THE ROLE OF SALINITY AS AN ABIOTIC DRIVER OF ECOLOGICAL CONDITION IN A RURAL AGRICULTURAL CATCHMENT

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ABSTRACT

The Kat River is an agricultural catchment that drains salt rich geology. Potential salinity impacts on ecological condition of the river were investigated. Monthly salt concentrations and flow discharges were monitored at ten sites along the Kat River below the Kat Dam. Monthly salt loads were computed to relate salinity to land use and ionic data used to assess the toxicity of major salts using the TIMS model. Concentration duration curves for sodium chloride were derived from flow concentration relationships, representing sodium chloride concentrations to which the aquatic ecosystem had been exposed. The ecological condition was assessed at nineteen sites using SASS5 biotic index over four seasons. Finally, the modelled instream salt concentrations and bioasessments were evaluated in terms of the modelled level of species protection afforded at different salt concentrations. Species Sensitivity Distributions (SSDs) were used for this exercise.

There was a general downstream increase in salinity with the minimum concentrations recorded at the Fairbain tributary (84 mg/L) and maximum levels at the sewage outfall in Fort Beaufort (1222 mg/L). There was evidence that citrus irrigation upstream of Fort Beaufort increased salinisation. Sodium chloride, and to a lesser extent magnesium sulphate, were the dominant salts in the Kat River catchment, with the latter being more toxic. However these had little or no impact on the aquatic ecosystem.

Flow-derived sodium chloride concentrations showed that both the Balfour and Blinkwater tributaries were in a fair/ poor condition. However with regard to ecological condition, it was demonstrated that the river is generally in a good state except for the Blinkwater River and the lower catchment. Degraded habitat condition at the Blinkwater was responsible for poor ecological condition. Integrating SSD derived classes, sodium chloride classes and ecological condition indicated that sodium chloride is a driver of ecological condition at the sewage treatment works and the subsequent site (only two of nineteen biomonitoring sites).

The study concluded that although there was evidence of salinisation this seemed to pose little threat to the aquatic ecosystem. However it was recommended that the sewage effluent be treated before discharge into the river and dam releases for dilution be increased for improving the situation downstream of Fort Beaufort.

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CHAPTER 1: INTRODUCTION

1.0 Overview

South Africa is a water scarce country owing to its largely semi-arid climate and constantly increasing water demands (Fuggle and Rabie, 1992). The country is blessed, however, with some of the finest water legislation (NWA Act no. 36 of 1998) in the world today. The act obliges the government to avail water for basic human needs to all citizens as a right. One of the main objectives in provision of sustainable water supply is the sound management and protection of water resources. This entails provision of the ecological Reserve; the amount and quality of water necessary to sustain aquatic ecosystems. In practice ecological Reserve determinations are not straightforward and this has stirred up research on appropriate methods since the law was enacted (Palmer *et al*., 2004a). These methods are aimed at assessing the ecosystem threat from a variety of stressors. One of the most pressing issues of water resources management in the country is that of 'water quality'. The term is a generalisation of an endless list of physical and chemical properties that may be of concern to the aquatic ecosystem.

Salinity has long been identified as one of the main water quality problems in the country (DWAF, 1986 and Du Plessis and van Veelen, 1991). High natural salinities in the country's rivers are mainly borne of the geology in which the rivers flow. In addition river salinisation may be signature to the low rainfall but high potential evapotranspiration areas. Such conditions encourage salt concentration in the soil and the groundwater and the subsequent river salinisation. In some coastal areas salts are introduced to rivers through sea spray. However, the most important causes of salinisation are from human impacts such as agriculture, mining and industrial and domestic waste disposal. There is enough evidence that rising river salinities are responsible for alteration in the aquatic ecosystem and the inherent uses (Hart *et al*. 1991; Bunn and Davies, 1992; Kefford, 1998; Nielsen and Hillman, 1999 and DWAF, 2004a).

There have been continuous studies and method development with regards to incorporation of salinity into the ecological Reserve determinations. Although still under development, these methods present the most effective way of assessing salinity threat to the aquatic ecosystem. However such methods have never been applied in many parts of the country where salinisation is perceived a real problem to the aquatic ecosystem. This research focuses on salinity impacts on a rural agricultural catchment ecosystem as part of a wider ongoing assessment in the management of the country's water resource for sustainable use. Available scientific methods are employed in order to assess the possible impact of salinity on the aquatic ecosystem. The first part of the work gives a background on salinity its extent and some of the possible impacts.

In order to fully understand the link between salinity and aquatic ecosystem condition, it is important to understand the process of salinisation and response of the aquatic ecosystem to salinity. In the next section, a brief account of work that has been done to date on salinity is provided, followed by aims and objectives of the study and a thesis structure.

1.1 Salinity Concepts

All water, wherever it exists in its natural state, contains some dissolved salts. In fact even a fresh water mountain stream has some salt dissolved in it (approximately 50mg/L), although this is quite minute compared to seawater (approximately 35000mg/L) (Goldsmith and Hildyard 1984 and Herczerg *et al.*, 2001). The salt is mainly derived from various hydrological cycle processes. When precipitation falls, a fraction either evaporates or is intercepted by vegetation; the remainder may either percolate into the ground as recharge or runs off directly into the rivers (Sharma *et al.*, 1987). Some salts that are dissolved in runoff end up in nearby rivers and streams. During infiltration some salt dissolves from the soil material and the salt concentration of soil water is higher compared to precipitation (Smedema and Shaiti, 2002). Usually water in the ground moves much more slowly and is therefore able to dissolve more salts before reappearing at the surface at rivers or as springs (Chourasia and Tellam, 1992 and Peck and Hatton, 2003). The term widely used to refer to the amount of dissolved material in water is that of 'salinity'.

Salinity may be measured as Total Dissolved Solids (TDS), a measure of all soluble materials in a sample, both organic and inorganic (Day, 1990 and Dallas and Day, 2004). The bulk of this in natural waters are actually made up of inorganic ions; Na^+, K^+, Ca^{2+}, Mg^{2+} , HCO_3^- , CO_3^{2-} and Cl^- that make up organic salts hence at times TDS is used to imply total dissolved salts (Day, 1990). The TDS of a water sample is measured by filtering water of known volume and allowing all the water to evaporate at 70°C and weighing the solid residue (Day, 1990). However Electrical Conductivity (EC) is often preferred because it is inexpensive and can be easily measured in the field with a hand held EC meter (Day, 1990). The EC is a measure of how readily current flows in a sample. There is high current flow (hence high EC) in waters that have high concentrations of dissolves salts due to abundance of free ions that conduct current. The EC and the TDS are therefore closely related. In South Africa, the measured EC can be approximately converted to TDS by a conversion (DWAF, 1996a):

$$\text{TDS (mg/L)} = \text{EC (mS/m)} * 6.5$$

Dissolved solids in fresh waters comprise inorganic ions; sodium, potassium, calcium and the anions bicarbonate, carbonate, chloride and sulphate (Davies *et al.,* 1993). The amount of dissolved material in river water can be influenced by several factors, some natural and some anthropogenic. A process whereby these materials are increased in rivers and on land is known as salinisation (Davies and Day, 1998). Gibbs (1970) evaluated water from different water sources and was able to show that differences could be attributed to three main sources: atmospheric deposition, geology and evaporation. These sources are collectively called ‘natural’ or ‘primary’ sources of salinisation. Other factors such as irrigation, mining, flow reductions by means of water quality monitoring points and treated sewage water disposal are collectively known as anthropogenic or ‘secondary’ sources of salinisation (Williams, 1987). In many instances, instream salinisation is a result of the combination of the two. For instance, irrigation in areas that already have naturally saline waters is likely to result in pronounced salinisation (Smedema and Shaiti, 2002*)*.

1.2 Natural Salinisation

Salinisation is a natural process (Peck and Hatton, 2003). In different parts of the world any of the three factors (climate, geology and the atmosphere) can control the salinity in natural waters (Cornish, 1987; Gibbs, 1970 and Day and King, 1995). Salinities at any one time are largely determined by relative contribution of these factors. The following section outlines how river salinisation is derived from each factor. In some instances, the geology is the main source of salt into a river system (Greeff, 1994) whilst coastal areas are sometimes salinised by the atmosphere in the form of sea spray (Milnes and Renard, 2004).

1.2.1 Climate

The climate of an area plays a role in the salinisation of rivers and affects hydrological processes such as precipitation and evaporation (Avila *et al*., 1996). Rivers exhibit high natural salinities mainly due to high evaporation rates coupled with low rainfall (Parsons, 2003). When water evaporates from open water bodies, salt concentration increases because some of the water has been taken away, but the salt mass remains almost the same (Smedema and Shaiti, 2002). Thus salinity increases with time as more water evaporates and is more rapid for surface waters, especially lentic systems (Herczerg *et al*., 2001). Occasionally evaporation occurs directly from the soil or ground water that is close to the surface (Williams, 2001). Salinisation usually occurs when saline groundwater is at less than a ‘critical depth’ of 2.5 metres from the surface. Above this level, the groundwater is drawn upwards through capillary action, making it prone to evaporation and subsequent salinisation (Goldsmith and Hildyard, 1984). Evidence of this is white efflorescence that is sometimes visible on the surface (Davis and Day, 1998). These salts may be washed-off the land surface into a river or stream in the area through surface run-off resulting in salinisation.

Evaporation is not only confined to open water bodies and shallow groundwater but is facilitated by vegetation through evapo-transpiration. Plants use up water from the soil for transpiration and at the same time takes up some nutrients. The remnant soil water is more concentrated with salts and can be mobilised to a water body (Williams, 2001). In areas where there is sufficient rainfall to wash out the salts from the soil profile into the groundwater, river salinisation is not a problem. Frequent flushing of salts in the soil profile restrains accumulation of salts in considerable amounts and hence there results in a lower salinity risk. Arid and semi-arid regions lack sufficient rain to prevent salt built up in the soil profile (Smedema and Shaiti, 2002). Seasonal and inter-annual variations in climate are also drivers of solute concentration in rivers (Interlandi and Crockett, 2003). Usually high salinity conditions are experienced during the dry period with the opposite in the wet season, and extreme weather events such as droughts aggravate salinisation of rivers due to lack of dilution water (Malan and Day, 2003).

1.2.2 Geology

One of the main determinants of river salinity is that of catchment lithology (Allanson, 1995). During weathering, some of the salts are dissolved in groundwater and ultimately end up in the rivers or streams (Goldsmith and Hildyard, 1984; Herczerg *et al*., 2001 and Woodford and Chevallier, 2002). The two important factors here are the salt content of the parent material (rocks) and their susceptibility to weathering. Rivers that drain areas overlain by dolerites, for instance, are likely to have lower TDS levels than those that drain sedimentary rocks such as shales as dolerites are more resistant to weathering (Woodford and Chevallier, 2002). Other sedimentary rocks such as sandstones, are also resistant to weathering (Sami, 1992). Even with high weathering rates, salinity in rivers can still be low if the parent rock contains low salt concentration in it e.g. Table Mountain Sand Stones (Dallas and Day, 2004). On the other hand, mudstones that are rich in salts drive the high ground water salinities in the Karoo (Woodford and Chevallier, 2002) and, similarly, high natural salinisation in the Berg River is linked to the Malmesbury shales (Davies and Day, 1998). In his study in the Breede River, Greeff (1994) concluded that about 40% of the river's salinity originated from shale formations in the study area. However, as noted by Cornish (1987), the relative contribution of the geology to river salinisation is increased when there is less rainfall dilution and rivers are mainly fed by base flow.

1.2.3 Atmospheric Deposition

Catchment studies in parts of the world have revealed that precipitation may contain significant salt concentrations, particularly in coastal areas (Skoroszweski, 1999 and Herold *et al*., 2001). The rain or snow contains small amounts of salt derived from the sea, which is then deposited on to the land (Hall *et al.*, 1984 and Williams, 1999). Salt concentrations in rainfall along the coast can go as high as 40mg/l (Boman and Stover, 2002). Precipitation in inland areas is an insignificant source of salts compared to areas along the coast line (Hall *et al*, 1984 and Williams, 1999). This is because some of the salt in sea spray is dissolved in the rain and re-routed into the sea and some coastal areas. Interlandi and Crockett (2003) found that precipitation is not a major salt source in Schulkill, an inland river in the United States of America (USA). However, strong winds off the ocean can deposit salt spray many kilometres inland (Boman and Stover, 2002). In addition, salts are deposited in catchments as "dry fall-out" (Hall *et al.*, 1984 and Williams *et al.*, 2001). Beresford *et al.* (2001) point out that rainfall and dust contributes about 20 to 200 kg of salt/hectare/year in parts of eastern Australia.

1.3 Anthropogenic Influences of river salinisation

In the natural environment, there is generally a balance between salt input and output (Williams, 1999 and Peck and Hatton 2003). Although there are many natural environments that are associated with saline waters, salinisation can be caused by human impact and socio-economic pressures. These activities alter the hydrological balance of salts and water within a catchment and therefore mobilise salts into the rivers (Peck and Hatton, 2003). The three activities that are most often responsible for anthropogenic salinisation of rivers are: agriculture, urbanisation, mining and industry (O’Keeffe *et al.*, 1992).

1.3.1 Agricultural salinisation

Perhaps the main salinisation impact is caused by agricultural activity. Actions such as application of fertilizers in the soil can result in increasing salt concentration in soil water (Chourasia and Tellam, 1992). The same water ultimately ends up in rivers and via groundwater (Smedema and Shaiti, 2002 and Farber *et al.*, 2004). Ploughing exposes salts that are held in the soil to possible wash-off into local streams (Aihoon *et al.*, 1997). Practices such as the addition of gypsum to improve soil structure, have also been cited as possible sources of salinity (Ongley, 1996).

The clearing of trees for expansion of cultivated land can result in the progressive elevation of the water table as a consequence of declining evapotransipiration and increased aquifer recharge (Flügel, 1991 and Williams, 2001). Beyond the critical depth, active evaporation from the soil is sometimes high causing salinisation as mentioned earlier (Orlob and Ghorbanzadeh, 1981). Nowhere in the world has this been more reported than in Australia where around 200,000 km^2 is affected (George and Clarke, 2001), with Schofield and Ruprecht, (1989) and Allison *et al.* (1990) all illustrating how land clearing results in river salinisation. According to Davies and Day (1998) South Africa suffers from salinisation from tree clearing to a minimal extent compared to Australia.

Irrigation

Of all the agricultural impacts, none has resulted in more widespread salinity problem than irrigation (Pillsbury, 1981; El-Ashry *et al.*, 1985; Allison *et al.* 1990; Rosenthal *et al*. 1992; Silva and Davies, 1999; Tedeschi and Meneti, 2002, etc.). Irrigation induced salinisation is closely linked to changes and modifications in the hydrological cycle through the landscape (Peck and Hatton, 2003). Most obvious of the impacts is the withdrawal of large quantities of water from the river for irrigation limiting the dilution of salts (Smedema and Shaiti, 2002). Agricultural use accounts for about 70 % of all surface water supplies in the world (Ongley, 1996). Excessive irrigation water can raise the water table such that the salt is mobilised up the soil profile (Konikow and Person, 1985 and Allison *et al.,* 1990). Once exposed to the surface, these salts are prone to washed off into a water body, contributing to river salinisation.

Poor farm management and planning mostly drives irrigation effects. The two processes mainly responsible in irrigation-induced salinisation are ‘salt loading’ and ‘irrigation return flows’ (El-Ashry *et al*., 1985 and Smedema and Shaiti, 2002). In order to understand the two processes it is important to note that irrigation water has some salts in it. Continuous irrigation and concurrent evapotranspiration result in accumulation of salts in the upper soil layers and is termed ‘salt loading’. When these salts are ultimately flushed out of the profile, they give rise to river salinisation. It is reported that even under moderate irrigation conditions, soil salinity levels of irrigated land in the arid zone are about 1.5 times that of the applied irrigation water (Smedema and Shaiti, 2002). It follows then that irrigation conservation methods such as drip are unlikely to result in salinisation compared to other methods such as sprinkler and flood irrigation (Lei *et al*., 2003). The reason behind is that little water is added to the soil and hence the salt. Sprinkler and flood irrigation methods also expose irrigation water to evaporation so that salts may be left behind and eventually result in elevated river salinities. The other important process by which irrigation contributes to river salinisation is that of ‘irrigation return flows’. These are a result of continuous salinisation of irrigation water as it moves through the soil, groundwater and ultimately back into the river (Lei *et al*., 2003). During this process, some of the applied water makes its way into the groundwater table, consistently dissolving salts and becoming saltier. A direct consequence of this is an increase in salt concentration in rivers.

To a lesser extent, surface flow from fields and through ditches may also pick up some salts on the way to a river (El-Ashry *et al*., 1985). Scheduling according to the plant's water demands, as well as flushing of accumulated salts in the soil profile, can optimise the efficiency of irrigation (Lei *et al*., 2003).

However, the extent of irrigation-induced salinisation is dependent on the prevailing rainfall, levels of irrigation and drainage conditions of the soil (McFarlane and Williamson, 2002). Under favourable conditions, (high rainfall, high over-irrigation and ready drainage), salts will be leached and drained and eventually returned to their rivers and groundwater of origin quick enough to avoid unwanted accumulation of salt in the soil (Sililo and Görgens, 1999). Irrigation does not result in river salinisation when it attains frequent leaching of salts and impedes short-term salt concentration.

1.3.2 Sewage Waste Discharge and other urban activities

Domestic sewage remains one of the most persistent sources of river salininisation (Davies *et al.*, 1993). Although rivers are usually the main sources of potable water, they are also regarded as dumping grounds for wastes (Roos and Pieterse, 1995). In urban areas, treated sewage is most often discharged directly into the river. This results in elevated dissolved solutes in the receiving waters that can be exacerbated by large withdrawals (Du Plessis and van Veelen, 1991). In the United States of America, Pennsylvania, the increasing solute concentrations in the Schulkill River were found to be proportional to the area developed over the past few decades (Interlandi and Crockett, 2003). In cold climates the practice of using salt to speed ice melting on the roads is an additional source of salinity in this parts of the world and other rivers where this is effected (Interlandi and Crockett, 2003). Closer to home, the Vaal River is under immense urbanisation pressure, both in terms of withdrawals and saline urban effluents (Roos and Pieterse, 1995).

1.3.3 Mining and Industry

Mining activities are some of the major causes of salinisation to date. A common phenomenon that results from mining is that of Acid Mine Drainage (AMD). The process occurs when pyrite (Fe_2S) is exposed to water and air in the presence of bacteria *Thiobacillus ferrooxidans* and is common in both operational and abandoned mines (DWAF, 1986; Thompson, 1987; Jovanovic *et al.*, 1998 and Lambert *et al.*, 2004). The high insidious seepage from slime dams and mine dumps, are therefore low in pH but elevated sulphate and trace metals (aluminium, calcium, magnesium, and sodium) (Dallas and Day, 2004). This leachate can find its way to surface water sources and result in salinisation. It is reported that AMD can affect streams as far as 18 kilometres downstream of a mine (Dallas and Day, 2004).

The salinity problem associated with saline mine effluents are of concern to semi-arid countries like South Africa due to lack of dilution water (Maree *et al*., 2004). The Vaal River in Gauteng is an example of a river that receives about 60 % of its salt load from only four mines (Jones *et al*., 1989 and Davies and Day, 1998).

In different parts of the world today, vast amounts of industrial and urban wastes are produced on a daily basis as by-products of economic activity. As an example, the Vaal River receives atmospheric borne salinity from industrial activities mainly in the lower Mpumulanga, as confirmed by Skoroszewski (1999) and Herold *et al*. (2001). Increases in salinity of surface waters are a result of the industrial use of water and arise from effluents from iron steel and textile industries among others. Additional salt loads can be traced from pulp and paper manufacturers and tanneries (Trusler *et al*., 1991).

1.4 Extent of the problem

The extent of salinisation in different world regions is not uniform. Both natural and anthropogenic salinisation are restricted to arid and semi-arid parts of the globe which is almost one third of the total land area (Williams, 1999 and Farber *et a*l., 2004). Mean annual rainfall in these parts of the world is between 250mm to 500mm (Smedema and Shaiti, 2002). River salinisation is therefore not necessarily important where most of the world population lives, but is however important in parts of central and South America, large tracts of northern and southern Africa, the middle East and central Asia and many parts of Australia (Williams, 1999). The population of these regions is not inconsiderable (about 400 million) and the largest rivers occur in this region. It is not surprising therefore that salinity is a major focal point in some countries. The list of countries that are afflicted with river salinisation is long; Libya, Pakistan, Egypt, Syria, Iraq, Iran (Smedema and Shaiti, 2002), China (Lei *et al.*, 2003), United States of America (Pillsbury, 1981, Caufield, 1984, Orlob and Ghorbanzadeh, 1981 and Hall *et al*. 2004), the Russian federation (O'Hara, 1997) and Australia (Peck and Hatton, 2003). As already mentioned, salinisation is also a major problem and an increasing concern in South Africa (Du Plessis and van Veelen, 1991).

1.5 Salinisation Impacts

The salinity of a water resource is an important descriptor of the general water quality properties. The most obvious impact of salinity in rivers is that related to direct users. Water can become so saline that it is no longer fit (or less fit) for drinking, irrigation and other uses (Du Plessis and van Veelen, 1991). This results in significant economic losses in different sectors of the economy.

1.5.1 Economic implications of salinisation

Salinisation impacts on different parts of the economy to a varying degree. In the case of agriculture the problem is associated with poor crop quality (Boman and Stover, 2002). In extreme cases, cash crops that are salt sensitive may be abandoned in favour of less profitable crops (El-Ashry *et al.*, 1985). Even worse, there have been reports of irrigation schemes closing down due to the rapid decline in productivity that is related to high salinities in the soil and water. Early irrigation developments in Mesopotamia are thought to have collapsed completely due to salinisation (Beresford *et al.*, 2001). Agricultural damage begins when the salt concentration in the irrigation water is between 700 to 850 mg/l, although this depends on the soil and crop types (El-Ashry *et al.* 1985). This is rather conservative compared to other author’s; Hall *et al.* (1984) suggest 1000mg/l whilst Boman and Stover (2002) proposes 1200mg/l as the highest salinity limit for irrigation water beyond which production declines.

Municipal water supplies and households are at risk in terms of corrosion of plumbing, inefficiencies of household appliances and increased water treatment costs (Caufield, 1984 and El-Ashry *et al.*, 1985). In the same way industrial processing and boilers may be impacted by high salinity water. Approximately 20 percent of all road and railway networks are currently affected by land salinisation in Australia (Beresford *et al.*, 2001).

In South Africa, a study on the economic, social and behavioural impacts on increased salinity in the Vaal River catchment revealed that both feeder systems and the environment would not incur significant incremental costs within a specified range of between 200 mg/l to 1200 mg/l (Urban-Esco, 2000). However 100mg/l increase from 500mg/l (average salinity level in the area) is expected to add R26 million in direct costs. If TDS were to increase from 500mg/l to 1200mg/l, the direct cost is estimated at R183 million/year (Urban-Esco, 2000). It is anticipated that a drop from 500mg/l to 200mg/l would result in a saving of R80 million/year. The cost of increased salinity in the Australian mining and industrial sector is estimated to be AUD 6 million a year and a further AUD 6 million could be lost a year due to crop losses resulting from land salinisation (Beresford *et al*., 2001). Measures of alleviating salinity include dilution and reverse osmosis are expensive and therefore raise input costs (O’Keeffe *et al*., 1992; Kirchner, 1995 and Causapé *et al*., in press).

1.6 Ecological hazards

Increase in the salinity of rivers and streams in many parts of the world may also pose an ecological hazard (Williams, 1987). Although salt is needed in the aquatic environment, excessive amounts may result in harmful impacts to different components of the aquatic ecosystem. The significance of this hazard has been largely overlooked, in favour of mitigation measures of other water quality impacts with more immediate economic implications (DWAF, 1986). The emphasis has been coupled with research on the mitigation of highly saline waters for industrial, agricultural and water supply purposes (De Clercq *et al*., 2001). Strategies such as desalinisation and re-use have been researched in the past for the sustainable use of the resource (DWAF, 2004a). This approach did not give direct attention to the impact of salinity on aquatic ecosystems. Once this is the case aquatic ecosystem function might be disturbed so that the intended use of the water resource declines.

1.6.1 Biotic Responses to salinity

Flora and fauna deal with elevated salinities through a range of physiological mechanisms and adaptations to balancing the amount of salt and water in their cells and tissues (Hart *et al*., 1991). Animals that are good regulators are known as *euryhaline* and are able to tolerate a wide range of salt concentrations and ‘acclimate’ swiftly (Hart *et al*., 1991). However most animals are poor regulators of salinity and are confined to a narrow range and are known as *stenohaline* (Hart *et al*., 1991). For most freshwater biota, especially macroinvertebrates, concentration of salt ions in body fluids is significantly higher than in the environment and this is maintained by excretion of dilute urine and actively taking up salt ions (Hart *et al*., 1991). These organisms are *hyper-osmotic* regulators, which mean they prefer salt concentrations in their body fluids well above that of the surrounding environment (Loewenthal, 1995). Marine organisms on the other hand are *hypo-osmotic* as their body fluids are less concentrated with salts compared to the environment. Other biota maintain the same osmotic pressure with the environment and are known as *osmoconformers* (Hart *et al*., 1991)

The efficiency of organisms to retain optimal salt concentration in their body fluids is dependent on several factors. From an evolutionary perspective, species that have long migrated inland will tend to be more salt sensitive when compared to the more recent migrants and, additionally, the state of an individual, degree of acclimation, life stage and temperature can also be influential factors (Hart *et al*., 1991 and Williams, 1998).

A direct impact of elevated salinity in the environment can result in the active uptake of salts and loss of water in the body fluids (Kefford *et al*., 2002) and can lead to changes in optimal salt concentrations, dysfunctional cells and ultimately mortality (Hart *et al*., 1991). Salt can also affect reproduction or alter the food supply of some biota and hence have an indirect impact on biota (Metzeling, 1993). Increasing salinity, therefore, may have wider implications on the species composition of the aquatic ecosystem (Hart *et al*., 1990; Hart *et al*., 1991 and Nielsen and Hillman, 1999). Generally the impact of increasing salt on the aquatic ecosystem is a loss of biodiversity as the composition of different organisms is slowly dominated by more salt tolerant biota (Hart *et al*., 1991). Testimony to this was borne by Bunn and Davies (1992) who found a shift in community structure to a crustacean-dominated one owing to increased salinity.

Some comprehensive literature that addresses the problem of salinity on the aquatic ecosystem is published in Hart *et al*. (1990) and Hart *et al.* (1991). In addition Nielsen and Hillman (1999) and Loewethal (1995) give summaries of some known effects on the major groups of animals and plants associated with rising river salinities. The literature varies from the description of communities and correlations with salinity (Williams and Williams, 1998; Bunn and Davies, 1992; Metzeling, 1993 and Short *et al*., 1991; Marshall and Bailey, 2004). Earlier, Hart *et al*. (1990) had suggested that for Australian macroinvertebrates, direct biological effects might be realised at 1000mg/L or even less. However, Metzeling (1993) and Williams (1998) found no significant relationship between lowland macroinveterbrate communities and salinity. They found, however, that macroinvertebrates were more resilient to salt than was originally thought. In the same part of the world, Kefford (1998) ascribed changes in macroinvertebrate community structure to salinity changes in the Barwon River catchments in southeastern Australia. Short *et al*. (1991) found that macroinvertebrate species richness increases linearly with decreasing ambient salinity levels in Kentucky, USA. Dallas and Day (2004) state that there is some circumstantial evidence to suggest that alterations in distributions and patterns of individual species or communities that may be a result of changes in salinity in South Africa. Information on individual salinity tolerances individual biota is therefore important.

1.6.2 Salinity tolerances

Other work worldwide has focused on establishing salinity tolerances for different aquatic organisms. Such information can be regarded as important for conservation purposes and for identification of species that are sensitive or tolerant to salinity (Kefford *et al*., 2003). Short *et al*. (1991) determined the salinity tolerances of some macroinvertebrates in the USA, whilst in Australia work has been undertaken by Bunn and Davies (1992) and Kefford, (1998) and Kefford (2000) in the Barwon Basin. Recently, Kefford *et al*. (2003) have compared salinity tolerances of Australian biota with that of other parts of the world and concluded that salinity tolerances are to a large extent comparable. In South Africa, the research on salinity tolerances was originally motivated by the need for quantitative guidelines in the Kruger National Park. The aquatic ecosystems guidelines (DWAF, 1996b) that followed were wholly derived from international toxicological databases as there was a lack of locally derived salinity tolerances. One of the first investigations of local macroinvertebrates and salts was carried out in 1990s (Goetsch and Palmer, 1997; Binder, 1999 and Palmer and Sherman, 2000). Salinity was selected as the first water quality challenge to be investigated because of the widespread nature of the problem in the country (Goetsch and Palmer, 1997).

It was soon realised that field macroinvertebrates were not always sufficient in numbers for running toxicity tests and this prompted research in laboratory-reared organisms (Haigh and Davies-Coleman, 1997). Initial studies indicated sodium sulphate as being more toxic than sodium chloride (Goetsch and Palmer, 1997). A follow up study was carried out in the Kruger National Park to investigate further the toxicity of the sulphate salts (Palmer and Sherman, 2000) and most recently the UCEWQ-IWR (Unilever Centre of Environmental Water Quality- Institute for Water Research) database on comparative macroinvertebrates salt tolerances has been published (Palmer *et al.*, in press). Sodium chloride was used as a positive control for toxicity tests, and international databases such as AQUIRE (Aqutic Toxiocology Information Retrieval) and USEPA's (United States Environmental Protection Agency) ECOTOX (ECOTOXIcology database) provides record on a range of salt tolerances (USEPA, 2002 and 2004). Mount *et al*. (1997) also investigated the relative toxicity of various ions.

1.7 Salinity Management for aquatic ecosystems

The main principle in the South Africa's (NWA No. 36 of 1998) is that of ensuring sustainability of aquatic ecosystems. This means the structure, function and biodiversity of should be maintained to for the long-term provision of goods and services offered by aquatic ecosystems (Palmer *et al*., 2002). Aquatic ecosystems offer among others, water supply, flood control, recreation, waste dilution, transport and places of cultural value (Palmer *et al*., 2002). Fundamental to the protection of aquatic ecosystems is the concept of providing for the ecological Reserve. This includes both the quantity and quality of water necessary for the maintenance of aquatic ecosystems in a desired state. Implications are that water resources managers require quantitative goals for decision-making to meet these legal obligations. These goals are termed Resource Quality Objectives (RQO's) and are mostly arrived at through the use of Instream Flow Requirements (IFRs) (King and Louw, 1998). Methods for the determination of IFRs are more developed compared to the ones for water quality component of the ecological Reserve. Salinity is a component of the latter therefore emphasis of this work is on water quality methods for ecological Reserve determination.

Most salinity guidelines for protecting aquatic ecosystems are still based on a percentage deviation from the natural salinity range (DWAF, 1996b and ANZECC and ARMCANZ, 2000). There is however a move towards toxicity-based guidelines (Jooste and Rossouw, 2002). Lately, Species Sensitivity Distributions (SSDs) have also been used in countries like Australia and New Zealand (Warne, 2001). The main objective of SSDs is protection of 95% of the species (Warne, 1998). The topic on SSDs is discussed in much detail in chapter 4. Regardless of the methodology employed, the main tool for decision makers with regard to the ecological Reserve is a classification system which identifies varying levels of protection according to the intended use. This is achieved through categorising ecosystem ‘health’ or integrity into ecological classes ranging from a “Natural” (unimpacted) to “Good” (slightly to moderately impacted), to “Fair” (heavily impacted), to “Poor” (unacceptably heavily impacted) (Figure 1.1).

Water Resource classification is important because it can be linked directly to goods and services offered by the resource so that the water use declines with deteriorating ecological health class (Palmer *et al.*, 2003). The system firstly classifies the current level of ecosystem health into one of five ecological Reserve categories (Figure 1.1). Secondly, these classifications are then selected defining the state towards which the water resource needs to be managed and appropriate management class is assigned to the resource.

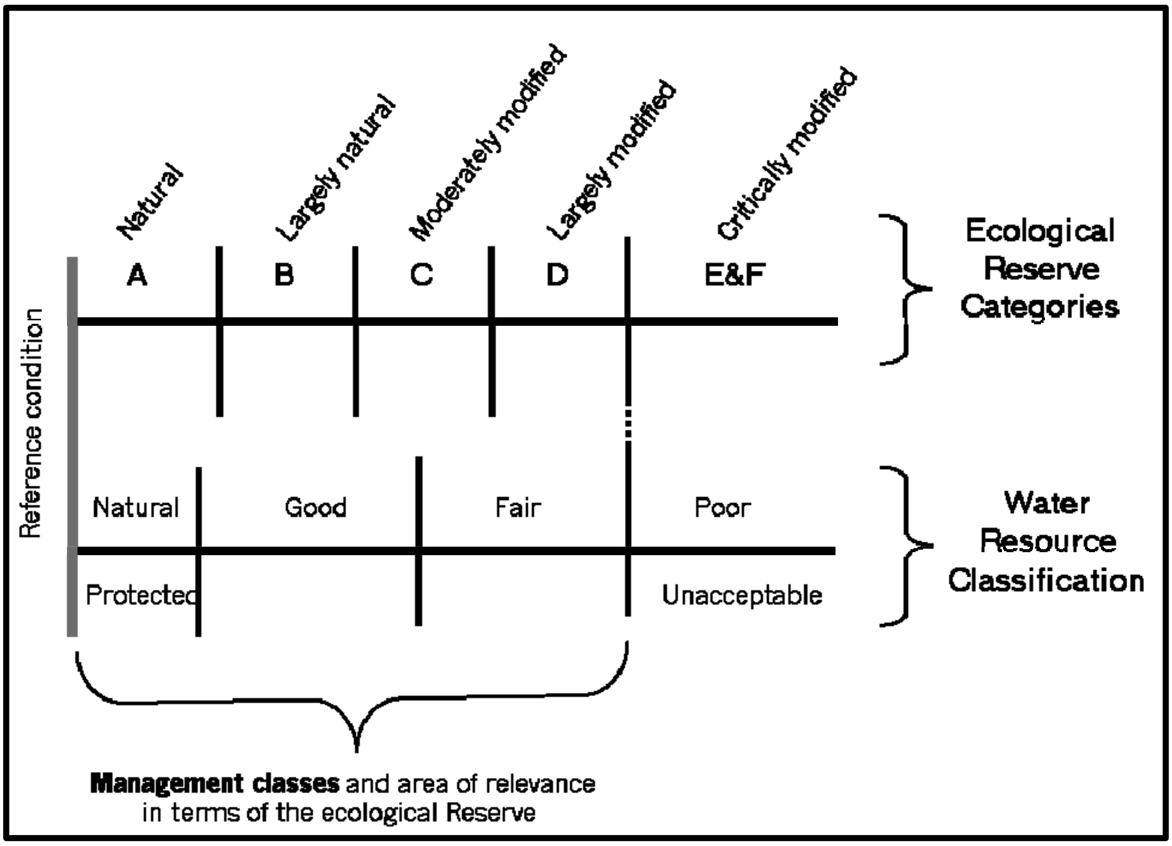


Figure 1.1: Showing the South African Ecosystem health and management classification system used in the management of aquatic ecosystems (Adopted from Palmer et al., *in press*)

For example, ecological classes of “D”, “E” and “F”, would usually require drastic steps from catchment managers whilst “A” and “B” may represent protected aquatic ecosystems, so that most of the goods and services are provided by the aquatic ecosystem.

1.8 Salinisation in the South African context

Examples of rivers faced with salinisation problems include, among others, the Great Berg and Breede in the southern-western Cape; the Sundays and the Fish Rivers in the Eastern Cape (Kirchner, 1995; Aihoon *et al.*, 1997 and Sililo and Görgens, 1999). The natural salinity of the Eastern Cape Rivers is high owing to the geology and the climate; but more importantly irrigation developments in the area (DWAF, 2004a). The region west of the Drakensburg is at hazard either potentially or actually (Day and King 1995). Most surface waters of this region have salinities in excess of 300 mg/L and are therefore saline in the view of water resources managers. The lower Orange and Olifants (Mpumalanga) rivers have also been identified amongst those with a serious salinisation threat (Day and King, 1995 and DWAF, 2000). Other rivers that receive mining effluents include the Buffalo, Mkuzi, Pongolo, Wasbank, Mfolozi and Tugela Rivers (Davies and Day, 1998). On the other hand, the Vaal River is in a highly industrialised catchment with notable mining activities where salinity from industrial effluents (Trusler *et al.*, 1991 and Roos and Pieterse, 1995) (section 1.3.3) and atmospheric deposition (Skoroszewski, 1999 and Herold *et al.*, 2001) are considered a problem.

In South Africa, research on the increasing salinity of some major catchments has been undertaken (Hall *et al.*, 1984). Because of the complexity of salinity, owing to heterogeneity in the geology, climate and land use, hydrosalinity models have been employed for resource planning and operation in different catchments, including the Great Fish and Sundays Rivers (Hall *et al.*, 1984), the Breede River (Pegram and Görgens, 2001), Berg (Flügel, 1991), the Vaal River (Skoroszewski, 1999), and the Mgeni, Buffalo and Crocodile Rivers (Deksissa *et al.*, 2003). Other studies include salinity impacts by specific irrigation schemes like the Vaalharts and the Coerney Valley (Herold and Bailey 1996 and Herald, 1999). Recently the feasibility of using saline waters for irrigation has also been investigated (De Clercq *et al.*, 2001).

It has been a challenge to assess the role of salinity in determining aquatic ecosystems health. Most of the rivers mentioned above have never been assessed with regards to the role of salinity on the aquatic ecosystem. Work done with regards to salinity impacts on the aquatic system has been limited to the Olifants, Breede, and Palmiet in the Western Cape (Malan and Day, 2003). More research is therefore needed in rivers that are salinised or those at least under threat.

1.9 Salinisation as a driver of ecological condition in a rural agricultural catchment

Despite a wide literature on the causes of river salinisation, and an increasing body of information on biotic responses to salts, these have seldom been integrated at a catchment scale. In this study the impact of salinisation on the aquatic ecosystem has been evaluated in a rural agricultural catchment. The Kat River flows through a small rural catchment in the Eastern Cape. Historically the area has gone through a number of land repossessions and resettlements between different ethnic groups (Appendix, A). Despite these hitches, rural communities and commercial citrus farmers who export their produce live side by side along the banks of the river. Citrus farming is mostly supported by releases from the Kat River dam in the upper reaches. Both agricultural and domestic needs are drawn from the river. The river is vulnerable to salinisation, mainly due to the mudstone and shales that have been identified as having high salts in areas underlain by the same geology (Greeff, 1994, Smart; 1999 and Woodford and Chavellier, 2002); climate of the area is sub-humid to semi-arid and hence the salinity threat is expected to be high; and importantly the river is the main driver for the local economy in the form of citrus irrigation, and irrigation poses a salinisation threat to the river.

The study incorporates a landscape scale salinity assessement carried out in the Kat River catchment, comprising assessment of historical salinity data, bioassessments for ecological “health” and salinity tolerances of tested macroinvetebrates. The study area was suitable because contact had already been established with local communities through previous work done by Rhodes University researchers (McMaster, 2002; Soviti, 2002 and Motteux, 2002). The catchment is accessible and of a manageable size, allowing for a two-year study. It has also been a collecting area for some ecotoxicological experiments (Palmer *et al.*, in press) and bioassessments would allow comparisons with the salinity tolerance data.

The main aim of the study has therefore been to assess the role of salinisation in to the aquatic ecosystem health in the Kat River.

Three main objectives have been identified:

- To describe spatial and temporal variability in water salinity.
- To evaluate the ecological state of the river.
- To asssess whether the ecological state has been affected by salinity.

