Tasmania

DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Water Quality
of Rivers in the Jordan Catchment

A Report Forming Part of the Requirements for State of Rivers Reporting

PART 2

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December 2003

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The Department of Primary Industries, Water and Environment

The Department of Primary Industries, Water and Environment provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.

The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

2 Current Study

The water quality data for the 'State of Rivers' study in the Jordan River catchment was collected between January 1999 and December 2001 in conjunction with studies of rivers elsewhere in Tasmania. The main aim of sampling in the Jordan River catchment was to collect data on the ambient quality of water and report on background conditions in the river system. This dataset, when viewed with land use and river condition data, will assist in identifying sites or areas that could be targeted for remediation activities or a different management approach in the future. The data will also assist in the future development of water quality objectives (WQO's) which may be developed for the catchment under the '*State Policy for Water Quality Management*' (1997).

The collection of data was carried out at several levels. Monthly visits were undertaken at twenty-eight sites to determine the physico-chemical nature of water quality (Table 2.1; Figure 2.1). The Jordan River catchment experienced drought conditions during the study period, and the river and associated tributaries were often reduced to no, or very low, flows. For those sites that remained dry for considerable periods of time it was necessary to sample at the closest water source to the original sample site until surface water flows returned to the original sample sites. Due to the costs associated with laboratory analyses, sampling for nutrients was carried out monthly at a subset (five) of these sites. Sampling for dissolved salts and general ionic composition was performed at these five sites on a quarterly basis.

The second level of sampling involved two catchment-wide 'snapshot' surveys, during which all sites in the main river and its tributaries were more comprehensively sampled. In addition to the normal suite of physio-chemical parameters, sampling also encompassed nutrients, bacteria and a number of the main heavy metals.

The third tier of monitoring involved the use of in-stream logging equipment to examine short-term variations in water quality such as dissolved oxygen and pH, which are known to undergo diurnal fluctuations.

Flow is continuously monitored at the Jordan River at Mauriceton (J11). However, due to the absence of continuous water quality monitoring at this site nutrient load estimates and export coefficients cannot be calculated as for previous State of Rivers reports.

The fourth tier of sampling investigated diurnal changes for a number of water quality parameters at sites without permanent continuous loggers. It is possible for parameters that appear to be within acceptable limits during daylight hours to increase or decrease to a level that falls outside the recommended concentrations during the night. Significant changes in pH and dissolved oxygen can occur where rivers are receiving organic pollution or nutrient enrichment, which can increase microbial respiration and encourage algal and aquatic plant growth (Cooke & Jamieson, 1995). This can lead to detrimental impacts on invertebrates and fish life. Hence, remote unattended monitoring equipment was deployed to record the diurnal changes in some selected water quality parameters

Table 2.1: Location of sites where monthly water quality monitoring was carried out during the present study. Sites in bold were sampled monthly for nutrients and quarterly for general ions.

SITE NAME	SITE No.	Easting	Northing
Jordan River upstream of tidal limit at old stream gauging station	J1	519300	5269500
Strathallan Rivulet at Tea Tree	J2	526300	5273450
Tea Tree Rivulet at Back Tea Tree Road	J3	525825	5271300
Strathallan Rivulet upstream ford at Pontville	J4	521700	5273250
Jordan River upstream confluence with Strathallan	J4b	521700	5273250
Jordan River at Midlands Highway at Pontville	J5	521700	5273850
Bagdad Rivulet at Rifle Range Road	J5a	522150	5274750
Bagdad Rivulet at Eddington Road	J5b	518300	5281100
Jordan River at bridge before Green Glory	J5c	515850	5273300
Jordan River at Elderslie Road bridge at Green Glory	J6	514800	5274100
Grahams Creek at Elderslie Road	J6a	509400	5279400
Stoneyhurst Creek	J6b	510250	5277050
Jordan at Andersons Road	J7	508950	5279950
Green Valley Rivulet at Cockatoo Valley Road	J8	508600	5281400
Jordan at Roydon Road downstream of bridge	J9	506600	5283900
Ford at Clifton Vale Road	J10	507050	5289300
Jordan River at Mauriceton	J11	510100	5291500
Quoin Rivulet at Midlands Highway	J12	514600	5296650
Jordan River at Sheepwash Corner on Lake Highway	J13	513000	5298650
Donnybrook Rivulet at Den Road	J14	511600	5299100
Little Den Creek at Lake Highway	J14a	511250	5302850
Jordan River at Apsley	J15	512000	5303000
Jordan River at Lower Marshes Road at Glen Iris	J16	513100	5307300
Jordan River at Lower Marshes Road at Glenmore Sugerloaf	J17	513950	5309600
Jordan River at Bellevale Road	J18	517650	5312650
Exe Rivulet at Exe Sugarloaf	J19	518300	5314700
Dulverton Rivulet at Waverly Lodge on Bowhill Road	J20	525000	5315555
Jordan River at Mud Walls Road	J22	525450	5305400

The physico-chemical parameters that were recorded in the field included pH (compensated for temperature), electrical conductivity (corrected to reference temperature 25^{o}C), water temperature, turbidity (as nephelometric turbidity units standardised against Formazin) and dissolved oxygen. Bottled water samples were taken and analysed in a NATA registered laboratory for the following nutrients; ammonia nitrogen (NH_3/N), nitrate nitrogen (NO_3/N), nitrite nitrogen (NO_2/N), total nitrogen (TN), dissolved reactive phosphorus (DRP) and total phosphorus (TP). General ions analysis of bottled samples was carried out quarterly, and included the variables presented in Table 2.2.

Table 2.2 Physico-chemical parameters tested for in the laboratory.

Parameter	**Units**
Laboratory pH	
Laboratory Conductivity (at 25°C)μS/cm	μS/cm
Colour (Apparent)	Hazen units
Total Dissolved Solids	mg/L
Total Suspended Solids	mg/L
Hardness (as $CaCO_3$)	mg/L
Total Alkalinity (to pH 4.5 as $CaCO_3$)	mg/L
Chloride (Cl)	mg/L
Flouride (F)	mg/L
Sulphate (SO_4)	mg/L
Iron (Fe)	mg/L
Total Manganese (Mn)	mg/L
Calcium (Ca)	mg/L
Magnesium (Mg)	mg/L
Potassium (K)	mg/L
Sodium (Na)	mg/L
Silica (SiO_2) (Molybdate Reactive)	mg/L

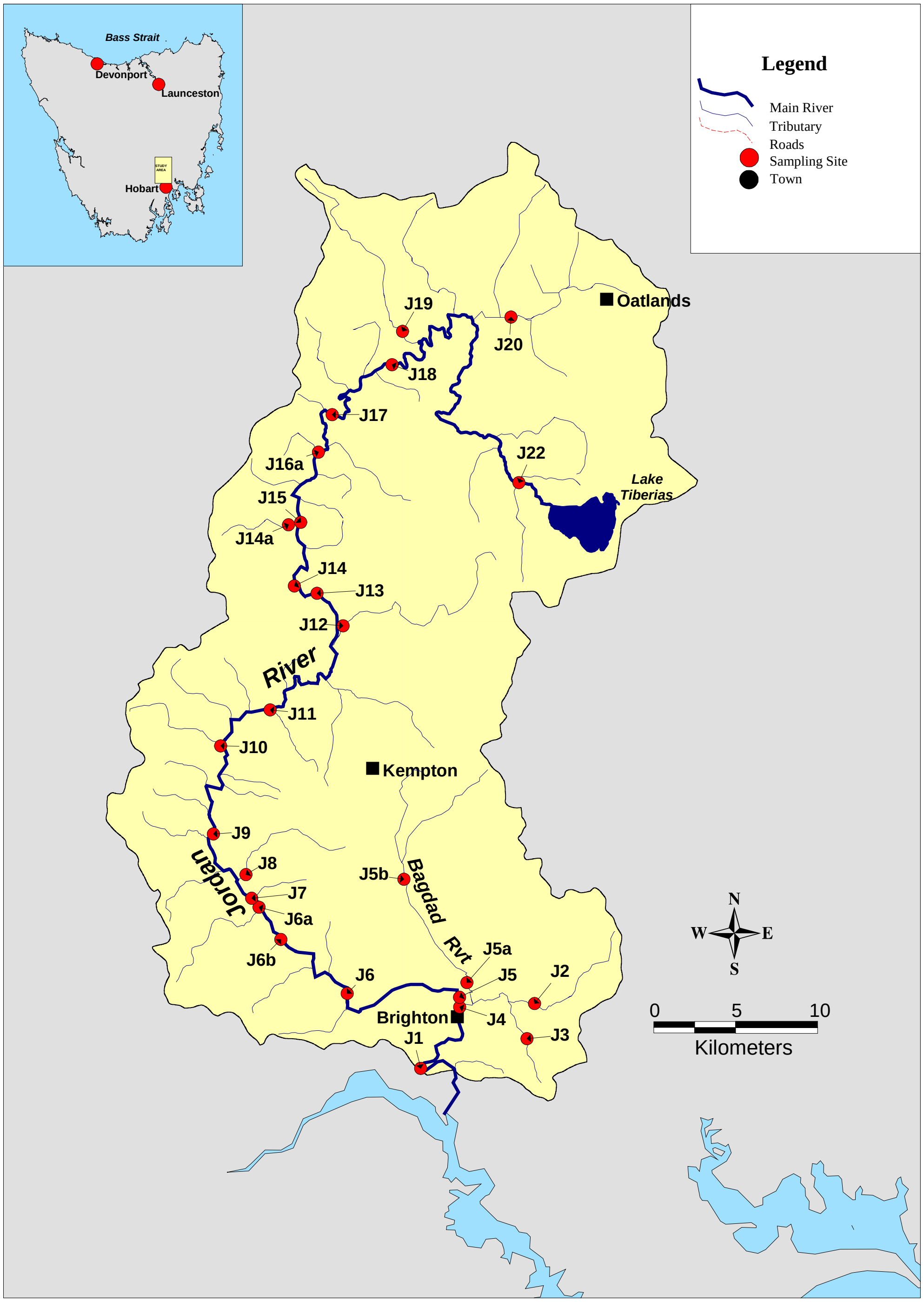

Figure 2.1: Location of all 21 sites monitored in the Jordan River catchment during the 'State of Rivers' investigations (1999-2001).

