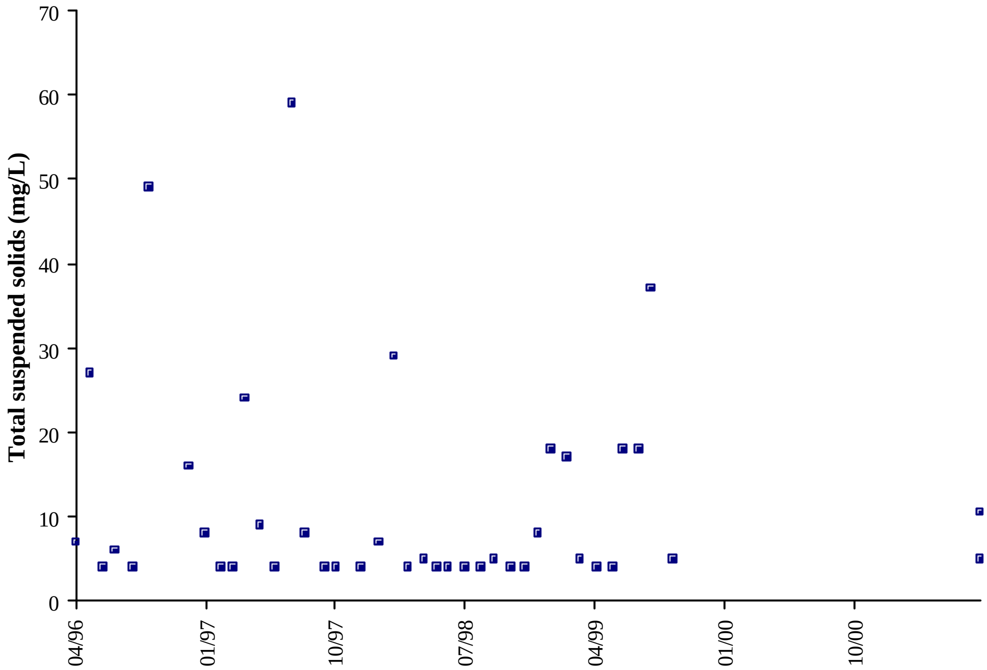

Figure A.107 TSS concentrations at DMME permitted site 4120018.

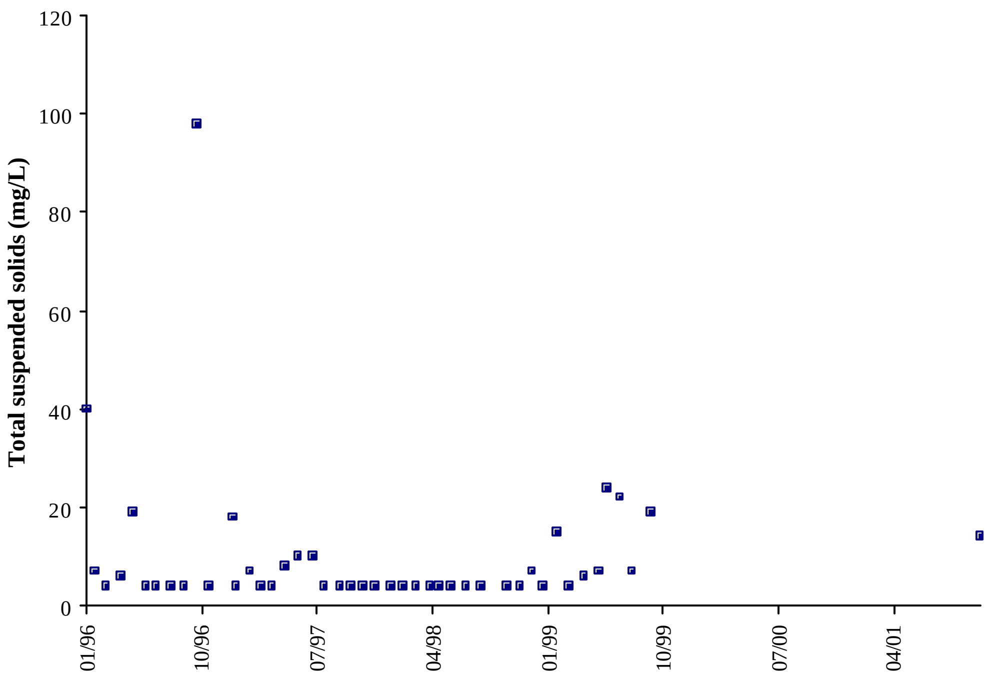

Figure A.108 TSS concentrations at DMME permitted site 4120086.