Chapter 1 is the general introduction to the study. Salinisation, its main sources and possible impacts on the aquatic ecosystem are highlighted before stating aims and objectives. **Chapter 2** is a brief introduction to the study area. The geographical, biophysical and landuse patterns in the area are discussed in relation to sources of salinity. **Chapter 3** outlines the nature of salinisation in the Kat River catchment and how it was assessed. Firstly the chapter deals with salinity and major ions and salt load trends. In addition the hazard posed by the aquatic ecosystem with regard to salinity stress is assessed through determination of the most likely salts. Lastly, flow-concentration relationships and associated salinities are employed to relate sodium chloride to different flow scenarios. **Chapter 4** describes the Environmental Water Quality (EWQ) approach and how it was implemented in the study. Here, both bioassessments and ecotoxicological data are used to assess the role of salinity on the macroinvertebrate community structure. The South African Scoring System version5 (SASS5) was used for the bioassessment whilst Species Sensitivities Distributions (SSDs) were used for deriving percentage protection classes. **Chapter 5** is a concluding discussion. The findings of the research and the implications are highlighted. Some general recommendations are also provided.

CHAPTER 2: THE KAT RIVER CATCHMENT

2.1 Study Area

The research was carried out in the Kat River catchment. The area under investigation forms part of the Nkonkobe municipality, which is in the heart of the Eastern Cape province (Figure 2.1). The catchment lies along 26^{o} 30’ and 26^{o} 55’ to the East and 32^{o} 30’ South, and located about 130 km west of East London. The total catchment area is estimated at around 1700km^{2} (McMaster, 2002). In terms of the present demarcated water management areas, the Kat River catchment is part of the Fish to Tsitsikama Water Management Area (DWAF, 2004a). The river valley lies at the foothills of the Katberg mountains and bounded by the Didima range to the north east and the Elandsberg to the northwest (Hill and Nel, 2000).

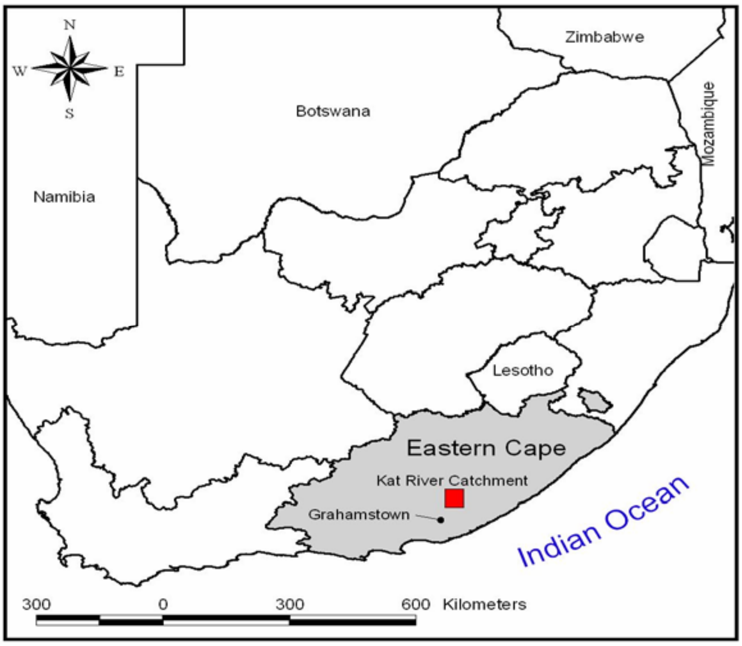


Figure 2.1: Location map of the Study area

The main river flows is from the Kat River dam, which was built at the confluence its three tributaries the Elands, Eyre and Lushington streams. The Kat River Dam was commissioned in 1969, for supplying water for farming and domestic use.

The Kat River provides domestic water supply to the historical service centre of Seymour and the bigger town, Fort Beaufort. Flow in the Kat River is controlled through dam releases from the Kat River dam (Everitt, 1999). Weirs are prominent features along the Kat river system, especially those associated with irrigation supply to the farms (Gaulana, 2003). Pipelines are used to connect the water quality monitoring points and some furrows are used to lead water into irrigation lands or into off-channel storage dams.

In all, the Kat River dam has a capacity of 25 million m^3 and is estimated to provide water for about 45000 consumers (Hosking *et al.*, 2002). An estimate of 7000 m^3/hectare of water is released to meet citrus farmer’s needs at a cost of R120 per year (Hosking *et al.*, 2002). Supply in Seymour is met by direct withdrawals from the dam whilst Fort Beaufort’s demands are met through withdrawals from a water quality monitoring point in the vicinity of the town.

2.2 Biophysical properties

2.2.1 Climate

Climate is arguably the most important factor that drives river salinisation. Generally, areas with low rainfall and high evaporation rates are characterised by high salinity rivers. Such climatic conditions encourage accumulation of salts in the soil and these contribute to river salinisation after dissolution from slope run-off (Hughes and Moolman, 1986). The climate of the study area can be described as sub-humid in the north to semi-arid in the south. The rainfall in the area peaks in March and is at its minimum in Winter (June and July). The Mean Annual Precipitation (MAP) of the study area according to Midgley *et al.* (1994) is shown in Figure 2.2.

Generally the catchment can be divided into two microclimate areas that are related primarily to topography (Figure 2.5). The higher ground zone (above 800 metres from mean sea level) is situated in the northern half of the area. This region receives orographic rainfall from the southwest with the windward slopes receiving more rain than the leeward side and MAP in the zone varies between 500 to 800 mm/annum (McMaster, 2002). The upper Elands and Balfour tributaries have the highest MAP at 800 mm/annum. Other tributaries; the Lushington River, Fairbain and Buxton streams receive MAPs around 700mm/annum.

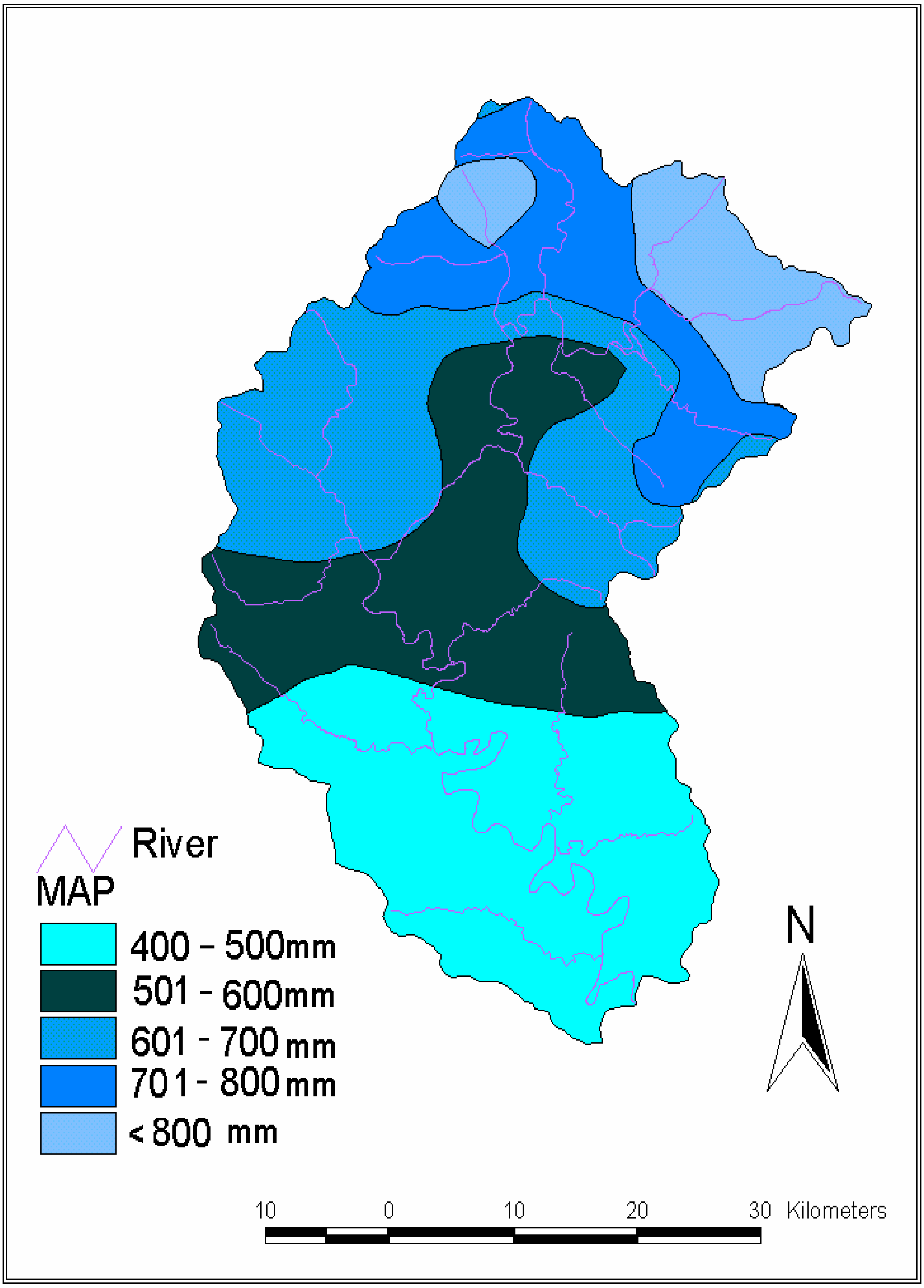


Figure 2.2: Showing Mean Annual Precipitation disstribution in the Kat River catchment (taken from Midgely *et al*. 1994)

The area between the Kat River Dam to the northeast and Balfour to the north and the upper Buxton to the lower Blinkwater, downstream of Upsher and the Mankazana stream receives MAP of 500mm/annum. South of this zone, down to below Fort Beaufort, the MAP is 600 mm/annum. The southern portion of the catchment receives the least MAP of below 400mm/annum and is relatively dry. Generally, a trend that has been established is that low rainfall areas in the catchment exhibit high temporal variations whilst higher rainfall areas have low variabilities (Hill, Kaplan and Scott, 1990).

Mean daily maximum temperatures vary from 30^{o}C in February to 21^{o}C in July, while mean daily minima are in the region of 17^{o}C and 8^{o}C for January and July respectively (Motteux, 2002). The winters are cold, with frequent severe frosts and occasional snowfalls in the higher altitude areas and are a threat to citrus farming. Little evaporation data are available in the study area. The Kat River dam and Fort Hare stations are the only records considered to be representative of conditions. Evaporation is highest in December and January (around 1600 mm) and is at its lowest in May to July (Motteux, 2002). Due to these climate attributes, the Kat River can be regarded as a perennial river.

At different points, main tributaries, namely Fairbain, Balfour and Blinkwater rivers, join the main Kat River (Figure 2.5). Other minor tributaries that drain the Kat River include the Buxton and Mankazana streams. The Fairbain River is the first tributary that joins the Kat River. Some distance downstream the Balfour River also joins the Kat as it flows south from the Kat Dam. This tributary rises from the Katberg Mountains and joins the Kat River below the Balfour village. A few kilometres upstream of Fort Beaufort, the Blinkwater stream also discharges into the Kat River. The river then meanders south, where it joins the great Fish River (Hill, Kaplan and Scott, 1990). One of the most important factors that can have a profound effect on the river salinity is the flow regime. The Mean Annual Runoff (MAR) of the Kat River catchment is shown in Figure 2.3, below. As would be expected, the MAR pattern is quite similar to the MAP (Figures 2.2 and 2.3).

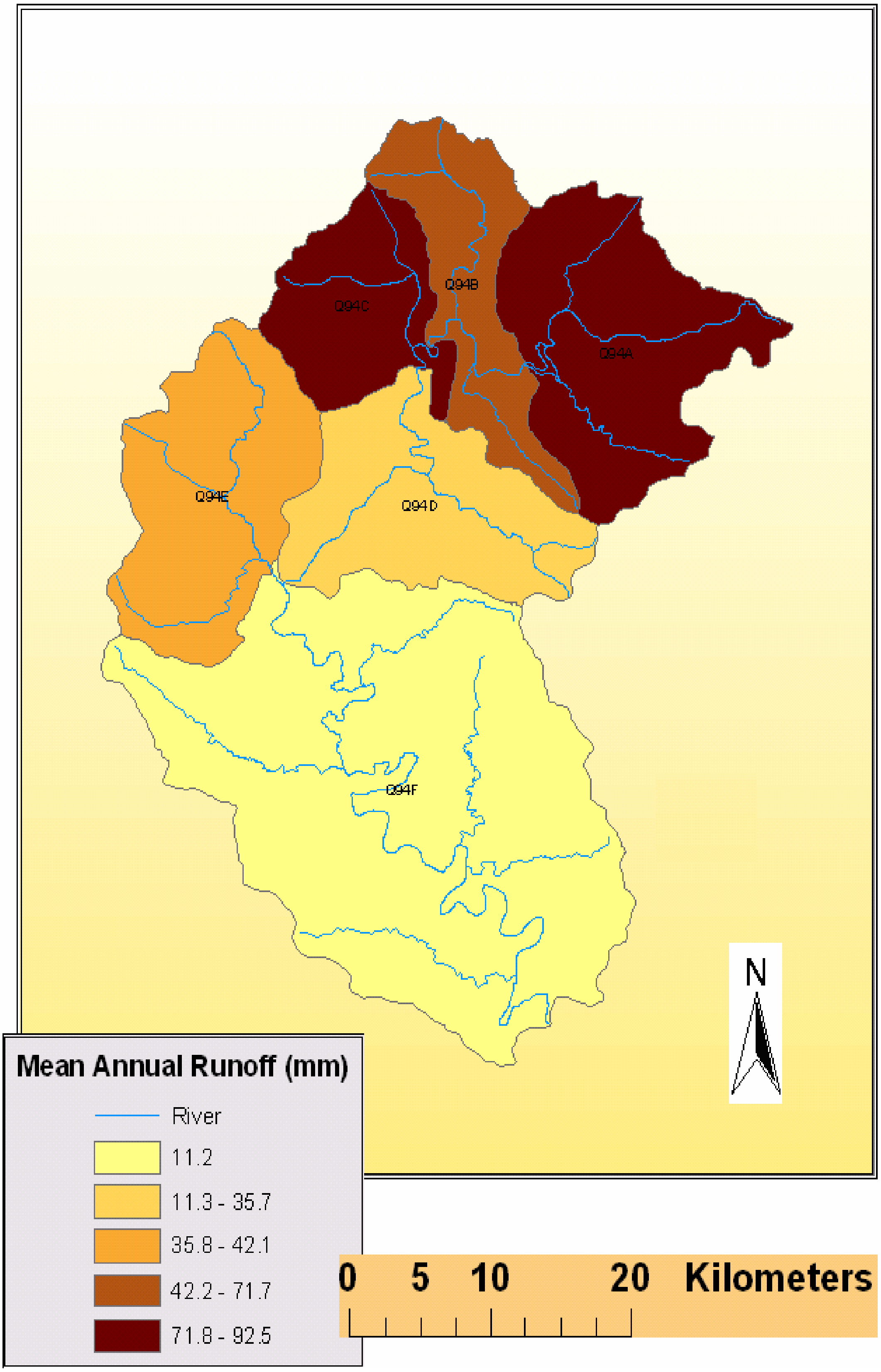


Figure 2.3: Showing Mean Annual Runoff from Quartenary catchments in the Kat River valley (taken from Midgely *et al*. 1994)

The highest MARs (71.7 to 92 mm) are along the Elands and Lushington tributaries upstream of the Kat River Dam and the Balfour River. Fairbain River has a MAR of between 42 and 71.7 mm and is the second highest in the catchment (Figure 2.3). Both the Blinkwater River and Mankazana Rivers appear to have insignificant MAR as values here range between 11.2 to 42.1 mm. The lower catchment is characterised by the lowest MARs below 11.2 mm. Naturally, high stream flows are associated with lower salinities and the opposite is apparent in the Winter season. In the Kat River catchment, the highest salinity levels can be expected from June to September when flows are at their lowest (Parsons, 2003).

2.2.2 Geology

The geology is the man driver of salinity and major ions in rivers (Allanson, 1995). The area is mainly underlain by the lower stage of the Beaufort system of the Karoo system (Vegter, 2000). These rock formations consist of layers of shales, mudstones and sandstones of varying thickness and texture (Hill, Kaplan and Scott, 1990). The predominant hard sandstone of the Katberg are found at the northern edge of the study area (Figure 2.4). These rocks are occasionally intruded by dolerite sills and dykes, which are of igneous origin (Vegter, 2000). At a few areas, dolerite is found along the main river, the most significant being downstream of the Kat Dam and upstream of Baddaford. Alluvial deposits are common along the Balfour and Kat River (from Amherst to Fort Beaufort). More significant alluvial deposits extend from downstream of Fort Beaufort to Klu Klu in the South (Figure 2.4). Starting from the road between Alice and Fort Beaufort road, towards the southern tip of the catchment, the area is underlain by mudstones and shales. This mainly consists of a sequence of deposits commencing with sandstone at the base and fining upwards into the greenish grey mudstones (Hill Kaplan and Scott, 1990). According to literature, both shales and mudstones have in the past been implicated as drivers of river salinisation (Greeff, 1994; Kirchner, 1995; Woodford and Chavellier, 2002). More importantly, the geology determines major ions proportions (Day and King, 1995) and perhaps major salts that are likely to impact on the aquatic ecosystem. This is important because different salts exhibit varying toxicity (Jooste and Rossouw, 2002), so that the geological considerations are very important in assessing aquatic ecosystem impacts due to salinity.

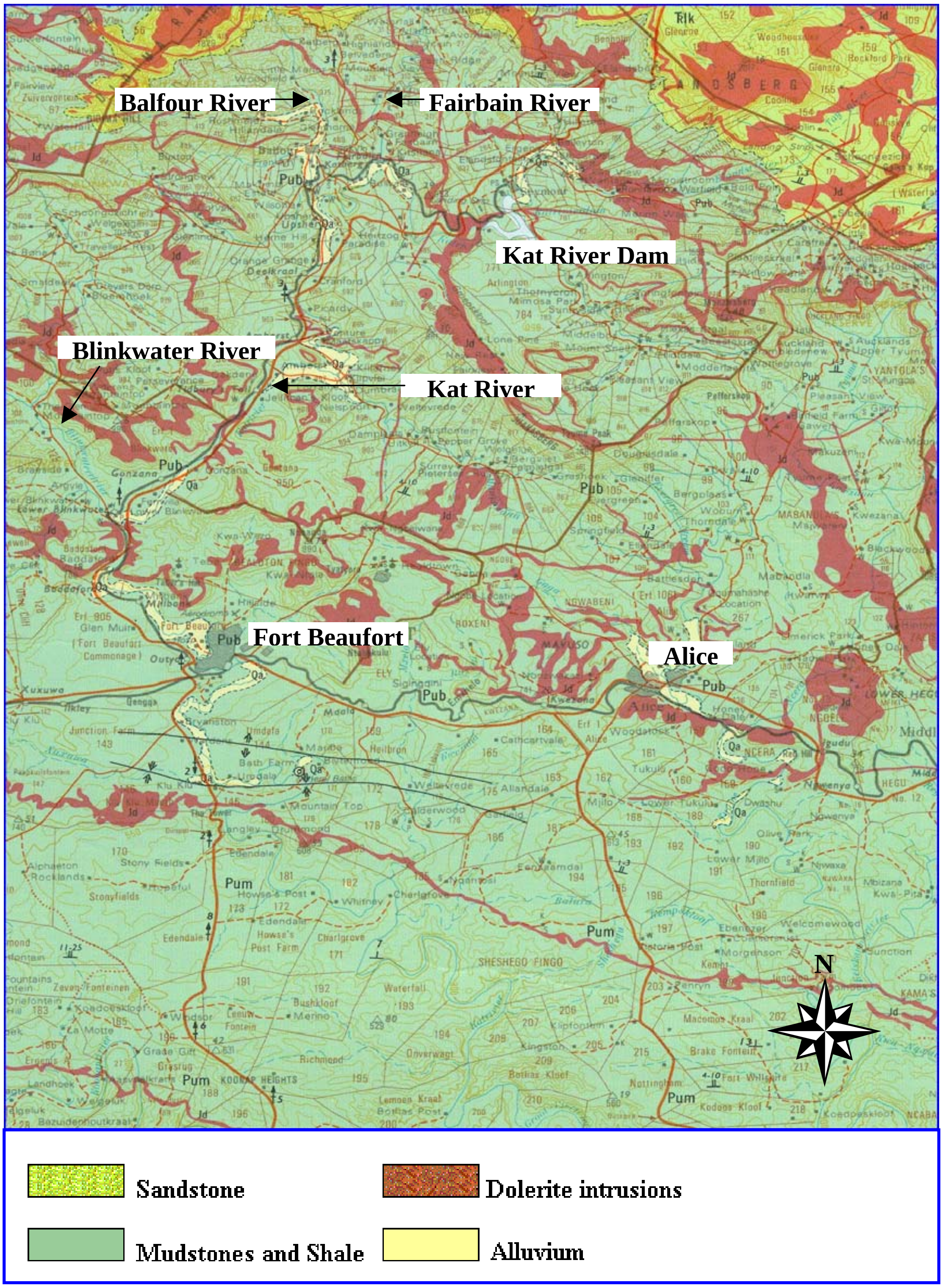


Figure 2.4: Geological map of the study area (taken from sheet 3226 geological map of King Williams Town, 1974)

Normally ionic composition in rivers during the rainy season will tend towards those of rainfall whilst it is mainly driven by ground water ionic composition over dry period (Parsons, 2003).

2.2.3 Soils

Soil characteristics that determine water salinity are always related to the salt content of the parent rock from which the soil was formed. The important role of soil and topography play in river salinity cannot be over-emphasized (Billett and Cresser, 1992). Physical properties of soils such as texture, structure, layering and aggregation are vital in the salinisation process and may be more important than the chemical properties (Sililo and Görgens, 1999).

Salts are not retained in the soil if the texture and depth allow for easy drainage following heavy rainfall. This has a direct bearing on the stream salinity in the vicinity. In common with the surrounding areas, soils in the study area are predominantly derived from *in situ* weathering of sedimentary rocks of the Beaufort series, with minor occurrences of those derived from dolerite dykes and on alluvial deposits along the banks of the river (Hill, Kaplan and Scott, 1990). Soils from the Beaufort formation are shallow in the southern part of the catchment, becoming moderately deep in the north. In the north and northeastern part, highly weathered soils are eminent, usually deep, well drained, fine grained and medium to heavy textured (Hill Kaplan and Scott, 1990). These soils, therefore have a low salt retention potential and are of high arable potential where topography is flat and are suitable for irrigation (Barratt, 1998). Shallow fine-grained sandy clay loams, overlying weathered rocks, dominate the southern part of the area. These soils are not recommended for irrigation because of their limited rooting depth and low water holding capacity. Where dolerite dykes occur, black and red heavy textured soils occasionally exist; however they normally occur on steep slopes with little to no irrigation potential (Hill Kaplan and Scott, 1990). Without irrigation being practiced in these areas, there is less soil water flow and hence minimal river salinity risks (Hill, Kaplan and Scott , 1990). The majority of lands suited for irrigation are located on alluvium deposits along the river channel (Barratt, 1998). Oakleaf and Valsrivier are the main soil types in the area suitable for cultivation, with the former dominant in the lower and middle terraces of the Kat River catchment. The Valsrivier soils form the lower pediment slope positions. These soils have clayey subsurface horizons, which restrict movement of water within the profile. Oakleaf soils tend to have a uniform texture, and movement of water within the profile is less limited in comparison with Valsrivier soils.

2.3 Service Centres

In addition to natural sources of salinisation, urban activities are possible sources of river salinisation. Seymour is situated upstream of the Kat Dam and is an old administrative town from the former Ciskei government. Reticulated sewage from this area were considered possible sources of river salinisation. Furthermore, dissolution of some salts during run off can be an additional source of salinity.

The second centre in the upper catchment is Balfour which is located a few kilometres to the southwest of Seymour. There are a number of schools and other services such as the post office and police station, however there is no piped water system to the households, and supply is by standpipes and a number of boreholes. Most people however still use the bucket system for sewage and fetch water directly from the stream. There is therefore no salt input that can be envisaged from sewage disposal from the Balfour village although groundwater seepage from pit latrines may elevate the salinity problem.

The urban municipality of Fort Beaufort is the main centre for services in the catchment and poses the highest threat from sewage disposal and other activities. The town is also undergoing growth, with the building of new RDP (Rural Development Programme) houses that will increase the sewage load disposed into the river.

2.4 Current Land use patterns

The history of land ownership in the study area has shaped present land use patterns particularly with regards to agriculture and settlements (Appendix A). An important point to mention is that irrigated agriculture has been practiced in the valley for more than a century (Rowntree *per comm.*, professor, Rhodes University, 2004). Water quality monitoring points were built along the river to store water, and furrows dug to lead water off to lands. Irrigated areas throughout the valley (i.e. below dam) will have increased after 1969 when the dam was closed. Historically, the catchment used to be renowned for its citrus and tobacco production countrywide.

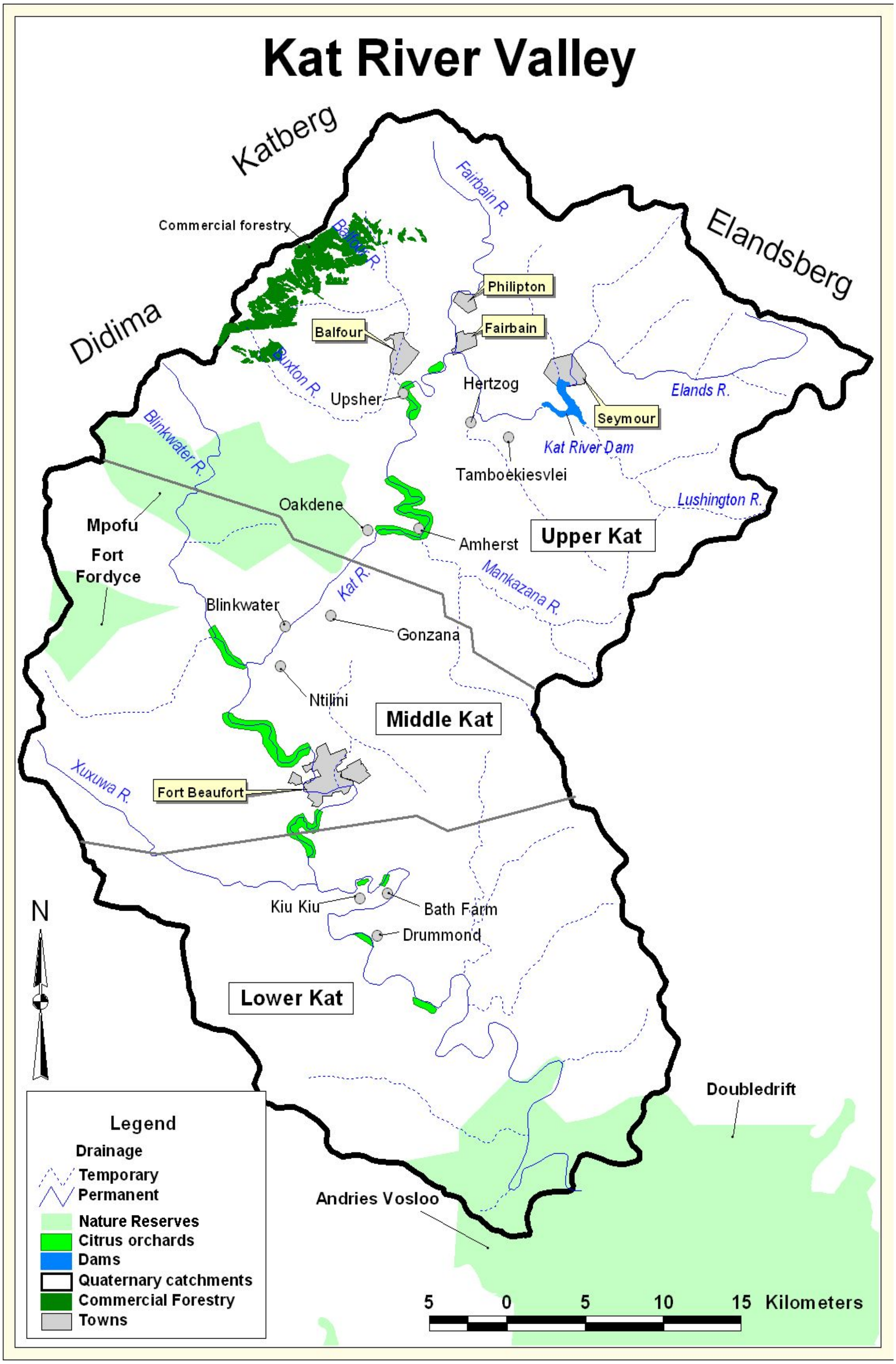


Figure 2.5: Showing Landuse in the Kat River catchment

After 1980, irrigation in the upper Kat River catchment greatly reduced following government policy that expropriated land to the former Ciskei homeland (Rowntree *per comm.*, 2004) There was some continuation on ULIMCOR (Ciskei Agricultural Co-poration) farms (farms that went over to Ciskei) but these were not well managed. After 1994, there were some initiatives to reinstate irrigation in the upper catchment for vegetable production e.g. HACOP and some citrus irrigation. There was also expansion of citrus irrigation in the middle to lower reaches catchment with access to international markets.

It is also important to reiterate that irrigation induced salinity is dependent on the irrigation methods employed. There has been a shift from furrow to overhead and micro-jet/drip irrigation over time. To date, HACOP and some upper catchment farmers still use over-head irrigation. From Amherst to the middle/lower Kat catchment, micro-jet/drip irrigation systems are in use. Since over-head irrigation generally adds more water to the soil it is envisaged that irrigation return flows would be more apparent in the upper catchment as opposed to the middle/lower catchment. As earlier pointed out, conventional methods such as overhead irrigation are associated with high return flows (Lei *et al.*, 2003).

2.4.1 Upper Catchment

The most prominent land use activity in the upper Kat River catchment is that of HACOP, a small rural cooperative around Fairbain and Hertzog. The population in this area is about 1 500 and is made up of about 330 households (Motteux, 2002). Similar to past ‘homelands’, the upper catchment is characterised by poor land management and degradation. Perhaps this can be attributed to uncontrolled livestock feeding and cutting of trees at an alarming rate exceeding their replenishment (Motteux, 1999). Evidence to this is several gullies visible especially around Hertzog, Fairbain and Ntilini. Erosion of top soil is anticipated to be a source of salts into the Kat River.

One of the notable landuses, in the upper catchment is citrus farming along the Kat River banks. This is in areas such as Upsher, Picardy, Amherst, White, Oakdene and Gonzana (Figure 2.5). The land has been formerly under ULIMCOR, a former Ciskei parastal that collapsed. Although the land is still productive, abandoned citrus orchards are evident in Upsher and Tidbury’s Toll. There are also some state commercial forestry activities to the north west of the upper catchment (Figure 2.5). Many small rural villages are also found in these areas. Apart from the above, there is commercial livestock farming and Mpofu nature reserve at the upper Blinkwater stream.

2.4.2 Middle Reaches

The Kat River Citrus Corporation (KATCO) and Riverside packing sheds, serve a number of farmers specializing in various types of citrus in the middle reaches. Citrus operations are the most visible from Baddaford past Riverside estate and the downstream farmers. Small-scale agriculture and stock farming are mainly practiced in the middle reaches of the catchment. Some land is being used for commercial rangeland purposes together with Fort-Fordyce and Mpofu nature reserves along the Blinkwater.

Fort-Beaufort is the main town that is found in the middle reaches of the study area with a population of about 25000 (Motteux, 1999). The town is located at crossroads between Alice, Queenstown, Grahamstown and Cradock. Most of the citrus produced in the area is headed for the lucrative European Union markets (McMaster, 2002). This is however a great challenge as highlighted by one of the Riverside farmers who was quoted saying, “foreign consumers are becoming more picky about conditions under which the fruit they buy is grown….These concerns govern the value of one’s product and it is our wish to meet these concerns” (Kat River Valley Project Newsletter, 1999). Both need to uphold high standards for them to benefit from selling their citrus in the overseas retail markets. High salinity waters might put demise to this trade.

2.4.3 Lower reaches

Most land in the bottom terraces of the valley is utilized for citrus farming at Drummond, Klu-Klu and the Bath farm. These farms are part of the broader KATCO within the catchment. River flow in the lower reaches is considerably reduced; hence the scale of citrus irrigation farming is limited. Fewer people and villages inhabit this part of the catchment. There are therefore long stretches for water quality recovery, between farms. One notable land use is the game reserve at the Kat-Fish confluence. The Sam Knott and the Double Drift nature reserves are on opposite sites of the river before it joins the Fish River. There is evidence of historical irrigation activities through abandoned fields and water quality monitoring points in Sam Knott game reserve. The proximity of the conservation area may provide future opportunities for tourism.

2.5 Current Water Quality Management

It is evident that the Kat River catchment has a broad array of stakeholder groups ranging from rural communities, emerging farmers, service centers, citrus farmers and game reserves. Despite this diversity and the associated range of needs, the key groups were motivated to form two water bodies the Catchment Forum (CF) and the Water Users Association (WUA) (Motteux, 2001). Formation of the two bodies came as a result of the Kat River Valley Project (KRVP), which began in 1996 when work was conducted in the upper catchment villages of Hertzog and Fairbain (Motteux, 2001). This work focused on raising awareness and capacity building on water resources management at a local scale. The willingness of the local community to become part of a broader water management structure within the catchment three years later resulted in a Water Research Commission (WRC) project led by Prof. Kate Rowntree from the Geography Department at Rhodes University. The project focused on facilitating the effective participation of Hertzog and Fairbain and other communities in both the transformation of the then Kat River Irrigation Board to into the Kat River Users Association and the development of a CF in which broader issues relating to catchment management could be tackled. The existence of WUA and CF in the area provide a good platform for water management issues to be resolved by concerned parties.

The Rhodes University Geography Department has conducted a number of studies in relation to water quality in the catchment. One of the first studies to be conducted was by Hill *et al*. (2000), which was aimed at assessing the suitability of river water for domestic use as many communities draw water directly from the river. The study was mainly confined to Fairbain and Hertzog areas. Another recent master’s degree study that aimed at assessing land use impacts on the river water quality, specifically instream detergent use, followed (Soviti, 2002). Almost the same physical and chemical parameters were measured in both studies, although Soviti (2002) covered a wider area and also took flow measurements. Salinity levels in both studies were generally low in this part of the catchment. This is in agreement with an assessment carried out by Hill, Kaplan and Scott (1990) who concluded that water in the upper catchment is generally of low salinity. However the area covered by the two studies was confined to parts of the upper catchment and no assessments were done on the rest of the catchment. The same can be said about the KATCO monitoring schedule, which is only concentrated around commercial citrus farms in the middle and lower reaches (Katco, 1990). Additional salinity data in the catchment can be sourced from the Department of Water Affairs and Forestry (DWAF), which are monitored at four different water quality monitoring points. Other studies that were carried out in the catchment include a river health assessment carried out during the KRVP (Kat River Valley Project) (Everitt, 1999). Unfortunately historical salinity records collected by KATCO were discarded shortly before this study began, which highlight the value of co-ordinated data management at a catchment scale.

The baseline salinity in the Kat river catchment may be naturally high because of the geology and the climate, but anthropogenic impacts such as waste disposal and irrigation may exacerbate the problem. As already highlighted in Chapter 1, it is not only of concern to major uses such as irrigation, but also to aquatic ecosystem structure and function. There has however been a lack of landscape salinity assessment and its potential impact on the aquatic ecosystem.

CHAPTER 3: SOURCES AND NATURE OF SALINISATION IN THE KAT RIVER VALLEY

3.1 Introduction

As already discussed in the previous chapter, the greater part of the Kat River catchment is underlain by sandstones, mudstones and shales of the Karoo sequence. Both shales and mudstones have a naturally high salt content and have in the past been associated with high river salinities (Greeff, 1994 and Woodford and Chevallier, 2002). The catchment is characterised by a semi-arid climate in the middle and lower reaches where rainfall is highly variable with a seasonal distribution that favours Summer. As evaporation exceeds precipitation throughout most of the year, leaching of salts is likely to be limited and soluble salts will accumulate near the soil surface. During heavy rainfall, the resultant runoff and percolation periodically flush these salts into the river (Hughes and Moolman, 1986). These natural conditions are therefore conducive to high salinity levels of the Kat River system. Moreover, the intense citrus irrigation that is practised mainly in the middle and lower reaches are suspected to exacerbate the problem, making the river even more vulnerable to salinisation. The Fort Beaufort sewage works outfall was identified as another possible source of river salinity.

According to KATCO (1990), salinities of up to 1200mg/L have in the past been recorded in the Kat River catchment. These are considered undesirable for the citrus farming industry, which is the main thrust to the economy in the area (El-Ashry *et al.*, 1985). More importantly literature has proven that these salinity levels can be a threat to the aquatic ecosystem as a whole and needs attention (chapter 1). Salinity has been identified as an abiotic driver of ecological condition (Hart *et al.*, 1991; Bunn and Davies, 1992 and Loewethal, 1995). Previous investigations on the Kat River catchment water quality were mainly restricted to the upper catchment and did not cover the possible negative impacts of salinisation on the aquatic ecosystem (Everitt, 1999; Hill *et al.*, 2000 and Soviti, 2002). There is therefore lack of broad scale detailed salinity assessment and its impacts on the aquatic ecosystem in the Kat River catchment. This chapter presents a detailed account on the landscape salinity assessment in the Kat River catchment. The salinity template was assessed at different scales (from sites, reaches and tributaries), which is the best way to allow for a link between salinity and biota.

Firstly, EC and flow measurements and associated loads were used to link salinity and land use patterns within the catchment. Secondly, DWAF salinity records comprising of EC, TDS and some major ions were used to determine both the temporal and spatial patterns at different water quality monitoring points. Lastly, major ion records from the DWAF water quality monitoring sites were applied to the Toxicologically Important Major Salts (TIMS) salt model, which was used to enable a link between the ionic data and the toxicity of salts to the aquatic ecosystem. The preceding section gives a brief account on the methodology chosen in relating salinity and land use in the study.

Based on observations made on the land use patterns, there are no main salinity point sources besides the Fort Beaufort sewage treatment works (Figure 2.5). This implies that the nature of salinisation in the Kat River catchment may be mostly of non-point source pollution in nature. That is it is a result of land use activities that result in the mobilisation of salts that are not discrete (Pegram and Görgens, 2001). The only notable point source of salinity may be the Fort Beaufort Sewage Treatment Works because treated sewage is discharged directly into the river. There are several techniques that can be applied in order to identify possible sources depending on the required level of accuracy. A range of techniques are listed in Pegram and Görgens (2001). Only a few techniques that are relevant are highlighted here. The most basic approach is that of knowledge base, where sources of water quality concern are borne from expert opinion (Pegram and Görgens, 2001). This approach needs to be supported with some quantitative data. Other methods include potential hazard maps, and unit loading (export coefficients) that are empirically derived values from a range of land uses, such that the load per unit area is estimated (Quibell *et al.*, 2003). Although this approach has been applied widely in South Africa, there is a great discrepancy between coefficients and this hampers the applicability of the approach (Pegram and Görgens, 2001).

In addition to these, there are complex models that may be used to project pathways of salts and their fate (Malan and Day, 2002a). The set back with complicated models is that they require high data inputs, which are usually lacking in most instances (Herold *et al.*, 2001). Furthermore, they do not give a guarantee that their solution is more accurate than other approaches as described by Pegram and Görgens (2001). However there are cases where this approach has been implemented with reasonable success

(Quibell *et al*., 2003). The simplest techniques are still preferred, especially where they are able to provide the required information (Herold *et al*., 2001).