2.1 Physico-chemical properties

The Jordan River is a highly disturbed system. The catchment has been significantly modified and impacts such as salinity, reduced native riparian vegetation along rivers and streams, poor longitudinal connectivity, willow infestation, fertiliser use, rural run-off, sewerage leachate, and urbanisation are all of concern with regard to water quality and ecosystem health. Furthermore, declining rainfall has resulted in low and variable flows, which are of particular concern within the Jordan River catchment.

There is evidence that the Jordan River catchment is a naturally saline system, strongly influenced by saline groundwater intrusion during low flows and salt input from tributaries. The Jordan River is characterised by medium to very high salinity, increasing downstream. Salinity levels above 1000 µS/cm are frequently experienced throughout the river.

The primary impacts in the lower reaches of the Jordan River are due to urbanisation. Point source pollution through stormwater outlets, septic tank effluent, litter, detergents, industrial discharge, and road runoff, all impact on water quality and river health.

Elevated nutrient and bacteria concentrations in the lower catchment are a further area of concern as concentrations above the recommended primary contact levels (ANZECC 2000) have been recorded. The Brighton Council have erected signs warning of the problems associated with recreational activities in the river given the high level of pollution.

2.1.0 Monthly Monitoring

Monthly monitoring of water temperature, pH, conductivity, dissolved oxygen (concentration and percent saturation) and turbidity was carried out at all 28 sites in the Jordan River catchment. The following box plots show the range and statistical features of these data, and allow comparison between sites. The sites have been arranged from the bottom of the catchment (J1) to the top of the catchment (J22) from left to right. For details of the site names and their locations, refer to Table 2.1 and Figure 2.1. Diurnal variations in the above mentioned parameters are discussed in detail in section 2.5.

2.1.1 Water Temperature

The functioning of aquatic ecosystems is closely regulated by temperature. For example, breeding and migration of many aquatic organisms are cued by changes in water temperature. Temperature changes occur naturally both on a daily basis and seasonally. However, anthropogenic influences will also impact on natural temperature regimes. In the Jordan River catchment some of the more obvious human impacts on the system are widespread loss of native riparian vegetation and infestation of the river channel by Crack willow. Both of these can significantly alter natural temperature regimes and lead to increases in water temperature in streams and rivers.

The monitoring data shows that water temperature in the Jordan River varies considerably during the year. Temperatures ranged from as low as 1.4 °C at Jordan River upstream of confluence with Strathallan Rivulet (J4b) in winter to 34.2 °C at Jordan River at Bellevale Road (J18) in summer. The plot of basic statistics of temperature for mainstream sites and tributary sites are given in (Figures 2.2 and 2.3 respectively). It must be noted that temperature was recorded at different times throughout the day for each site and this will compound any comparisons that are made between sites.

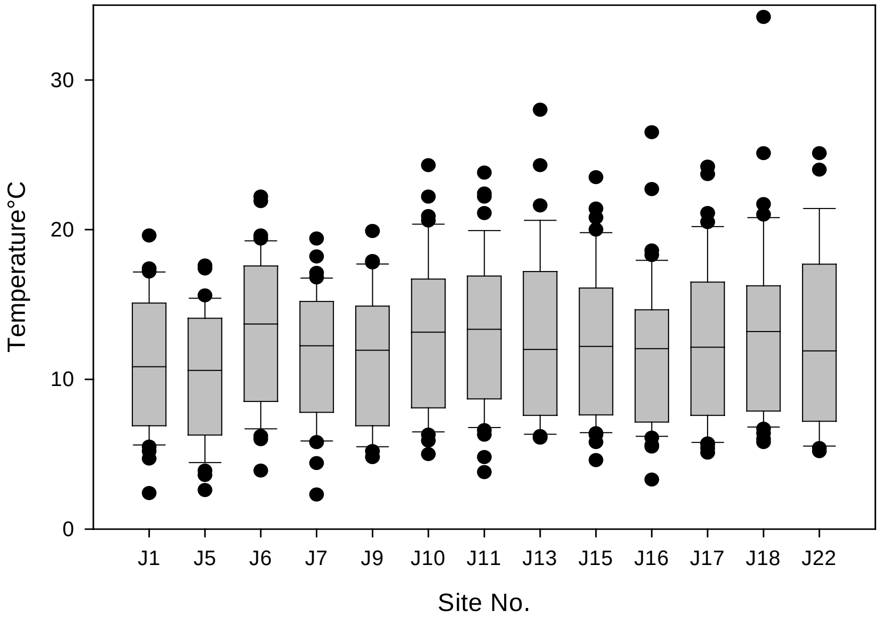

Figure 2.2: Statistics of water temperature at monitoring sites in the Jordan River Catchment (February 1999-December 2001).

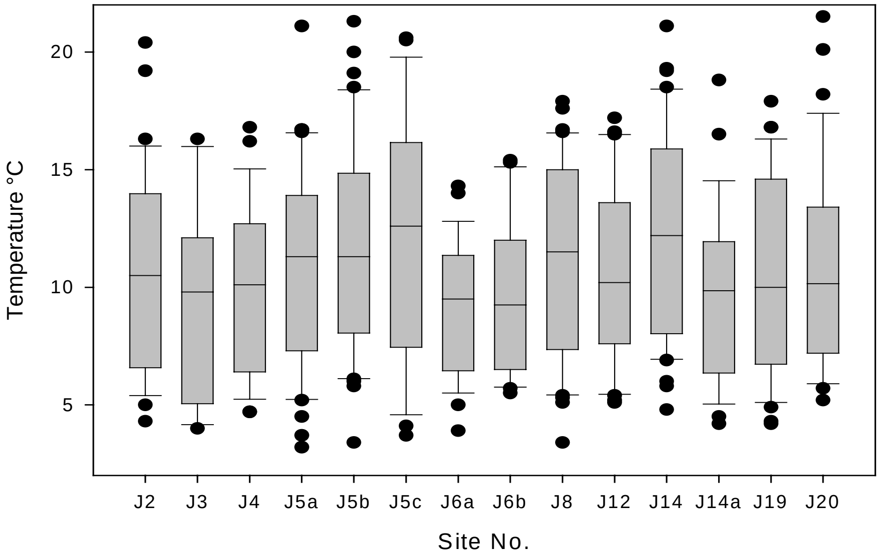

Figure 2.3: Statistics of water temperature at monitoring sites located on tributaries in the Jordan River catchment (February 1999-December 2001).

The seasonal variation in water temperature at a subset of sites in the Jordan River catchment is shown in Figure 2.4. These sites were chosen for their location in the upper, middle and lower regions of the catchment. Seasonal trends in water temperature are observed at all sites with temperatures ranging from a low in winter of 2-5 °C to a high in mid summer of around 17-26 °C. The greatest difference in water temperature between sites occurs during the summer months, when sites in the upper catchment may be up to 8 °C warmer. This is mainly an artefact of the sampling regime whereby sites in the upper catchment were visited later in the day than those at the bottom. The shallower nature of the river and streams at these locations, along with the general lack of riparian vegetation, also means that water temperature at these sites can increase more rapidly as a result of solar radiation and increases in air temperature.

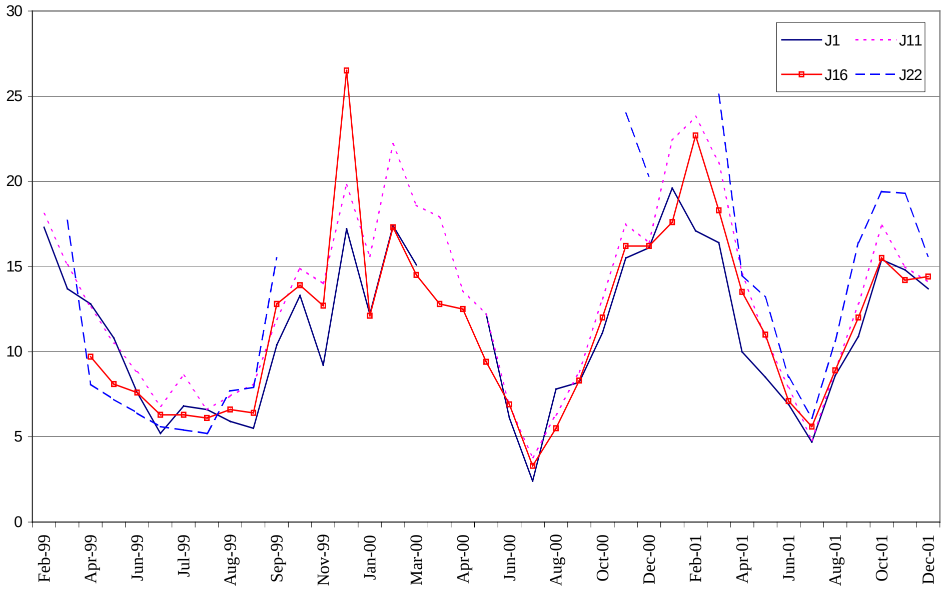

Figure 2.4: Monthly monitoring of temperature at four sites on the Jordan River (February 1999-December 2001).