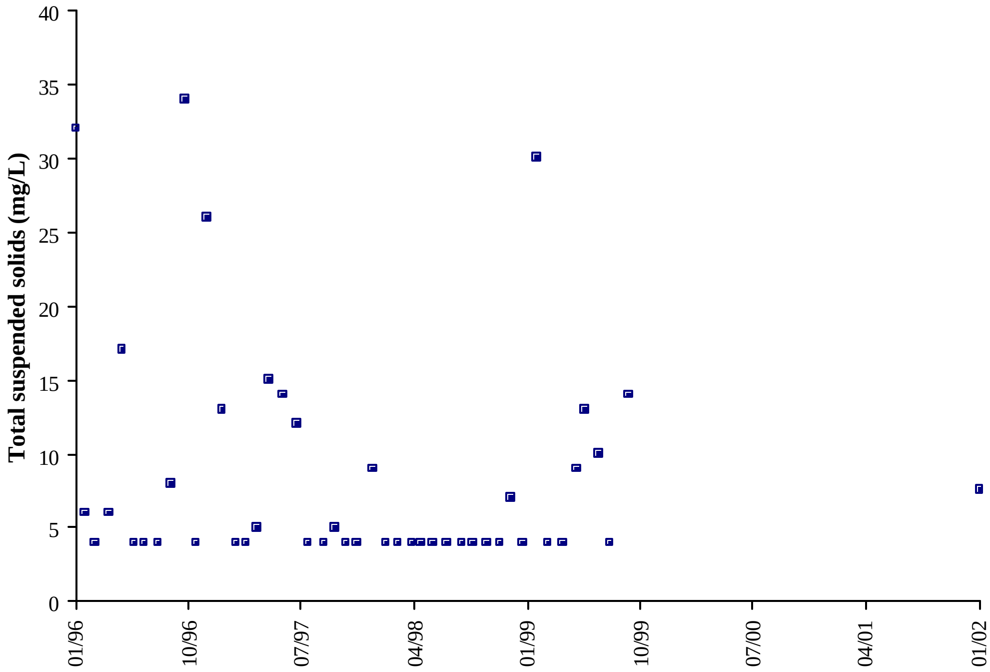

Figure A.109 TSS concentrations at DMME permitted site 4120087.