Conventional methods of monitoring diffuse source loads warrants for continuous flow gauging in conjunction with high frequency water sampling (Herold *et al*., 2001). This approach is both expensive and requires technical competence to maintain equipment and process large volumes of data. The field equipment is also vulnerable to vandalism (Herold and van Eeden, 2000). Moreover the constraints imposed by locating suitable flow-gauging stations often prevent the optimal selection of monitoring sites. These factors have tended to limit research to a few small site-specific study catchments. A large number of monitoring stations would be required to derive any relationships between land use and salinity (Herold and van Eeden, 2000). These have raised a need for simplified approaches to be developed in computing salt loads. Salt loads can be related to sources of salts (where the most salt originates) whereas concentration (salinity) is a direct measure of water quality. Natural decay in the delivery system between the land use in question and the point of monitoring reduces the accuracy with which non-point sources loads can be estimated (Pegram and Görgens, 2001). However this is not an apparent problem for conservative water quality components such as salts (Malan and Day, 2002a). In this research, a simple salt mass balance approach was selected to evaluate possible sources of salinity at different monitoring sites (Berndtsson, 1990; Jain, 1996 and Jain *et al*., 1998 and 2000). A mass balance approach is deemed useful where dynamic and highly variable relationships between physical and chemical mechanisms on a larger scale within a given reach need to be understood (Berndtsson, 1990).

3.2 Methods

3.2.1 Site selection

A number of sites were selected for the measurement of monthly flow and salinity, to allow salt loads to be calculated from different parts of the catchment and from tributaries. This was aimed at an assessment of both the salinity profile along the main river course, and loads from the tributaries using data collected during the study and supplementary data from DWAF water quality monitoring sites. In catchment management, salt loads are always important in describing salt dynamics. The load is the amount of salt that passes a specific point/cross-section in a river per unit time, and is measured, by computing the product of flow and salt concentration (TDS) (Herold *et al.*, 2001). The use of salt concentration alone may be misleading, as large rivers may be have lower concentrations, which are not necessarily related to low salt loads (Jain, 1996). However organisms will respond physiologically to the experienced salt concentrations not loads.

The approach adopted in site selection was largely guided by land use. There are only four water quality monitoring points in the catchment, which are not necessarily located at ideal sites to simulate salt loads from the mosaic of land use practices. The main selection criterion was coverage of a range of salinising land uses. These included:

- Upstream and/or downstream of citrus orchards.
- Upstream and downstream of tributaries
- Downstream sewage treatment works and urban activities.
- At least one site was per river reach.

Following a desktop study and an examination of sites, nine sites were selected for monthly salinity monitoring. The number was later extended to ten by inclusion of a site around citrus orchards in the middle reaches. The sites also covered a range of climatic and geographic regions within the catchment. Salinity levels in the Lushington and the Elands streams were found to be very low in earlier surveys. They were therefore considered not to have a big impact on the salt dynamics of the catchment. A brief description of the ten monitoring sites is given below. It should be highlighted here that these sites were also part of a wider seasonal catchment biomonitoring programme (chapter 4). The locations of different salinity monitoring sites are shown in Figure 3.1 and the corresponding biomonitoring site numbers are highlighted in brackets to avoid confusion. The four DWAF water quality monitoring sites where salinity and flow data were sourced for additional salt loads computations are also shown in the same figure.

Site 1: Fairbain (32º 32’ 21.8” S, 26º 42’ 30.6” E)

This site was located on the lower Fairbain stream (Figure 3.1) a few hundred metres before it joined the Kat. The upper sub-catchment was mainly subsistence farming and small rural villages. The monitoring site was on a straight stretch of a river before it curved and joined the Kat River. There is evident erosion on both river banks; probably due to poor land management practices. The geology is mostly shales and mudstones as is the case with the majority of sites. There are no DWAF water quality monitoring sites on the stream and it was selected on the basis that it would reflect the upper Fairbain salt contribution into the Kat River system (plate 7 in Appendix B).

Site 2: Kat upstream of Upsher (32º 33’ 20.5” S, 26º 41’ 22.7” E)

This site is located on the Kat River downstream of the confluence with the Fairbain stream and is on the same geological setting as the previous site. It is downstream of old settlements such as Tambloesvlei, Hertzog and Fairbain and upstream of Balfour river (Figure 3.1). Downstream of the confluence there is some vegetable irrigation from HACOP members. The flow here was considerably higher than site1 probably due to water released from the Kat River dam. The bed mainly consists of sand and cobbles at intervals. Selection of this site was motivated by the fact that it would show salt loads from the upper catchment and HACOP activities. The picture of the site is shown in plate 10, Appendix B.

Site 3: Kat @ Upsher (32º 35’ 39.4” S, 26º 40’ 43.7” E)

Site 3 is located downstream of the confluence with the Balfour River. There is some citrus farming in Upsher and a number of abandoned fields just upstream of the site. The geology is mainly shales and mudstones. A series of water quality monitoring points upstream of the site were used for impounding water for irrigation. The riverbed is a largely sand with occasional cobbles at intervals. Salt loads at this site may have accounted for salinisation from the upstream citrus irrigation together with contributions from the Balfour stream (Figure 3.1) (plate 16, Appendix B). The latter was determined by calculating salt loads at the Balfour water quality monitoring point.

Site 4: Kat @ Tidbury’s Toll (32º 39’ 2.0” S, 26º 39’ 8.0” E)

The site is located downstream of a number of rural communities along the river (Figure 3.1). The higher ground is mainly shales and mudstones whilst the riverbanks are characterised by alluvial deposits. With regards to salinity, more important land use is that of citrus irrigation in the former ULIMCOR farm. The riverbed is mainly sand, although a few cobbles can be found downstream of the road crossing. The flow at this site is characterised by pools and it branches into two channels downstream of the road bridge. From there the water joins in a pool downstream of a bar. This site was considered for monitoring to represent salinisation from the upstream citrus farms (plate 19, Appendix B).

Site 5: Kat @ Gonzana (32º 41’ 30” S, 26º 36’ 46.4” E)

This site is in the same reach with Tidbury’s Toll but was later included in the monitoring scheme in order to evaluate salt loads between sites 4 and 5 (Figure 3.1). The site is situated in the same geological setting to site 4 above. Although there is some citrus irrigation a few hundred metres upstream this is of minimal extent when compared to site 4. Here the riverbed is mostly made up of large rounded cobbles. The site is also on a river crossing and there is a water quality monitoring point upstream. As the river flows over a water quality monitoring point, it drops into a large pool before flowing over the cobbles (plate 20, Appendix B).

Site 6: Kat @ Blinkwater confluence (32º 42’ 56.8” S, 26º 35’ 17” E)

Site 6 is located downstream of the Kat and Blinkwater Rivers confluence (Figure 3.1). The most predominant geology features at the site are the large dolerite boulders on which the river flows. Flow at this site is reduced considerably compared to site 5. There is a water quality monitoring point just downstream of the confluence, which may be the main reason for the marked reduction in flow due to abstraction. Some citrus orchards are found on the lower Blinkwater hence some salinity impacts may be anticipated. Fortunately there is a DWAF monitoring water quality monitoring point on the stream that can be used to evaluate salinity on the Blinkwater. However there is some citrus irrigation downstream of this water quality monitoring point, hence salinity impacts are not catered for. The site was selected to evaluate salinity impacts from the Blinkwater and other upstream impacts. It was also the last site upstream of KATCO farms and Fort-Beaufort town. The photograph of the site is given in Appendix B (plate 21).

Site 7: Kat River @ Fort Beaufort (32º 47’ 10.6” S, 26º 39’ 3.0” E)

This monitoring point is located downstream of Fort Beaufort town (Figure 3.1). It is directly downstream of the town’s sewage treatment works. The geology at this site is mainly alluvial deposits bordering the river. There is a DWAF monitoring site about a kilometre upstream of this site (Figure 3.1). Reasoning behind the selection of the site was that it would be representative of salt loads from the sewage treatment works and the town. The riverbed is mostly small cobbles and some sand. Erosion is visible particularly on the right bank (plate 29, Appendix B).

Site 8: Kat @ Bath farm (32º 50’ 20.7” S, 26º 40’ 17.8” E)

This site is located downstream of the Winterberg Agricultural school and some citrus farms affiliated to KATCO (Figure 3.1). The geology at site 8 can be described as mainly shales and mudstones. Flow here is sometimes minimal as downstream citrus farmers suck water through pipes to sustain flow to their lower citrus plantations. This site is on private property and the site was the only one in this river reach. Motivation for selecting this site was that it represents salt loads that maybe attributed to Winterberg Agricultural College and citrus irrigation downstream of Fort Beaufort town (plate 30, Appendix B).

Site 9: Kat @ Howrse’s Post (32º 53’ 26.2” S, 26º 41’ 3.8” E)

Located further downstream of the previous site, this site is surrounded by dryland farming and stock farming of goats, sheep and cattle. However there is some citrus farming upstream of the water quality monitoring point (Figure 3.1). The site shares the same geological attributes to site 8. There is a straight stretch that was suitable for flow measurements. The site is displayed in plate 31, Appendix B.

Site 10: Kat River @ Sam Knott Game Reserve (32º 58’ 7” S, 26º 45’ 0” E)

Site 10 is the last site selected for monitoring salt loads in this study. The site was an obvious choice because it represented salt loads from the whole catchment area that is discharged into the Fish River. It is located in the Sam Knott Game Reserve and is the last site before the confluence of the Kat the Great Fish River. Here the river channel had widened extensively compared with the previous site. There is not much irrigation between the last two sites. Abandoned fields are the only evidence that there was once some agricultural activity around the site.

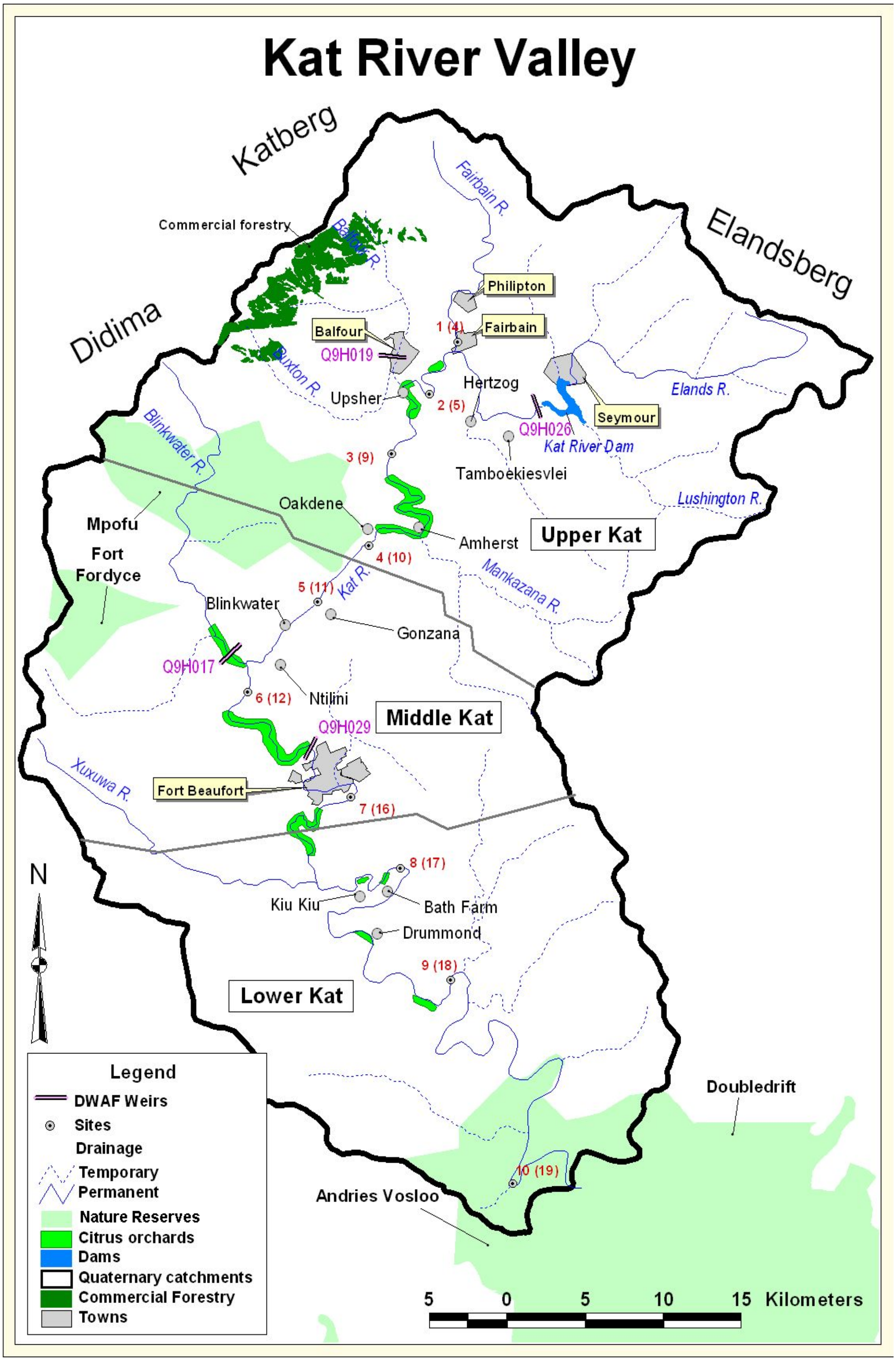


Figure 3.1: Monthly salinity monitoring sites and DWAF water quality monitoring stations in the Kat River Valley. The numbers in brackets signify corresponding biomonitoring site numbers.

There are large boulders found downstream of the road crossing bridge, before the river divides into two channels. A few tens of metres downstream these join into one channel (plate 32, Appendix B).

3.2.2 Salt loads

In this study salinity and flow measurement were monitored monthly at selected sites between July, 2003 and June, 2004 to compute salt loads. In addition salt loads were calculated from the Balfour, Blinkwater and Fort Beaufort water quality monitoring points from salinity and matching daily mean flows over the same period. However no salt loads could be calculated from the Kat dam water quality monitoring point because of lack of salinity data over the above-mentioned period.

Salt mass balance has been used with some success to predict the effect of upstream catchment land use on salinity (Jain, 1998). It is more advantageous to select salt load monitoring sites based solely on land use, rather than on constraints imposed by the availability of suitable gauging water quality monitoring points. The following equation was used to calculate salt loads at different monitoring sites (Verhoff *et a*l., 1982).

$$\text{Salt load (Kg/S)} = [\text{TDS (mg/L)} * \text{Q (m}^3\text{/S)} * 1000 \text{ L/m}^3] / 1\text{x } 10^6 \text{ mg/Kg}$$

In the following section the criteria and description of individual salinity monitoring sites are highlighted. The subsequent sections give an account on how salinity (section 3.2.3) and flow measurements (section 3.2.4) were taken at different monitoring sites.

3.2.3 Salinity Measurements

In most cases EC and TDS are used as surrogates of salinity especially where dissolved organic matter levels are low compared to inorganic components (Day, 1990). There are several methods that can be employed to measure the total dissolved salts in a water sample. One method is that of titration of chlorinity (chloride) and calculation of salinity based on the assumption that the composition of ions is the same as that of seawater.

Although known to have low error estimates (2.5%) between salinity and TDS, titration is time consuming (Day, 1990). Other methods that can be used in salinity

measurements are those of hydrometers and refractometers (Bergstrom, 1997). Of all water properties used in measuring the water salinity, the most widespread use is that of measuring its electrical conductivity (Day, 1990). The more charged the particles in water, the greater their ability to conduct an electrical current. This then presents a good measure of the salt content in water. However this ability is dependent on temperature.
Handheld conductivity meters are widely used in the field today because they are relatively cheap and portable (Day, 1990). Most of these devices are able to take measurements with temperature corrections. For water with the same ionic composition, the relationship between electrical conductivity and TDS is well defined. In most South African streams a conversion factor of 6.5 can be used in converting electrical conductivity to TDS (DWAF, 1996a).

$$\text{TDS (mg/L)} = \text{EC (mS/m) @ } 25^{\circ}\text{C} * 6.5$$

In this study a Cyberscan hand held Electrical Conductivity meter was used to measure salinity. The meter’s probe was immersed in flowing river water for about a minute or until the reading on the meter stabilised. At the same time care was taken to prevent the probe from hitting against rocks. After every measurement the probe was rinsed off with deionised water so that the next measurement was not affected by the previous. The electrical conductivity was then converted to TDS using the above-mentioned relationship.

3.2.4 Discharge measurements

To measure the flow at different sites, either a water quality monitoring point is installed or it is calculated from water velocities and cross-sectional area (Brassington, 1990 and Gordon *et al*. 1992). Although water quality considerations should take flow into account often, positions of water quality monitoring points are not always ideal for water quality investigations (Herold *et al*., 2001). Other ways of measuring flow have been used, where there are no water quality monitoring points installed. In this study, velocity-area method was used (Gordon *et al*. 1992).

At all the sites, a straight stretch of the river with a fairly constant depth was selected for taking flow measurements (Brassington, 1990). A cup rotor flow meter was used to measure the water velocity at a specific point. This device consists of a propeller that rotates in proportion to the velocity of river flow (Figure 3.2). The propeller is mounted on a graduated pole in inches that allows for the water depth to be determined. Rotating cups of the flow meter were placed at approximately 0.6 of the depth (Shaw, 1994). Theoretically this has been proven to be a depth at which average flow velocities can be taken (Shaw, 1994).

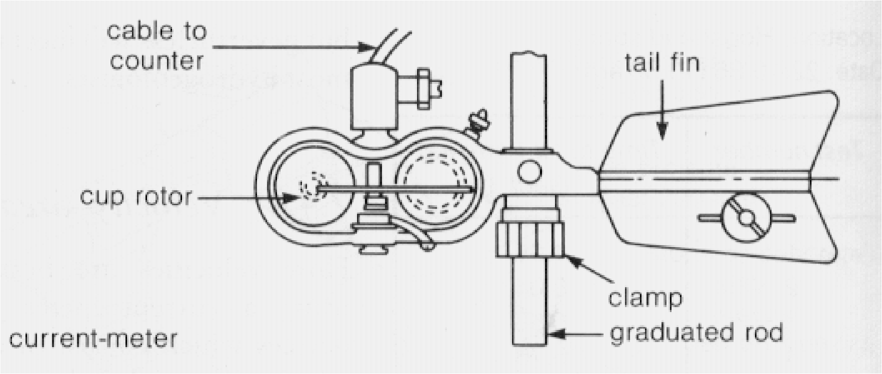


Figure 3.2: Showing a cup rotor current meter used in flow measurements (adapted from Brassington, 1990).

Firstly, a measuring tape was stretched across a river normal to the direction of flow (Figure 3.3). This was used to identify stations at which to take velocity measurements.

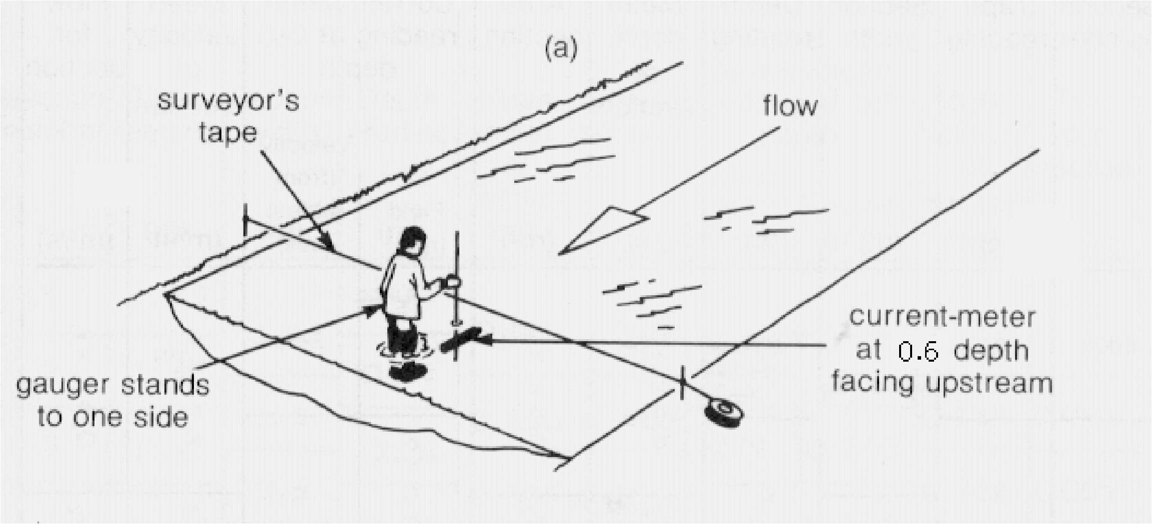


Figure 3.3: Measuring flow through the velocity area method (adapted from Brassington, 1990)

A regular interval of 0.5 metres was selected in this case so that there were between 10 and 20 intervals (Brassington, 1990), at all sites to ensure that less than 10% of the total flow was accounted for by each segment (Shaw, 1994).

3.2.5 Trends in EC and ions

All existing salinity records in the catchment were collated so as to make an assessment of trends that may be discernable. Unfortunately, EC and TDS data that had been collected by KATCO over a period of twenty years was lost by the cooperation shortly before this project began. This meant that the only source of long-term data that could be accessed and used in the study is that from DWAF. The Department has four water quality monitoring points where EC has been measured over varying periods. The Kat Dam water quality monitoring point (Q9H026) is located downstream of Seymour, and downstream of the Kat Dam (Figure 3.1). The second water quality monitoring site (Q9H029) along the Kat River is situated upstream of Fort Beaufort town (Figure 3.1). There is citrus irrigation farming from both KATCO and Riverside estate upstream that may be contributing salinity due to irrigation return flows. The other two water quality monitoring points are located on the Balfour (Q9H019) and Blinkwater (Q9H017) tributaries (Figure 3.1). Although there are no irrigation practices along the Balfour River, high salinities may be apparent from the local geology, dissolution of fertilizers and run off from the degraded landscape (Chourasia and Tellam, 1992). The Blinkwater water quality monitoring point is located downstream of citrus irrigation farming that may influence river salinity. Both scatter plots and box and whisker plots were used in STATISTICA software for individual water quality monitoring points for EC, sodium, potassium, calcium, magnesium, chloride and sulphate.

3.3 TIMS MODEL

3.3.1 The concept

The Toxicologically Important Major Salts (TIMS) model estimates salt concentrations from ion concentration data (Jooste and Rossouw, 2002). It was developed as a tool for water quality specialists for ecological Reserve determinations in the country. The underlying philosophy is that although salts are essential for different metabolism for biota, at high concentrations they are toxic (Kefford *et al.*, 2002). Moreover, different salts have been found to be differentially toxic (Goetsch and Palmer, 1997; Mount *et al.*, 1997 and Jooste and Rossouw, 2002). It is however acknowledged that the toxicity of salts is ascribed to its ions (Jooste and Rossouw, 2002). Data in this regard is lacking so that individual salt toxicity is measured instead of ions. When relating ecosystem integrity to salinity, the preferred method is to assess the potential toxicity of reconstituted salts from ionic concentrations (routinely recorded in the DWAF water quality monitoring programme). This is achieved through applying the TIMS model (Jooste and Rossouw, 2002) which is readily available on the DWAF website at http://www.dwaf.gov.za/iwqs/iwqso/ecorivereserve.htm.

The TIMS model is based on an assessment of the hazard different salts (previously identified as important) posed to the aquatic ecosystem. The toxicity data (salts and other toxics) used was extracted from the ECOTOX database (USEPA, 2002) as it was considered the most extensive and accessible. It included fish, macroinvertebrates, invertebrates and plants toxicity data to ensure realism of the natural aquatic ecosystem (Jooste and Rossouw, 2002). The only toxicity data extracted was one with fresh water as a medium, reliable laboratory results and all end-points (mortality, immobilisation, behaviour, population etc) (Jooste and Rossouw, 2002). The data was further refined by omission of experiments with insufficient control data and calculating the geometric of end-point concentrations for identical records. In order to allow for comparisons, LC_{50} (concentration at which half of the population dies) were all projected from 48 hours tests to 2 weeks. An exponential model used in the projections because generally LC_{50}'s decrease with increasing exposure time until a state where the concentration of a substance in the water and in the organism is in a steady state (Jooste and Rossouw, 2002).

Lethality and sub-lethality benchmarks for reach salt were then determined. The former was set as the 5th percentile of the projected $LC_{50.}$ On the other hand, the latter was set as the 5th percentile of all available sub-lethal data (Jooste and Rossouw, 2002). Boundary values for each salt were determined based on an approach by Aldenberg and Slob (1993) where the distribution of tolerance data is assessed to protect a specific percentage of biota in the aquatic ecosystem. Either the acute (short-term) is used as a measure of mortality or chronic (long-term) as some form of sub-lethal measure is used. The Natural boundary values are based on international CEV (Chronic Effects Value) data extrapolated from protection of 95 percent of the species. On the contrary, the Fair boundary was set based on the international AEV (Acute Effects Value) data.

In this class none of the species would be acutely affected. Lastly the Good boundary was linearly extrapolated between the Natural and the Fair boundary values. As already explained in chapter 1, the importance of this classification in aquatic ecosystem management cannot be over-emphasized. It acts as a decision making tools for the resource managers to make informed decisions as highlighted in the first chapter. In the subsequent sections, a detailed account on how the TIMS model was used in assigning major salts ecological classes ("Natural", "Good" and "Fair") is provided.

3.3.2 Data cleaning

The water quality (ionic) data that were used in the TIMS model were obtained from the DWAF database. In the Kat River catchment there are four water quality monitoring points (section 3.2.5). The data utilised in this research comprised varying durations and gaps. The Kat dam water quality monitoring site has ionic data from 10/28/77 to 1/12/2001 and from 12/29/1992 and 4/5/2004 at the Fort Beaufort water quality monitoring point. Water quality records on the Balfour and Blinkwater water quality monitoring points dated from 9/15/1972 and 5/18/2004 and 8/30/1971 and 2/23/2004 respectively. The files were downloaded into the excel spreadsheet to allow for manipulation and compatibility with the TIMS model. These original files had numerous attributes that are not required to run the TIMS model. All descriptive columns besides those of date and water quality monitoring point number were removed together with all physical water quality components. Data describing the date and water quality monitoring point code were deleted and those of major ions of salts that are considered toxicologically important, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-} were retained. All ionic records that had at least one or more concentrations missing were deleted from the data set; in order to run the TIMS model all the ions need to have been determined. The DWAF water quality data occasionally had some values that were below detection limits (denoted by <). In such cases, half the detection limit value was used as the measured concentration. Statistical motivation for this is that half of the time the measured concentrations could be above the detection limit whilst half the time it may be above this value (Muller, Senior Researcher Institute for Water Research, Rhodes University, *per comm.*, 2004).

Once the data were manipulated as described above, the TIMS model was run, creating a corresponding output file in text format. This output file was then exported into an Excel spreadsheet. It is important to note that the output file produces salt concentrations in molarity (mMoles/litre). In order to obtain salt concentrations in milligrams per litre each concentration was multiplied by the formula mass of that particular salt (Jooste and Rossouw, 2002) and a final out put file of salt concentrations (mg/L) was then produced.

3.3.3 Determination of salt Reference Conditions and Present Ecological State

In order to relate salt concentration to the classification of ecosystem condition (Figure 1.1), it is important to determine both the Reference Conditions (RC) and Present Ecological State (PES) in terms of the ‘virtual’ salts modelled by TIMS. RC provides benchmarks against which PES for each salt are compared, in order to make a decision on whether or not there has been an impact. Both the RC and PES are defined between specific water quality sub-units. This are stretches of the river with perceived “homogeneous” water quality (Palmer *et al*., 2004a). The Blinkwater and Balfour water quality monitoring points were used to define water quality sub-units at the Balfour and Blinkwater streams respectively, whilst the Kat Dam and Fort Beaufort water quality monitoring points were used to define conditions on the Kat River.

Reference Conditions

Reference Conditions are usually derived from sites that are known to have minimal anthropogenic salt impacts or pre-impact data. Ideally, RC for the Kat River would not be adequately defined by both the Kat Dam and Fort Beaufort water quality monitoring points data because of the dam and land use impacts around Fort Beaufort respectively. However, since all sites in the catchment are already impacted, earliest records best define them. This has been used in other studies to define RC (e.g. Malan and Day, 2002b, used data from the mid 1990s to define RC in the Olifants since it was the best available). Reference conditions were established by calculating the 95th percentile for the first three years of the TIMS derived salt records (Jooste and Rossouw, 2002). TIMS salts used were from 1977 to 1980 for the Kat Dam, Balfour and Blinkwater water quality monitoring points and 1993 to 1995 for the Fort Beaufort water quality monitoring point for RC.

All data were checked for conformity with conditions for high confidence assessements (Jooste and Rossouw, 2002). The following criteria had to be satisfied:

1) For high-confidence reference condition determination, a minimum of 60 data points over a three-year period were used extending over wet and dry seasons.
2) 95th percentiles for the first three years of the earliest record were compared to default boundaries proposed by Jooste and Rossouw (2002) (Table 3.2). This represents the hazard posed by the salts to the aquatic ecosystem.
3) If the 95th percentile values were higher than the natural benchmark, values were adjusted by:
    (i) The 95th percentiles were assigned as new Natural boundary.
    (ii) The good boundary was moved by half the amount by which the natural boundary was changed [calibrated Good boundary = (Fair-calibrated Natural) x 0.5 + calibrated Natural)] (Palmer *et al.*, 2004b).

Present Ecological State

1) The PES indicates the current state that can then be compared to RC and provides for ecological classes to be determined. These ecological classes are dependent on the departure from the RC and are directly linked to management initiatives (chapter 1). The most recent one to three year records were taken to represent present ecological state conditions at the four water quality monitoring points (Jooste and Rossouw, 2002)

Table 3.1 Default boundaries for major inorganic salts (Jooste and Rossouw, 2002)

Salt	Natural (mg/L)	Good (mg/L)	Poor (mg/L)
MgSO4	16	27	37
Na2SO4	20	36	51
MgCl2	15	33	51
CaCl2	21	63	105
NaCl	45	217	389
CaSO4	351	773	1195

PES conditions were determined from 2001 to 2004 for the Balfour, Blinkwater and the Fort Beaufort water quality monitoring point. For the Kat dam water quality monitoring point TIMS data between 1999 to 2001 was used in determining PES.

2) 95th percentiles were calculated from all the reconstituted salts.
   These values were compared to benchmarks in Table 3.1 where no adjustments were made. Where there were adjustments, new benchmarks were used to assign categories (“Natural”, “Good”, “Fair” or “Poor”).

3.3.4 Confidence assessment

It is important to assess the confidence of the data for the PES (Jooste and Rossouw, 2003). Confidences in each dataset were calculated using the G Power freeware program, version 2 (Faul and Erdfelder, 1992) available at the following website; http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/. This software makes use of the mean, standard deviation and the number of data points to calculate the power in a data set. Confidence in a data set was classified as: power above 0.8 is regarded as high confidence, medium confidence between 0.6 and 0.8, and less than 0.6 low confidences (Jooste and Rossouw, 2003).

3.4 NaCl Concentration profiles

For many rivers, discharge varies significantly from season to season and this can have a profound influence on the salt concentration (Malan and Day, 2002a). The salt concentration is usually low during high discharge and vice versa during low flows due to dilution effects (Parsons, 2003). These relationships are, however, not always simple in agricultural catchments, largely due to salt wash off from the surrounding lands following heavy rains (Malan and Day, 2002a). They are also site-specific and cannot be extrapolated to other sites. Unfortunately, there are presently no complex models in place to relate changing salt concentrations to river flow in South Africa (Sherman *et al.*, 2003). However, in cases where such relationships hold, simple flow-concentration can be utilised to estimate the implication of the varying flow on the salt concentrations, hence the effect on the aquatic ecosystem (Malan and Day, 2003).

Salt concentrations reconstituted from individual major ions in section 3.3 above only show the potential negative impact to the aquatic ecosystem at specific sampling moments. Flow-concentration relationships were therefore determined for each of the water quality monitoring points to estimate salt concentrations that are likely to have occurred in the aquatic ecosystem under different flow conditions. According to section 3.3 above, sodium chloride is one of the most likely salts to be encountered by the biota. Secondly there is some salinity tolerance data on sodium chloride for selected indigenous macroinvertebrates from the Kat River. Relationships between flow and salt concentrations were therefore only considered with respect to sodium chloride. Firstly only mean daily flows that had corresponding salt concentrations were extracted from the entire record (conventional practice in hydrology). Instead of using all data points, mean daily flows and median salt concentrations were used to derive flow concentration relationships. Motivation for this is that for a particular flow, there were several sodium chloride concentrations, with single extreme events significantly altering the mean. It therefore statistically correct to use median salt concentrations over mean values (Malan and Day, 2002b). In addition, this approach had been applied in the Breede and the Olifants Rivers and offered an opportunity for comparisons to be made (Malan and Day, 2002b). The median monthly salt concentration and the mean monthly flows were therefore plotted in Excel and the relationship explored by determining the correlation coefficient (r^2). The power, exponential and linear expressions were fitted to the individual graphs, and the highest correlation identified as the best fit. The resultant relationships and the mean daily flows were then employed to extrapolate sodium chloride concentrations at different water quality monitoring points using T-SOFT (Hughes *et al.*, 2000). The sodium chloride time series generated from concentration-flow relationships and flow records in T-SOFT (Hughes *et al.*, 2000). This software ensures easy visualisation and analysis of cumbersome hydrological data. Sodium chloride concentrations were derived using the entire flow records, which varied for the Balfour and Blinkwater tributaries.

3.5 Frequency of occurrence of NaCl concentrations

The analysis in section 3.4 above was done in order to compare different flow scenarios with regard to the different sodium chloride concentrations in the aquatic ecosystem. There is however a shift from assessing salinity hazards towards risk based approaches worldwide Jooste *et al.*, (2000). This does not only present concentrations but their likelihood of occurring and implications to the aquatic ecosystem (Malan and Day, 2002b). In other words, not only the potential negative impacts are implicated but also the likelihood (frequency and duration) of that hazard occurring. Sodium chloride concentration time series were therefore transformed to concentration duration curves using T-SOFT. This then facilitated essential data for the evaluation of different scenarios that comprise of the risk posed by sodium chloride on each water quality sub-unit. That is, the percentage time that sodium chloride concentration equalled or exceeded specific concentrations. The approach employed in this study is similar to the one employed in the Olifants ecological Reserve determination (DWAF, 2000). Similar studies have also been carried out in the Pienaars, palmiet and Breede rivers (Malan and Day, 2002).

3.6 Results

The following section presents monthly salinity monitoring results from July 2003 to June 2004. Total dissolved salts, flow and salt loads are presented with reference to their spatial and temporal variations. Box and whisker plots for the three measurements were plotted in STATISTICA version 5 to interrogate the salinisation question in the catchment further. This is followed by the presentation the spatial and temporal trends of major ions at different DWAF water quality monitoring sites.

3.6.1 Monthly Salinity Monitoring

EC and TDS trends

The TDS (hence EC) is important in assessing the likely impact of salinity on the aquatic ecosystem although a further data analysis on the ion chemistry may be more important (Palmer *et al*., 2004b). The TDS profile during the monthly monitoring between July 2003 and June 2004 is presented in Figure 3.4. BF, BK and FB represents salinity levels at the Balfour, Blinkwater and Fort Beaufort water quality monitoring points respectively. Salinity results here are presented as Total Dissolved Solids (TDS), which is a good estimation of dissolved salts in a water sample as stated in the first chapter.

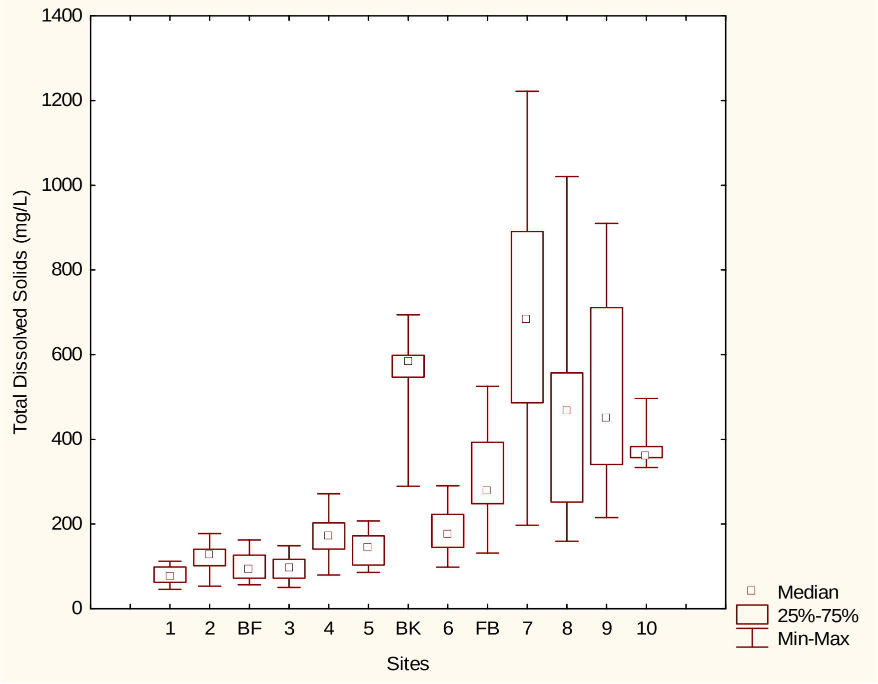


Figure 3.4: Showing Total Dissolved Solids TDS (mg/L) during monthly salinity monitoring from July 2003 to June 2004 (BF-Balfour water quality monitoring point, BK-Blinkwater water quality monitoring point and FB-Fort Beaufort water quality monitoring point)

From the results it would appear that salinity levels along the Kat River stem could categorically be divided into two distinct salinity areas; sites 1, 2, 3, 4, 5 and the Balfour water quality monitoring point recorded salinities below 250mg/L over the monitoring period (Figure 3.4). The second salinity area extends from the Blinkwater water quality monitoring point, to downstream sites, where salinity levels were above 250 mg/L (Figure 3.4). The lowest salinities were recorded at site 1 with the least variation (Figure 3.4). This is comparable with Soviti (2002) where he noted the same result. Salinity at the Blinkwater water quality monitoring point varied between 300 and 700 mg/L from July 2003 to June 2004 (Figure 3.4). This seemed to have little influence on the salinity levels in the Kat River as a result of the low flows in the Blinkwater stream. There was a notable increase in salinity levels from site 6, Fort Beaufort water quality monitoring point and site 7. Salinity increases between site 6 and the Fort Beaufort water quality monitoring point may be attributed to irrigation return flows at the KATCO and Riverside citrus farms upstream of the water quality monitoring point. A further increase between the Fort Beaufort water quality monitoring point and site 7 may on the other hand show salinity influence from the Fort Beaufort town, especially the sewage treatment works. Site 7 recorded the highest salinity values over the 12 months period (1222mg/L). There was a decrease in salinity levels between sites 7 and 8. In addition salinity levels decreased further at site 9. Site

10 recorded distinctively lower salinity compared to other lower catchment sites. However there was a general trend of increasing salinity from the upper to the lower reaches. Minimum standard deviation was recorded as 55 mg/L at site 6 showing least variation from the mean. Site 7 had the highest standard deviation of 324mg/L followed by site 8 and 9. During the twelve months of monitoring, the salinity trend between consecutive sites stayed relatively constant and high concentrations were recorded during low flows. Land use influence on river salinity was only confirmed by comparison of salt loads at different sites and DWAF water quality monitoring sites.

3.6.2 Flow variation

According to the flow results (Figure 3.5), most measurements were taken during low flows. Thus the Summer period did not yield high flow as would be expected. During this time the study area experienced unusually high temperatures with no rainfall. This is further supported by the flow median values that are skewed towards the minimum flow. Nonetheless, high flows were experienced during the months of February and April 2004 during the monitoring period. The river has a maximum flow of 2.36 m^3/S during the high flows and a minimum flow of 0.002 m^3/S for the rest of the monitoring duration.