2.1.2 In-stream pH

In-stream pH values are influenced by a variety of factors relating to catchment geology, soil chemistry, vegetation and land use practices. Changes in pH affect the concentration and toxicity of chemical substances (eg. ammonia, heavy metals) and the ionic and osmotic balance of aquatic organisms (Gallager, 1997). Waters of low alkalinity (<24 m/L as CaCO3) tend to have a lower buffering capacity and are therefore more susceptible to fluctuations in pH. The pH levels in water can vary both seasonally and diurnally depending upon environmental conditions.

Most natural freshwaters have a pH in the range of 6.5-7.5 (ANZECC, 2000). The pH of river waters in the Jordan River catchment varied considerably, with individual values ranging from 5.9 to 10.1. Median pH at sites in the catchment was generally between 7.5 and 8.1 (Figure 2.5 and 2.6). The lowest pH readings were recorded from sites on the tributaries (Figure 2.6) and the highest within the Jordan River mainstream (Figure 2.5). Diurnal variations in pH are discussed in detail in section 2.5.

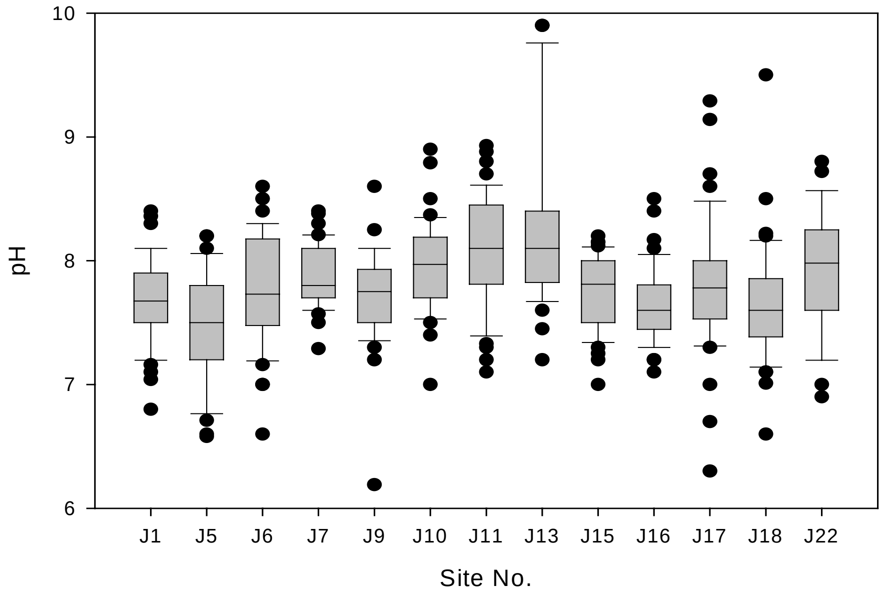

Figure 2.5: Statistics of pH variation at mainstream monitoring sites in the Jordan Catchment (February 1999-December 2001).

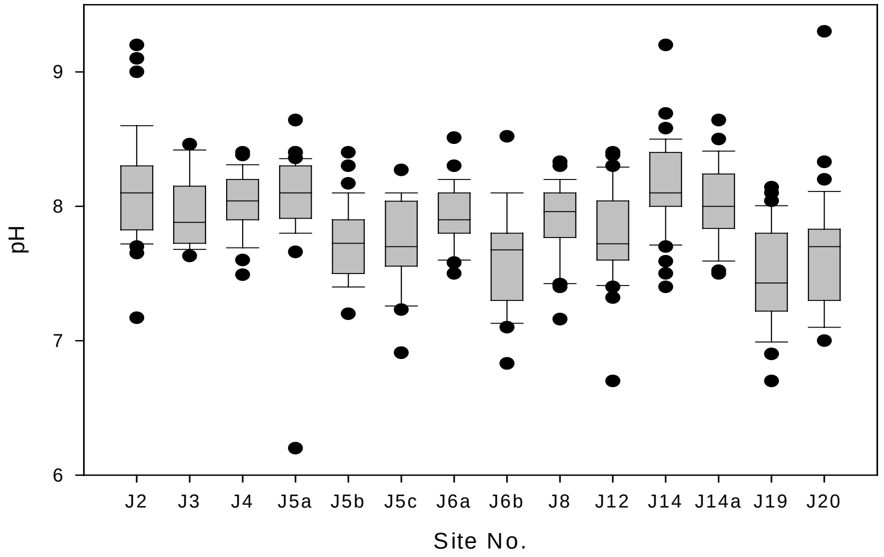

Figure 2.6: Statistics of pH variation at tributary monitoring sites in the Jordan Catchment (February 1999-December 2001).

2.1.3 Electrical Conductivity

Salinity has become a highly significant environmental issue around Australia and for some specific regions in Tasmania. Increasing concentrations of salts in soil and water can adversely affect the growth of non salt-tolerant plants and animals, and the distribution of natural salt can be significantly influenced by land management practices such as vegetation clearance, over-irrigation or inadequate drainage.. If salinity concentrations increase to around 1500 µs/cm, direct adverse biological effects are likely to occur in river, stream and wetland ecosystems, with many aquatic macrophytes and invertebrate fauna affected at these concentrations (Murray-Darling Basin Commission, 1999). Water salinity of more than 700 µS/cm is unsuitable for irrigating most horticultural crops. Furthermore, concentrations above 800 µS/cm make it difficult to manage irrigation and damage to tree crops can occur (MDBCMC, 1987). While the ANZECC Guidelines (2000) state that Tasmanian rivers should have conductivity levels of approximately 90 µS/cm, these values are unrealistic for certain catchments in Tasmania with naturally high water salinities. The data collected during this project shows that conductivity throughout the Jordan catchment is well above this recommended trigger value.

There is a general increase in surface water salinity concentrations in the Jordan River as it flows to the Derwent estuary. Figure 2.7 illustrates the general increase in median conductivity for the Jordan River in a downstream direction, with Site J22 at the top of the catchment and J1 at the bottom. This is a common trend for most unregulated Tasmanian rivers. Conductivity within the mainstream sites (Figure 2.9) is generally lower than in the tributaries (Figure 2.8). The highest median conductivity in the Jordan River was 1443 µS/cm at Jordan River at Andersons Rd (J7), while the maximum value (4440 µS/cm) was recorded at the Jordan River upstream of the tidal limit (J1). Tea Tree Rivulet (J3) clearly had the highest median conductivity of any tributary (3370 µS/cm) and also recorded the highest individual value for conductivity (6220 µS/cm).

Generally, rivers collect groundwater (which can be very saline) in the lower reaches and carry it to sea. As such, salinity in rivers has been considered to be a downstream problem however studies in the Murray-Darling basin have found increases in levels of salinity in associated tributaries (Murray-Darling Basin Ministerial Council, 1999). A similar trend is observed in the Jordan River catchment with more elevated levels recorded at sites located on tributaries of the Jordan River, in particular Tea Tree Rivulet (J3), Strathallan Rivulet (J2) and Bagdad Rivulet (J5).

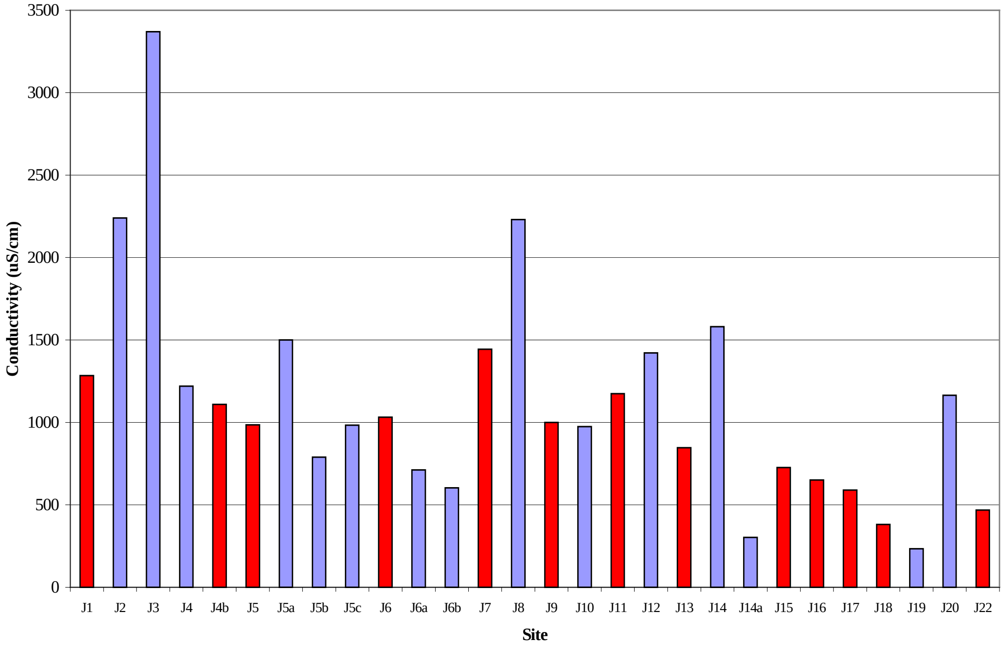

Figure 2.7: Median conductivity concentrations for both mainstream (red) and tributary sites (blue) in the Jordan River catchment.