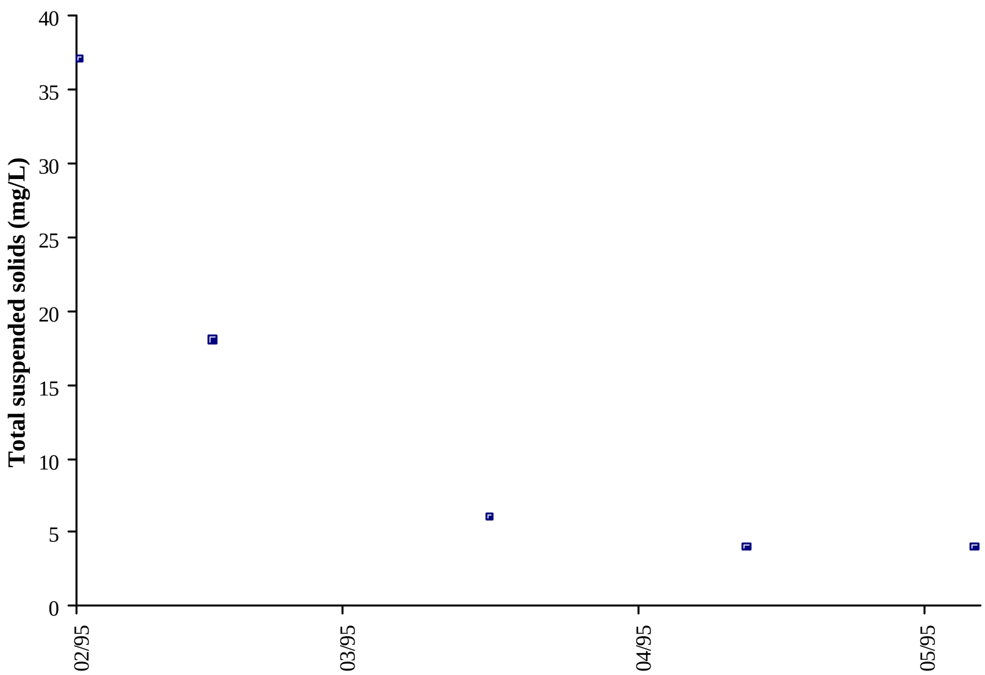

Figure A.110 TSS concentrations at DMME permitted site 4120099.

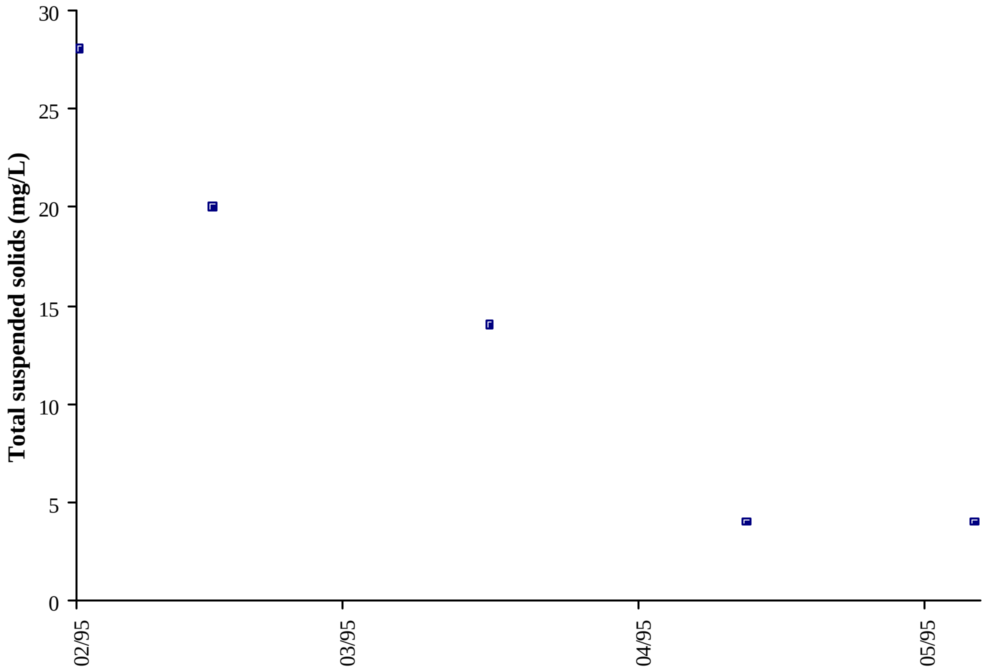

Figure A.111 TSS concentrations at DMME permitted site 4120100.