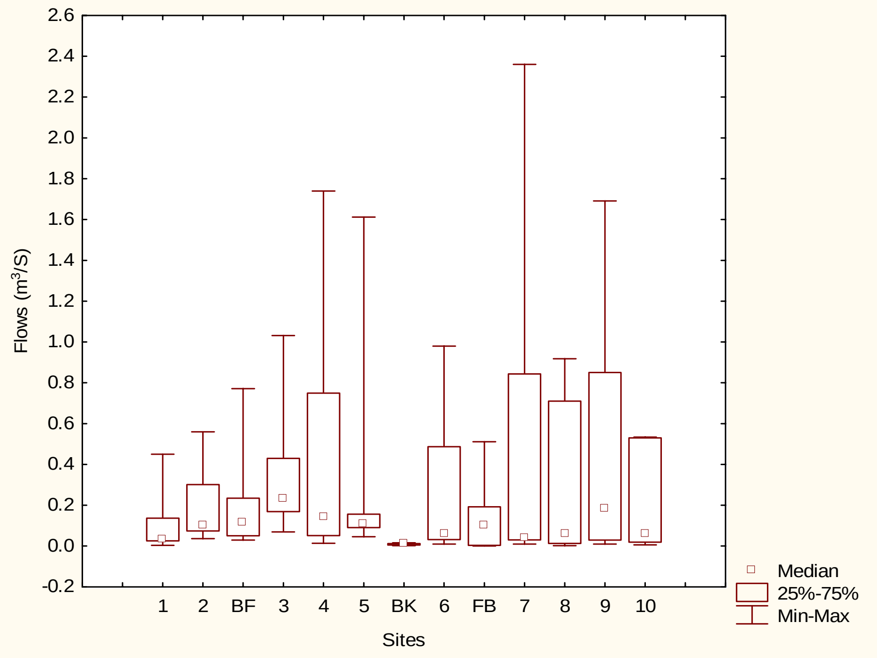


Figure 3.5: Measured minimum, median and maximum flows (m^3/S) during monthly salinity monitoring from July 2003 to July 2004 (BF-Balfour water quality monitoring point, BK-Blinkwater water quality monitoring point and FB-Fort Beaufort water quality monitoring point)

The increase of discharge from site 1 to 3 was likely due to additional flow from Fairbain and Balfour tributaries. Hence flow at site 3 always exceeded the one in site 2. This may be due to withdrawals at water quality monitoring point impoundments as the river progresses downstream. Increased flow between sites 2 and 3, were probably a result of additional flows from the Balfour stream. Sites 4 and 5 showed comparable flows with a significant drop at site 6. Under natural conditions this site would have had higher discharge because of additional flow from the Blinkwater River. However flows at this tributary appeared to have minimal or little impact to flow conditions in the Kat River. Abstractions from a water quality monitoring point upstream of site 6, was thought to reduce flow at this site significantly. Generally there was an increase in flow between site 6 and the Fort Beaufort water quality monitoring point. Flows then increased between the water quality monitoring point and site 7 owing to the significant outflow from the Fort Beaufort town. Sites 8 experienced reduced flows from abstraction by the lower citrus farmers (Figure 3.5). There was however evidence of increased flow between sites 8 and 9 probably due to contribution from tributaries between the two sites. During the monitoring schedule the river was completely dry on at least three occasions at these sites. Flow at site 10 in February could not be measured due to flooding.

3.6.3 Salt loads

Figure 3.6 illustrates the salt loads that were transported by the river system during the monthly monitoring from July 2003 to June 2004. A comparison of salt loads in any consecutive sites provided a framework to assess the degree to which the river was in balance with salt sinks and sources. Results revealed that although salt concentrations were higher during low flows, the actual salt loads were highest during high flows (Figures 3.5 and 3.6). This is understandable since salt loads are a product of salinity and flow. Salt loads were computed over the twelve months for each of the ten monitoring sites and DWAF water monitoring sites. The minimum, maximum and mean daily salt loads at the different sites over the monitoring period are shown in Figure 3.6.

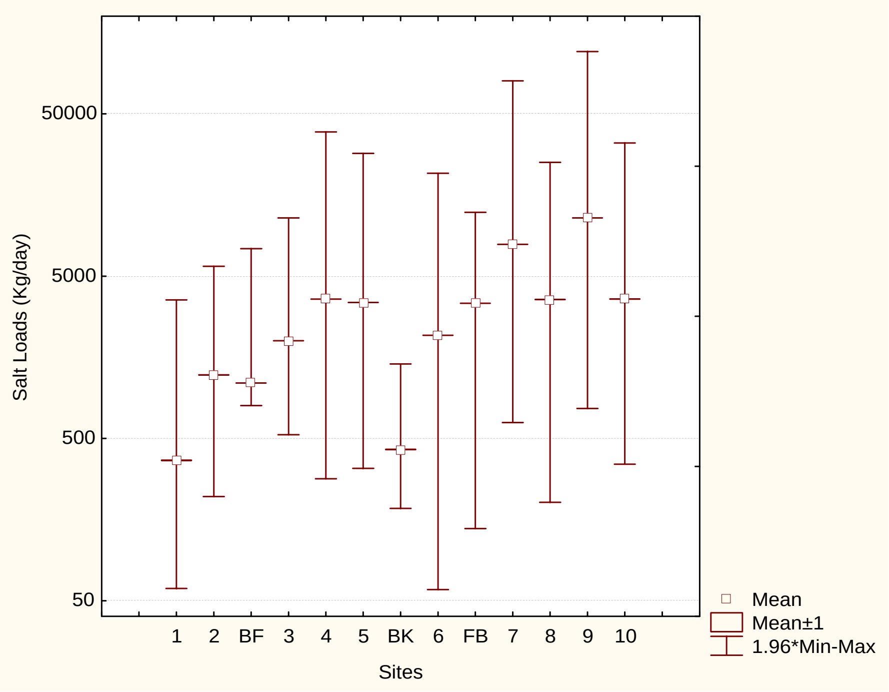


Figure 3.6: Mean Daily Salt Loads from monthly TDS and flow monitoring from July, 2003 to June 2004 (BF-Balfour water quality monitoring point, BK-Blinkwater water quality monitoring point and FB-Fort Beaufort water quality monitoring point)

Comparisons of mean daily salt loads in the tributaries and the main river gave an indication of probable salt sources from different tributaries and parts of the catchment. For example Fairbain River (site 1) contributed only 30% of the mean daily salt load at site 2 (Figure 3.6). Soviti (2002) observed the same pattern during his work in the upper catchment. The average daily salt loads between site 2 and site 3 increased to some extent for the duration of sampling. According to Soviti (2002), both human settlements and geology are sources of salts in the Balfour River. This tributary was however a minor source of salts in the Kat at the confluence of the two rivers (Figure 3.6).

The average daily salt load increased by more than 1500kg/day between sites 3 and 4 over the monitoring period (Figure 3.6). In this case, the most likely source of salts is the former ULIMCOR citrus farms. A further support to this deduction is that the mean salt daily load increased from 1998 (Kg/day) in site 3 to 3610 (Kg/day) in site 4. Site 5 was included at a latter stage in the study to assess the possible impact of the upper catchment. Reduction in mean flow and hence mean daily salt loads between sites 4, 5 and 6 may suggest that most of the salt from the upper catchment is not being transported downstream and possibly being stored along the river banks (Hughes and

Moolman, 1986). Of all tributaries, the Blinkwater has distinctively low mean daily salt loads suggesting that it is a minor source of salt to the main Kat River (Figure 3.6). The increase in the mean daily salt loads between site 6 and the Fort Beaufort water quality monitoring point may be indicative of irrigation return flows from the citrus orchards upstream of the town (Figure 3.6). The mean daily salt load peaks at site 7, which is downstream of the Fort Beaufort town and was a result of salt sources from the town and the sewage treatment works. Mean daily salt loads dropped by more than half between sites 7 and 8 (from 7855 to 3592 Kg/day) (Figure 3.6). There was therefore no evidence of irrigation return flow between sites 7 and 8. A closer examination of the records revealed that the mean daily load at site 8 is heavily skewed by a flood event in February, 2004. The daily salt load during this event alone made up more than half of the annual salt load. An increase in mean salt loads between sites 8 and 9 is most likely a result of irrigation return flows and between the respective sites. There was a decrease in the mean daily salt loads between sites 9 and 10 and possibly the salt is being deposited along the riverbanks.

3.6.4 Trends in major ions

Kat Dam water quality monitoring point

The long-term data analyses in major ions at the Kat Dam water quality monitoring point are illustrated in Figures 3.7 to 3.13 for EC, calcium, chloride, magnesium, potassium, sodium and sulphate respectively.

For calcium, chloride, magnesium and sodium, there was a general decrease in the ionic concentration from 1972 to the end of 2001. However there appears to be increases around 1980 and 1983 respectively. The highest concentrations were recorded during these periods (24 mg/L for calcium, 80mg/L for chloride, 10mg/L for magnesium and 26 mg/L for sodium) (Figures 3.8, 3.9, 3.10 and 3.12). There were however different trends with regards to potassium and sulphate ions concentrations from 1972 to the end of 2001 (Figures 3.11 and 3.13).

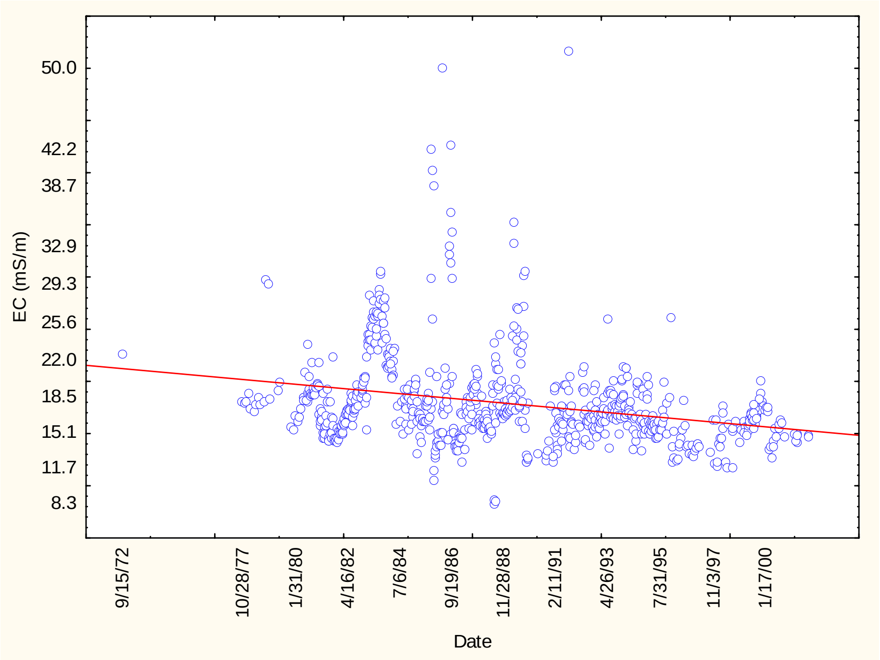


Figure 3.7: Measured EC (mS/m) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November, 2001

Figure 3.8: Measured calcium (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

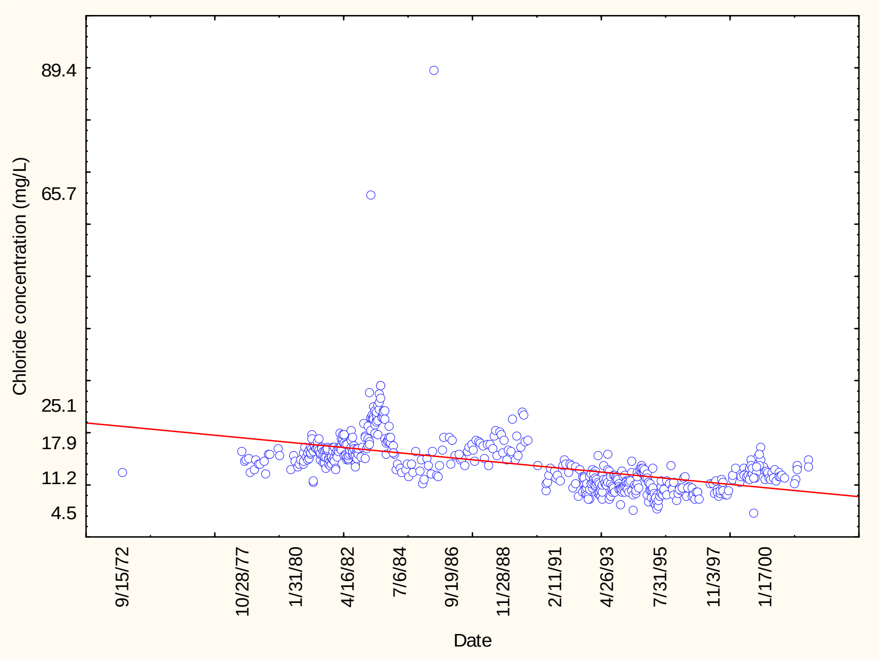


Figure 3.9: Measured chloride (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

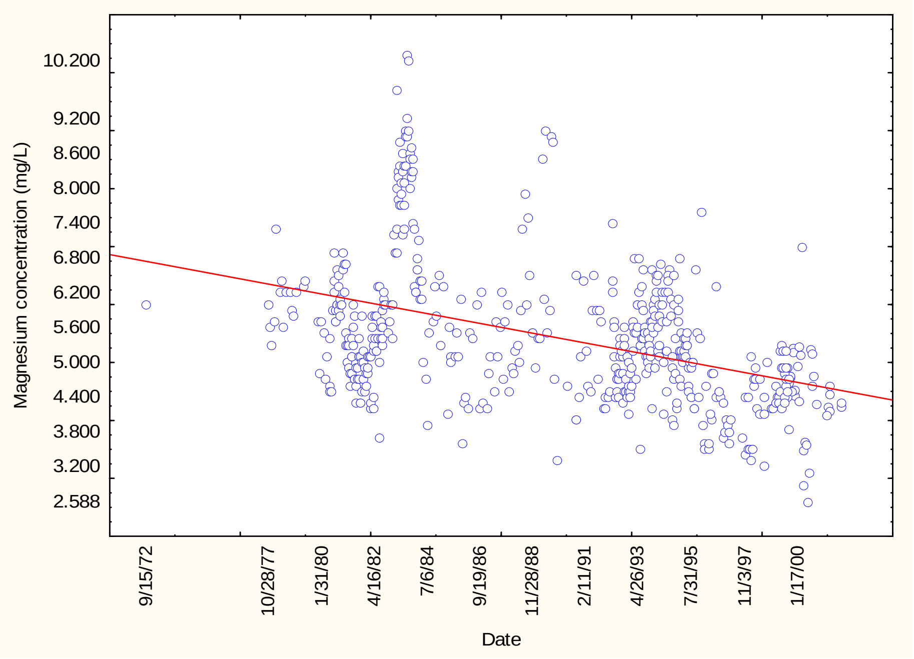


Figure 3.10: Measured magnesium (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

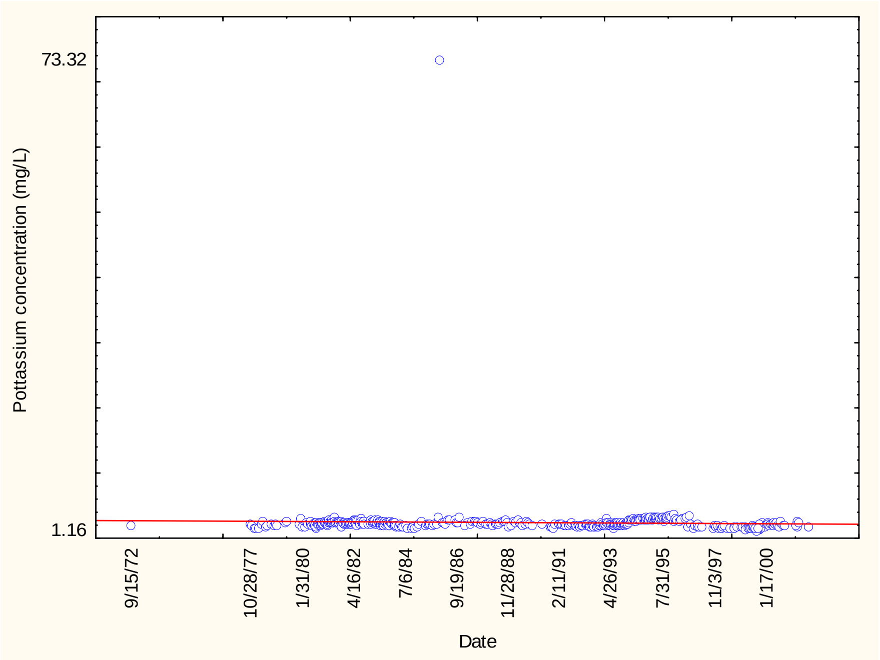


Figure 3.11: Measured potassium (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

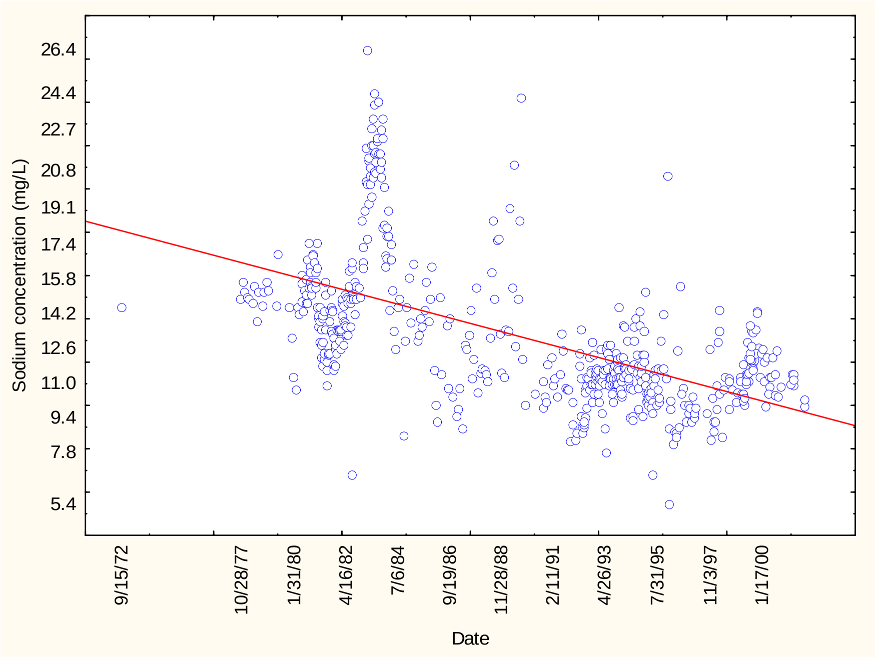


Figure 3.12: Measured sodium (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

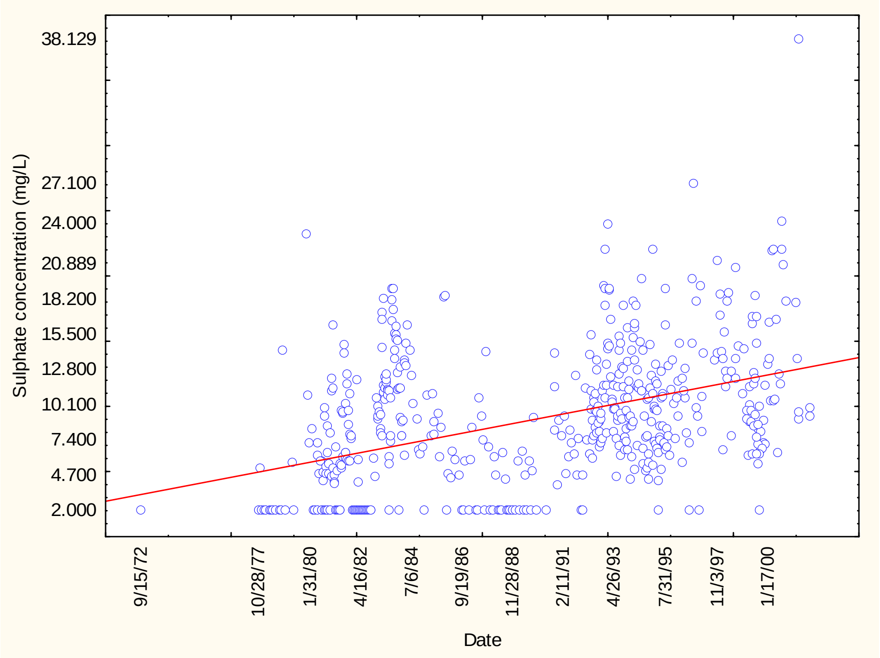


Figure 3.13: Measured sulphate (mg/L) at the Kat dam water quality monitoring point, and trend line, from September 1972 to November 2001

The potassium concentrations remained more or less constant, around 1 mg/L and did show neither an increasing nor a decreasing trend (Figure 3.11). On the other hand there was a slight increase in terms of sulphate concentrations that varied between 2 to 38 mg/L (Figure 3.13).

It was noted that although the concentrations of individual ions were different, there seemed to be a direct relationship between EC (Figure 3.7) and calcium, chloride, magnesium and sodium. The increase in EC, calcium, chloride, magnesium and sodium coincided with the 1980 and 1983 droughts. Since then, concentrations of different components levelled off. On the other hand, potassium concentrations were independent of the hydrological regime as they remained constant through out the 1972 to 2001 period. In 1980 and 1983, high sulphate concentrations coincided with droughts.

Balfour water quality monitoring point

The long-term EC and major ions at the Balfour water quality monitoring point are illustrated in Figures 3.14 to 3.20 for EC, calcium, chloride, magnesium, potassium, sodium and sulphate respectively. Different ions exhibited varying trends in their measured concentrations between September 1972 and May 2004. Calcium and magnesium showed a general decreasing trend. However there are notable instances of high values for both ions in year 2000 with calcium and magnesium concentrations reaching 54 (mg/L) and 46 (mg/L) respectively (Figures 3.15 and 3.17). Chloride only exhibited a slight decrease in the general trend over the period September, 1972 to May, 2004 (Figure 3.16). Highest concentrations were recorded in 1990 and 1997 as 396 and 317 (mg/L) respectively. Potassium, sodium and sulphate at the Balfour water quality monitoring point were all generally stable (Figures 3.18, 3.19 and 3.20). Potassium concentrations had varied mostly between 0.15 and 3.56 (mg/L) over the thirty-two year period (Figure 3.18).

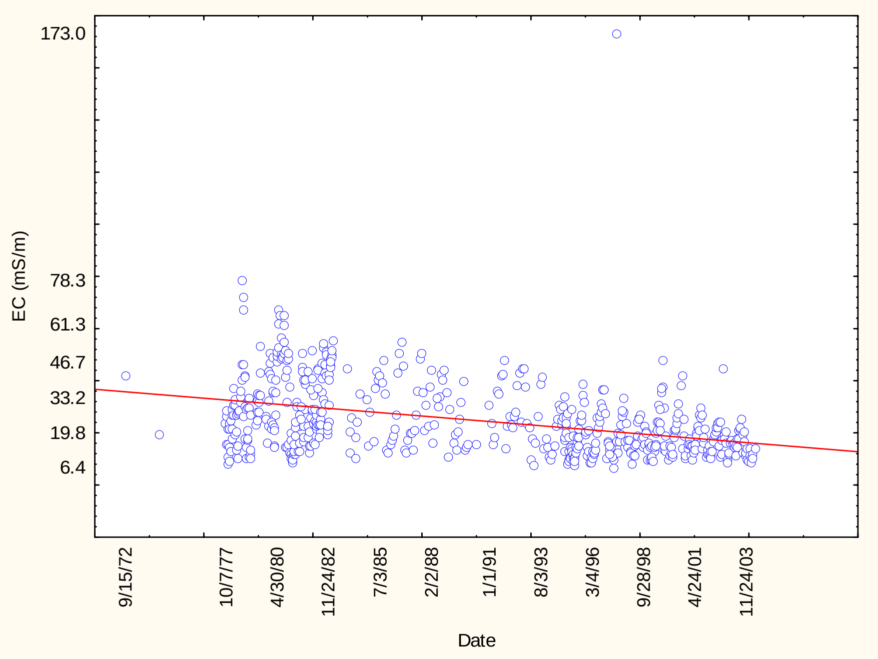


Figure 3.14: Measured EC (mS/m) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

Figure 3.15: Measured calcium (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

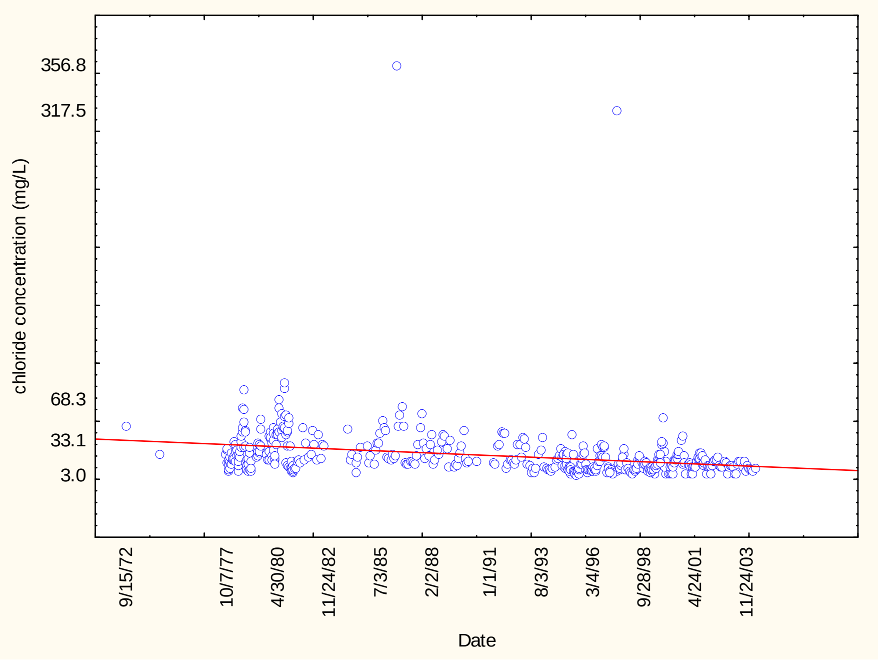


Figure 3.16: Measured chloride (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

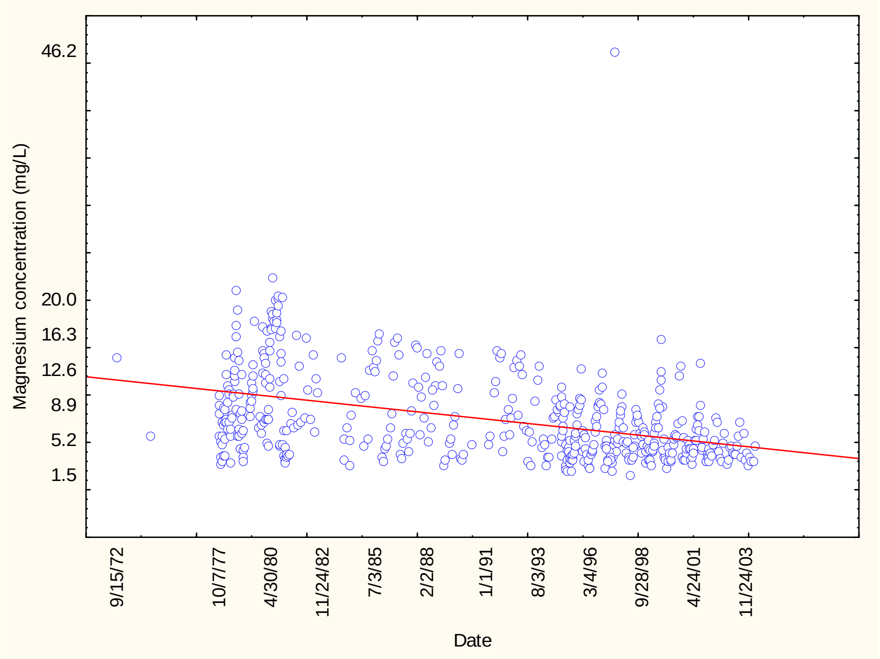


Figure 3.17: Measured magnesium (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

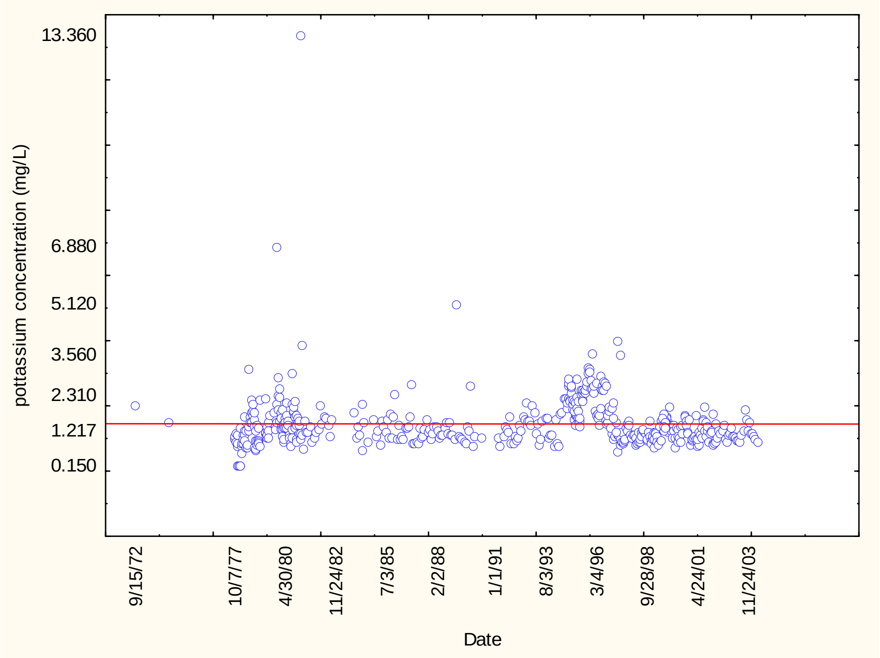


Figure 3.18: Measured potassium (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

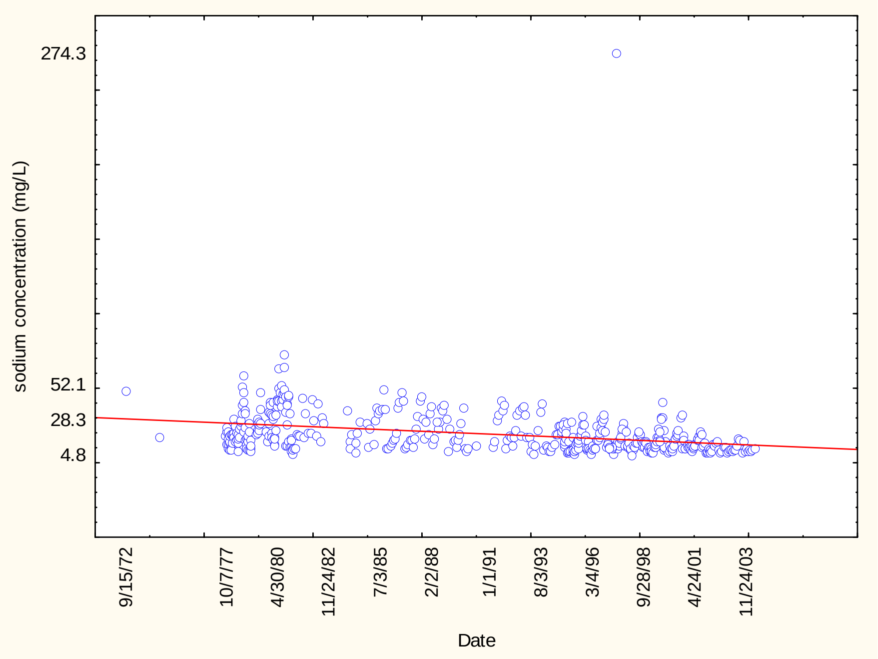


Figure 3.19: Measured sodium (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

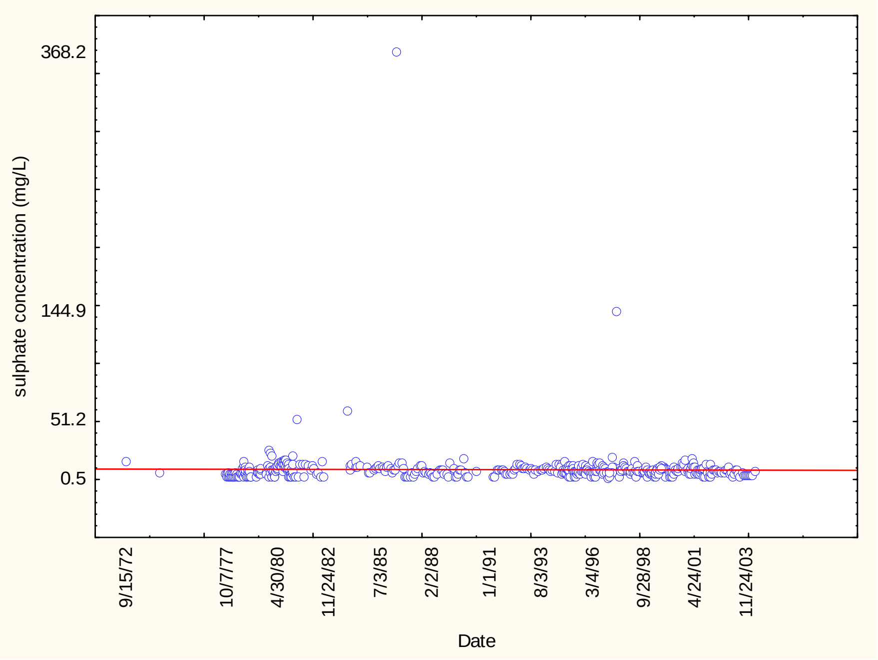


Figure 3.20: Measured sulphate (mg/L) at the Balfour water quality monitoring point, and trend line, from September 1972 to May 2004

The highest potassium concentrations were recorded at 13 mg/L in 1980 (Figure 3.18). Sodium concentrations varied between 4.8 and 52 mg/L (Figure 3.19) whilst sulphate concentrations remained around 0.5 (mg/L) for the entire period (Figure 3.20). In both these ions there were notably high concentrations some time in 1997 (274 (mg/L) for sodium and 368 (mg/L) for sulphate).

Similar to the Kat Dam water quality monitoring point, EC, calcium, chloride and magnesium concentrations showed the same comparable trends from 1977 to 2004. The high concentrations between 1977 and 1981, is possibly linked to drought. Potassium concentrations were once again independent of the hydrological regime as concentrations were more or less constant. Unlike at the Kat Dam water quality monitoring point, sulphate concentrations remained more or less constant and not related to the flow regime.

Blinkwater water quality monitoring point

Trends at the Blinkwater water quality monitoring point for EC, calcium, chloride, magnesium, potassium, sodium and sulphate scatter plots are shown in figures 3.21 to 3.27 below. None of the ions showed a general increase in the trend between May 1977 and February 2004.