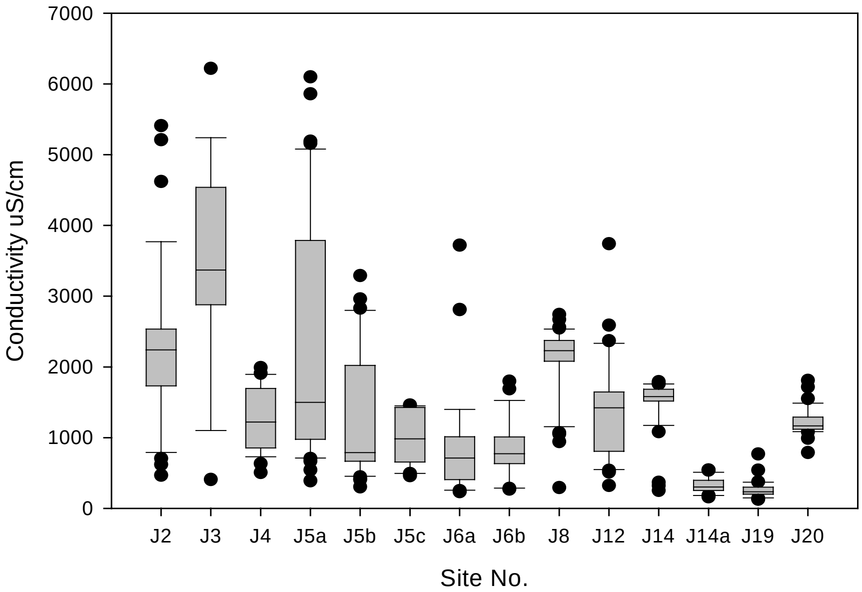

Figure 2.8: Box plots showing statistics for electrical conductivity from monthly monitoring at sites on tributaries in the Jordan River catchment.

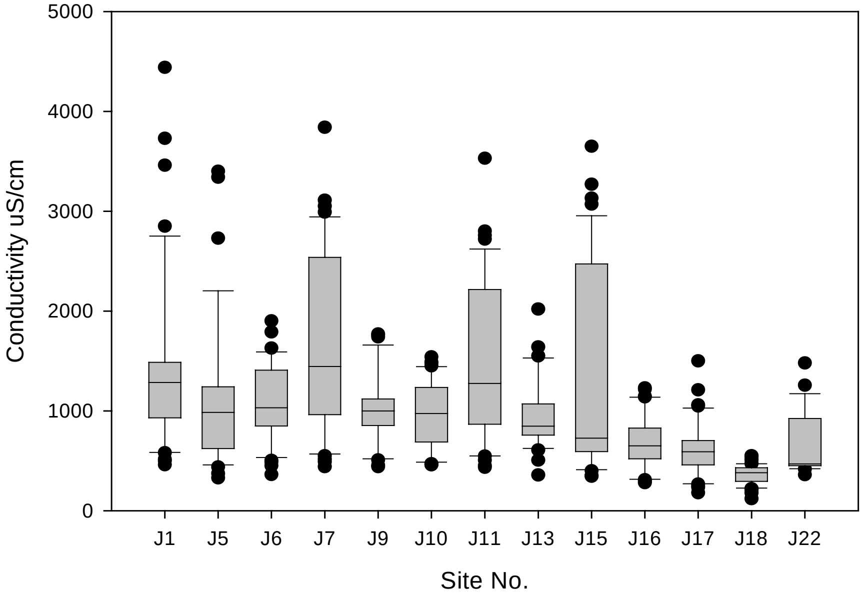

Figure 2.9: Box plot showing statistics for electrical conductivity for monthly monitoring at mainstream sites on the Jordan River.

Conductivity in waterways within the Jordan River catchment are usually lowest during the winter months when there is typically a greater occurrence of rainfall. As rainfall diminishes there is a tendency for conductivity to increase as groundwater sustains river flow and evaporation rates increase, which result in salt concentrations in surface water becoming further concentrated. Very low rainfall for the majority of the study resulted in the Jordan River being reduced to a series of ponds or regions of very low flow. The relationship between conductivity and average monthly flow at Jordan River at Mauriceton (J11) is depicted in Figure 2.10 and illustrates that as flow within the catchment declines or ceases, conductivity increases. Between January 1999 and August 2000 there was very little flow in the Jordan River and this resulted in a steady increase in surface water salinity.

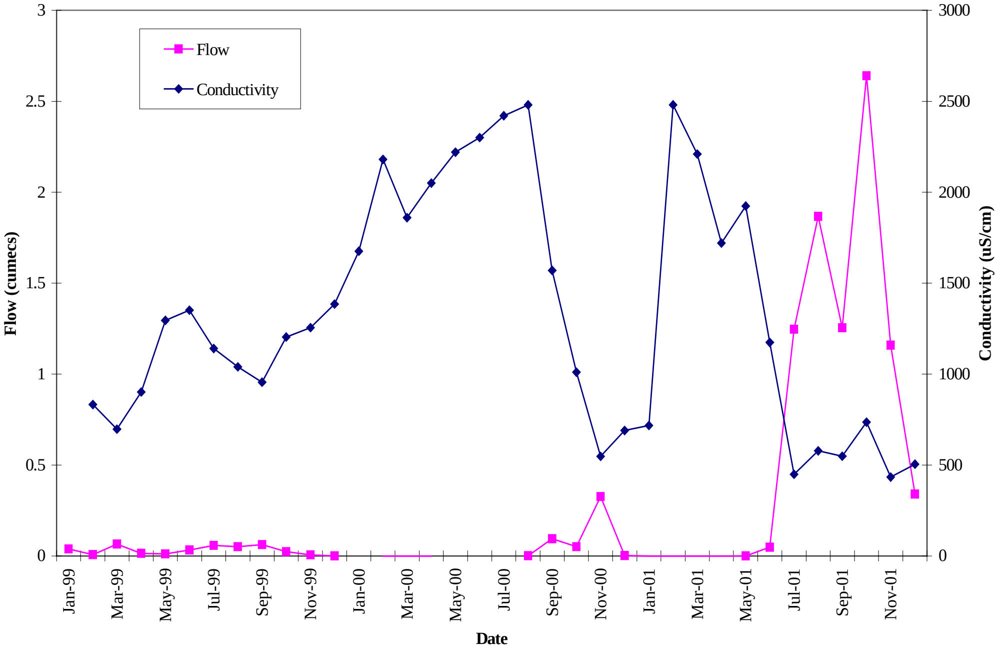

Figure 2.10: Conductivity and flow in the Jordan River at Mauriceton (J11) between January 1999 and December 2001.

A rain event early in September 2000 resulted in a dramatic reduction of conductivity levels. However, as flows decreased immediately following this event, there was a similarly dramatic rebound in conductivity. In mid-2001 as a result of increased rainfall across the catchment, sustained flow returned to the Jordan River, and this resulted in a lower conductivity that persisted for the remainder of the study (Figure 2.10). This general relationship between conductivity and flow in the Jordan River at Mauriceton (J11) is represented in Figure 2.11, although the correlation is weak (R^2=0.5155) due to the dilution that minor runoff events can cause at low flows.

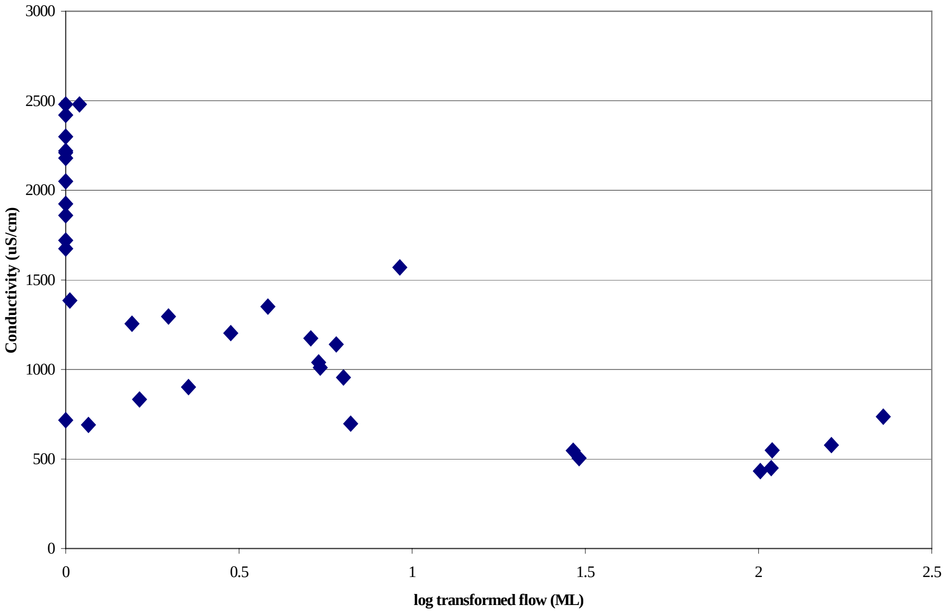

Figure 2.11: The relationship between conductivity and log transformed flow (ML) in the Jordan River at Mauriceton (J11) between January 1999 and December 2001.