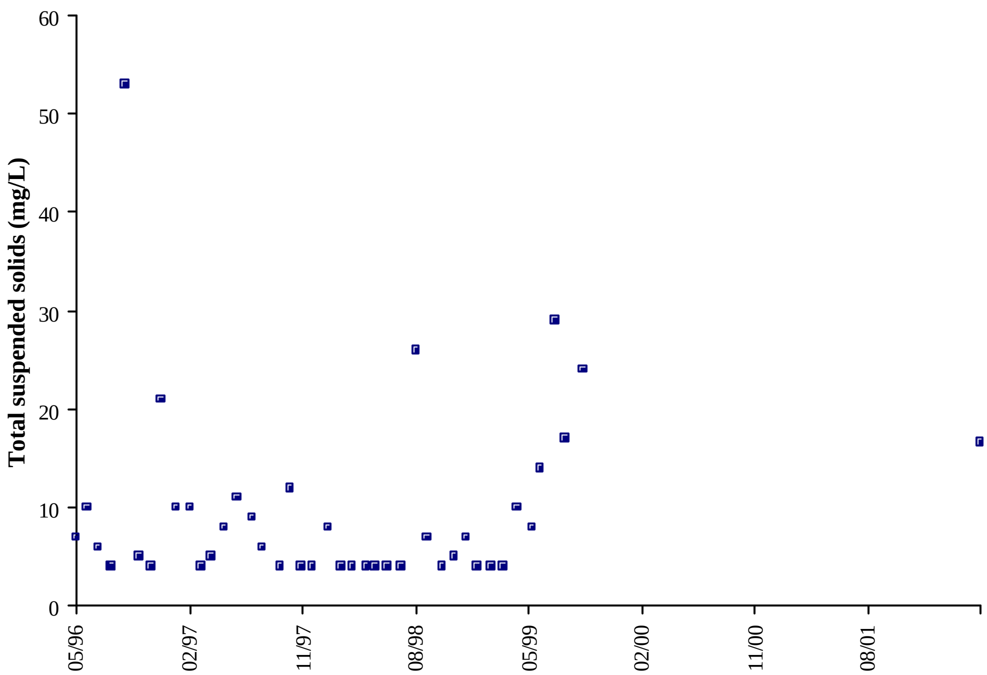

Figure A.112 TSS concentrations at DMME permitted site 4120115.

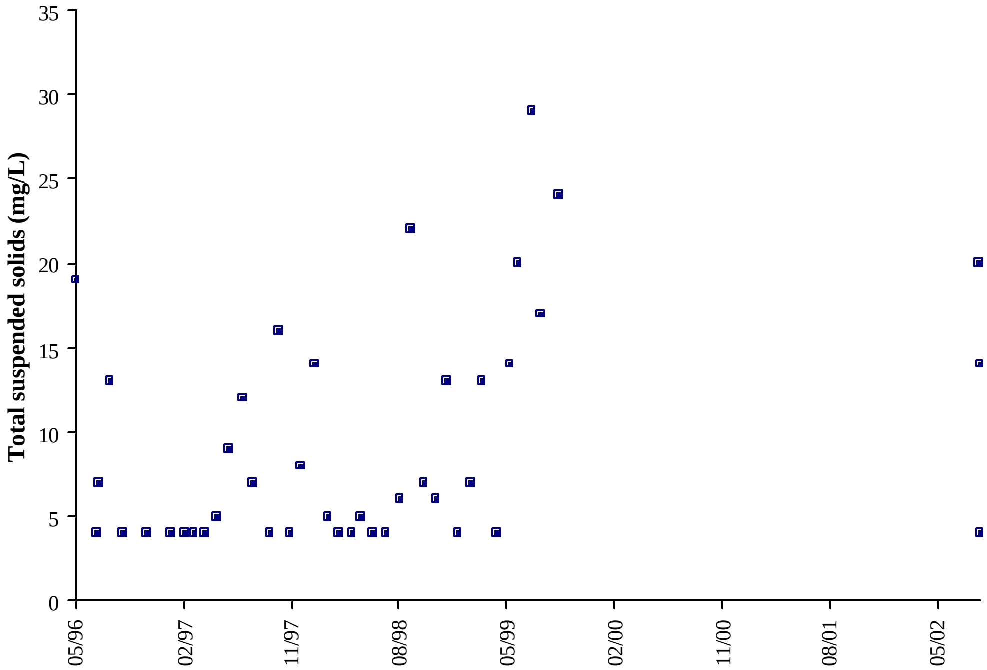

Figure A.113 TSS concentrations at DMME permitted site 4120116.