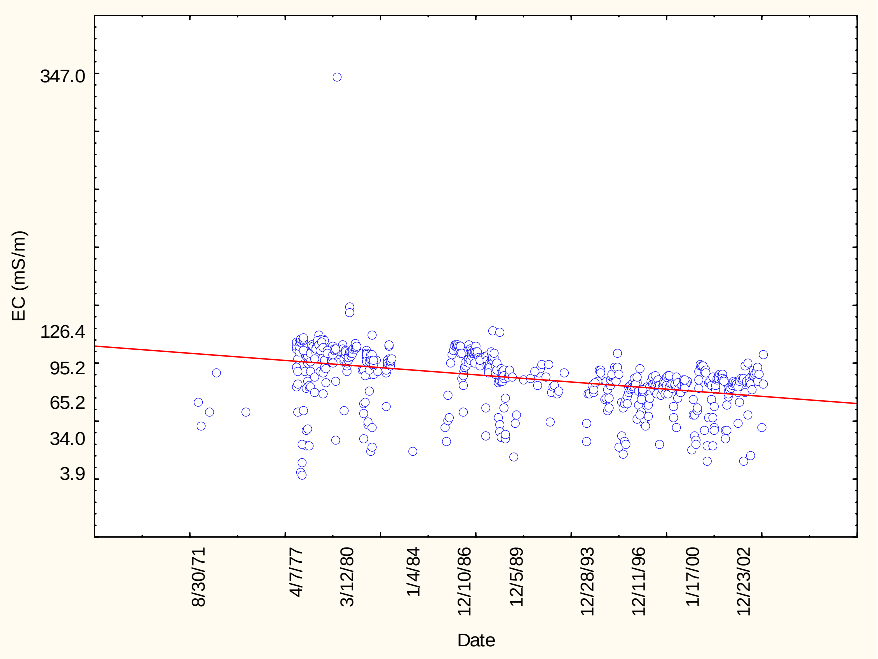


Figure 3.21: Measured EC (mS/m) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

Figure 3.22: Measured calcium (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

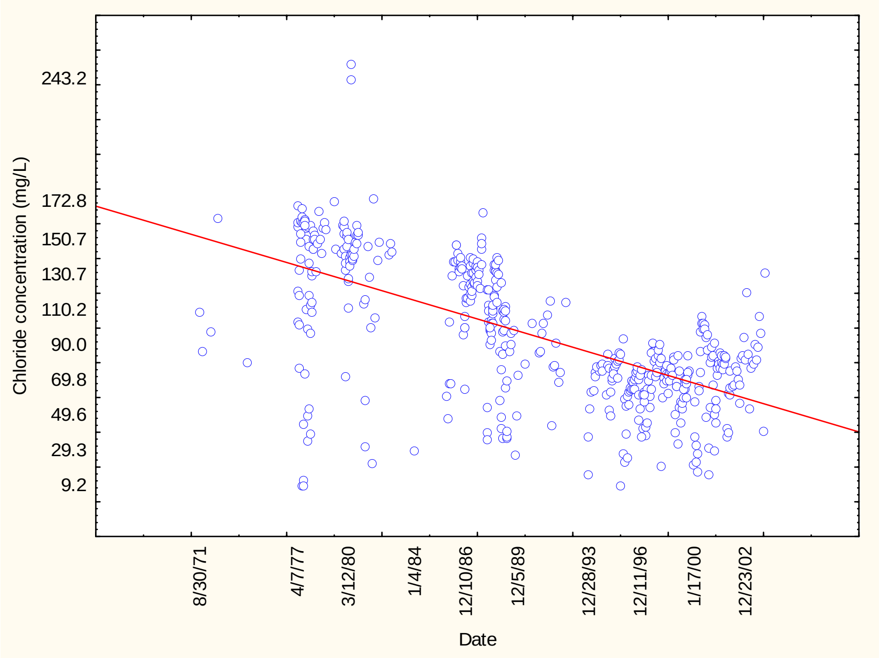


Figure 3.23: Measured chloride (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

Figure 3.24: Measured magnesium (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

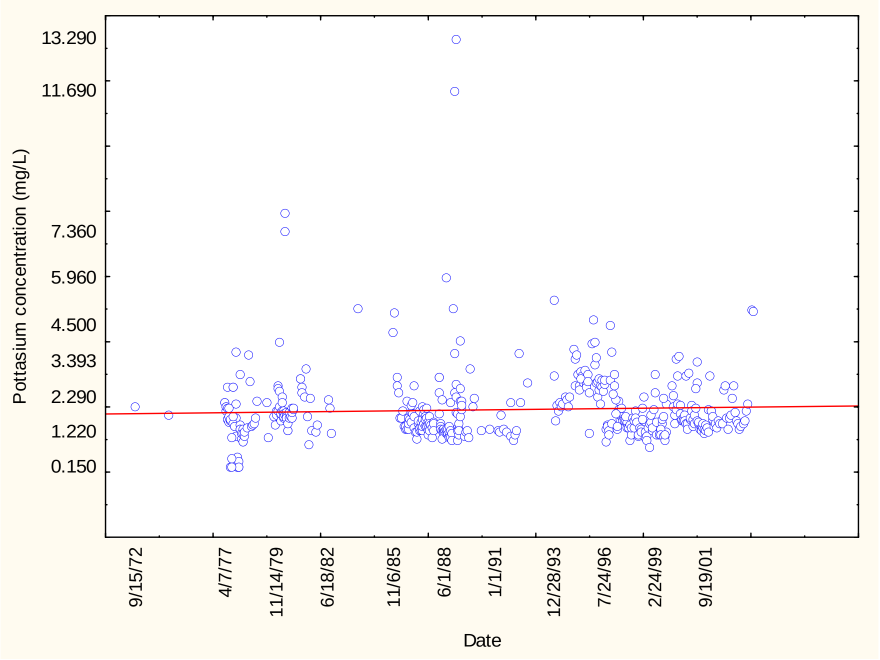


Figure 3.25: Measured potassium (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

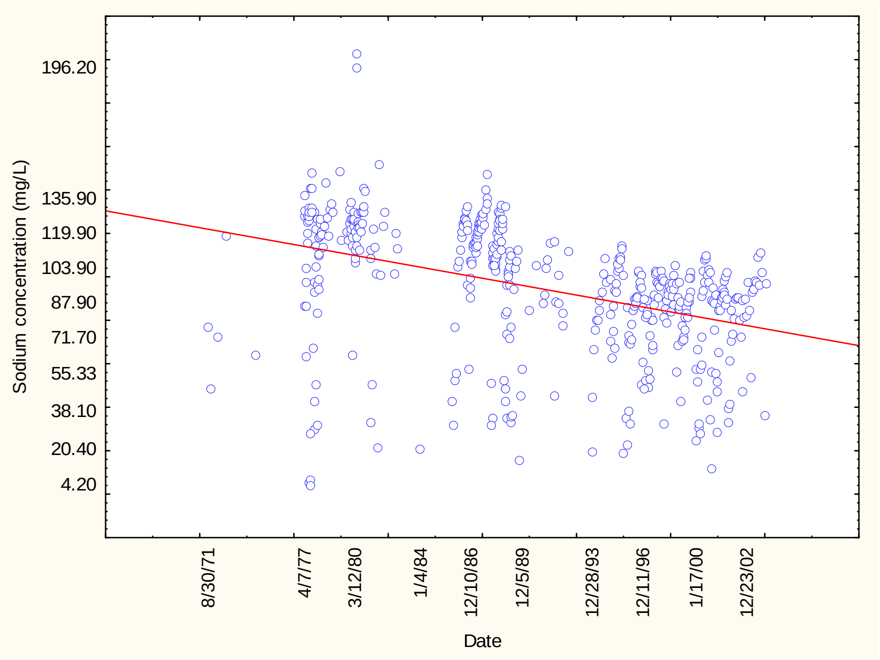


Figure 3.26: Measured sodium (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

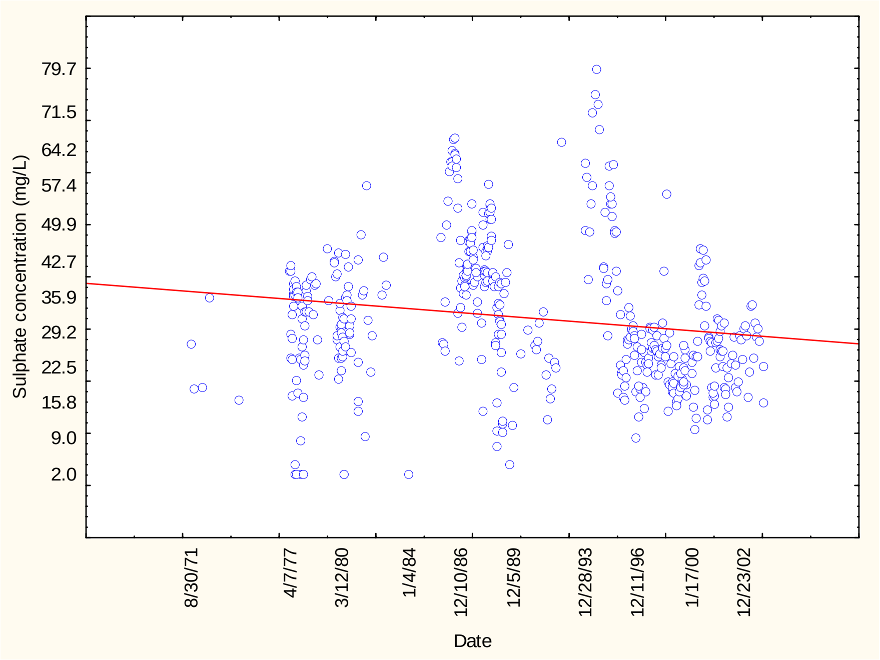


Figure 3.27: Measured sulphate (mg/L) at the Blinkwater water quality monitoring point, and trend line, from May 1974 to February 2004

Calcium and potassium concentrations remained more or less the same over the period (Figures 3.22 and 3.25). For calcium, concentrations varied between 2 and 72 (mg/L) over the duration of the DWAF records (Figure 3.22). In both 1980 and 1990 the highest potassium concentrations were recorded at 7 and 13 (mg/L) respectively (Figure 3.25). The rest of the ions (chloride, magnesium, sodium and sulphate) exhibited a decreasing trend over time (Figures 3.23, 3.24, 3.26 and 3.27). It was however noted that for this water quality monitoring point, chloride and sodium concentrations showed similar trends in terms of the slope and the period in which highest concentrations were recorded (Figures 3.23 and 3.26). For both ions there was a rapid decline in the concentrations from the beginning of the data set and the highest concentrations were recorded in 1980 (243 mg/L for sodium and 196 mg/L for chloride). Magnesium and sulphate ions only showed a gently sloping trend (Figure 3.24 and 3.27). There is however a notable increase in the sulphate concentrations in 1994, where there were isolated instances where concentrations went above 70 mg/L (Figure 3.27). Potassium concentrations at the Blinkwater water quality monitoring point were relatively constant from 1974 to 2004. A steady decrease in EC, calcium, chloride and magnesium concentrations after 1980 may be explained by land use history in the area (Figures 3.21, 3.22, 3.23 and 3.24). After 1980, some farmlands were incorporated into Mpofu nature reserve, but probably little change to irrigated area above.

Fort Beaufort water quality monitoring point

Trends of different ions at the Fort Beaufort water quality monitoring point from 1992 to 2004 are presented in Figures 3.28 to 3.34. It seemed there was no increase or decrease in EC, calcium, chloride, magnesium, sodium and sulphate ions concentrations over the stipulated monitoring period (Figure 3.28, 3.29, 3.30, 3.31, 3.33 and 3.34). The maxima and minima concentrations were however variable; such that calcium concentration varied between 6 and 47 mg/L (Figure 3.29).

Figure 3.28: Measured EC (mS/m) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

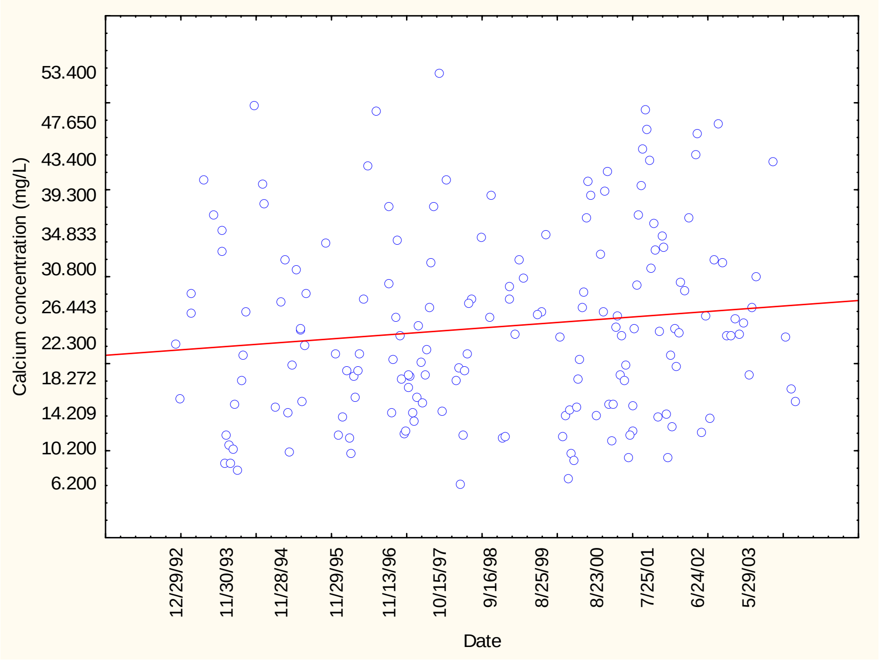


Figure 3.29: Measured calcium (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

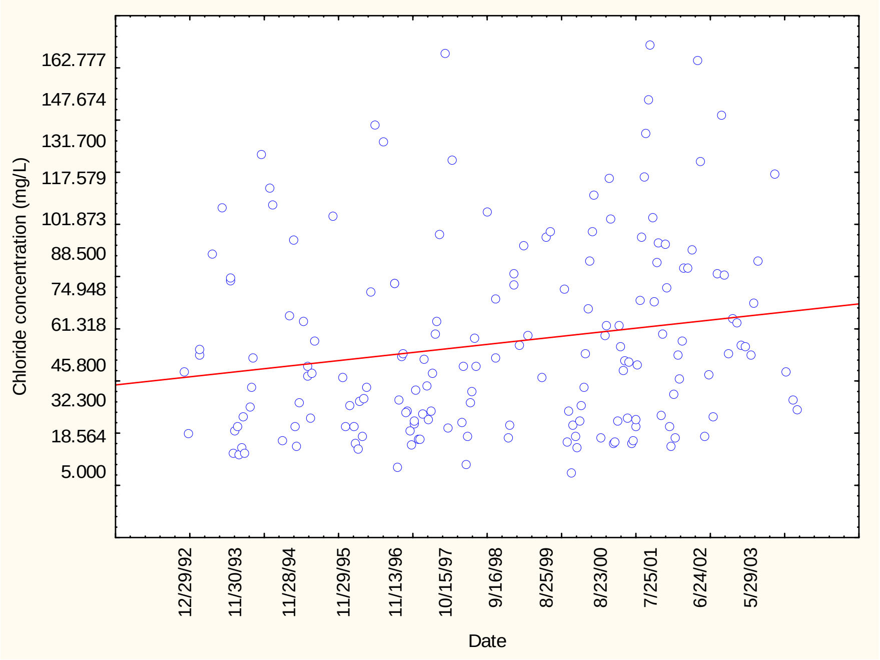


Figure 3.30: Measured chloride (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

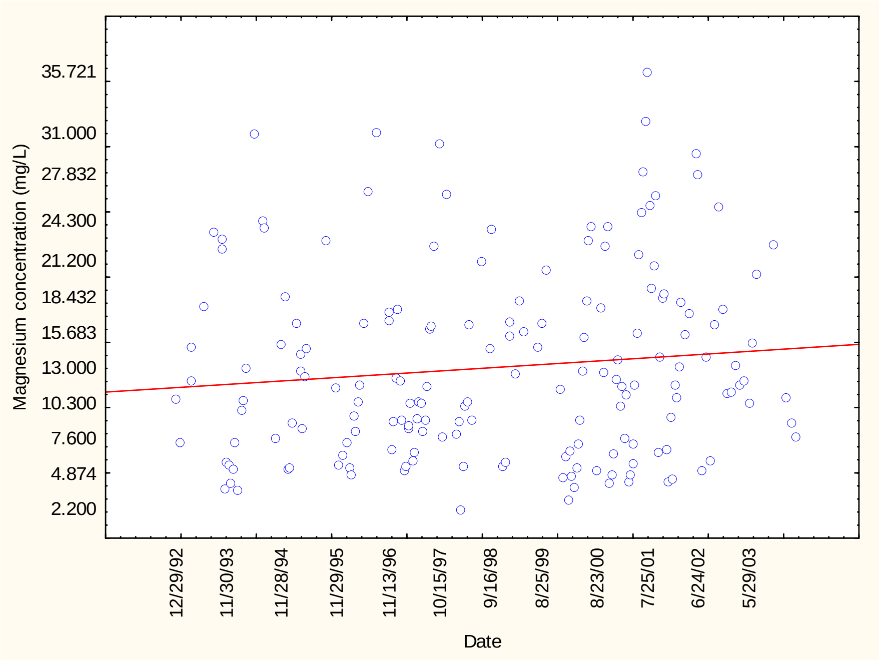


Figure 3.31: Measured magnesium (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

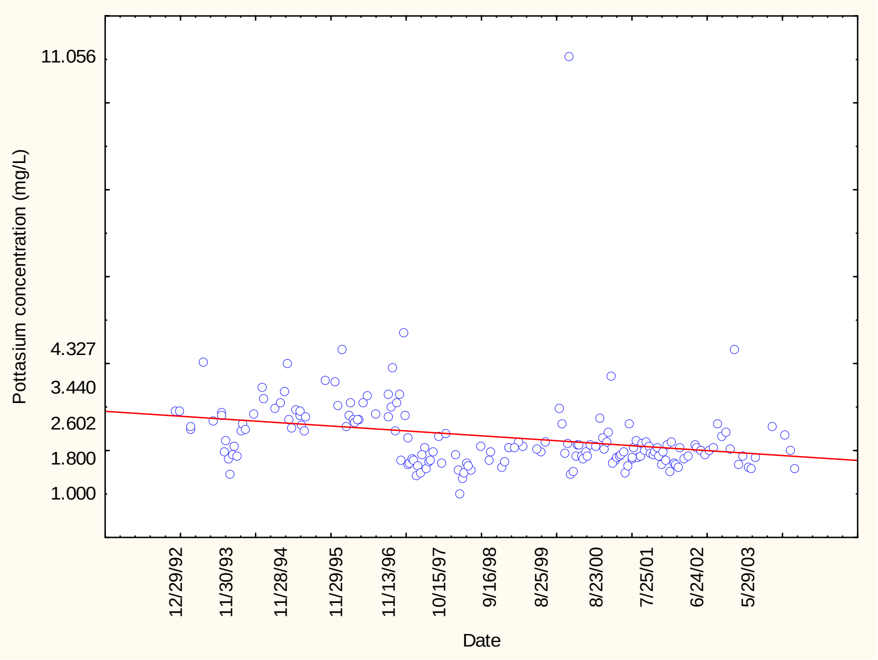


Figure 3.32: Measured potassium (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

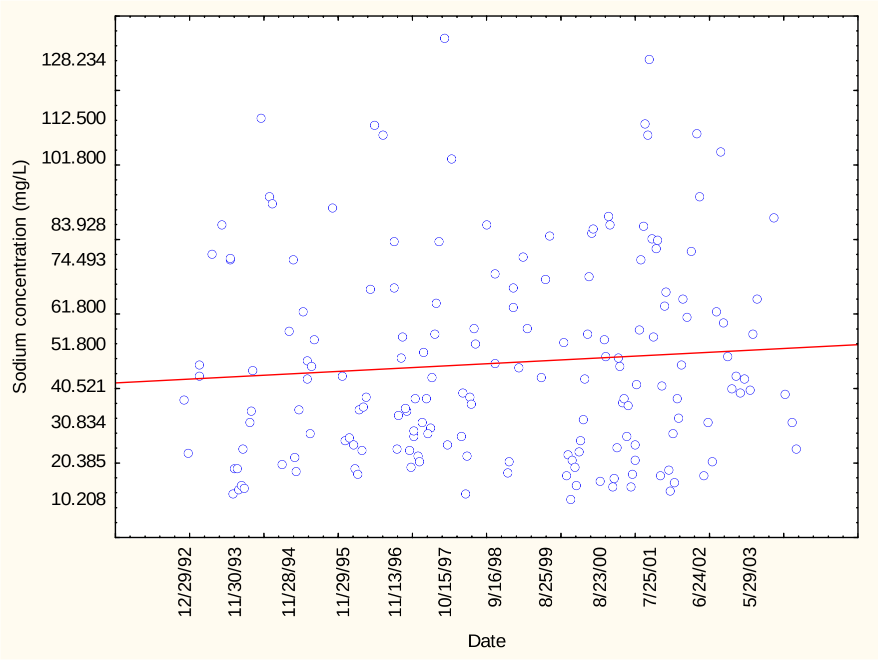


Figure 3.33: Measured sodium (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

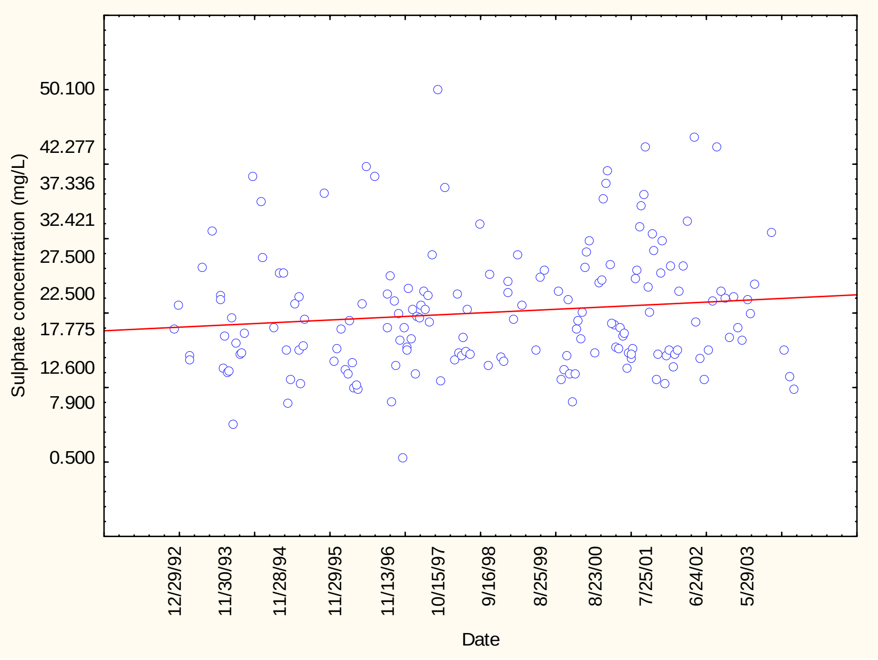


Figure 3.34: Measured sulphate (mg/L) at the Fort Beaufort water quality monitoring point, and trend line, from December 1992 to May 2004

Maximum and minimum chloride concentrations were recorded between 5 and 163 mg/L (Figure 3.30), whilst for sodium they ranged between 10 and 28 mg/L (Figure 3.33). With regards to sulphates, ionic concentrations varied between 0.5 and 50 mg/L (Figure 3.34). The only ion that exhibited a clear trend over the monitoring period was that of potassium. There was a general decrease in the potassium concentrations at the Fort Beaufort water quality monitoring point over the period, December 1992 and May 2004 (Figure 3.32). Most of the data seemed to vary from 1 to 4 mg/L. On one occasion during 1999, potassium concentrations went as high as 11 mg/L.

In all there were no evident trends in the EC, calcium, chloride, magnesium and sodium. The records were too short to allow for comparison with historical droughts. In exception potassium concentrations remained more or less constant between December 1992 and May 2004. The data records at this particular water quality monitoring point were too short for comparison with historical trends in the late 1970s as in the other three water quality monitoring points.

3.6.5 Predominant major salts

The TIMS model produced salt time series of magnesium sulphate, sodium sulphate, magnesium chloride, calcium chloride, sodium chloride and calcium sulphate for all data with full ionic records. Different salt concentrations at individual water quality monitoring points are presented in Appendix E. Figures 3.35 to 3.38 show box and whisker plots of major salts from different water quality monitoring points. One fact that came out at all the four water quality monitoring points was that concentrations for sodium sulphate, magnesium chloride, calcium chloride and calcium sulphate were almost always zeros. Yet concentrations for calcium ions were relatively high at all water quality monitoring points (Appendix D). Magnesium sulphate and sodium chloride were the predominant salts at all the four DWAF monitoring water quality monitoring points. Sodium chloride had higher concentrations compared to magnesium sulphate throughout, although the salt concentrations exhibited different ranges at different water quality monitoring points (Figures 3.35 to 3.38). Mean and median magnesium sulphate and median sodium chloride concentrations at different water quality monitoring sites are shown in Table 3.2 below.

Table 3.2 Mean and median sodium chloride and magnesium sulphate concentrations (mg/L) at DWAF water quality monitoring sites

	Kat Dam		Balfour		Blinkwater		Fort Beaufort	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Magnesium Sulphate	6.93	10.91	4.39	9.47	36.58	40.26	17.31	24.7
Sodium Chloride	22.56	24.7	32.66	23.33	232.8	148.26	89.62	69.43

At the Kat dam water quality monitoring site, average magnesium sulphate and sodium chloride concentrations were 6.93 mg/L and 22.56 mg/L respectively (Table 3.2). Salt concentrations varied between 0 and 28 mg/L for magnesium sulphate and between 7.42 and 49.09 mg/L in the case of sodium chloride (Figure 3.35). The Balfour water quality monitoring point exhibited the lowest mean in terms of magnesium sulphate concentrations, but interestingly the Kat dam had the lowest sodium chloride mean concentration (Table 3.2). Both the maximum magnesium sulphate (181mg/L) and sodium chloride (523mg/L) concentration within the catchment were recorded at the Balfour water quality monitoring point (Figure 3.36). However median concentrations (9.47mg/L and 23.33mg/L) for both salts were among the lowest, which may imply that the river does not necessarily experience high salt concentrations (Table 3.2). At the Blinkwater water quality monitoring point, the highest salt concentrations experienced with regards to magnesium sulphate and sodium chloride were 99.87 and 414 mg/L respectively (Figure 3.37). The minima concentrations (2.48mg/L for magnesium sulphate and 10.68mg/L for sodium chloride) recorded were however comparable to the rest of the water quality monitoring points (Figure 3.37). Unlike the Balfour water quality monitoring point, here the medians (40.26mg/L and 148.26 mg/L) and the means (36.58mg/L and 232.8mg/L) are in support of the fact that magnesium sulphate and sodium chloride concentrations are quite high. In terms of means (17.31mg/L and 89.62mg/L), the Fort Beaufort water quality monitoring point had the second highest salt concentrations (Table 3.2). Magnesium sulphate median concentration was 24.7mg/L and 69.43mg/L for sodium chloride (Table 3.2). The lowest concentrations that were likely to be experienced by the aquatic ecosystem at this site are 0.63mg/L and 8.24mg/L for magnesium sulphate and sodium sulphate respectively.

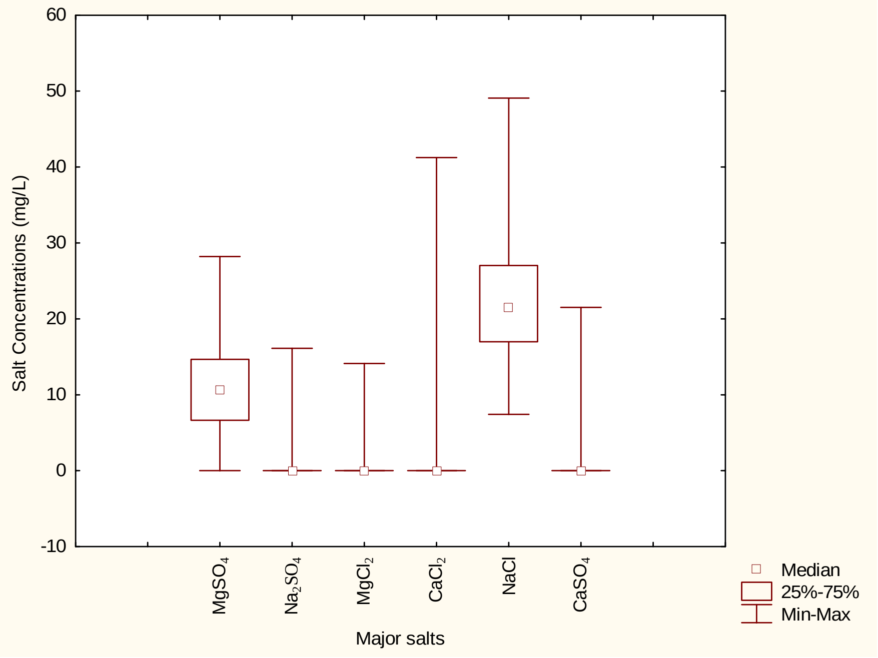


Figure 3.35: Showing box and whisker plots of major salts at the Kat River Dam water quality monitoring point

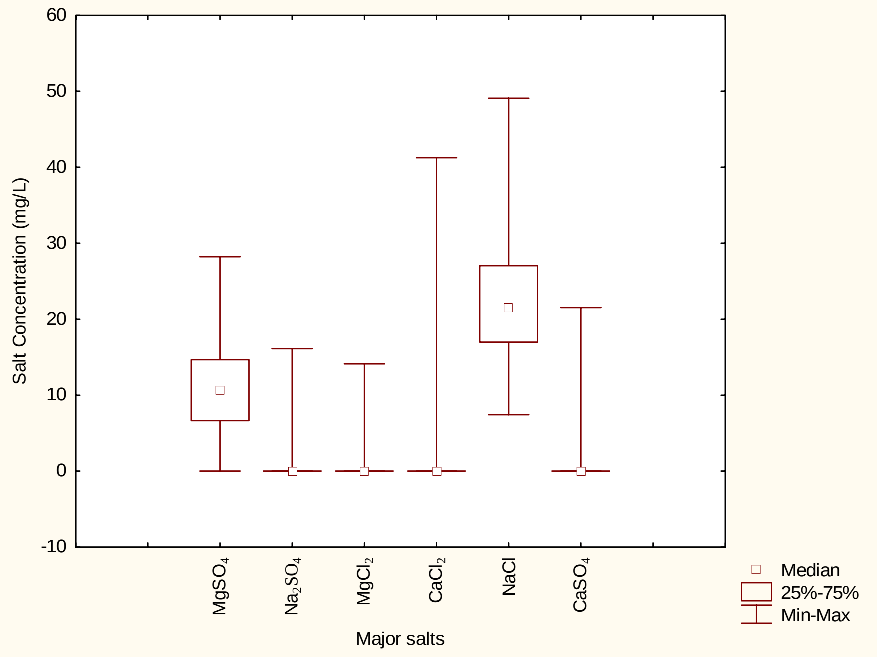


Figure 3.36: Showing box and whisker plots of major salts at the Balfour water quality monitoring point

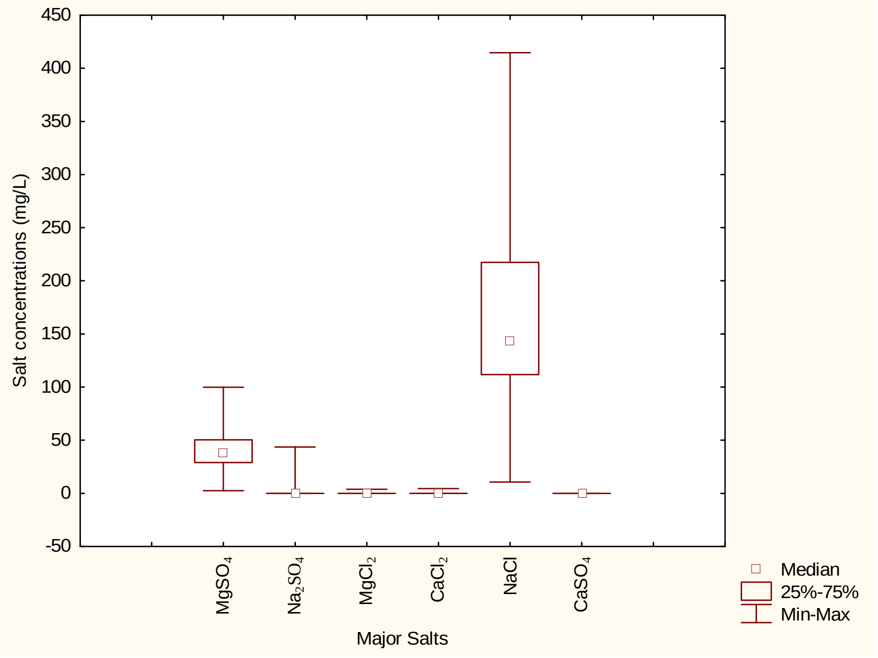


Figure 3.37: Showing box and whisker plots of major salts at the Blinkwater water quality monitoring point

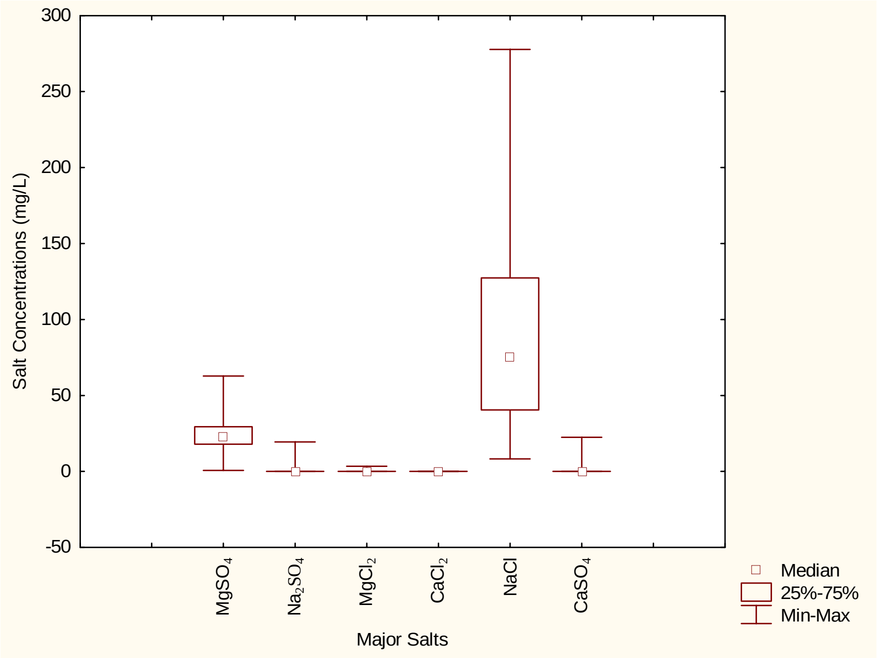


Figure 3.38: Showing box and whisker plots of major salts at the Fort Beaufort water quality monitoring point

3.5.6 Reference condition 95th percentiles

Table 3.3 below shows 95th percentile concentrations used in defining reference conditions at each water quality monitoring point. The 95th percentile represents the concentration that is equal or less for 95 % of the time (Wayne, 1995). Most of the 95th percentiles for major salts were zeros throughout the catchment (Appendix E). The highest magnesium sulphate 95th percentiles were 44 mg/L at Fort Beaufort and for sodium chloride 274 mg/L at the Blinkwater water quality monitoring point.

Table 3.3 Showing 95th percentiles for major salts at different DWAF water quality monitoring water quality monitoring points

	Weir	95th Percentiles (mg/L)					
		$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
Reference Conditions	Kat Dam	16	0	0	0	29	0
	Balfour	13	0	0	0	81	0
	Blinkwater	52	0	0	1	274	0
	Fort Beaufort	44	0	0	0	180	0

As mentioned earlier, benchmarks are important in making decisions as to the category or class of each salt. When comparing Tables 3.1 and 3.3, it became clear that default benchmarks for sodium sulphate, magnesium chloride, calcium chloride and calcium sulphate did not warrant adjustments because the 95th percentiles concentrations were below the default benchmarks proposed by Jooste and Rossouw (2002). The default benchmarks were therefore adopted with no adjustments with regards to afore mentioned salts. In addition, 95th percentiles for magnesium sulphate at the Kat Dam and the Fort Beaufort water quality monitoring points were short of the default natural benchmarks and the former were adopted as criteria for salt classes. On the other hand the Blinkwater water quality monitoring point (52mg/L) and Fort Beaufort water quality monitoring point (44mg/L) were much higher than the default natural benchmark for magnesium sulphate (16mg/L) in Table 3.1. There was therefore a need to adjust the benchmarks accordingly for this salt at the two water quality monitoring points.

For sodium chloride, only the Kat Dam water quality monitoring point yielded 95th percentile (29mg/L) that was less than the default natural benchmark (45mg/L) (Table 3.3). Sodium chloride 95th percentiles for the Balfour, Blinkwater and Fort Beaufort water quality monitoring points were 81, 274 and 180 (mg/L) respectively (Table 3.3). These values are all higher than 45 (mg/L), which was the set natural benchmark for sodium chloride.

Table 3.4 Showing adjusted default boundaries for the assessment of the PES

Weir	Salt categories (mg/L)								
	$MgSO_4$			Na_2SO_4			$MgCl_2$		
	Natural	Good	Fair	Natural	Good	Fair	Natural	Good	Fair
Kat dam	16	27	37	20	36	51	15	33	51
Balfour	16	27	37	20	36	51	15	33	51
Blinkwater	53*	72*	91*	20	36	51	15	33	51
Fort Beaufort	44*	58*	72*	20	36	51	15	33	51
Weir	Salt categories (mg/L)								
	$CaCl_2$			NaCl			$CaSO_4$		
	Natural	Good	Fair	Natural	Good	Fair	Natural	Good	Fair
Kat dam	21	63	105	45	217	389	351	773	1195
Balfour	21	63	105	82*	101*	120*	351	773	1195
Blinkwater	21	63	105	274*	389*	503*	351	773	1195
Fort Beaufort	21	63	105	179*	246*	313*	351	773	1195

*shows boundary conditions that have been adjusted from benchmark categories given in table 3.1

Benchmarks for the three water quality monitoring points were adjusted accordingly and the new benchmarks for all salts are summarised in Table 3.4. The fact that site specific salt boundary conditions had to be adjusted may suggest that the Kat River system generally has naturally high sodium chloride and to some extent magnesium sulphate. Default sodium chloride boundaries were adjusted for the Balfour, Blinkwater and the Fort Beaufort water quality monitoring point whilst the Kat dam boundaries were unaffected. With regards to magnesium sulphate, the Blinkwater water quality monitoring point was the only water quality sub-unit that had default boundaries adjusted (Table 3.4). It is important to note that the reference conditions that were set by the earliest records coincided with the closure of the Kat Dam in the early 1970s. From then on major salts concentrations declined or were at least steady.

3.6.7 Assigning PES salt categories

The major salts sodium sulphate, magnesium chloride, calcium chloride and calcium sulphate (Table 3.5) were all at concentrations within the natural category (Jooste and Rossouw, 2002). It can then be concluded that these salts are unlikely to have a significant impact on the aquatic ecosystem.

Table 3.5 showing 95th percentiles for the different major salts according to adjusted benchmarks and associated ecological classes at different DWAF water quality monitoring sites

Present Ecological State	**Weir**	**Sample size**	**$MgSO_4$**		**$NaSO_4$**		**$MgCl_2$**	
			(mg/L)	**category**	**(mg/L)**	**category**	**(mg/L)**	**category**
	Kat dam	60	22	G	9	N	6	N
	Balfour	59	15	N	0	N	0	N
	Blinkwater	54	53	G	0	N	0	N
	Fort Beaufort	82	45	G	1	N	0	N
	Weir	**Sample size**	**$CaCl_2$**		**NaCl**		**$CaSO_4$**	
			(mg/L)	**category**	**(mg/L)**	**category**	**(mg/L)**	**category**
	Kat dam	60	0	N	24	N	0	N
	Balfour	59	0	N	33	N	0	N
	Blinkwater	54	0	N	168	N	0	N
	Fort Beaufort	82	0	N	209	G	0	N

According to the TIMS results, all water quality monitoring points have sodium chloride and magnesium sulphate as predominant salts (Appendix E). The Balfour is the only water quality monitoring point that was categorised under natural conditions with regards to both salts (Table 3.5). On the other hand the Kat dam, Blinkwater and Fort Beaufort water quality monitoring points categorised as good for magnesium sulphate. Sodium chloride concentrations at the Kat dam, Balfour and Blinkwater water quality monitoring points show that they all fall under the natural category. At the Fort Beaufort water quality monitoring point sodium chloride concentrations were categorised as good.

3.6.8 Data confidence

According to the Jooste and Rossouw (2002) method, the most vulnerable reach is the one represented by the Fort Beaufort water quality monitoring point. At this water quality monitoring point both magnesium sulphate and sodium chloride show good conditions. However Table 3.6 shows that confidences for both salts fall within the low confidence category (less than 0.6) (Jooste and Rossouw, 2002). Magnesium sulphate at the Balfour water quality monitoring point and sodium chloride at the Blinkwater also categorised as low confidences (Table 3.6). The reason behind the low confidences is the high standard deviations in different datasets.

Table 3.6 Showing power and confidences in data sets used to determine the PES state from 2001 to 2004

Water quality monitoring site	**Sample size**	$MgSO_4$ **power**	**Confidence level**	**NaCl power**	**Confidence level**
Kat dam	60	0.9682	High	0.8997	High
Balfour	59	0.1724	Low	1	High
Blinkwater	54	0.614	Medium	0.4981	Low
Fort Beaufort	82	0.1616	Low	0.1604	Low

This then down weighed the significance of any conclusions that might be drawn from the Jooste and Rossouw (2002) method with regards to the magnesium sulphate and sodium chloride at the respective water quality monitoring points. The sodium chloride concentrations at the Blinkwater were also of low confidence (Jooste and Rossouw, 2002). However, magnesium sulphate and sodium chloride concentrations at the Kat dam were high confidence datasets with powers of 0.9682 and 0.8997 respectively (both greater than 0.8) (Table 3.6). The sodium chloride at the Balfour was also considered a high confidence data set with a confidence of unity. The only water quality monitoring points that fully met data requirements for a high confidence assessment were the Kat dam and Fort Beaufort water quality monitoring points. These sites had at least 60 data points used in the assessment whilst the Balfour and the Blinkwater water quality monitoring points were short of 1 and 6 data points respectively.

3.6.9 Flow-salt concentration relationships

Q-C relationships using mean monthly sodium chloride and mean flows are given in Figure 3.39 to 3.42 for the Kat dam, Balfour, Blinkwater and the Fort Beaufort water quality monitoring points respectively.