Figure 2.12 shows that the temporal pattern of change in conductivity recorded at J1 (Jordan River at Mauriceton – shown above in Figure 2.10) is similarly found at other mainstream sites, although the scale is markedly different, with conductivity not increasing as dramatically at sites higher in the catchment.

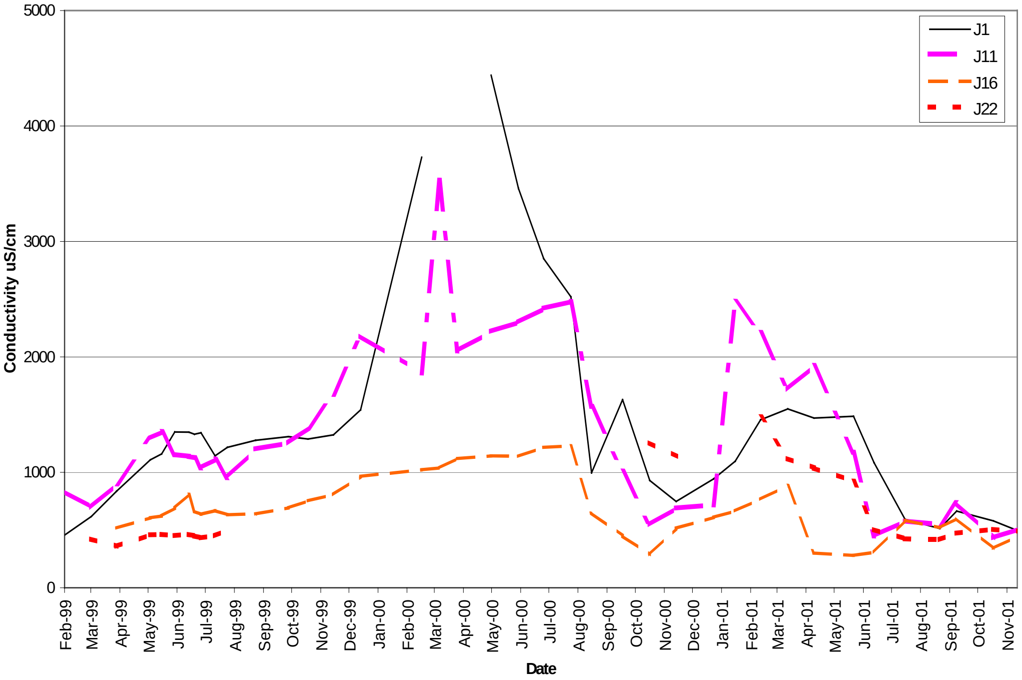

Figure 2.12: Monthly conductivity concentrations at four sites along the length of the Jordan River (February 1999-December 2001).

2.1.4 Turbidity

Turbidity in flowing water is an indicator of the amount of suspended material being transported by the river at the time of sampling. This suspended material consists of both organic (ie. algae, plant material) and inorganic (ie. clays, silt etc) materials. In the Jordan River catchment the primary sources for increased turbidity levels are stream bank erosion and erosion from surrounding hill slopes and paddocks, construction of dams and in-stream works, and widespread stock access to waterways.

When establishing ‘baseline’ turbidity levels it is important to avoid sampling during periods of heavy rainfall or following a rainfall event when higher velocities in the river actively erode stream banks. The highest turbidity and greatest quantity of suspended sediment is transported during peak flows. Separate sampling during ‘flood’ events was undertaken in order to compare flood related turbidity levels to ‘normal’ conditions in the river. This is useful for determining export loads and showing how sediment concentrations in the rivers increase due to runoff. The nutrient loads for the Jordan River shall be discussed in further detail in section 3.0.

According to the ANZECC Guidelines (2000) values for turbidity that are indicative of slightly disturbed ecosystems in south eastern Australia range from 2-25 NTU. Median turbidity for all mainstream sites on the Jordan River fell within these limits, however individual turbidity readings that exceeded 25 NTU were recorded at Jordan River at the Midlands Highway (J5), Jordan River at Elderslie Road Bridge (J6) and Jordan River at Mauriceton (J11) (Figure 2.13). Median turbidity at all sites located in tributaries of the Jordan River was below 25 NTU (Figure 2.14).

Turbidity throughout the catchment ranged from 0.6 NTU at Bagdad Rivulet at Rifle Range Rd (J5a) to 177 NTU for the Jordan River at Lower Marshes Road at Glen Iris (J17). Extremely high turbidity levels recorded at this site and the Jordan River at Mauriceton (J11) were related to instream and offstream road construction activities that caused elevated turbidity at these locations.

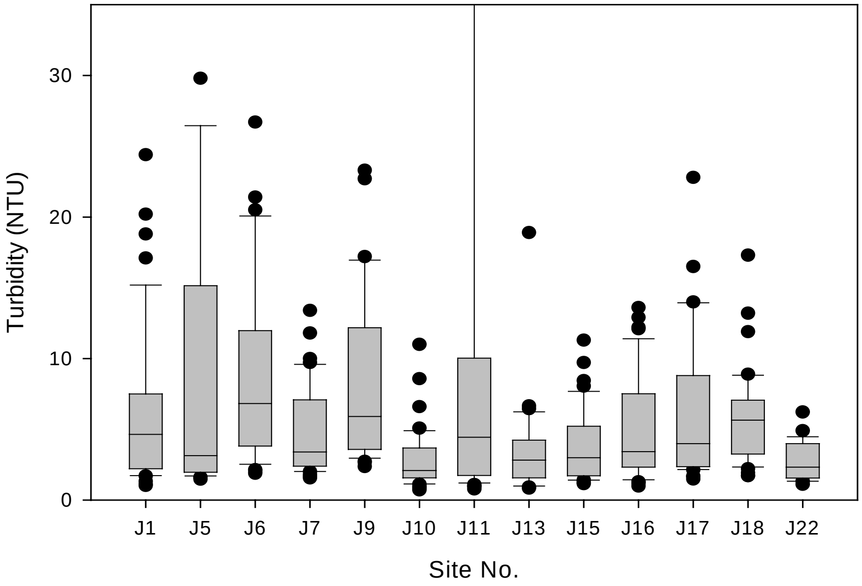

Figure 2.13: Box plots of statistics for monthly turbidity data at mainstream sites on the Jordan River from February 1999 until December 2000**.** Jordan River at Pontville (J5), Elderslie road Bridge (J6) and Mauriceton (J11) recorded elevated turbidity levels which have not been included in this graph. The highest turbidity recorded at J5 was 119 NTU, for J6 the highest value was 87 NTU and for J11 it was 235 NTU.

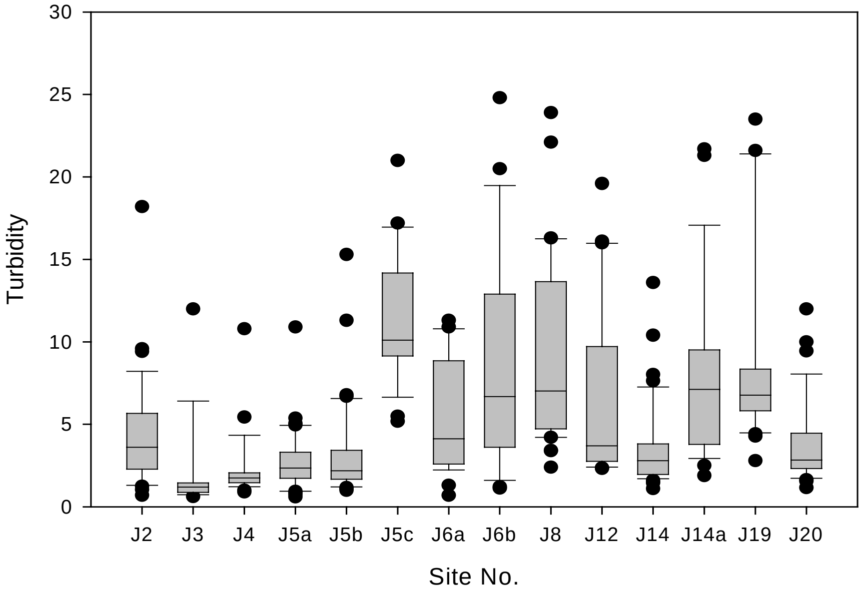

Figure 2.14: Box plots showing statistics for monthly turbidity at sites on tributaries of the Jordan River.

2.1.5 Dissolved Oxygen

Dissolved oxygen is a simple indicator of the health of aquatic systems. In waters that are not influenced by anthropogenic activities there is a relationship between respiration, photosynthesis and diffusion that drives in changes in dissolved oxygen concentrations. Unnatural organic enrichment of waterways often creates an imbalance to the system and can result in extremes in dissolved oxygen concentration. Low oxygen concentration can often be the first sign of stress or degradation and should be prevented where possible (ANZECC, 2000). However, care needs to be taken when using dissolved oxygen as an indicator of water quality as concentrations can fluctuate widely over a twenty-four hour period. This is due to the fact that dissolved oxygen concentrations vary with water temperature, salinity, photosynthetic activity and microbial activity. Respiration by aquatic plants and algae at night often lowers dissolved oxygen, and this can have an adverse effect on many aquatic organisms, which depend upon oxygen dissolved in water for efficient functioning. Furthermore, existing problems may be exacerbated if surface layers of sediments become anoxic, increasing the potential for release to the water column of previously bound nutrients and toxicants (ANZECC, 2000).