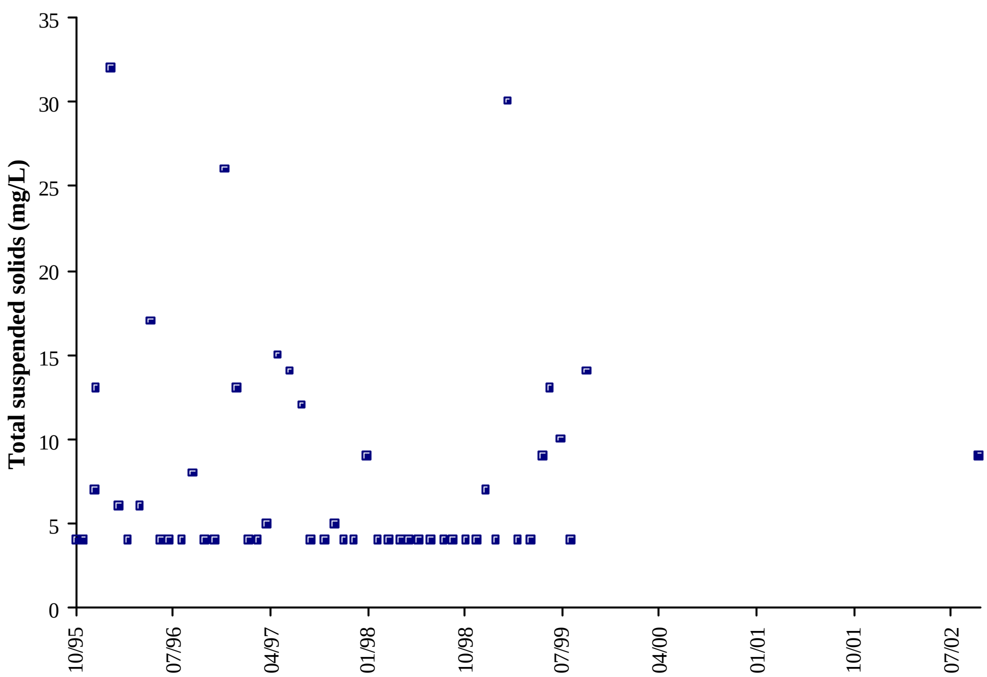

Figure A.114 TSS concentrations at DMME permitted site 4120120.

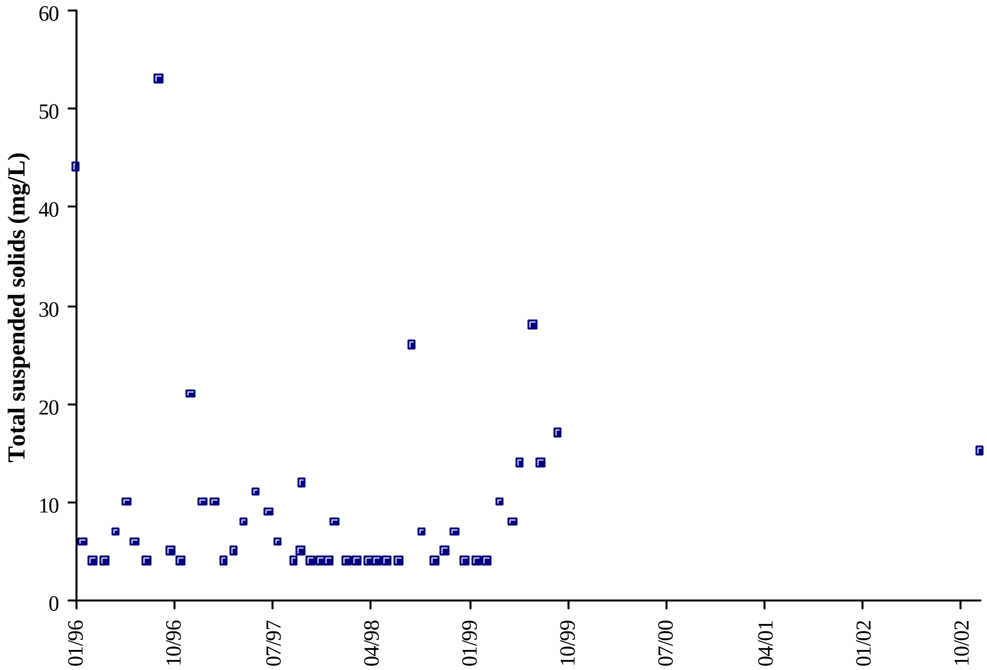

Figure A.115 TSS concentrations at DMME permitted site 4120121.