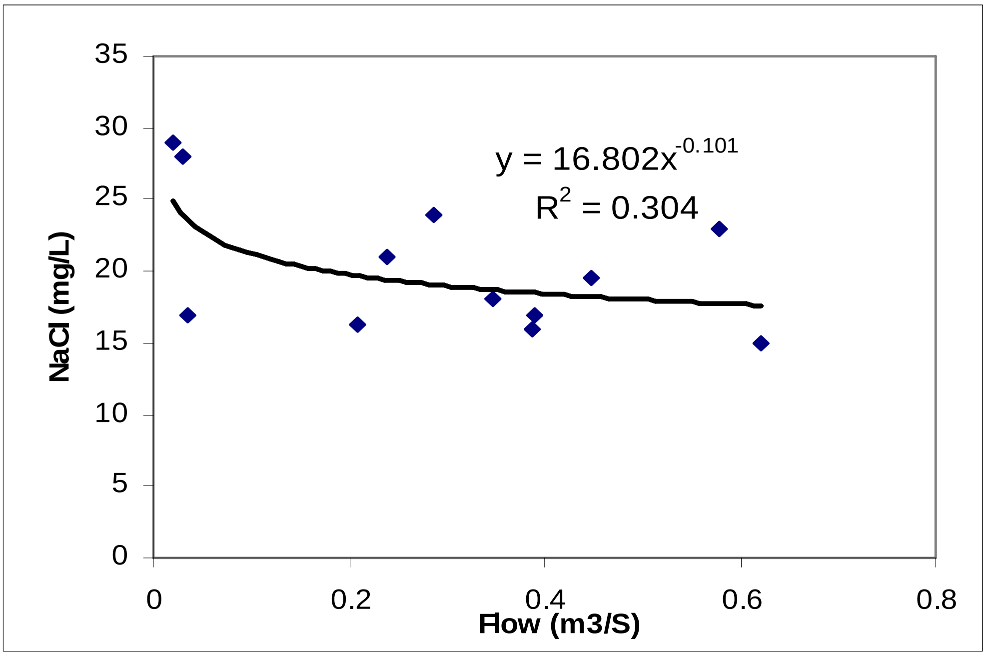


Figure 3.39: Monthly mean flow and median sodium chloride at the Kat dam water quality monitoring point

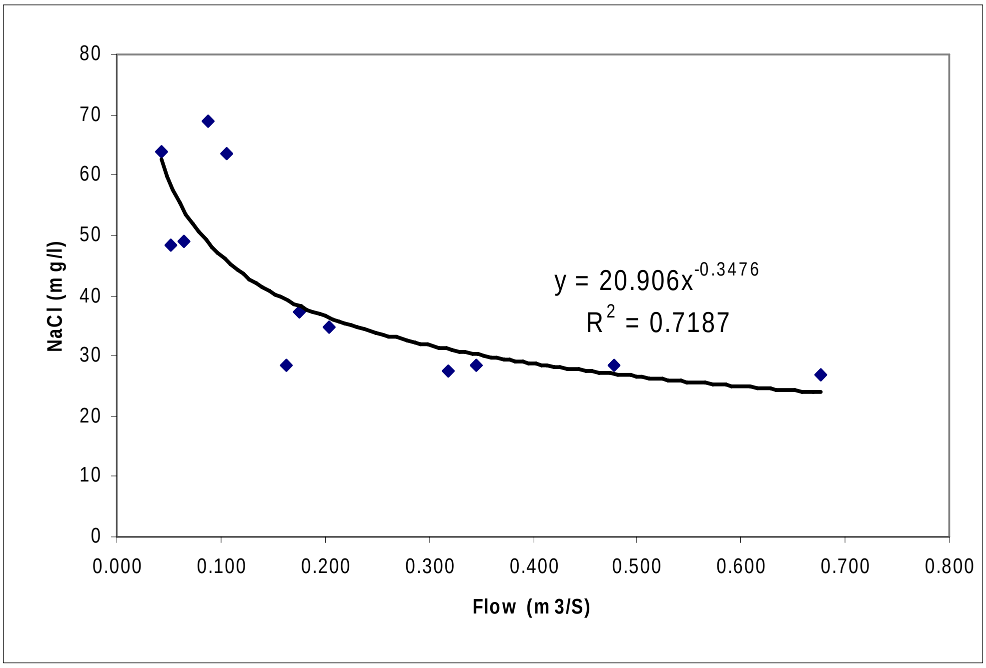


Figure 3.40: Monthly mean flow and median sodium chloride at the Balfour water quality monitoring point

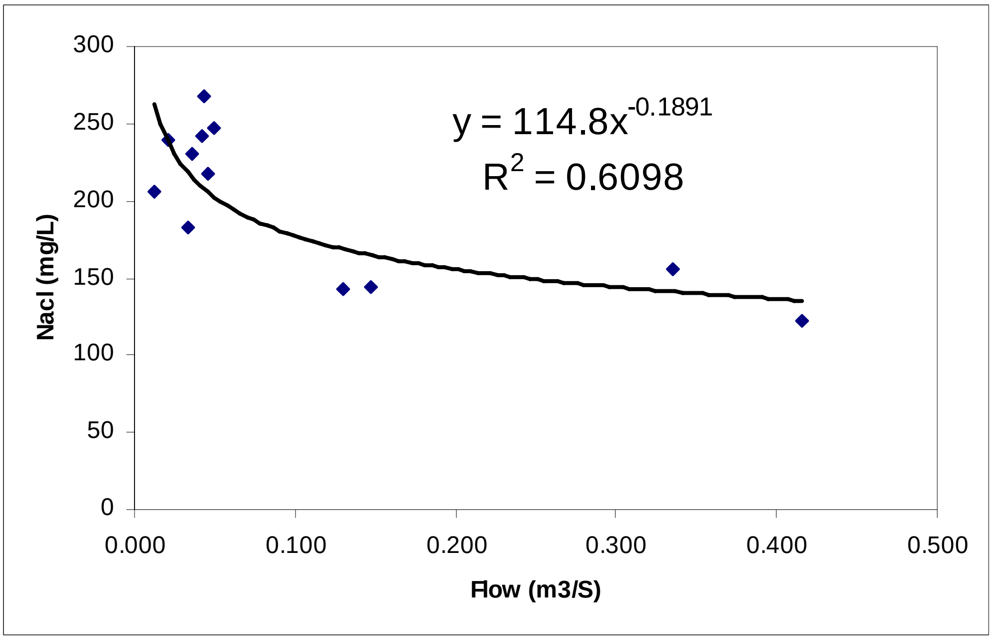


Figure 3.41: Monthly mean flow and median sodium chloride at Blinkwater water quality monitoring point

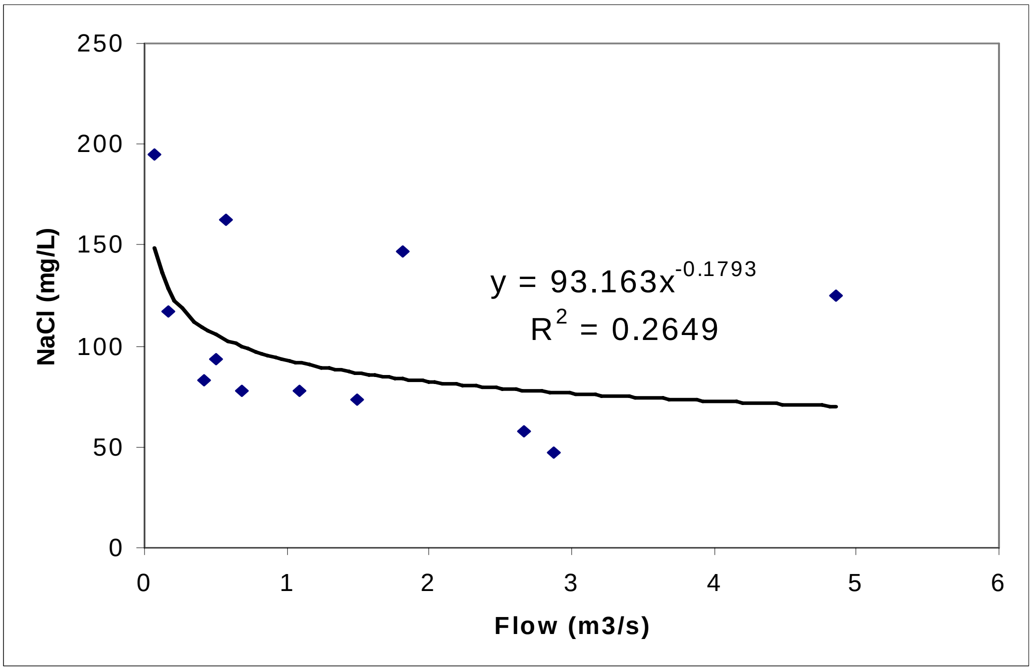


Figure 3.42: Monthly mean flow and median sodium chloride at the Fort Beaufort water quality monitoring point

The figures show the best regressions attained between median sodium chloride concentrations (mg/L) and mean monthly flows (m^3/s) at different DWAF water quality monitoring sites. At all the four water quality monitoring points, the power function exhibited highest correlation coefficients. The first two water quality monitoring points exhibit good relations with instream sodium chloride concentrations. Poor relationships are evident for both water quality monitoring points along the Kat River. According to a criteria set by Malan and Day (2002), correlation coefficients above 0.5 are good, between 0.5 and 0.2 are average and below 0.2 the relationship is poor.

Sodium Chloride concentrations frequency of occurences

Since there were poor correlations along the Kat river, it was decided therefore to use only the Blinkwater and the Balfour flow-concentration relationships to create salt profiles in terms of sodium chloride using historical flow records at respective sites. Both sodium chloride profiles from the Balfour and the Blinkwater water quality monitoring points are presented in Figures 3.43 and 3.44 below. According to these figures, sodium chloride concentrations at the Balfour water quality monitoring point varied between 10 and 195 (mg/L) whilst they changed between 55 and 520 (mg/L) at the Blinkwater water quality monitoring point.

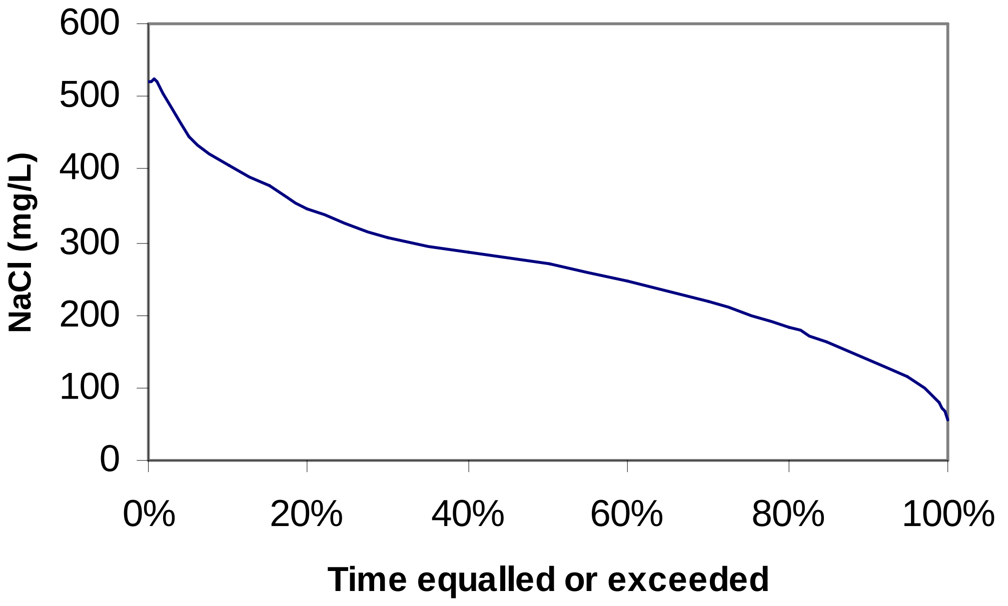


Figure 3.43: Sodium chloride frequency duration curve generated in T-SOFT from Q-C relationships at the Balfour water quality monitoring point.

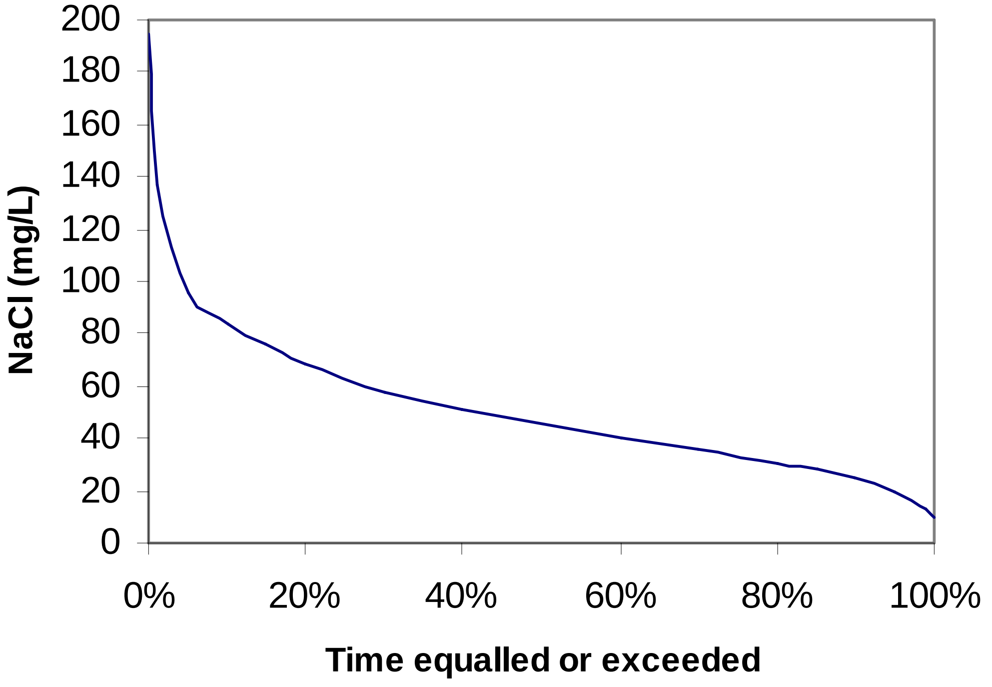


Figure 3.44: Sodium chloride frequency duration curve generated in T-SOFT from Q-C relationships at the Blinkwater water quality monitoring point

The respective sodium chloride profiles allowed for assessment of durations and associated ecological classes. Figures 3.43 and 3.44, shows the Balfour and Blinkwater Rivers were in a fair to poor condition in terms of sodium chloride concentrations derived from long term flow records. This shows that for 95% of the time both rivers are better than the poor/fair boundary. It was evident that although the risk approach employed is vital in salinity impacts assessments, the results should be interpreted with care. The approach employed considered monthly median concentrations and mean monthly flows. This is in itself an approximation of sodium chloride concentrations that exist in the field. Secondly, the use of flow records in simulating salt concentration is a further approximation (Malan and Day, 2002b). More importantly, the method employed discrete salt concentration records. There is a need to therefore ascertain the state of the aquatic ecosystem by undertaking bioassessments and integrating salinity tolerances for biota.

3.7 Discussion

In terms of the aims of this chapter, the spatial and temporal landscape salinity trends have been assessed. Generally salinity increases from the upper to the lower reaches. The upper catchment (upstream of site 6) had salinity concentrations of less than 250mg/L (Figure 3.4) whilst the lower reaches recorded salinities above this value. Salinity concentrations increased between site 6, Fort Beaufort water quality monitoring point and site 7, reaching a maximum of 1222mg/L. There was a marked decrease in salinities concentration between site 7 and site 10 in July 2003 to June 2004 (Figure 3.4). Although the catchment is dominated by citrus irrigation, mean daily salt loads results suggest that it is has limited impact on the river ecosystems. Highest mean daily salt loads were recorded during high flows and was a similar pattern recognised by Jain (2001) (Figure 3.6). However citrus irrigation upstream of Fort Beaufort and the sewage treatment works were identified as the main sources of salinity into the Kat River system. There is a need to efficiently treat the sewage for salinity before being discharged back into the river by the use of relevant biotechnology methods (Rose, 2002).

Long-term trends of major ions were also assessed for the four DWAF water quality monitoring sites. In order to understand trends in different ionic concentrations, it must be kept in mind that ions dissolved in water originate from either the geology through which the river flows or the soil through which it percolates or from the atmosphere (Day, 1993). Trends of major ions at different water quality monitoring points can also be explained in part by geochemical processes in the catchment (Palmer and Cherry, 1984). These include evaporative concentration, ion exchange, dissolution and precipitation (Kilham and Cloke, 1990). In addition, major ion concentrations in surface waters are influenced by the hydrological regime (Sami, 1992 and Britton *et al*., 1993).

Seasonal variations in the intensity of rainfall may play a role in the salinity variation as discussed above (Malan and Day, 2002a). During the rainy season, more dilution water is available so that most salts are dissolved in river water (Parsons, 2003). According to the literature of previous work in the area, most of the rainfall in the catchment falls within the Summer season (Hill, Kaplan and Scott, 1990, and Soviti, 2002) and only 37% of the annual rainfall falls within the Winter months (Hosking *et al*., 2002) and maximum ionic concentrations are expected then.

In the Kat River catchment, maximum EC, calcium, chloride, magnesium and sodium concentrations at the Kat dam, Balfour and Blinkwater water quality monitoring points coincided with historical droughts in the area. In addition, there was a general decreasing trend from the 1970s to 2004, which may suggest that historical land use in the upper catchment played a major role in these parameters. Details on both historical climatic conditions and land use are highlighted in chapter 2. Potassium and sulphate concentrations appeared not to be influenced by land use and climate as they remained more or less constant at the Blinkwater and the Balfour water quality monitoring point. There was an evident increase in sulphate concentrations at the Kat Dam water quality monitoring point, probably owing to the decomposition of plant residues (Rowntree, professor, Rhodes University, *per comm*., 2004). Despite a general downward trend in EC and many major ions (calcium, chloride, magnesium and sodium) being recognised at the upper catchment, the Fort Beaufort water quality monitoring point showed maintained or steady increasing trends. The reason for this may be that after 1994, there was expansion of citrus irrigation in the middle to lower reaches with access to international markets.

Both the RC and PES were defined between specific water quality sub-units. This are stretches of the river with perceived "homogeneous" water quality (Palmer *et al.*, in press). The Blinkwater and Balfour water quality monitoring points were used to define water quality sub-units at the Balfour and Blinkwater streams respectively, whilst the Kat Dam and Fort Beaufort water quality monitoring points were used to define conditions on the Kat River.

The TIMS model yielded the potential major salts concentrations on the Kat dam, Balfour, Blinkwater and Fort Beaufort water quality sub-units. Major salts, sodium sulphate, magnesium chloride, calcium chloride and calcium sulphate concentrations were found to be in the "Natural" range for all sub-units, hence their potential hazard to the aquatic ecosystem was considered less important. However two salts (magnesium sulphate and sodium chloride) appeared to have a potential impact on the aquatic ecosystem, especially at the Fort Beaufort water quality monitoring point (Figure 3.38). Although the aquatic ecosystem is still in a satisfactory state, attention should be paid to the causes of the class drop from "Natural". Possible sources of sodium chloride are irrigation return flows and withdrawals from Riverside citrus farming upstream of the water quality monitoring point. On the other hand, magnesium sulphate seemed to occur naturally from the geology, since there were no mining activities in the area that may be associated with elevated sulphates. This is of interest as magnesium sulphate is the most toxic of the salts (Jooste and Rossouw, 2002). However some of the PES data sets used have mainly low confidences and could not meet all requirements for a high confidence assessment (Table 3.6). Determination of reference conditions confirmed that salt levels in the Kat River system are relatively high, especially with regards to magnesium sulphate and sodium chloride. Default salt benchmarks had to be adjusted for the Balfour, Blinkwater and Fort Beaufort water quality sub-units for sodium chloride. Magnesium sulphate benchmarks at the Blinkwater and Fort Beaufort water quality monitoring points were also adjusted in order to assess the hazards to the local conditions (Palmer *et al.*, in press).

It must be stressed that the RC conditions set in the study may have been influenced by several factors and do not represent the real natural state. The climatic conditions and historical land use collated very well with major ionic concentrations over the years. These inevitably had a direct influence on the salt concentrations during the said periods. As highlighted in the previous chapter, the catchment has a long history of agricultural farming. The duration of the DWAF ionic data only started in the early 1970s and this is by no means the real reference condition. Implication of this is that results from the Jooste and Rossouw (2002) method should therefore be interpreted with caution. However since the RC at the Kat Dam, Balfour and Blinkwater water quality monitoring points were defined during relatively dry period, it is highly likely that the assessment was more conservative because concentrations are usually high under such conditions. The hazard posed by different salts may have therefore been exaggerated. However, the best data available was used in defining reference conditions in the Kat River catchment.

Results revealed that there was no hazard posed by sodium sulphate, magnesium chloride and calcium chloride throughout. All water quality sub-units were categorised as natural in terms of these salts. The Balfour River was categorised as Natural with regards to magnesium sulphate and sodium chloride. The Kat River at the Kat Dam and the Blinkwater River fell in the Natural category with regards to sodium chloride. On the other hand, the Kat River at the Kat Dam and the Blinkwater categorised as Good. For the Fort Beaufort sub-unit, the Kat River fell within the Good category with regards to sodium chloride and magnesium sulphate. These results therefore drove to the conclusion that none of the major salts has been a driver of the aquatic ecosystem. It is still important not to loose sight of the fact that Jooste and Rossouw (2002) benchmarks were set using international ecotoxicological data. Furthermore although only fresh water organisms were pooled from the AQUIRE database, the data needed to be extrapolated for comparisons. This then suggests that caution should be exercised when interpreting the results. However Kefford *et a*l., (2004) demonstrated that there were no major discrepancies between Australian and South African organisms with respect to salts. This finding may suggest that international ecotoxicological data was probably sufficient to describe the hazard posed by the aquatic organisms in relation to different salts. It therefore follows that the application of the method in this study is valid in this regard. Jooste and Rossouw (2002) acknowledge that the hazard posed by salts to aquatic organisms is attributable to the ions and not the salts as such. Mount *et al*., (1997) and Palmer and Goetsch (1997) had earlier cited that salts are differentially toxic to the aquatic ecosystem. The main advantage of the Jooste and Rossouw (2002) is that it takes cognisance of this important fact. However the method is a simplification of the real situation since there lack of ecotoxicological data on individual ions. This is still the only evaluation method that takes into consideration the hazard of different salts to the aquatic ecosystem in South Africa to date. It is taken to be sufficient to evaluate the potential impact different salts may have on the aquatic ecosystem.

Since the Jooste and Rossouw (2002) approach is hazard based, an attempt was made to assess the risk posed by the aquatic ecosystem with respect to sodium chloride. This was achieved through investigating flow-sodium chloride concentrations relationships at the different water quality monitoring points. The relationships were used to extrapolate sodium chloride profiles using flow records. Sodium chloride showed no correlation with flow at the Kat dam and Fort Beaufort sub-units. A reasonably high correlation at the Blinkwater and Balfour sub-units allowed for derivation of a sodium chloride time series. Conditions at the Balfour water quality monitoring point site pose no sodium chloride related risk but risk at the Blinkwater was high. There are a number of reasons that might explain the poor concentration flow relationship for the other water quality monitoring points. The first is that salinisation in the catchment may be driven by irrigation to some extent. During the irrigation season, salt may build up in the soil through application of irrigation water and high evaporation rates (Malan and Day, 2002b). These salts are washed into the river during rain events so that the salt concentration will depend on timing of sample collection. Thus for the same discharge, salt concentration may vary depending on whether the sample was collected during the initial salt ‘wash off’ or when the flow is receding (Gregory and Walling, 1974 and Malan and Day, 2002a). The relationship cannot be assessed using simple flow-concentration relationships. Secondly the irregular dam releases from the Kat dam are solely managed on request from citrus farmers. Both the Kat dam water quality monitoring point and the Fort Beaufort water quality monitoring points may exhibit low correlation coefficients due to variable flow regulation. More importantly the use of mean daily flows and median sodium chloride concentrations had masked aspects of the relationships.

Conversion of discharge-concentration relationships to sodium chloride concentration duration curves was an attempt to assess the various ranking flow scenarios with regards to their sodium chloride concentrations and the associated risk to the aquatic ecosystem (Figures 3.43 to 3.44). When the adjusted Jooste and Rossouw (2002) benchmarks were used to categorise flow derived sodium chloride time series from the Balfour and Blinkwater water quality monitoring points, both rivers were in a fair to poor state (Figures 3.43 and 3.44). However it must be highlighted here that studies in the past have shown that assessing salinity impacts on ecotoxicological data (especially international) alone, may over-estimate the extent of the problem (e.g. DWAF, 2000). Evaluating salinity impacts on the aquatic ecosystem requires consideration of other useful data. These include bioassessments, physical and chemical characteristics of water body. The approach that incorporates all these data sources is termed Environmental Water Quality (EWQ) and was applied in assessing salinity impacts on the Kat River catchment ecosystem in chapter 4.

CHAPTER 4: ENVIRONMENTAL WATER QUALITY APPROACH IN ASSESSING SALINITY IMPACTS

4.1 Introduction

It is a difficult task to assess the role of salinity in structuring aquatic ecosystems because of their complex nature and unknown interactions between different components. In order to understand how salinity and salts link to responses in the aquatic ecosystems, three sources of information need to be used. First are the physico-chemistry data, which in this case would be comprised of the salt concentrations. Second is information on the aquatic ecosystem state, gathered through bioassessments. The last component is about the responses of the biota to salts and salinity. Although important on their own, none of the components can fully provide a link between salt concentrations and the aquatic ecosystem. The major salts and salinity data only describes the concentrations to which the aquatic ecosystem was exposed during sampling. This does not provide the condition of the aquatic ecosystem over time, hence more information is necessary in describing the link between salinity and the aquatic ecosystem. Bioassessments integrate impacts on the ecosystem over time as biota are part of the ecosystem and are exposed to all the salt concentrations that may exist. They may be able to show the condition of the aquatic ecosystem, but their use alone in relating ecological condition to salinity can not ascertain if the ecological condition is driven by salinity or any other stressor. Knowledge of the response of biota to salinity is therefore vital and ecotoxicology provides such information. In combining the different sources of data, the role of salinity on the aquatic ecosystem can be understood better as each provides vital information that is not offered by the rest.

It is proposed that the approach where physico-chemical information is used together with bioassessments and salinity tolerance levels be called the Environmental Water Quality (EWQ) approach (Palmer *et al.*, 2003). Such an approach was applied in this study, to provide a link between ecological conditions in the Kat River catchment and the possible effects of salinity.

In chapter 3, physico-chemical (major ions) data were used to show the different concentrations of major salts at different water quality monitoring points in the Kat River catchment. A bioassessment was undertaken between Autumn 2003 and Summer

2004 to infer the condition of the aquatic ecosystem. Salinity tolerances were sourced from local and international literature since no salt toxicity tests were carried out in this particular study. The first part of the chapter covers a brief background on bioassessments and methods employed in the study. Subsequently the results and the implication for the ecological condition are highlighted. The second part of the chapter is based on the use of relevant local and international data to derive salt concentration classes through the use of Species Sensitivity Distributions (SSDs). The last part of the chapter then deals with EWQ and highlights the use of salt concentrations in chapter 3, an SSD and ecological condition results indicated by bioassessments to give a full assessment of the role of salinity in the Kat River catchment.

4.2 Bioassessment

4.2.1 Theoretical background

Bioassessments may be defined as the utilization of one or more living components of the aquatic ecosystem to assess its ecological state (Dallas, 1995). The term is sometimes used synonymously with “biomonitoring” as is the case in this study. They are becoming more popular because of numerous shortcomings in the use of physical and chemical monitoring programmes (De la Rey *et al.*, 2004). One of the main setbacks of using traditional chemical monitoring schemes to monitor aquatic ecosystem condition is that this only shows snap shots of conditions of the ecosystem and no inference to the period between sampling events. Furthermore financial and time resources are almost always limited as it is impossible to monitor all components so that indicators are used instead (Madikizela *et al*., 2001). Only indicators of ‘integrity’ or state can be assessed and, in turn, used to infer the ecological status (Roux, 2001). The advantage of using biota is that they are exposed to all salinity perturbations that affect them, including high and low concentrations. Thus species present in the riverine ecosystems provide both the historical and present state of water quality and allow realisation of events that could have been missed (Thorne and Williams, 1997). The underlying philosophy in bioassessments is that if chemical conditions are favourable, biota have the potential to thrive. On the other hand when concentrations approach or exceed their tolerance limits, they might diminish and disappear all together (Dallas and Day, 2004). Since different organisms have different tolerance levels, their presence and absence or change in community composition can indicate effects of salinity.

A wide variety of organisms are used in bioassessments as they exhibit specific advantages that make them suitable for the particular initiative. Of all organisms macroinvertebrates appear to be the most widely used (Rosenberg and Resh, 1993). Advantages of using this group of organisms are that they are numerous and they have a wide range of salinity tolerances (Bunn and Davies, 1992 and Rosenberg and Resh, 1993). Although they have relatively short life spans, their immobility allows for them being good indicators of ecological condition. Other authors have criticized the use of macroinvertebrates in assessing ecological status of an ecosystem (Karr, 1981; Kleynhans, 1999 and De la Rey *et al*., 2004). It is difficult to get a quantitative sample, similar substrates need to be sampled at all sites, sorting and identification in the laboratory is labour intensive and expensive, identification requires taxonomic expertise (Reynoldson and Metcalfe-Smith, 1992) and meaningful results are often difficult to relate to the general public. Furthermore, the heterogeneous nature of macroinvertebrates in rivers is problematic with regards to quantitative sampling (Dallas, 1995 and Kay *et al*., 1999). Their distribution can also be affected by a whole range of other factors and water quality components besides salinity (Kefford, 1998). This may include seasonality and type of habitat (Parsons and Norris, 1996). It is therefore difficult to separate impairments of water quality from natural variability to that associated with water quality (Rosenberg and Resh, 1993). All these factors cannot be over looked when drawing inferences between resident macroinvertebrates and salinity. However, the use of macroinvertebrates has changed over time to address some of these concerns. Most biomonitoring programmes (River Health Programme, British River Invertebrate Prediction and Classification, Australian National River Health Programme and Rapid Bioassessment Protocols For Use in Streams and Rivers of the United States) (Roux, 2001; Wright *et al*., 1993; Smith *et al*., 1997 and Barbour *et al*., 1997) make use of identification of macroinvertebrates in the field only to family level. These do not need a high level of taxonomic expertise and can be done by well-trained technicians (Chutter, 1998). Protocols for sampling have also been developed to account for the qualitative sampling and data interpretation has also been made relatively easy (Dickens and Graham, 2002 and Vos *et al*., 2002).

In South Africa, bioassessments have been existent over thirty years back although only becoming popular in the 1990s with the launching of the River Health Programme (RHP) (Roux, 2001). The aim of the programme was to expand ecological information on managing the country’s rivers (Uys *et al*., 1996). The RHP as it is known, strives for scientifically derived methods in assessing ecological condition to aid decision-making. It provides a systematic framework for quality controlled collection and assessment of river health data and for reporting the results. The main objective of this initiative is a countrywide assessment of ecological conditions or integrity of rivers and streams (Roux, 2001). Rapid bioassessments methods were developed that require only basic training. Most of these are based on attributes of organisms such as fish, macroinvertebrates, algae and riparian vegetation (Chutter, 1998; Kleynhans, 1999; Kemper, 2001 and De la Ray *et al*., 2004). These biotic indices, as they are sometimes called, have been tested in parts of the country. Although they have been existent for some years, they are still being refined from their original form. Bioassessments have only been incorporated into routine monitoring of South African River resources for less than ten years, but are considered an integral part in ecosystem management (Hohls, 1996). The first step in the assessment of ecological integrity is that of site selection. It provides a basis for analysis of biomonitoring data (Dallas, 2000). The natural variability of the system both spatially and temporally is also taken into account (Dallas, 2002). This is because aquatic ecosystems are highly variable in space and season (Dallas, 2002). Spatial variabilities comprise catchments, reach characteristics and habitats along a river. Gradual changes in the altitude, water temperature, dissolved oxygen and flow have a direct bearing on the resident in-stream biota (Dallas, 2002). Environmental factors at a particular site along the river can also vary from seasonally. This was expected in the Kat River catchment, where the rainfall is highly seasonal (Chapter 2).

4.3 Bioassessment Methods

The methods employed in this study include site selection and different biomonitoring indices that are currently being used in the country. This section includes a detailed account of each of the indices and procedure that was followed in the field whilst sampling. The indices that were employed include SASS5 for macroinvertebrates and IHAS for habitat quality assessments (Dickens and Graham, 2002 and McMillian, 1998).

4.3.1 Site selection

In biomonitoring site selection, reference and monitoring sites are selected (Dallas, 2000). Reference sites are those that are perceived to be minimally impacted and are used as benchmarks with which to compare monitoring sites. In the Kat River catchment, reference sites were very difficult to find since almost every site has been impacted. The following methodology was carried in selecting reference and monitoring sites to infer the biological integrity. The criteria followed included gradient, land-use, habitat and accessibility.

4.3.2 Delineating river reaches

The river was divided into reaches, using 1:50,000 topographic maps of the catchment by measuring the gradient along the river course and identifying where it changed considerably (Gaulana, 2003). Thus the gradient is the distance between two points on the river divided by the contour interval between them. The rationale behind dividing a river into segments or reaches is that, naturally changes in components of the aquatic ecosystems are expected (e.g macroinvertebrate community structure in the upper reaches are different from the lower reaches) (Dallas ,2002).

4.3.3 Acessibility

As one of the criterion, all accessible sites by road on the map were highlighted as possible sites for biomonitoring. Some potential sites were not selected for ground-truthing, since they were not accessible and hence were not eligible for selection.

4.3.4 Land use

Land use around a site weighed heavily on the decision whether or not a site could be considered for monitoring. A paired site selection approach was initiated. The citrus farming in the catchment was considered a potential source of salinity in the catchment, therefore a paired site approach was initiated and reference sites (upstream) and monitoring sites (downstream of the farming activities) were selected. Other considerations included sites selected downstream of Fort Beaufort and rural villages.

4.3.5 Field surveys and ground truthing

All the sites that were identified during a desktop study were located and visited. The GPS co-ordinates, land use and habitat were then noted. An observation on the reliability of the flow was also made. Photographs of particular sites were then taken and results presented in Appendix B.

4.3.6 Finalising site selection

It is not an easy task to visualize all the sites and their habitat conditions to make a final site selection. A schematic of the Kat and its tributaries was drawn on a white board in order get a good synoptic view of the catchment. GPS coordinates were then used to locate each site on the map. Photographs of each site were then stuck next to their particular sites to allow comparisons of flow and habitat. Notes that were made during the site visits were then used to delineate land use whilst reaches from the topographic map were delineated on the catchment. Reference sites and monitoring sites were then selected on the basis of reach, land-use and available habitat.

4.4 Field collecting Methods

4.4.1 SASS (South African Scoring System version 5)

Sampling in the Kat River Valley was undertaken in April, 2003 to December, 2004. Surveys were undertaken every three months so as to account for four seasons of the year. SASS sampling took place in all the four seasons, since macroinvertebrates were to be used further in evaluating salinity impacts.

SASS was originally developed in response to a need for an easy, rapid and cost effective method of biological monitoring of water quality (Therion *et al*., 1995). The method is a modification of the British Biological Monitoring Water Programme (BMWP) System by Chutter for evaluating rivers (Chutter, 1998). SASS 5 evaluates the impact of changes in water quality, using aquatic macroinvertebrates as indicator organisms. It is based on the presence of families of aquatic invertebrate fauna and their perceived sensitivity to water quality changes such that sensitive species are assigned the highest scores whilst the more resilient once are assigned low scores.

Results from a SASS exercise are the SASS score and the Average Score Per Taxon (ASPT). The SASS score was computed by adding all individual scores (1 to 15) for each macroinvertebrate family recorded at a site. The ASPT score was computed by dividing the total SASS score by the number of taxa found at a site (Graham and

Dickens, 2002). Although SASS can provide some insights on the nature or type of impact, it is primarily intended to provide a “warning light” for any water quality deterioration (Dallas, 1995). Sampling involved collecting macroinvertebrates in different biotopes, using a specified net (300 x 400mm frame, 950µm mesh). The biotopes sampled include stones in current, vegetation and gravel, sand and mud.

The net was held immediately downstream of stones that were being kicked such that the current carries the dislodged macroinverterbrates into the SASS net (Graham and Dickens, 2002). The total kicking time at all riffles was approximately two minutes (Chutter, 1998). During this time all riffles were sampled especially when they are of different sizes. The contents of the net were tipped into a SASS tray filled with a bit of river water. The remainder of the macroinvertebrates, were removed carefully from the net into the SASS tray using fine paint brushes.

The net was rinsed with river water and the next biotope sampled. The vegetation was sampled by pushing the net vigorously on a total length of 2 meters (Graham and Dickens, 2002). In some instances this were spread over two or more locations. In the process, the net was kept under water to avoid collecting macroinverterbrates from the surface (Graham and Dickens, 2002). The contents of the net were then carefully emptied into a SASS tray filled with a bit of river water. In the case of gravel, sand and mud, SASS net was swept whilst agitating these biotopes. These were sometimes sampled in isolation and the total time taken for the sampling was 30 seconds (Graham and Dickens, 2002).

With all biotopes, twiggs, leaves, stones and other material were removed from the samples before the macroinvertebrates could be identified. However caution was taken that no organisms were clinging to the debris. The macroinvertebrates were then identified to family level and their abundances estimated (1, A=2-10, B=11-100, C=100-1000) and marked on a standard SASS5 sheet. The identification took 15 minutes or until no new families were identified for 5 minutes. A field guide on aquatic invertebrates of South Africa (Gerber and Gabriel, 2002) was used in identifying the different macroinvertebrate families.

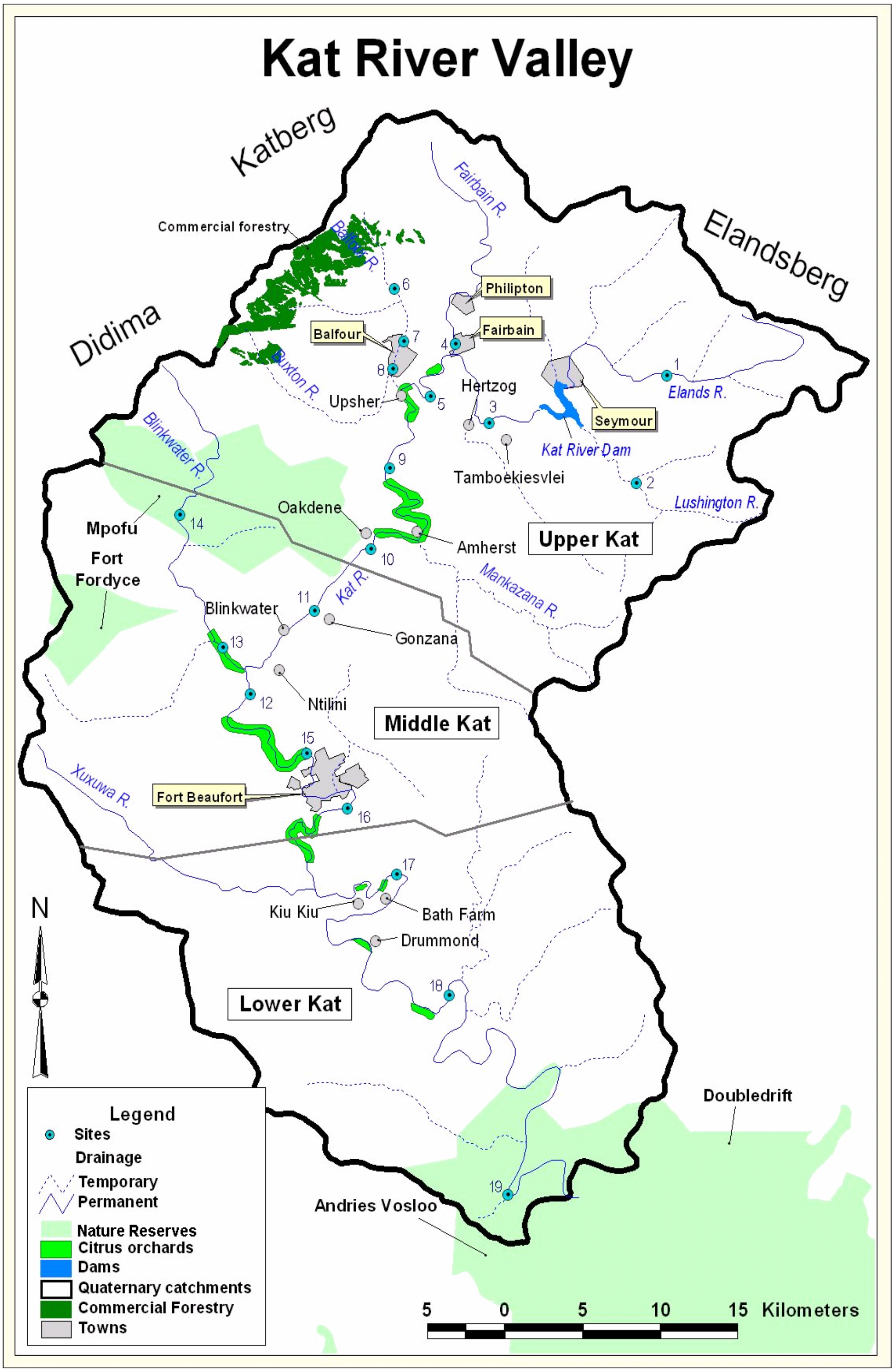


Figure 4.1: Kat River landuse map and locations of selected biomonitoring sites

Each sample was then sieved through a hand net before being preserved in 80% alcohol. Labels were then inscribed with pencil on small piece of paper. The date, site number, biotope and name of sampler were noted, and labels placed in the honey jar. These samples were later sorted in the laboratory and each individual counted to obtain abundances. Later statistical tests were performed to investigate the relationship between salinity and macroinvertebrates abundances by computing the correlation coefficient in Excel. The significances of these correlations were then tested in STATISTICA software.

4.4.2 Determination of Ecological state categories

The most important information extracted from any biomonitoring programme would be the ecological state. As already mentioned in the first chapter (section 1.7), this can be directly linked to the level of goods and services that an aquatic ecosystem can offer. An ecological condition determination entails a comparison between the present state of the ecosystem and its natural state. Although there were sites selected in the Kat River catchment as natural biomonitoring sites, results later revealed that they were more impacted compared to some of the monitoring sites. In the absence of any real reference sites, default ASPT boundaries were adopted to assign ecological classes at different sites (DWAF, 2004b).