The ANZECC Guidelines (2000) recommend that dissolved oxygen in slightly disturbed streams in the southeast of Australia should not fall below 90% or rise above 110% saturation. Even in highly modified ecosystems, dissolved oxygen should not be permitted to fall below 60% saturation, determined over at least one diurnal cycle (ANZECC, 2000).

Monthly dissolved oxygen readings were measured at all sites using hand held probes. The data is displayed in Figure 2.20 and shows that of the 28 sites sampled in the Jordan River catchment only 13 sites had median dissolved oxygen concentrations within the bounds recommended by the ANZECC Guidelines (2000) at the time of sampling.

The concentrations of dissolved oxygen recorded in the monthly sampling regime are not representative of the diurnal fluctuations in dissolved oxygen concentrations at each site but rather provide only an indication of daytime concentrations. As stated above, dissolved oxygen at each site will fluctuate around these daytime levels, and the scale of this change will depend on other influences (refer to section 2.5).

Exceptionally high dissolved oxygen concentrations were recorded at Jordan River at Sheepwash Corner (J13) and Jordan River at Lower Marshes Road (J17) (Figure 2.15). During the summer months these sites had extensive algal and macrophyte growth, which during the middle of the day would be generating significant quantities of oxygen through photosynthesis. In situations of substantial aquatic plant growth, photosynthesis can generate supersaturation of oxygen during warm, windless days (Boulton & Brock, 1999). For each of the occasions when elevated dissolved oxygen concentrations were recorded at these sites they had extensive algal or macrophyte cover and water temperatures between 17 °C and 28 °C. When a water body warms, temporary supersaturation can occur. Data in section 2.5 shows that dissolved oxygen at this location does undergo large diurnal changes in concentration, indicating that the ‘oxygen sag’ due to night-time respiration from plants is significant.

There are a number of sites that show signs of oxygen imbalance. These sites were Jordan River upstream of tidal limit at old stream gauging station (J1), Jordan River at Pontville (J5), Jordan River at Elderslie Road bridge (J6), Jordan River at Sheepwash Corner (J13) and Jordan River at Lower Marshes Road (J16) (Figure 2.15). The tributary sites showing signs of oxygen imbalance were Bagdad Rivulet at Rifle Range Road (J5a), Bagdad Rivulet at Eddington Road (J5b), Bridge before Green Glory (J5c), Green Valley Rivulet (J8), Exe Rivulet at Exe Sugarloaf (J19) and Dulverton Rivulet (J20) (Figure 2.16). At all of these sites dissolved oxygen concentrations fell below 60 % saturation at some time during the period of monitoring. Oxygen concentrations as low as this are likely to cause significant stress or death to aquatic organisms. Diurnal variations in dissolved oxygen concentrations are discussed in detail in section 2.5.

Assessing ecosystem health using the 90% trigger level for percent saturation of dissolved oxygen (ANZECC, 2000) revealed that the majority of sites in the Jordan River catchment are ‘impacted’ or ‘disturbed’, with median values at fifteen sites falling below the 90% saturation level. However, simply assessing condition using the median of daytime sampling can be misleading. The Jordan River at Sheepwash Corner (J13) had a median dissolved oxygen concentration of 98 % saturation, however this site also exhibited occasional oxygen levels reaching nearly 200% saturation. It is therefore important to view all data in making an assessment.

There is a general decline in median dissolved oxygen concentrations from the top to the bottom of the Jordan River (Figure 2.15). Dissolved oxygen concentrations at the tributary sites (Figure 2.16) shows that approximately half recorded median dissolved oxygen saturation below the recommended 90 % saturation (ANZECC, 2000).

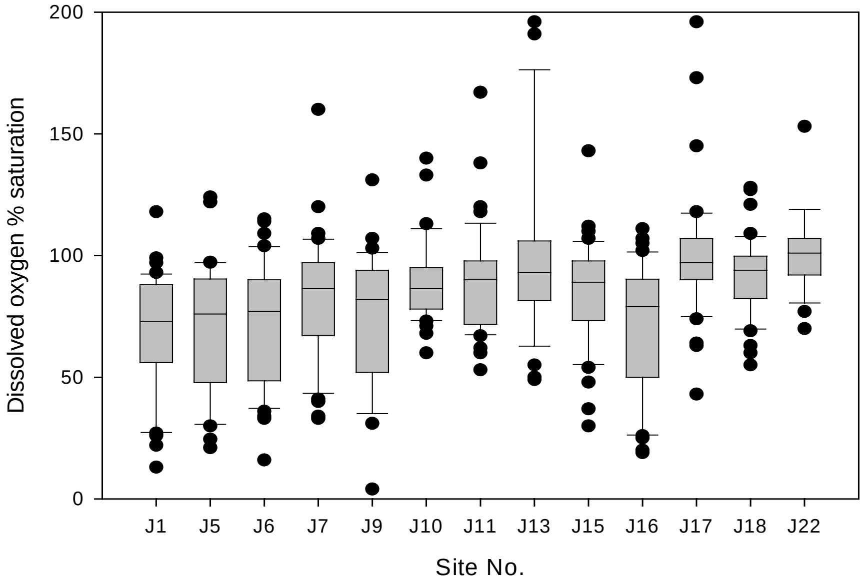

Figure 2.15: Box plots showing statistics for monthly dissolved oxygen at sites on the Jordan River. Sampling occurred at different times of the day for each site.

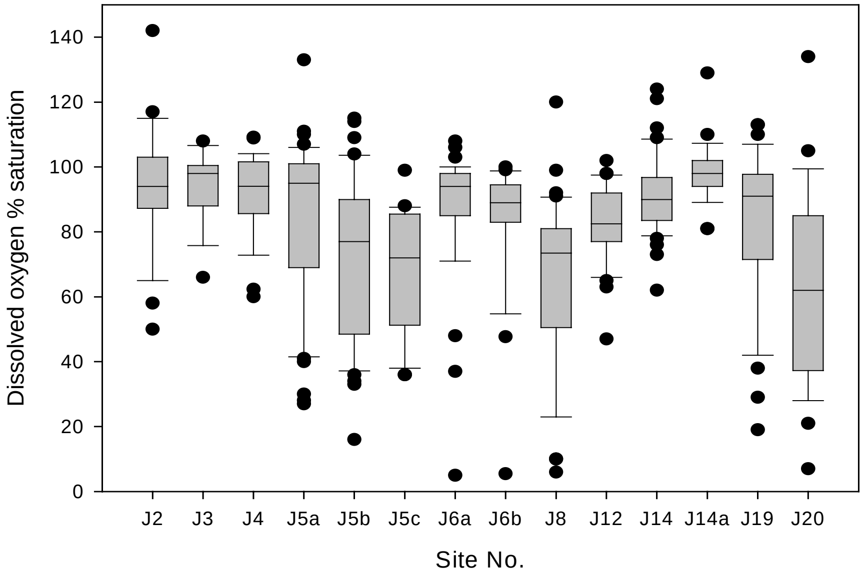

Figure 2.16: Box plots showing statistics for monthly dissolved oxygen for sites on tributaries in the Jordan River**.** Sampling occurred at different times of the day for each site.

Dissolved oxygen concentrations are highly dependent on temperature, salinity, biological activity and the rate of transfer from the atmosphere (ANZECC, 2000). Cooler waters are more capable of holding dissolved oxygen than warmer water. This is illustrated in Figure 2.17, which plots the relationship between temperature and dissolved oxygen at J11.

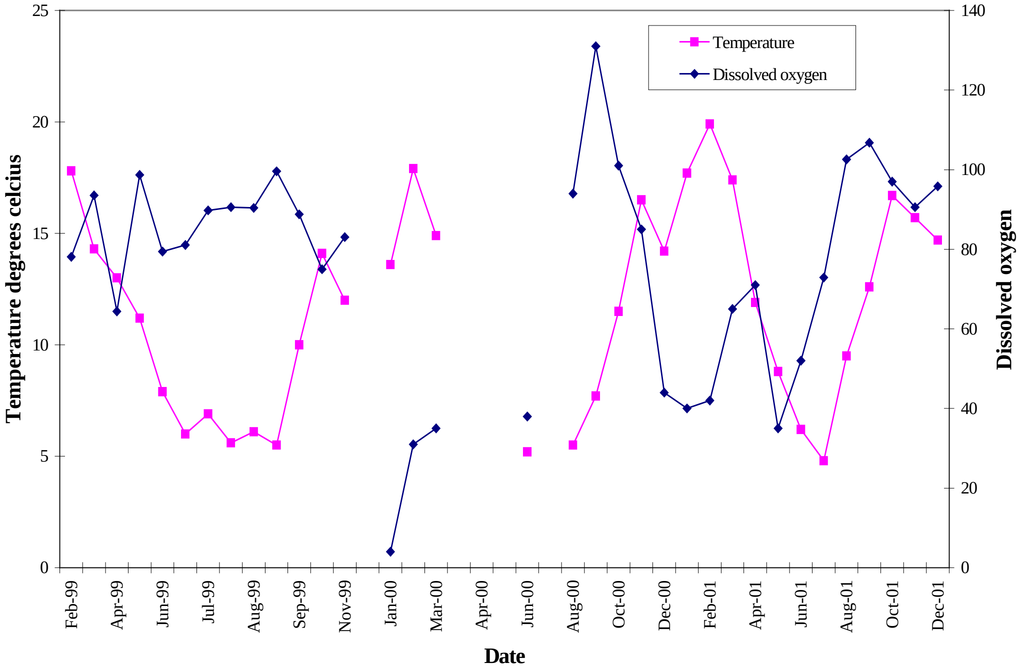

Figure 2.17: Time series plots showing the seasonal variation in dissolved oxygen saturation and temperature at Jordan River at Mauriceton (J11) using monthly monitoring data from February 1999-December 2001.