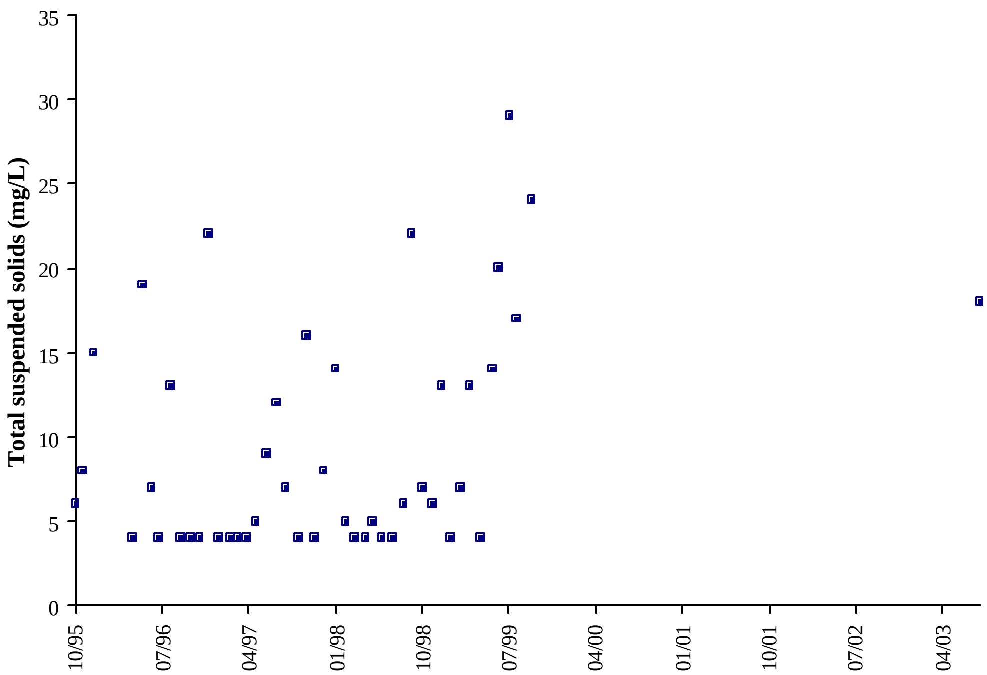

Figure A.116 TSS concentrations at DMME permitted site 4120204.

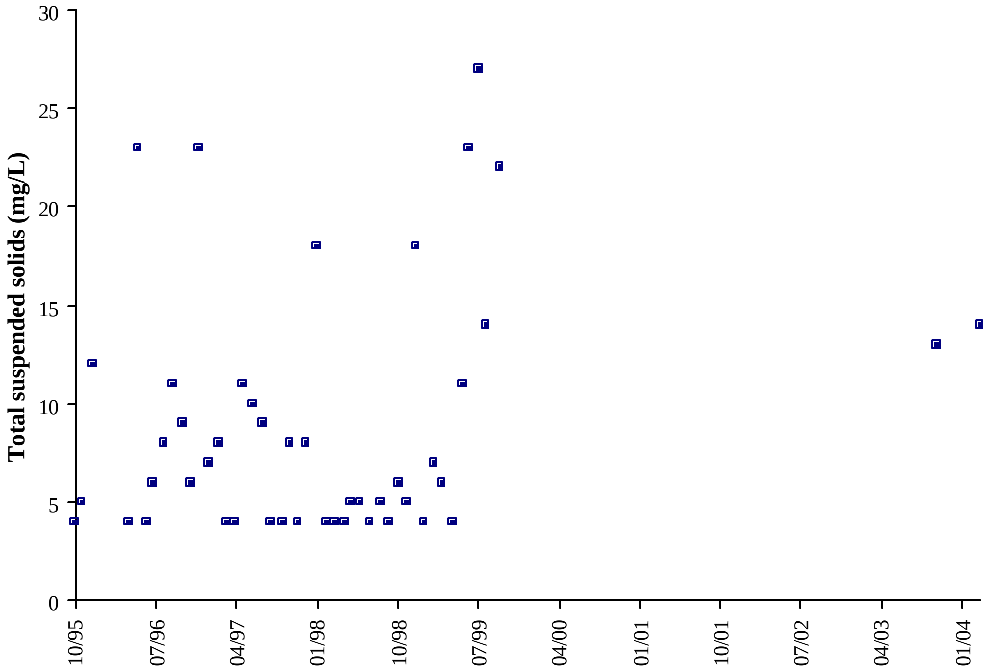

Figure A.117 TSS concentrations at DMME permitted site 4120205.