Table 4.1 Ecological condition boundaries according to ASPT scores (Adopted from DWAF, 2004b)

Class Boundary	ASPT
Natural	7
Good	6
Fair	5
Poor	< 5

4.4.3 Physical and chemical collection methods

Water quality measurements are taken during SASS sampling to relate the scores to water quality components. The temperature was taken using a thermometer, whilst pH, Dissolved Oxygen and the EC were measured using handheld meters. Results were noted on a standard SASS 5 sheet.

4.4.4 Integrated Habitat Assessment System (IHAS)

Resident macroinverterbrate families are not only dependent on the water quality, but can also be influenced on availability and quality of habitat (Barbour, 1991 and Parsons and Norris, 1996). Thus to evaluate the salinity impacts, the influence of the habitat was also evaluated. An assessment of habitats samples and the general condition of the site were evaluated using IHAS (McMillian, 1998). This index involves evaluating the quality of the habitat sampled and the physical stream conditions in general based on a total of 100 points. The two components are assigned the same weighting of 50 points each. The physical characteristics score is derived from river width, velocity, depth, water colour, extent of land use impacts and nature of bank cover. Each of these is assigned a score between 0 and 5 and the total computed from summation of individual scores. The 50 from the sampled habitat is divided between stones in current, vegetation and other habitat. The total IHAS scores for a particular site are derived from the total score for the sampled habitat and the physical conditions scores. A standard IHAS sheet was filled in after every SASS sampling, and the total scores worked out at a later stage. The higher scores (close to 100) are interpreted as representing sites with good habitat condition.

4.5 Biomonitoring Results

4.5.1 Total SASS scores

The SASS method produced two different scores that were used in ecosystem condition classifications, SASS and the ASPT score. The two measures are used to complement each other in resource classification, although the ASPT is the least variable and also provides the most reliable measure (Dallas, 2000 and Dickens and Graham, 2002). However, Chutter (1998) warns that the ASPT scores are more reliable in clean rivers whilst they can be exceptionally high in polluted rivers. Therefore the SASS score and the number of taxa were used to aid interpretation to get a clearer picture on the ecological condition. The individual SASS5 scores sampled at each of the sites over four seasons are summarised in Figures 4.2 to 4.5.

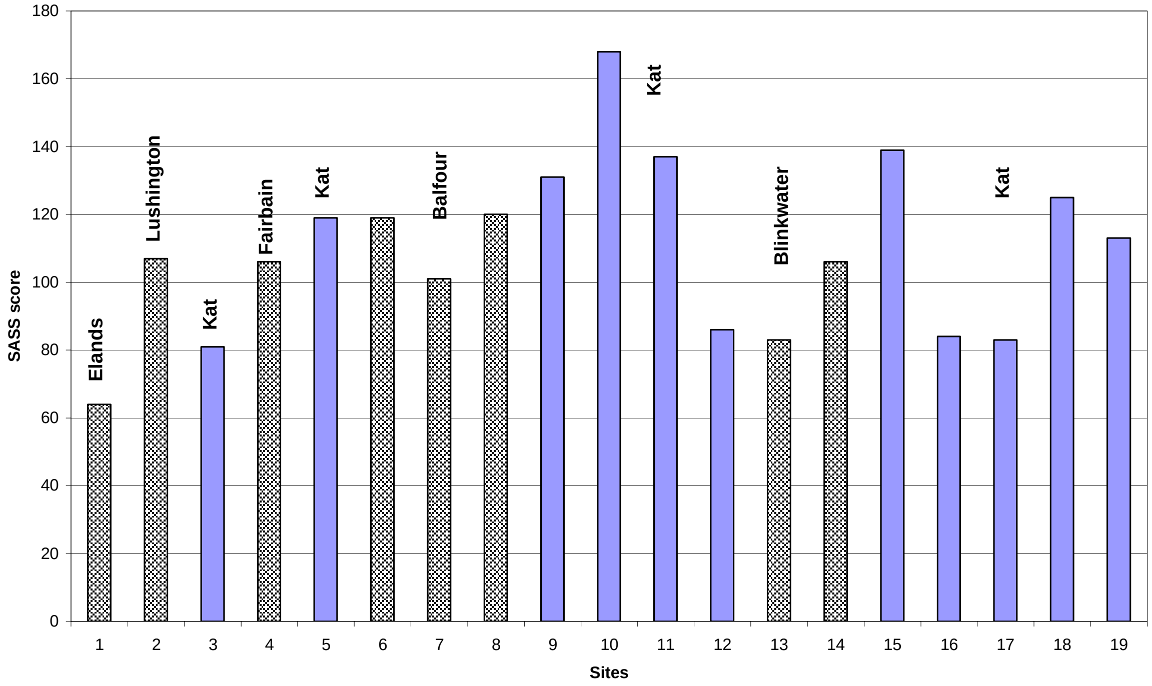


Figure 4.2: Calculated total SASS5 scores at different Biomonitoring sites in April, 2003 (Autumn)

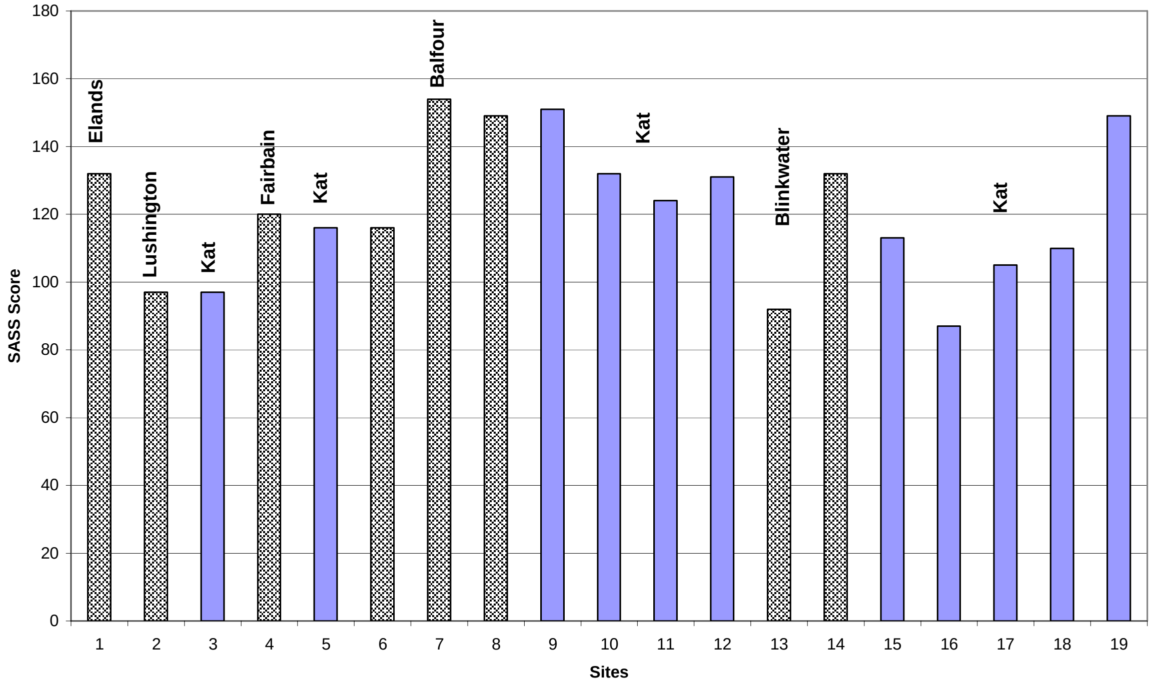


Figure 4.3: Calculated total SASS5 scores at different Biomonitoring sites in July, 2003 (Winter)

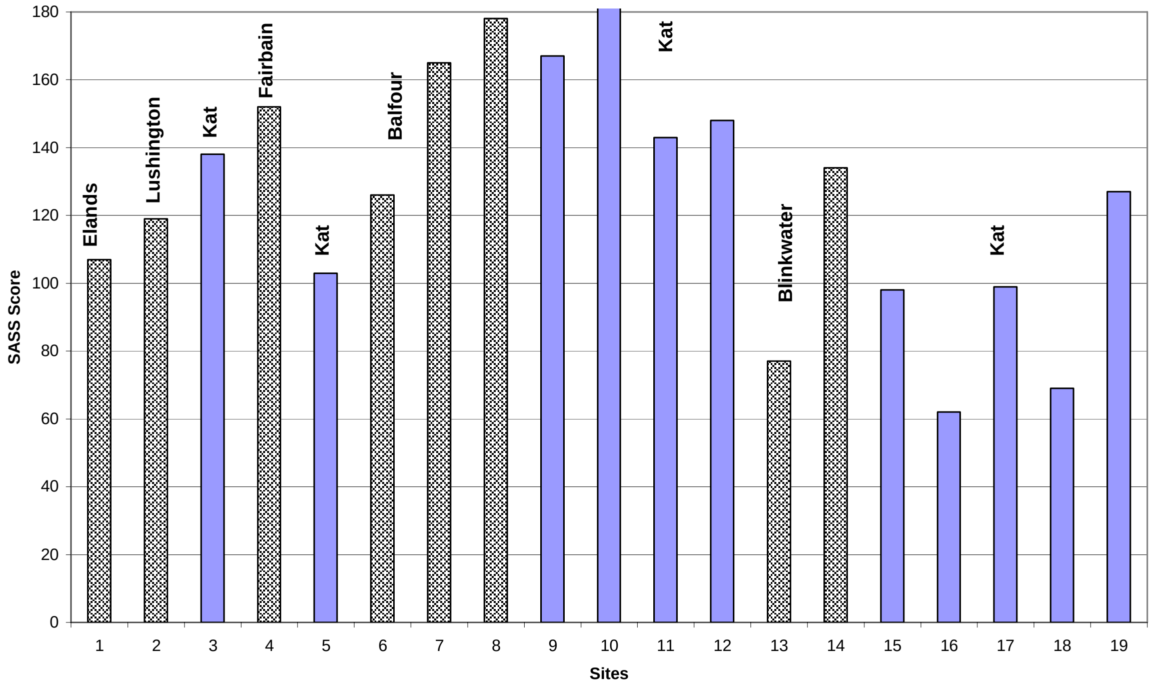


Figure 4.4: Calculated total SASS5 scores at different Biomonitoring sites in October, 2003 (Spring)

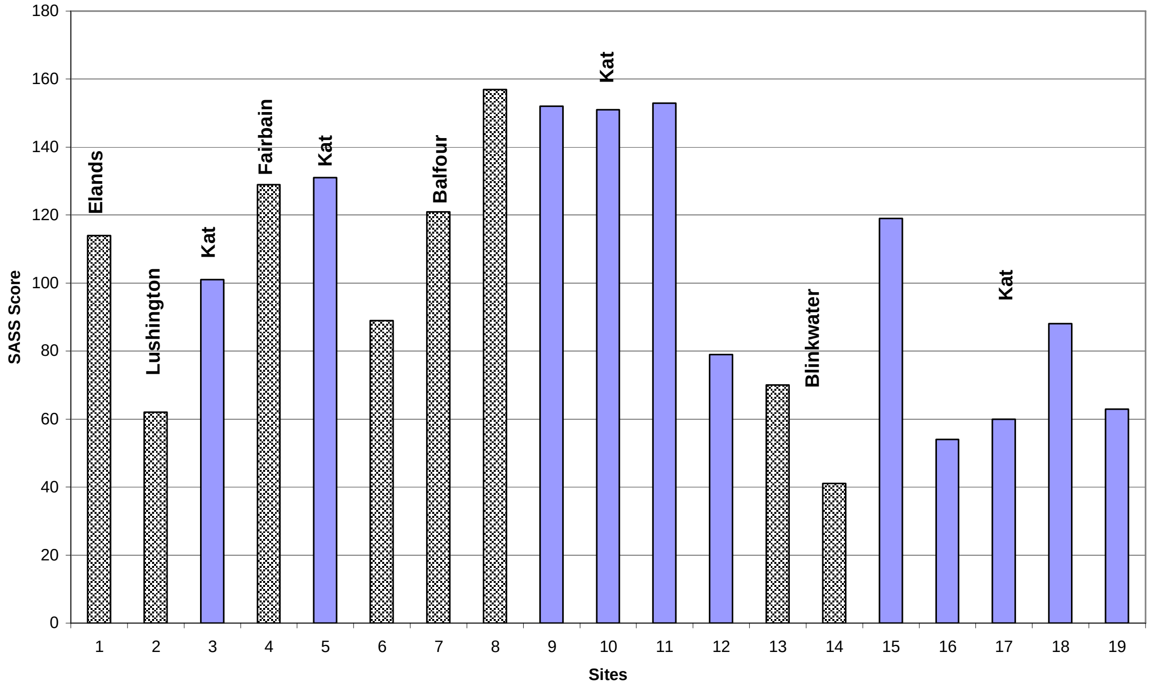


Figure 4.5: Calculated total SASS5 scores at different Biomonitoring sites in January, 2004 (Summer)

These SASS5 scores varied to a large extent over the different seasons as illustrated in Figures 4.2 to 4.5. Results are also summarised in Table 4.2 below for better visualisation and comparison. Generally the scores were low during Autumn (Figure 4.2) and Spring (Figure 4.4) seasons for the majority of sites with sites 1, 3, 12, 13 and 14 having SASS scores less than 80. On the other hand, the highest SASS scores in Autumn were recorded at sites 5 and 6 on the Balfour River and 8, 9, 10, 11, 15 and 18 along the Kat River. Sites 2, 4, 7, 14 and 19 had SASS scores between 100 and 120 whilst marginally lower (between 80 and 100) at sites 16 and 17.

Table 4.2 Showing total SASS5 scores at different biomonitoring sites over the four seasons

Site no.	River	Season			
		Autumn	Winter	Spring	Summer
1	Elands	64	132	107	114
2	Lushington	107	97	119	62
3	Kat	81	97	138	101
4	Fairbairn	106	120	152	129
5	Kat	119	116	103	131
6	Balfour	119	116	126	89
7	Balfour	101	154	165	121
8	Balfour	120	149	178	157
9	Kat	131	151	167	152
10	Kat	168	132	183	151
11	Kat	137	124	143	153
12	Kat	86	131	148	79
13	Blinkwater	106	132	134	41
14	Blinkwater	83	92	77	70
15	Kat	139	113	98	119
16	Kat	84	87	62	54
17	Kat	83	105	99	60
18	Kat	125	110	69	88
19	Kat	113	149	127	63

With the coming of the Winter season, there was a clear increase in the total SASS scores at sites 1, 7, 14, 17 and 19 (Figure 4.3). Relatively high scores were maintained at sites 8, 9, 10 and 11whilst there was sites 5, 6 and 13 were not affected by the change of season from Autumn to Winter. However a slight drop in the SASS scores was realised at sites 2, 15 and 18 between the two seasons.

Most of the sites recorded SASS scores above 100 during the Spring sampling (2, 3, 4, 6, 7, 8, 9, 10, 11, 14 and 19) (Figure 4.4). The same figure shows the lowest scores were recorded at sites 13 and 16 (80 and 64) whilst the SASS score at site 17 was just below 100. Relatively high SASS scores were maintained during the Summer sampling; sites 1, 3, 4, 5, 7, 8, 9, 10, 11 and 15 all had SASS scores above 100 (Figure 4.5). Whilst SASS scores at sites 2, 17 and 19 dropped, the low scores at sites 13 and 16 remained evident.

4.5.2 Macroinvertebrate family abundances

A closer look at the abundance of selected macroinvertebrates families showed that there were prominent patterns in their distributions spatially and seasonally. These families included Turbellaria, Baetidae, Leptophlebiidae, Tricorythidae, Corixidae and Ancylidae, which were the only ones that had some ecotoxicity data in the UCEWQ (Unilever Center for Environmental Quality) database. Figures 4.6 to 4.9 show the different abundances of the above-mentioned macroinvertebrate families along the main Kat River stem. Abundances at different tributaries during the Biomonitoring are summarised in Appendix I.

The above-mentioned macroinvertebrate families fall in four different orders. The majority of these (Baetidae, Heptagiinaidae, Leptophlebiidae and Tricorythidae) are Ephemeroptera. Corixidae are classified under the Hemiptera order whilst Ancylidae are classified under Gastropods. Animals from Ephemoreptra order are regarded as being the most salt-sensitive (Kefford *et al.*, 2003). However Trycorythidae and Leptophlebiidae are filter feeders and their abundance will certainly not be dependent on salinity alone (Palmer *et al.*, 1991). The second salt-sensintive families are Corixidae followed by Ancylidae and Turbellaria. Ancylidae and Turbellaria are very salt tolerant macroinvertebrates and may not be affected by salinity (Kefford *et al.*, 2004). However, their dominance in the macroinvertebrate community structure may give an indication of salinity impacts on the aquatic ecosystem. The selected macroinvertebrates offer a wide range of salinity tolerances and are representative of the aquatic ecosystem. A more direct approach in the use of salinity tolerances on most of these macroinvertebrate families is discussed in section 4.6.

Abundances of selected macroinvertebrates revealed that Baetidae were the most abundant macroinvertebrate family across all biomonitoring sites (Figure 4.6, 4.7, 4.8 and 4.9). This family was recorded at all biomonitoring sites in each and every season. Their highest abundances were recorded in Winter, when their numbers went as high as 500 in site 10 (Figure 4.7). A general trend with Baetidae was that their numbers increased from the upper most sites (3, 5 and 9) to the maxima at site 10 in the middle Kat River reaches. There was a discernable drop in abundances from site 11 until the minima at site 16 over the seasons (Figures 4.6, 4.7, 4.8 and 4.9). There was then a rise in numbers of Baetidae sampled between sites 16 and 17, although this was not realised during the Spring season.

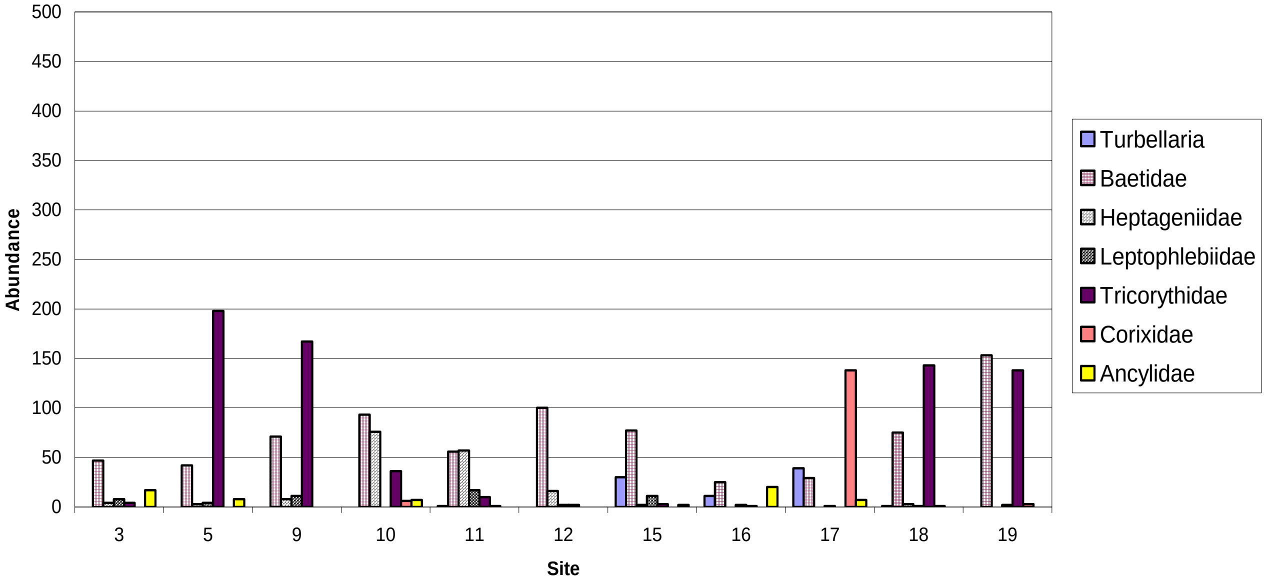


Figure 4.6: Showing abundances of selected macroinvertebrate families along the Kat River stem during Autumn Biomonitoring

Heptageniidae abundances seemed to follow a similar pattern to the Baetidae family over the seasons although their abundances were markedly lower. The highest numbers were always recorded at sites 9, 10 and 11 although there were notably lower at site 9 in Autumn and Spring (Figures 4.6 and 4.8). The numbers of Heptageniidae sampled were highest in Autumn when they reached above 70 (Figure 4.6). During Winter, Spring and Summer however, abundances were comparable with the highest being recorded around 40 and the lowest around 5 (Figure 4.7, 4.8 and 4.9). Heptageniidae have never been sampled at sites 16 and 17 over the seasonal biomonitoring.

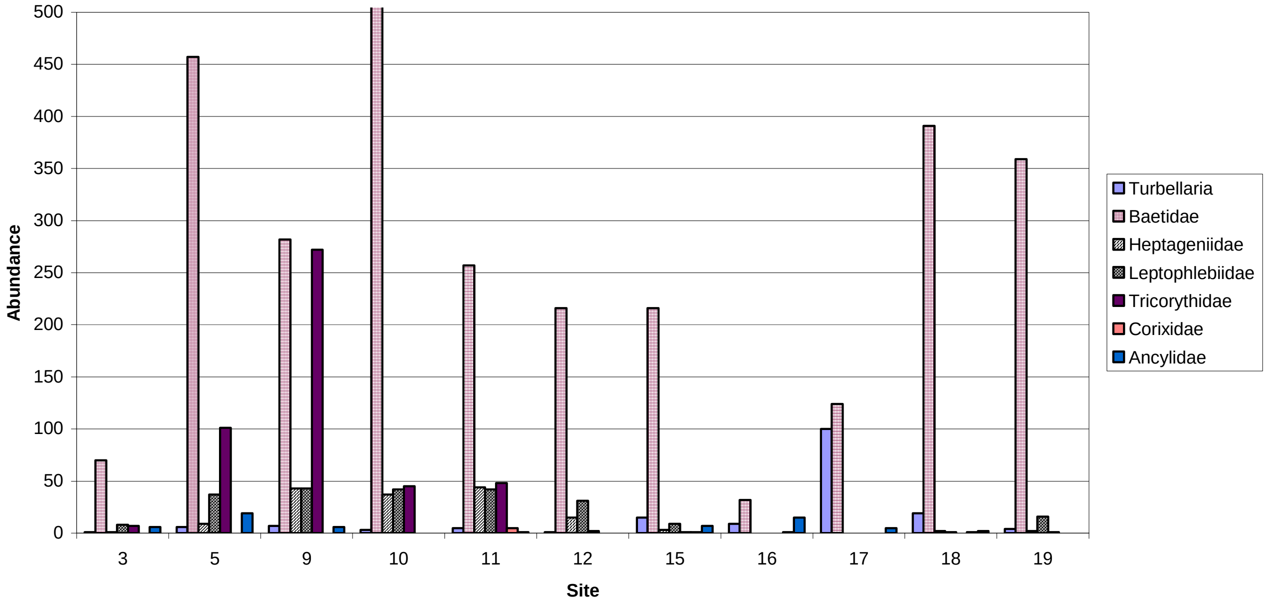


Figure 4.7: Showing abundances of selected macroinvertebrate families along the Kat River stem during Winter Biomonitoring

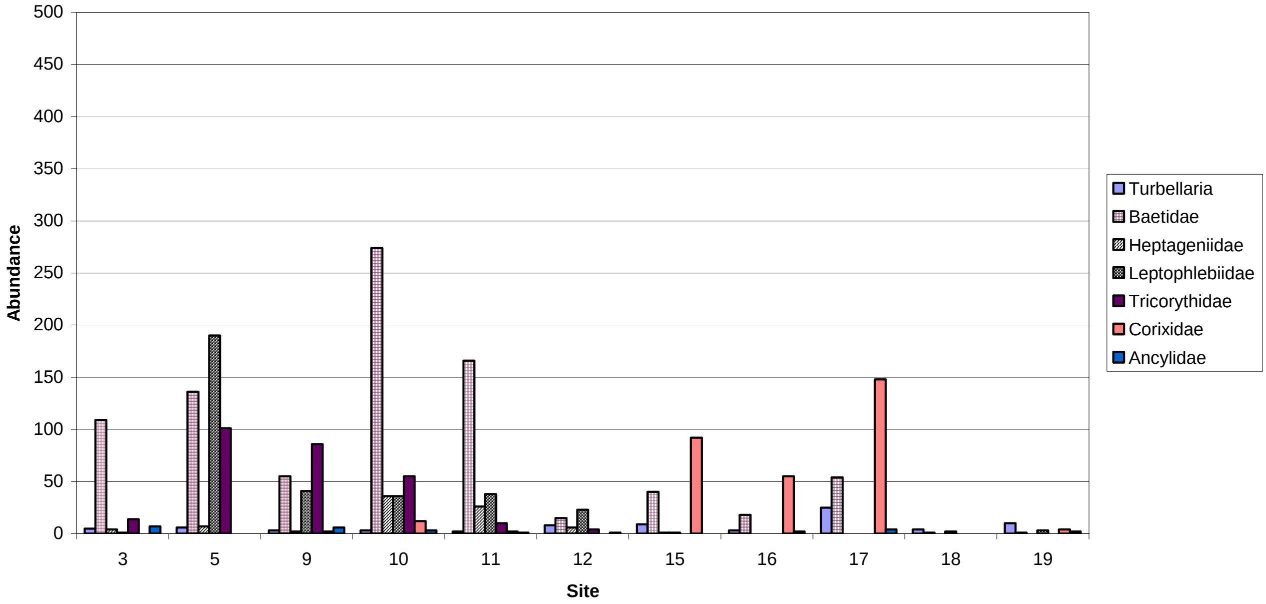


Figure 4.8: Showing abundances of selected macroinvertebrate families along the Kat River stem during Spring Biomonitoring

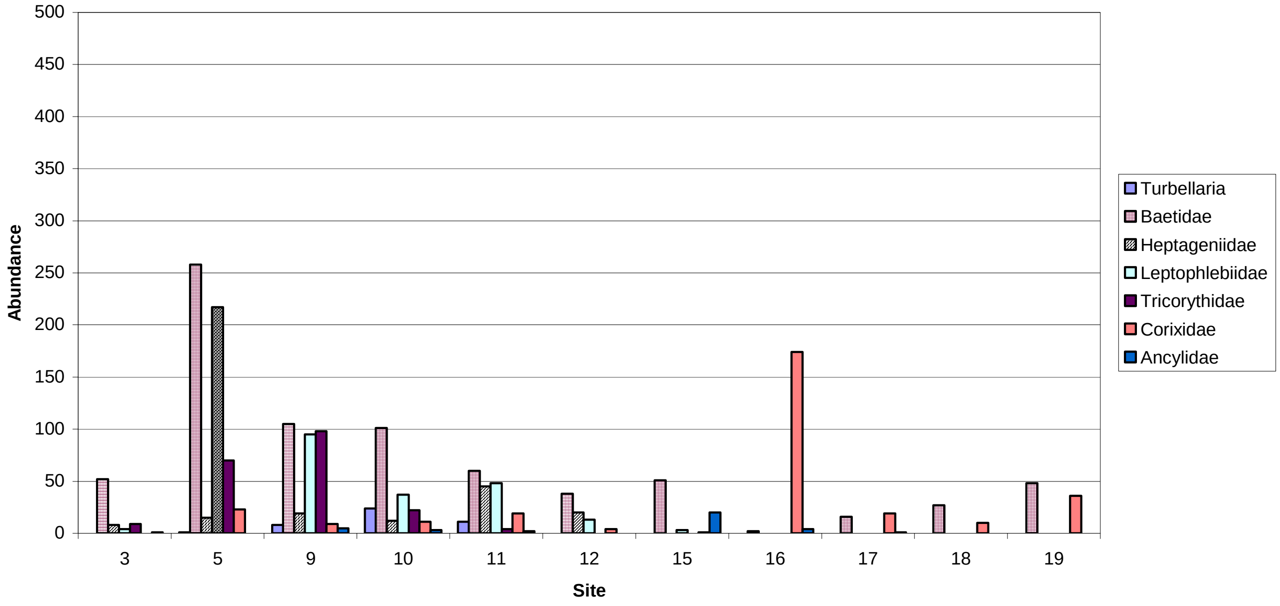


Figure 4.9: Showing abundances of selected macroinvertebrate families along the Kat River stem during Summer Biomonitoring

In fact, whilst there were 2 recorded at sites 18 and 19 during the Winter season, none were present in these sites in Spring and Summer (Figures 4.8 and 4.9). Although 2 Heptageniidae were recorded at site 18, none were recorded at site 19 in Autumn (Figure 4.6). Abundances for Tricorythidae were highest in site 9 (275) in Spring (Figure 4.7), with the exception of site 5 in Autumn were numbers were highest (198) (Figure 4.6). According to Figures 4.7 to 4.9, Tricorythidae distributions were mostly confined to the uppermost biomonitoring sites (3, 5, 9, 10 and 11) although abundances of up to 140 were recorded at sites 18 and 19 in Autumn (Figure 4.6). Sites 12, 15 and 16 in Autumn and 12, 15 and 16 had less than 5 individuals recorded during Autumn and Winter seasons respectively.

Leptophlebiidae abundances showed distinct patterns over the four seasons from the uppermost to the lowest biomonitoring sites. The Autumn peak was around site 11 with only 17 individuals recorded (Figure 4.6); whilst in Winter it was around site 9 with 42 individuals recorded (Figure 4.7). Relatively lower individuals were recorded during this season as compared to the other two. The highest Leptophlebiidae abundances in Spring and Summer were at site5 and were 190 and 220 respectively (Figure 4.8 and 4.9). It was notable that Autumn and Winter Leptophlebiidae abundances are quite similar whilst it was the same with regards to Spring and Summer abundances. Although Leptophlebiidae appeared to be found mostly in the upper most Kat River sites, there were none at site 10 in Autumn, site 16 and 17 in Winter, Spring and Summer and sites 18 and 19 in Summer (Figures 4.6 to 4.9).

Turbellaria, Ancylidae and Corixidae abundances in different seasons did not show any particular patterns. In Autumn, Turbellaria were recorded at sites 15, 16 and 17 with abundances less than 40 (Figure 4.6). The presence of Turbellaria widened to include all sites along the Kat River beside sites 3 and 10 in Winter (Figure 4.7). These macroinvertebrates were most abundant at site 17 in Winter when more than 100 individuals were collected (Figure 4.7). In the same way abundances were highest at the same site in Spring (Figure 4.8). In the subsequent season (Summer), Turbellaria abundances of less than 25 were collected in sites 9, 10, 11, 15 and 16 (Figure 4.9). Ancylidae seemed to be more widespread compared to Turbellaria especially in Autumn, Winter and Spring (Figures 4.6 to 4.8). Ancylidae were present in almost all sites through out the year with exceptions of sites 9, 11 and 12 in Autumn, sites 3 and 10 in Winter, site 5 in Spring and sites 3, 5, 12, 18 and 19 in Summer. The number of Ancylidae individuals ranged from a few less than 5 to 20 over the four seasons (Figure 4.6 to 4.9). Corixidae on the other hand had numbers ranging from 170 in Summer to a few individuals in Winter (Figure 4.7 and 4.9). There were only four sites (10, 11, 16 and 17) in Autumn where Corixidae were counted. However they were only present in site 11, along the Kat River stem. The number of sites increased to cover sites 9, 10, 11, 15, 16, 17 and 19 in Spring with sites 15, 16 and 17 all recording abundances above 50 (Figure 4.8). With the exception of site 16 that had 170 individuals, sites 5, 9, 10, 11, 12, 15, 17, 18 and 19 all had individuals less than 50 in Summer (Figure 4.9).

It was evident that macroinvertebrate abundances were highest in Winter (Figures 4.7). This was probably due to the fact that the other seasons were extraordinarily dry during the biomonitoring. During the survey it was observed that the flows went quiet low at most sites.

Correlation results between the abundances and salinity in the catchment were found to be -0.55448, -0.53656, -0.62116 and -0.61026 for the Autumn, Winter, Spring and Summer seasons respectively. In order to test if these were not obtained by chance their level of statistical significance were evaluated. The STATISTICA software yielded the following p-values -0.55, -0.62, -0.84 and -0.61 for Autumn, Winter, Spring and Summer seasons respectively.

According to (Wayne, 1995) in many sciences results that yield p-values less than or equal to 0.05 are considered borderline statistically significant. However it is important to note that this is nothing else but arbitrary conventions that are only informally based on general research experiences. This is not to dispel the significance of statistical significance in any way but just to put things in perspective. Results suggest that none of the p-values above were statistically significant owing to the fact that they were all greater than 0.05. The implications are that the result may just have occurred by chance and not much should be read into the fact that macroinvertebrate abundances and salinity are marginally correlated.

4.5.3 ASPT Scores

Elaborate results of ASPT scores calculated on SASS and number of families over the seasonal biomonitoring at different sites are presented in Figures 4.10 to 4.13 below. A summary of seasonal ASPT scores over the four seasons is also presented and summarised in Table 4.3. In Autumn the upper most sites (2 and 3) scored ASPT scores above 7, which was the highest in the catchment (Figure 4.10). The majority of biomonitoring sites had calculated ASPT scores between 6 and 7, these included sites 5, 9, 10, 11, 12, 15 and 18 along the Kat and 6 and 8 along the Balfour tributary.

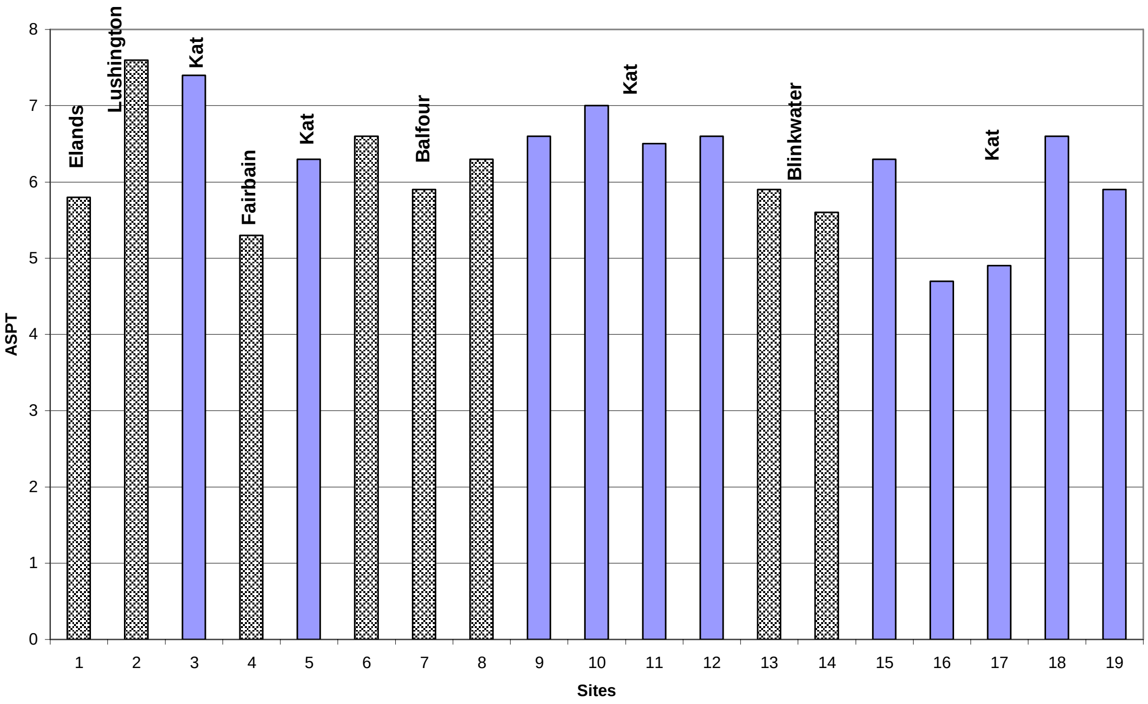


Figure 4.10: Calculated ASPT scores at different Biomonitoring sites in April, 2003 (Autumn)

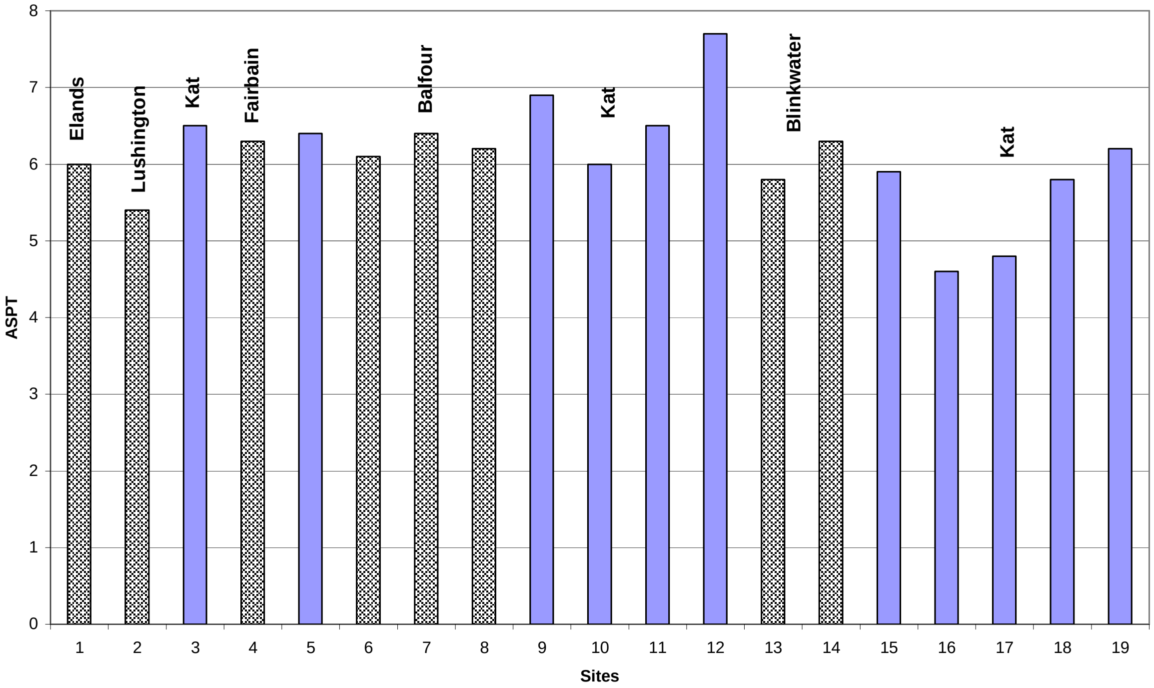


Figure 4.11: Calculated ASPT scores at different Biomonitoring sites in July, 2003 (Winter)

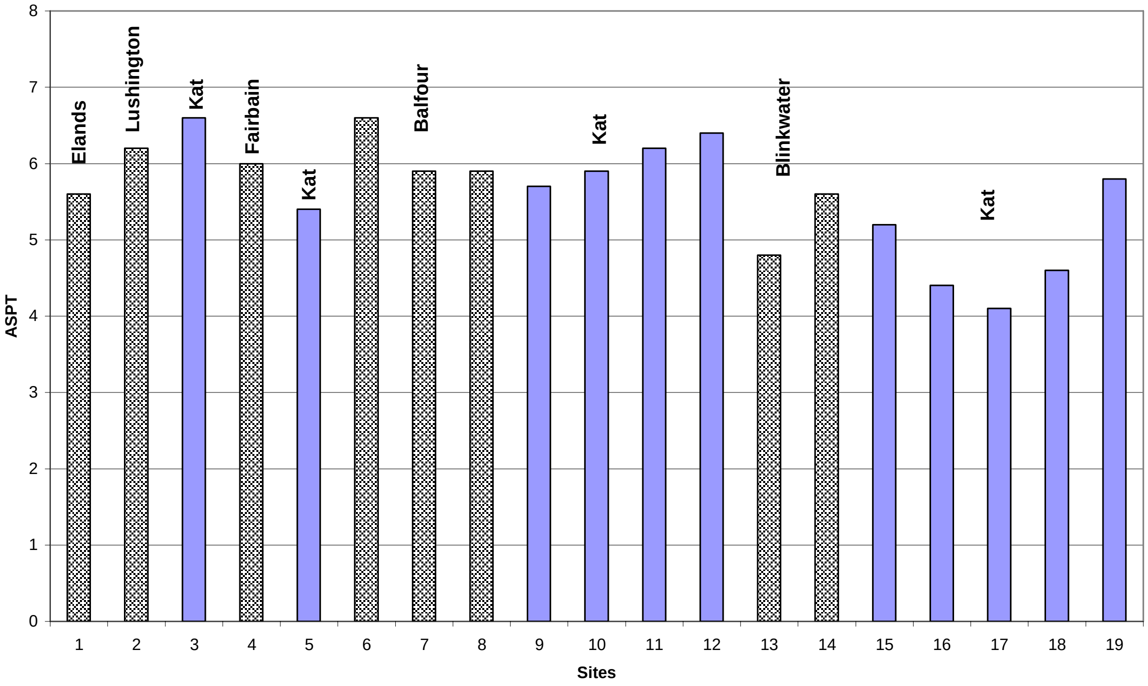


Figure 4.12: Calculated ASPT scores at different Biomonitoring sites in October, 2003 (Spring)

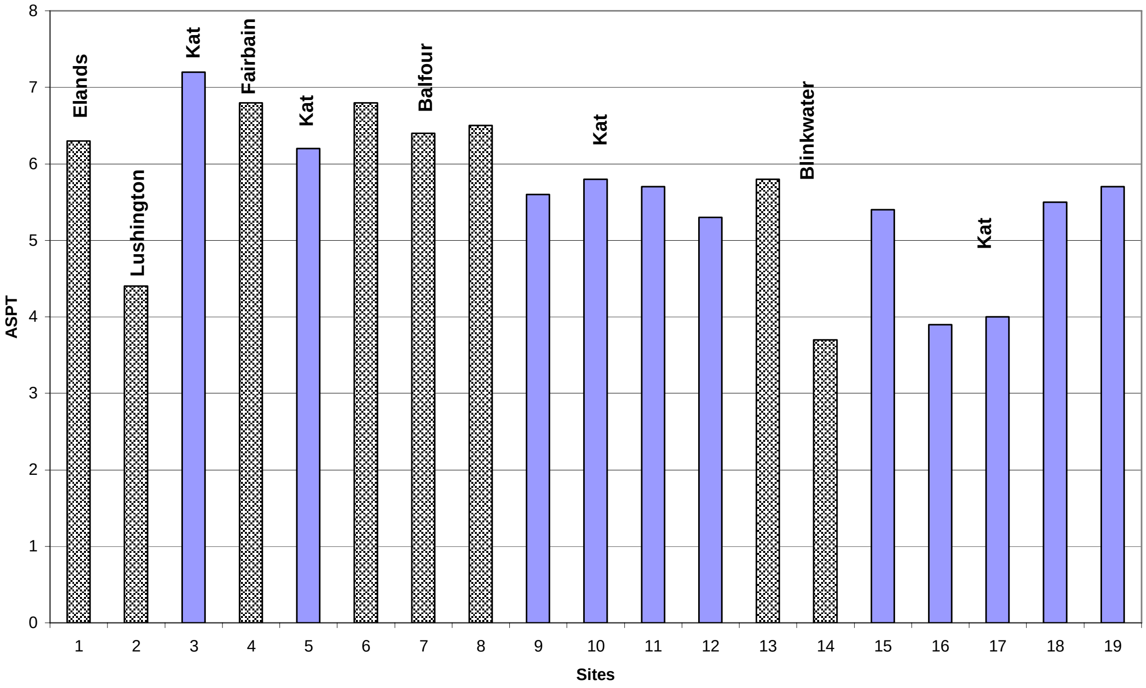


Figure 4.13: Calculated ASPT scores at different Biomonitoring sites in January, 2004 (Summer)

Site 1 on the Elands tributary, sites 13 and 14 along the Blinkwater tributary, together with site 19 along the Kat River, had calculated ASPT scores falling between 5 and 6. The lowest ASPT scores were in the middle and lower Kat River catchment, at sites 16 and 17 (Figure 4.10). Generally ASPT scores increased in the Winter season as compared to Autumn although sites 16 and 17 were still between 4 and 5 (Figure 4.11). However at no fewer than 11 biomonitoring sites ASPT scores were in the range of 6 to 7 (sites 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 19).