2.2 General Ionic Composition

Samples for characterising the ionic composition of waters in the catchment were collected on a quarterly basis from a subset of sites in the catchment. These sites are listed below and referred to by their site labels in the following graphs.

Site Label	**Site Name**
J1	Jordan upstream tidal limit at old stream gauging station
J4	Strathallan Rivulet upstream ford at Pontville
J4b	Jordan River upstream confluence with Strathallan
J5a	Bagdad Rivulet at Rifle Range Road
J6	Jordan at Elderslie Road Bridge at Green Glory
J11	Jordan at Stream Gauging Station at Mauriceton
J15	Jordan at Apsley
J18	Jordan at Bellvale Road
J19	Exe Rivulet at Exe Sugarloaf

The analyses included determination of apparent colour, hardness, alkalinity, suspended solids and dissolved minerals and salts. Many of these reflect the geochemical composition of the rocks and soil of the area, although they can be influenced to some degree by human related activities such as agriculture. A table presenting the summary statistics for all these parameters is shown below (Table 2.3) and illustrated graphically in Figures 2.19 to 2.24. For the purpose of this section all values have been reported and discussed in mg/L.

Table 2.3: Summary statistics for ionic parameters from the Jordan River catchment. Samples collected every three months.

	Lab pH	**Lab EC25** (uS/cm)	**Total Dissolved Solids** (mg/L)	**Total Suspended Solids** (mg/L)	**Apparent Colour** Hazen units
Median	7.7	1040	620	10	50
Min	6.0	110	130	10	5
Max	8.9	4200	3520	94	250

	Alkalinity (mg/L)	**Chloride** (mg/L)	**Fluoride** (mg/L)	**Sulphate** (mg/L)	**Hardness** (mg/L)	**Iron** (mg/L)
Median	200	220	0.1	8.7	290	0.3
Min	53	33	0.02	0.2	64	0.044
Max	453	930	27	1600	1700	3.0

	Manganese (mg/L)	**Calcium (mg/L)**	**Potassium (mg/L)**	**Magnesium (mg/L)**	**Sodium (mg/L)**	**Silica (mg/L)**
Median	0.021	45.3	1.9	42	94	9.4
Max	0.005	12	0.3	7.6	3.2	0.3
Min	3.72	373	2.0	188	440	31

Apparent colour

The apparent colour of river water usually reflects the amount of dissolved organic matter (ie. humic substances) and suspended particles in the water column. Apparent colour is caused by coloured particulates and the refraction and reflection of light on suspended particulates and is measured in Hazen Units. In natural waters this can range from <5 in very clear waters to 300 in dark peaty waters. Colour can generally be related to flow with higher concentrations recorded during flood events. Polluted water may have quite a strong apparent colour (UNESCO, 1992). Colour can be affected by the presence of natural minerals such as iron hydroxides.

The waters in the Jordan River catchment contain varying levels of dissolved organics and dissolved minerals, and this is reflected in the plots below. The Jordan River at Elderslie Road bridge (J6), Jordan River upstream tidal limit at old stream gauging station (J1) and Jordan River at Mauriceton (J11) showed the greatest range in values, with summer values as high as 250 units and winter values as low as 20 units. The Jordan River catchment remained in drought conditions for the majority of the study. As such, higher colour concentrations are occurring in the summer months when the river is reduced to a series of turbid ponds. At those times when high apparent colour concentrations were recorded there were also high turbidity levels recorded. Apparent colour is caused by coloured particulates and the refraction and reflection of light on suspended particles (UNESCO, 1992). The high apparent colour values recorded may therefore be an indication that the water is polluted at these sites.

The majority of sites sampled had median apparent colour values of 50 units and under. The highest median value was 70 units for the Jordan River at Elderslie Road Bridge at Green Glory (J6) (Figure 2.19). This site has been highly impacted as a result of the surrounding land-use practices. The streamside vegetation is primarily composed of the introduced Crack Willow (*Salix* sp.) on one bank and pasture on the other. This reach of the river is prone to forming deep ponds that have been infested with *Azolla* sp. Stock can also freely access the river and run-off from the dairy farm/pastures is likely to be contributing to the higher values for apparent colour at this site.

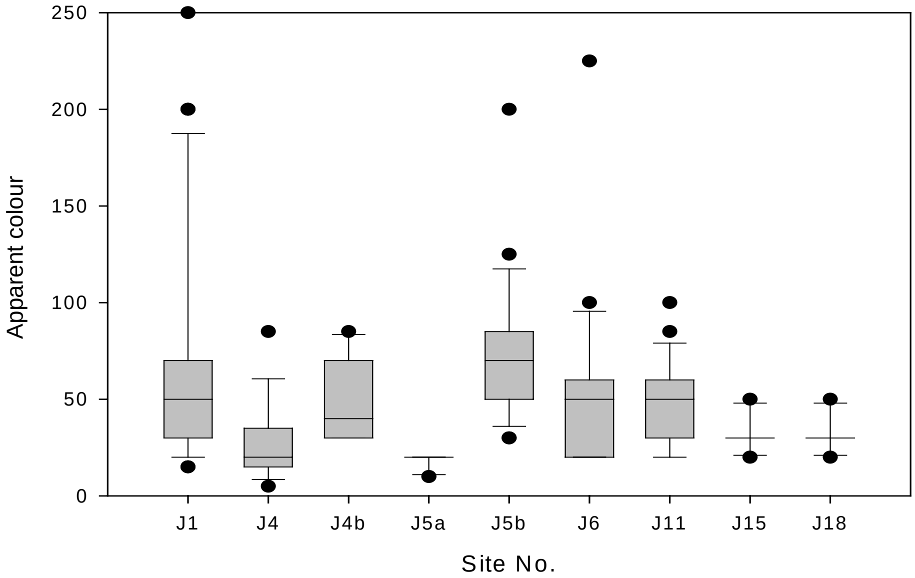

Figure 2.19: Box plots showing statistics for apparent colour at nine sites in the Jordan catchment (January 1999- December 2000).

Alkalinity

The median alkalinity values for Strathallan Rivulet upstream ford at Pontville (J4) and Jordan River upstream of the confluence with Strathallan (J4b) were higher than at all other sites sampled. The high median alkalinity values reflect the higher concentrations of dissolved salts (see data for calcium in Figure 2.22 and sulphate in Figure 2.23) at these sample points. Jordan River upstream confluence with Strathallan Rivulet (J4b) and Bagdad Rivulet at Rifle Range Road (J5a) also had high median alkalinity values. Sites higher in the catchment, Jordan at Bellvale Road (J18) and Exe Rivulet at Exe Sugarloaf (J19) had lower alkalinity values and lower concentrations of dissolved salts than sites lower in the catchment.

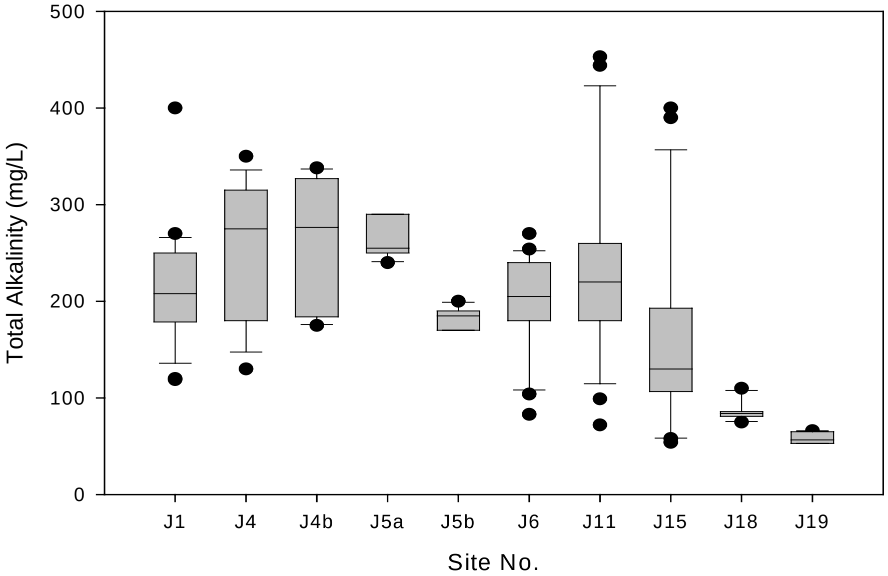

Figure 2.20 Box plots showing statistics for alkalinity at nine sites in the Jordan catchment (January 1999- December 2000). N= number of samples collected. N=18 for J1, J6, J11, and J15. N=6 for J4b, J5, J18 and J19. N=12 for J4.

Hardness and Calcium

The hardness of most fresh surface waters in Australia lie between 25 and 400 mg/L as $CaCO_3$. Water hardness is a total measure of the major cations (predominantly calcium and magnesium) and it is an important parameter in freshwaters as it can have a major effect on the toxicity of metals. Water hardness (measured by mg $CaCO_3$) can range from <1 (very soft) to >400 (very hard) (ANZECC, 2000). Figure 2.21 indicates that sites lower in the catchment are generally harder than the upper sites. The hardness of water is dependent mainly on the presence of dissolved calcium and magnesium salts. Accordingly the plot for calcium reflects the generally increase in concentration from the top of the catchment to the lower sites (Figure 2.22). The lowest site in the catchment, Jordan upstream tidal limit at old stream gauging station (J1), showed the greatest range in calcium concentrations and hardness. Exceptionally high hardness values were recorded at this site in May 2000 when the flow in the river had predominantly ceased to flow. Seasonal variations of river water hardness often occur reaching the highest values during low periods (UNESCO, 1992). High calcium concentrations were also recorded at this time (Figure 2.22).

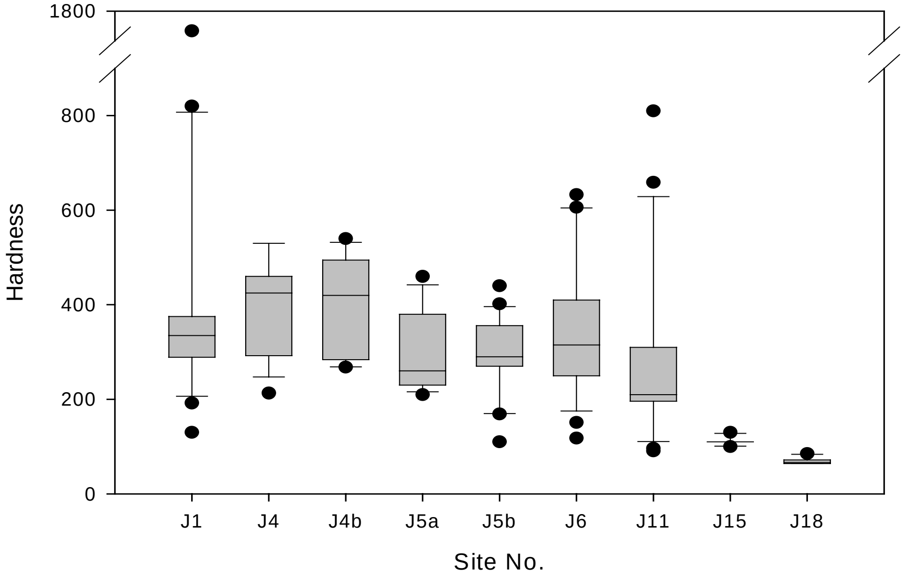

Figure 2.21: Box plots showing statistics for hardness at nine sites in the Jordan catchment (January 1999- December 2000). N= number of samples collected. N=18 for J1, J6, J11, and J15. N=6 for J4b, J5, J18 and J19. N=12 for J4.

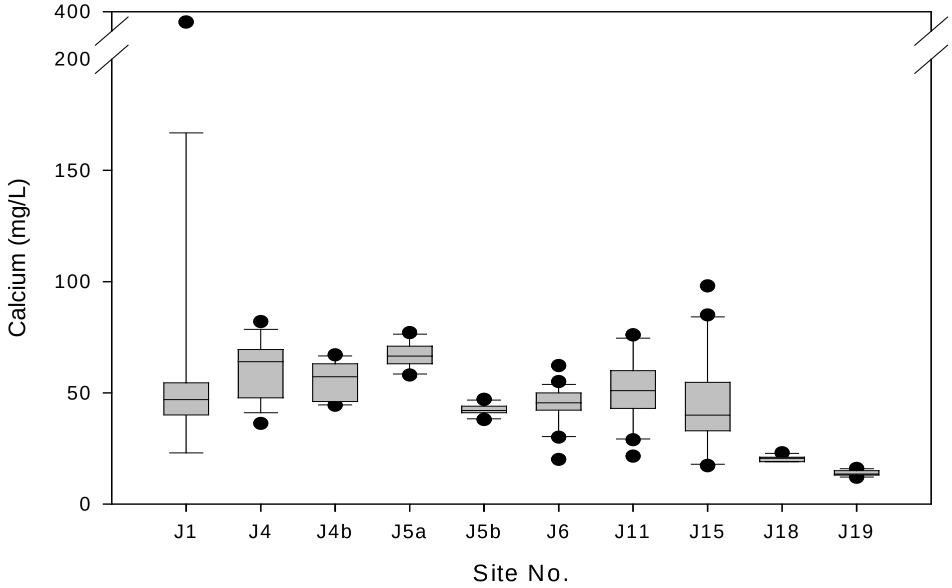

Figure 2.22 Box plots showing statistics for calcium at nine sites in the Jordan catchment (January 1999- December 2000). N= number of samples collected. N=18 for J1, J6, J11, and J15. N=6 for J4b, J5, J18 and J19. N=12 for J4.

Sulphate

Sulphate is naturally present in surface waters as SO_4^{2-}, and originates from the atmospheric deposition of ocean aerosols or from geological processes (UNESCO, 1992). In Tasmania several studies have shown that sulphate concentrations in natural waters are usually around 5mg/L (Bobbi *et al.*; 1996). The concentration of sulphate in the Jordan catchment (Figure 2.23) is slightly above this range (median at sites between 3-12 mg/L). Streams receiving some form of polluting effluent often have higher sulphate concentrations (15-30 mg/L) and concentrations above this were detected at 6 of the nine sites monitored. The direct cause of these high sulphate concentrations is not clear, however as the surface waters in this region are saline higher it is not surprising that there are higher sulphate concentrations. The exceptionally high sulphate concentration of 1600 mg/L recorded at J1 may be linked to some sort of pollution (given its proximity to urban development), but may also be a result of sample contamination during handling.

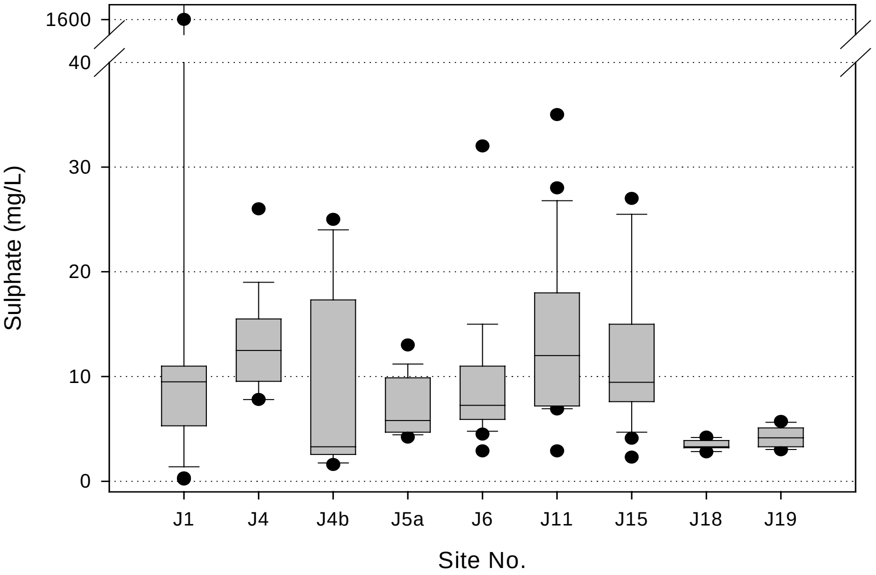

Figure 2.23: Box plots of statistics for sulphate at nine sites in the Jordan catchment (January 1999-December 2000). N= number of samples collected. N=18 for J1, J6, J11, and J15. N=6 for J4b, J5, J18 and J19. N=12 for J4.

Iron

Iron concentrations throughout the catchment are generally below 0.5mg/L (Figure 2.24). These concentrations are relatively low compared to data collected from other rivers in Tasmania (Bobbi *et al*., 2003a, Bobbi *et al*., 2003b).

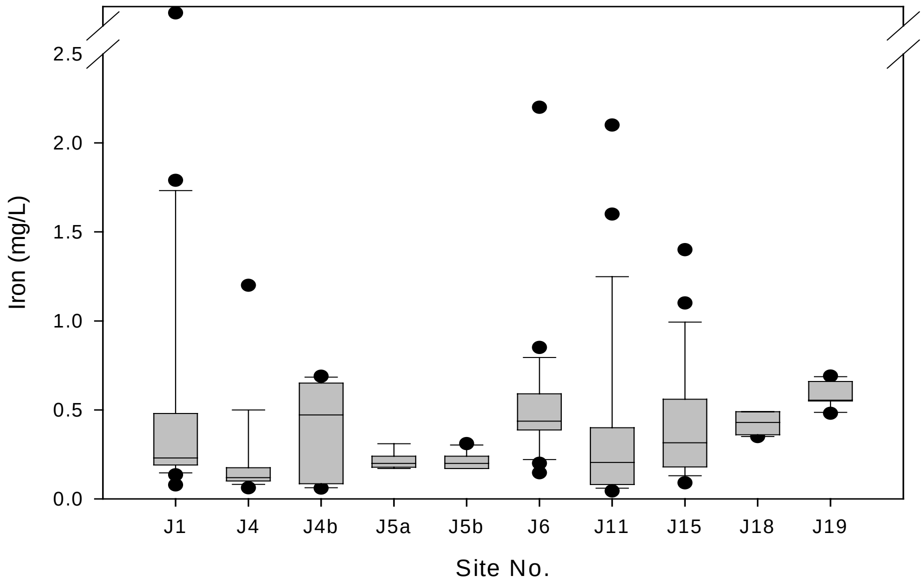

Figure 2.24 Box plots for statistics of iron at nine sites in the Jordan catchment (January 1999-December 2000). N= number of samples collected. N=18 for J1, J6, J11, and J15. N=6 for J4b, J5, J18 and J19. N=12 for J4.