Site 2 on the Lushington tributary had an ASPT score of between 5 and 6 with the same being recorded at sites 3 and 18. The highest score was at site 12, where the ASPT score was above 7. There was a general drop in ASPT scores during Spring, with the highest ASPT scores being recorded at sites 2, 3, 6, 11 and 12, between 6 and 7 (Figure 4.12). However, sites 1, 5, 7, 8, 9, 10, 14, 15 and 19 managed ASPT scores between 5 and 6. Similar to Autumn and Spring, ASPT scores at sites 16 and 17 were among the lowest at between 4 and 5. Similar values were assigned to sites 13 and 18 during the Spring season biomonitoring.

The lowest ASPT scores over the four seasons were recorded during the Summer season at sites 14, 16 and 17 (Figure 4.13). These sites scored ASPTs between 3 and 4 followed by site 2 with an ASPT between 4 and 5. Comparable to Spring, ASPT scores at most biomonitoring sites were in the range 5 to 6 (sites 9, 10, 11, 12, 13, 18 and 19). Higher ASPT scores were recorded at sites 2, 4, 5, 6, 7 and 8 all with scores between 6 and 7 whilst at site 3 the score was above 7. Table 4.3 below presents a summary of ASPT scores over the four seasons between April, 2003 and January, 2004. These were a basis for assigning ecological classifications at the different Biomonitoring sites (Table 4.1).

The ASPT scores varied at most sites between seasons. This is to be expected since some families (Oligoneuridae and Prosopistomatidae) that are assigned high SASS scores were only recorded in Spring and Summer (Appendix H). The ASPT scores are much more stable compared to total SASS scores (Dickens and Graham, 2002) and are therefore more reliable in assigning ecological classes (Chutter, 1998).

Table 4.3 Showing ASPT scores in different Biomonitoring sites over the four seasons

Site no.	River	Season			
		Autumn	Winter	Spring	Summer
1	Elands	5.8	6	5.6	6.3
2	Lushington	7.6	5.4	6.2	4.4
3	Kat	7.4	6.5	6.6	7.2
4	Fairbairn	5.3	6.3	6	6.8
5	Kat	6.3	6.4	5.4	6.2
6	Balfour	6.6	6.1	6.6	6.8
7	Balfour	5.9	6.4	5.9	6.4
8	Balfour	6.3	6.2	5.9	6.5
9	Kat	6.6	6.9	5.7	5.6
10	Kat	7	6	5.9	5.8
11	Kat	6.5	6.5	6.2	5.7
12	Kat	6.6	7.7	6.4	5.3
13	Blinkwater	5.9	5.8	4.8	5.8
14	Blinkwater	5.6	6.3	5.6	3.7
15	Kat	6.3	5.9	5.2	5.4
16	Kat	4.7	4.6	4.4	3.9
17	Kat	4.9	4.8	4.1	4
18	Kat	6.6	5.8	4.6	5.5
19	Kat	5.9	6.2	5.8	5.7

4.5.3 Ecological condition classes

The different ASPT scores (Table 4.3) were used to determine the ecological state of the Kat River and its tributaries over the four seasons by comparison with Table 4.1. Results of the ecological classes at different biomonitoring sites in different seasons are given in Table 4.4 below. The same results are presented in Figure 4.14 below (page 114). These offer easier visualisation and comparison of seasonal ecological conditions at different biomonitoring sites. Ecological condition results revealed that the state of the aquatic ecosystem varied between seasons at the majority of sites. The only sites that retained the same ecological conditions throughout the year were sites 6, 11, 16 and 17 (Table 4.4). The table further revealed that all selected biomonitoring sites were no longer in their Natural state besides site 2 and 3 in Summer and site 12 in Winter.

Table 4.4 Seasonal ecological classes based on ASPT scores at different biomonitoring sites.

Sites	Ecological Class			
	Summer	Autumn	Winter	Spring
1	F	F	G	F
2	N	G	F	G
3	N	G	G	G
4	F	F	G	G
5	G	G	G	F
6	G	G	G	G
7	G	G	G	F
8	F	G	G	F
9	G	G	G	F
10	N	G	G	F
11	G	G	G	G
12	G	G	N	G
13	F	F	F	P
14	F	F	G	F
15	G	F	F	F
16	P	P	P	P
17	P	P	P	P
18	G	F	F	P
19	F	G	G	F

However for most part of the year, the ecological state at sites 2, 3, 5, 9, 11 and 12 were Good. The same pattern was realised for sites on the Balfour tributary (6, 7 and 8) although the ecological condition was categorised as Fair in Spring. The Blinkwater tributary was in a more degraded state with sites 13 and 14 in a fair state for most of the year.

For the Kat River the main change in ecological conditions was evident between sites 12 and 15 where it changed from a Good to a Fair state. Downstream of site 15, ecological conditions were worst with Poor conditions evident throughout the year at sites 16 and 17. Generally the ecological state improved to Fair at site 18 and Good at site 19.

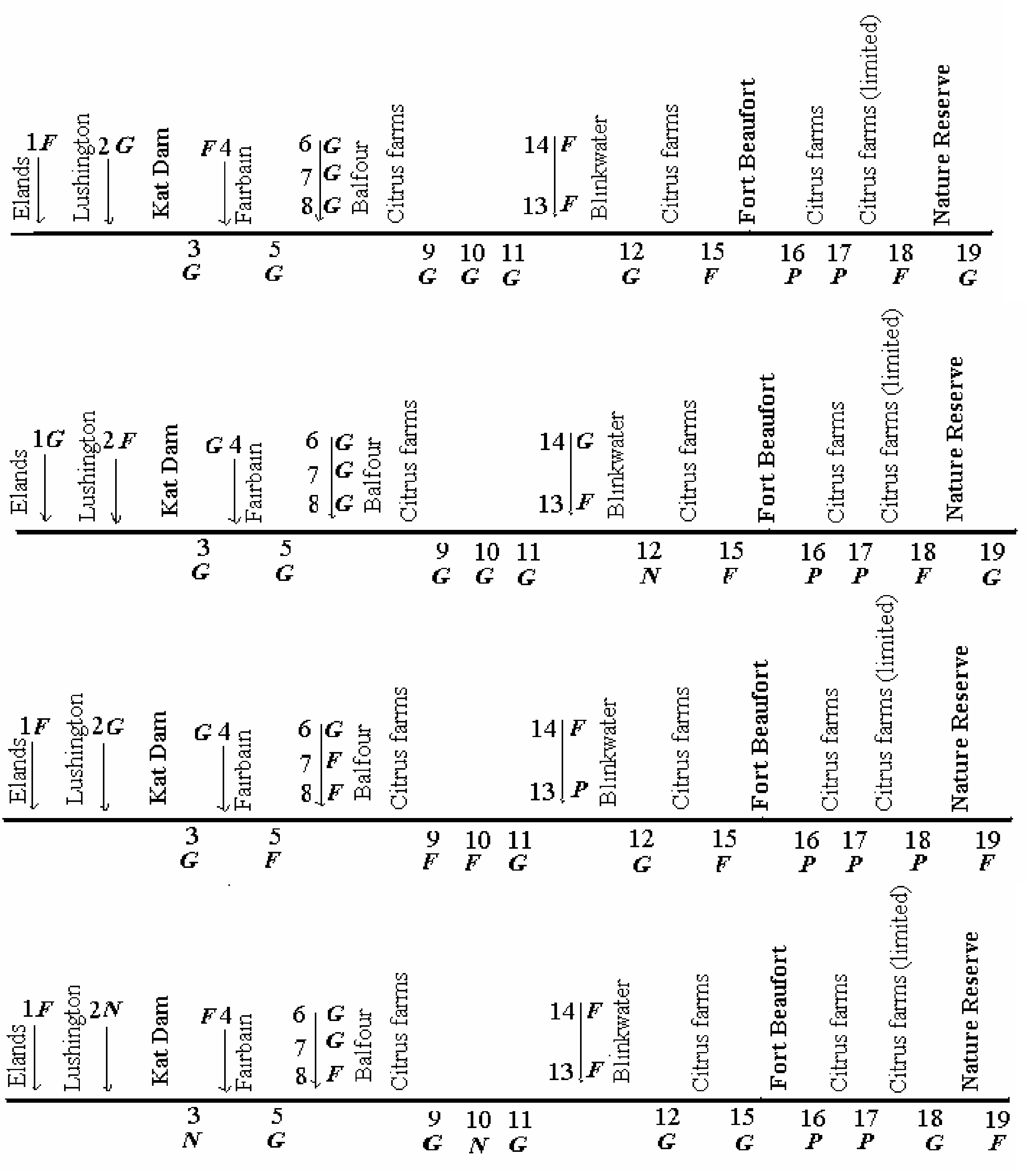


Figure 4.14 Ecological condition line transects for Autumn, Winter, Spring and Summer seasons (N-natural, G-good, F-fair and P- poor)

4.5.4 Physical parameters

Figures 4.15, 4.16, 4.17 and 4.18 show EC, DO, pH and temperature (ºC) results at different biomonitoring sites during SASS5 surveys between April 2003 and January 2004 respectively. Results from each of the parameters are briefly discussed below.

Electrical Conductivity (EC)

Electrical Conductivity results showed that the Elands and the Lushington tributaries had median salinities less than 20 mS/m (Figure 4.15). Salinities during the seasonal SASS5 surveys varied between 10 and 50 mS/m at sites 1 and 2. Amongst the tributaries, the Balfour River had the least variability in EC measurements during the biomonitoring (Figure 4.15).

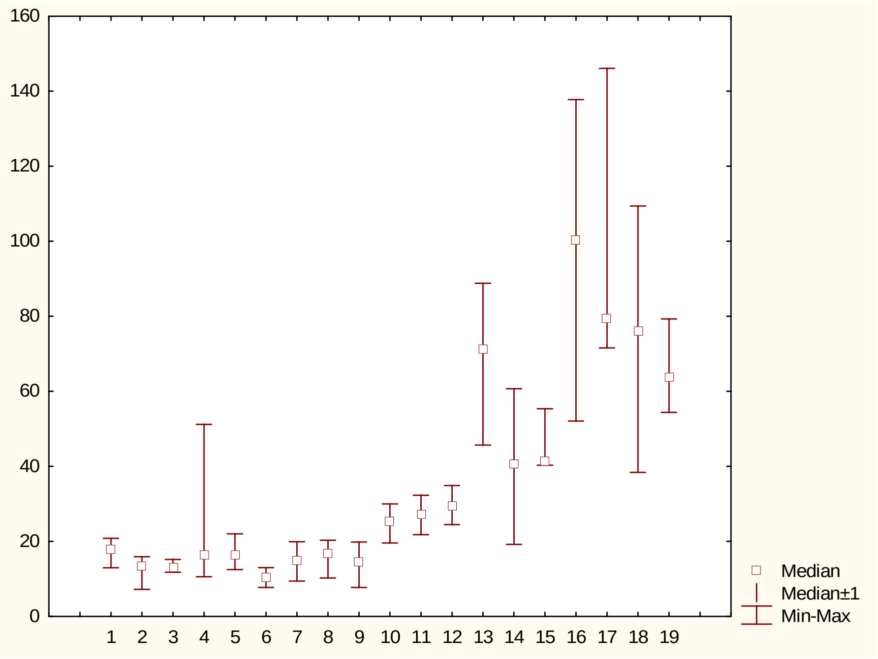


Figure 4.15: Measured EC (mS/m) at different biomonitoring sites during SASS5 surveys over different seasons of the year between April, 2003 and January, 2004.

Salinity levels at sites 6, 7 and 8 had a median of 10 mS/m although there is a progressive increase downstream (Figure 4.15). The same downstream trend is evident along the Blinkwater River (sites 13 and 14) where EC levels were always higher at site 13 (downstream) compared to site 14 (upstream) (Figure 4.15). Maximum and minimum salinities recorded along the Blinkwater during the SASS5 sampling were between 90 and 42 mS/m at site 13 and between 60 and 22 mS/m. Salinities along the Kat River catchment, were lowest at site 3 (7.73 mS/m in Spring), which is the uppermost site along the Kat River (Figure 4.15). At site 9, the median, minimum and maximum EC values were all below 20 mS/m. Sites 10, 11 and 12 had slightly higher concentrations with salinities less than 30 mS/m. The maximum salinity recorded at site 15 is 50 mS/m and salinity levels over the four seasons were higher than upstream. Maximum salinities along the Kat River were recorded at sites 16 and 17 with values reaching 140 and 150 mS/m respectively. The EC values were 50 and 72 mS/m for site 16 and 17 respectively and were amongst the highly variable sites. There was a drop in the measured EC in sites 18 and 19 although the minima were 32 and 50 mS/m respectively. A similar pattern was observed in which salinity levels recorded during salinity monitoring schedule discussed in chapter 3.

Dissolved Oxygen (DO)

The different DO concentrations measured during the SASS5 biomonitoring seasonal surveys are illustrated in Figure 4.16. The DO concentrations in the upper most sites (1, 2, 3, 4 and 5) were ranging between 8 to 12 mg/L over the duration of the biomonitoring although they are situated along different rivers. Sites 6 and 7 on the Balfour had DO values between 8 and 13 mg/L recorded although the lowest DO was 7 mg/L at site 7 along the same river (Figure 4.16).

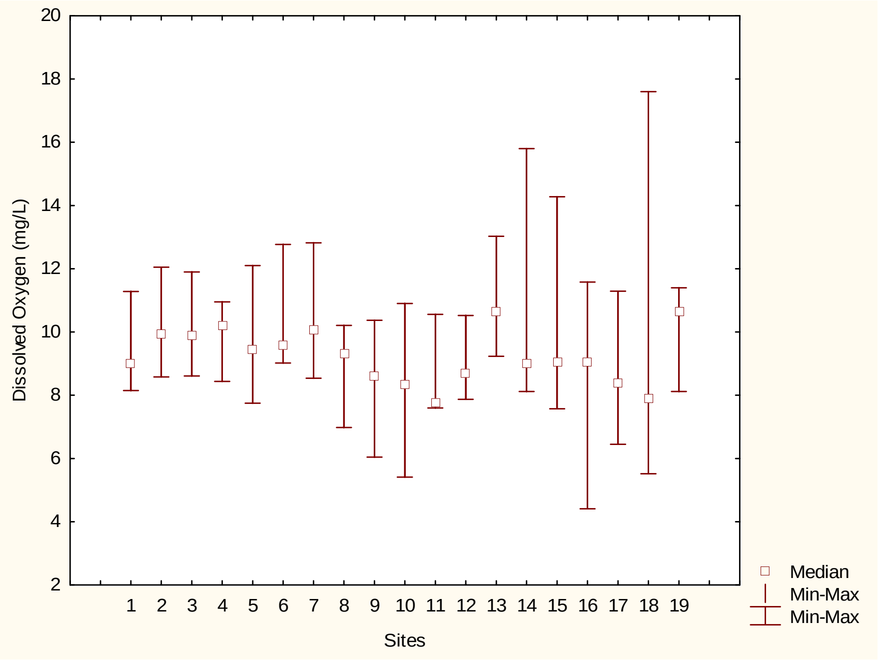


Figure 4.16: Measured DO (mg/L) at different biomonitoring sites during SASS5 surveys over different seasons of the year between April, 2003 and January, 2004.

Sites 9, 10, 11 and 12 had DO concentrations between 5 and 11 mg/L over the four seasons. On the other hand DO concentration range on the Blinkwater River (sites 13 and 14) was from 7 to 15 mg/L (Figure 4.16). Minimum DO concentrations recorded at sites 15 and 19 were around 7 mg/L, although DO concentrations at site 15 went as high as 14 mg/L in Spring season (Figure 4.16). Over the biomonitoring surveys, the lowest DO concentration was measured at site 16, at 4 mg/L.

pH

The pH values measured at the different sites during the biomonitoring surveys between April, 2003 and January, 2004 are illustrated in Figure 4.17. This figure showed that generally the water in the catchment is slightly alkaline. Besides in Spring, pH levels at site 14, all pH values recorded at all sites were above 7 perhaps due to the geology (Dallas and Day, 2004). The pH varied by within 1 unit throughout the year at sites 1, 2, 3, 6, 7, 8, 9, 10, 16 and 18 (Figure 4.17). On average pH at sites 4, 5, 11, 12 and 19 had pH readings between 7.5 and 9. The highest pH was recorded at site 13 (9.5) during Winter.

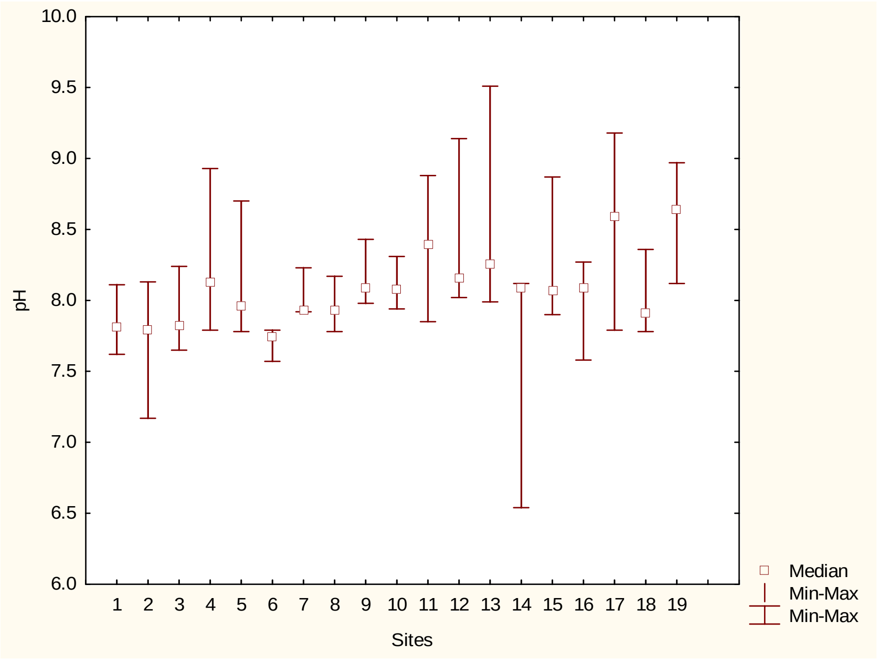


Figure 4.17: Measured pH at different Biomonitoring sites using SASS5 surveys over different seasons of the year between April, 2003 and January, 2004.

Temperature

Results of temperature variations during the SASS survey, are given in Figure 4.18. The figure indicates that there were marked temperature changes across the sites during biomonitoring. As would be expected, the lowest temperatures were recorded in Winter, whilst the highest were recorded in Summer at all sites (Figure 4.18). Temperature ranges between the hottest and the coldest seasons were 9 ºC at sites 3, 4, 5, 6, 7, 8 and 14 whilst they were 11 ºC at sites 1, 2, 16, 18 and 19 (Figure 4.18). The majority of sites recorded lowest temperatures of 12 ºC (sites 3, 4, 5, 11, 12, 13, 14, 15, 17 and 18) whilst on the other hand sites that are on high altitude recorded the lowest temperatures of less than 8 ºC (sites 1, 2 and 6) (Figure 4.18). On the contrary the highest temperatures were recorded at sites 15, 16 and 17, with temperatures reaching 24 ºC in sites 14 and 16 and 26 ºC at site 17 (Figure 4.18). Highest temperatures were slightly lower at sites 18 and 19, at 22 ºC, indicating cooler conditions than site 17.

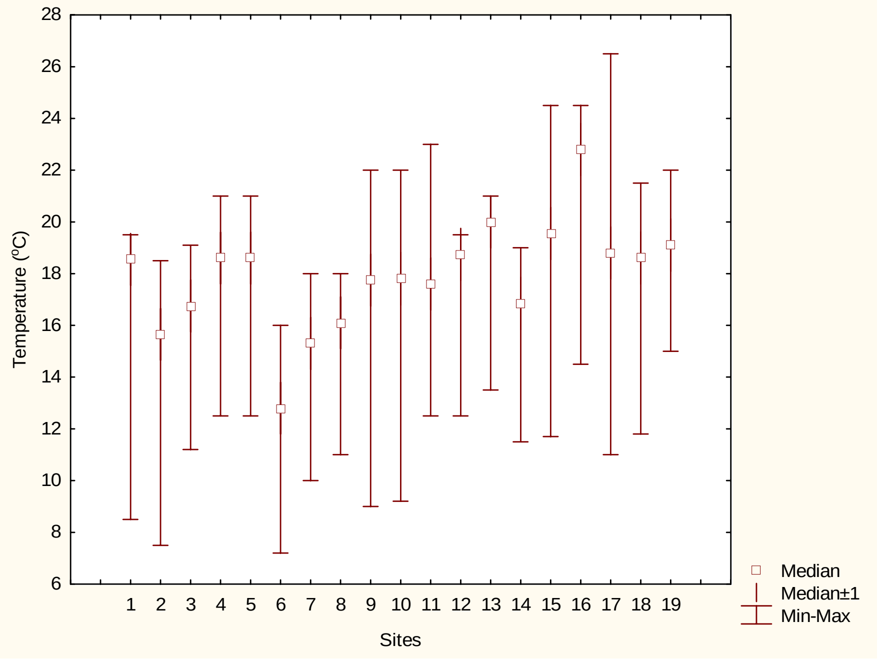


Figure 4.18: Measured temperatures at different biomonitoring sites during SASS5 surveys in different seasons of the year between April, 2003 and January, 2004.

4.5.5 Habitat Quality Results

It is important to consider whether or not the habitat quality played any role in the observed SASS and ASPT trends above. Results from the IHAS evaluation are presented in Figure 4.19 to 4.22 with Table 4.5 below as a summary. IHAS scores revealed a seasonal variability within sites depending on the season. The majority of sites were classified under Poor habitat quality and there seemed to be correlation with the SASS and ASPT scores. In general low IHAS scores were recorded where there was no marginal vegetation as was the case with Everitt (1999). Habitat quality at sites 1 and 2 were comparable throughout even though there was no marginal vegetation at site 2 (Figures 4.19, 4.20, 4.21 and 4.22). This is not surprising since IHAS takes into consideration a range of other factors at a site (McMillan, 1998). As already mentioned this includes both the availability and quality of habitat and physical factors at a site that may influence water quality.

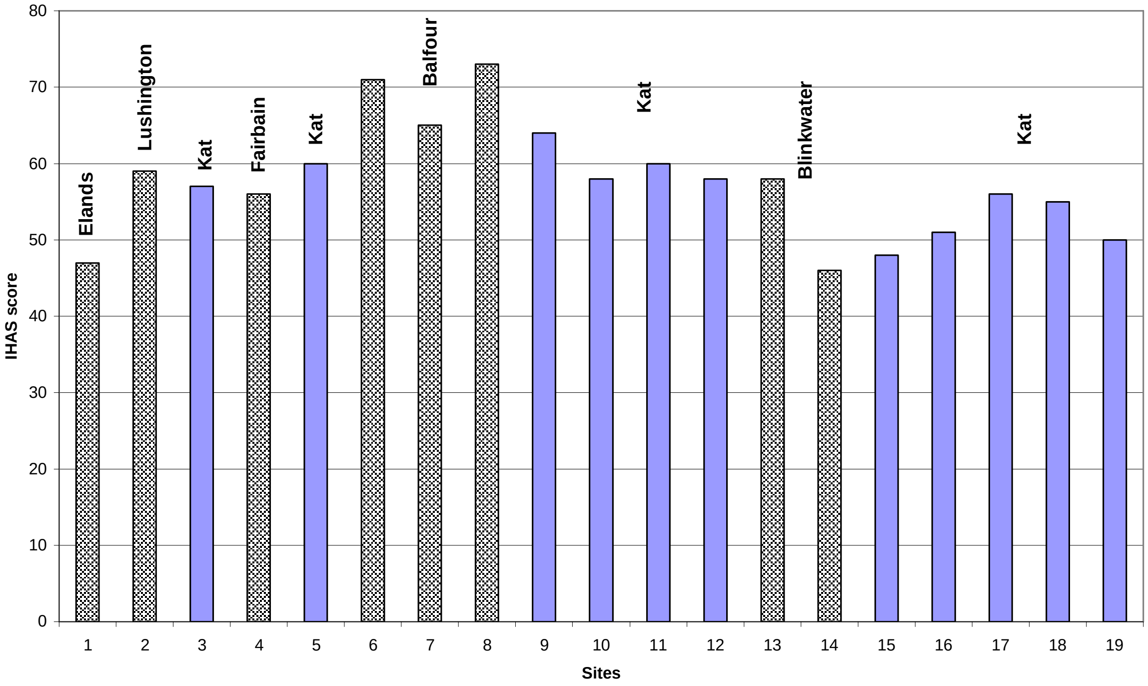


Figure 4.19: Calculated IAHS scores at different biomonitoring sites during SASS5 surveys in Autumn

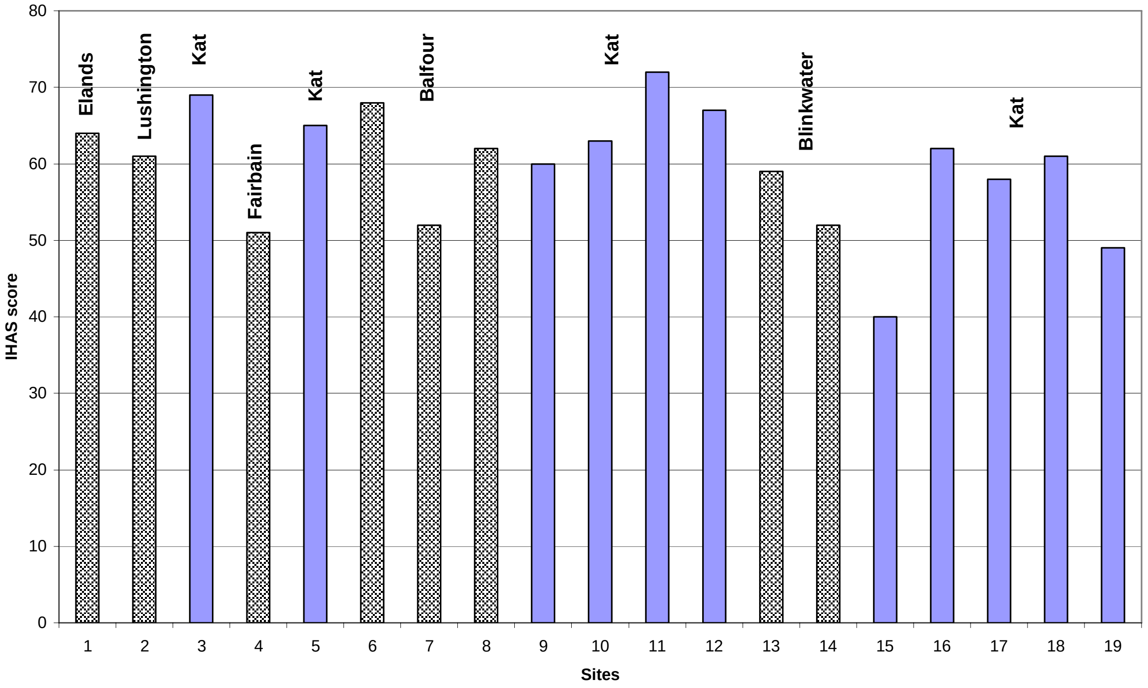


Figure 4.20: Calculated IAHS scores at different biomonitoring sites during SASS5 surveys in Winter

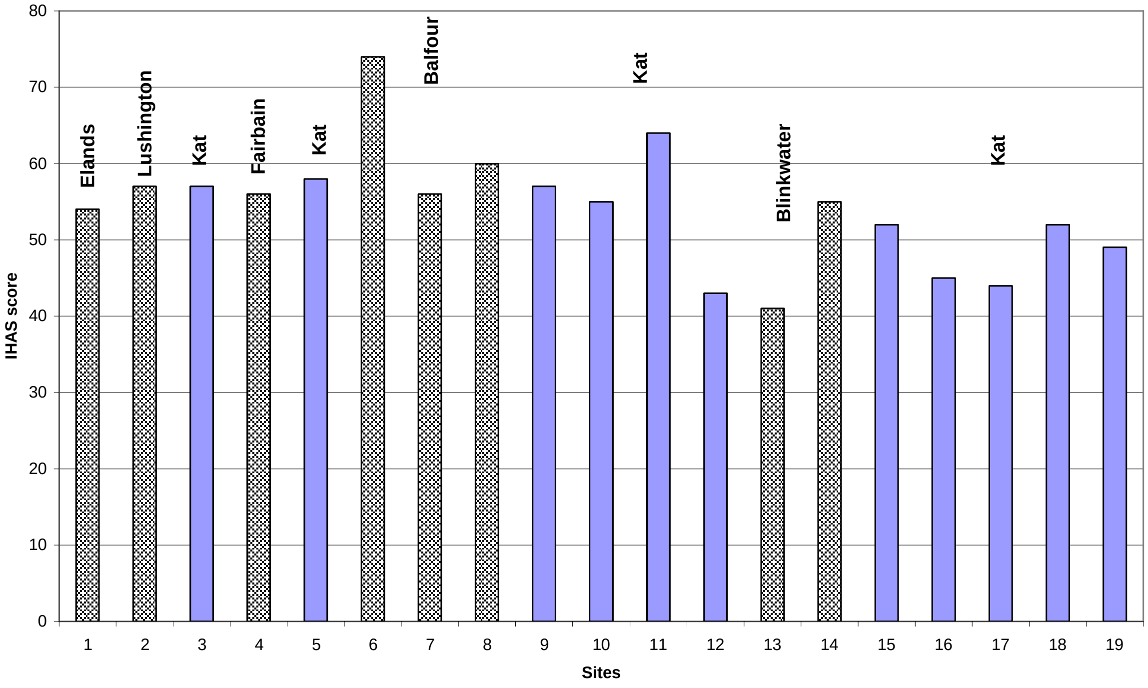


Figure 4.21: Calculated IAHS scores at different biomonitoring sites during SASS5 surveys in Spring

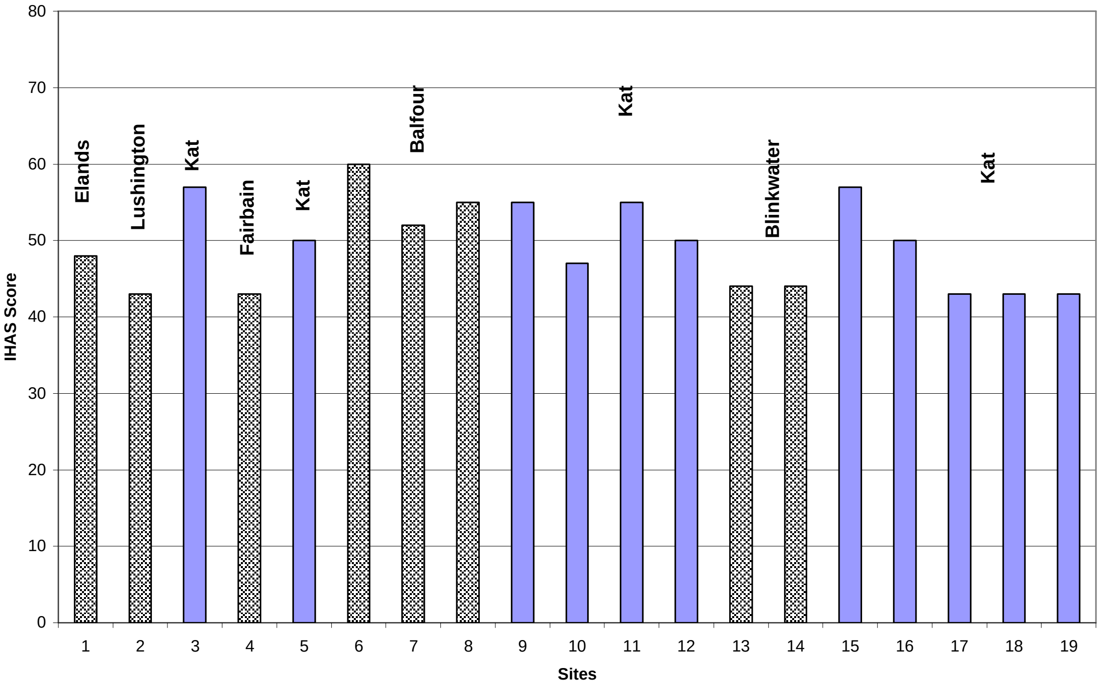


Figure 4.22: Calculated IAHS scores at different biomonitoring sites during SASS5 surveys in Summer

The conclusion that the low IHAS scores may have been due to lack of marginal vegetation then does not apply in this case. Sites 3, 5, 9 and 10 appear to have more or less the same habitat quality (Figures 4.19, 4.20, 4.21 and 4.22). Along the Balfour there was a slight drop in habitat quality between sites 6 and 7 before it gets to the same score at site 8. There was always a slight improvement in the habitat quality between sites 10 and 11. Because there was no marginal vegetation at sites 12 and 16, the habitat score from the two sites were always comparable (Figures 4.19, 4.20, 4.21 and 4.22). Some of the lowest habitat qualities were recorded at sites 13 and 14 on the Blinkwater stream, perhaps also owing to the low flows in the river. The lower reaches sites (16, 17 and 18) scored around the same IHAS scores during the four seasons with the exception of 19, which showed a slight drop in the habitat quality over the four seasons (Figures 4.19, 4.20, 4.21 and 4.22).

Table 4.5 Showing IHAS scores at different Biomonitoring sites over the four seasons

Site no.	River	Season			
		Autumn	Winter	Spring	Summer
1	Elands	47	64	54	48
2	Lushington	59	61	57	43
3	Kat	57	69	57	57
4	Fairbairn	56	51	56	43
5	Kat	60	65	58	50
6	Balfour	71	68	74	60
7	Balfour	65	52	56	52
8	Balfour	73	62	60	55
9	Kat	64	60	57	55
10	Kat	58	63	55	47
11	Kat	60	72	64	55
12	Kat	58	67	43	50
13	Blinkwater	46	52	55	44
14	Blinkwater	58	59	41	44
15	Kat	48	40	52	57
16	Kat	51	62	45	50
17	Kat	56	58	44	43
18	Kat	55	61	52	43
19	Kat	50	49	49	43

4.5.6 Relationship between SASS5 and ASPT scores and salinity

On the other hand instream macroinvertebrates were compared with electrical conductivity measurements during biomonitoring surveys. Generally the EC was highest in the middle to lower reaches of the Kat River (from site 16 to 19). Over the duration of the research, highest salinities were recorded at site 16 with an exception in Winter when site 17 recorded the highest salinity. The Blinkwater stream recorded relatively high salinity values compared to sites in the upper catchment (34 to 88 mS/m). There appeared to be a relationship between ASPT scores and salinity as higher salinities corresponded with low ASPT scores in the lower catchment (Table 4.3). Both the lower catchment and Blinkwater therefore may represent sites that are under potential salinity risk. The expectation was that macroinvertebrate community structure may have been affected by either the absence of some sensitive species or the dominance of salt tolerant species. Metzeling (1993) suggested that rare species are confined in a particular salt range; hence they may be more salt-sensitive than common ones. Abundances of SASS samples showed that the Tricorythidae and Leptophlebiidae were mostly confined to the upper catchment (Figure 4.6, 4.7, 4.8 and 4.9). Although on first consideration these may suggest that their distribution was limited by the high salinities in the lower catchment, studies have illustrated that they are normally restricted to the upper reaches because of their feeding mechanism that prefers fast flowing waters (Palmer *et al.*, 1991). An observation was also made of the absence of other families and the dominance of Chironomiidae and Simuliidae at sites 16 and 17. Kefford *et al*. (2003) regard Chironomiidae as being among the most salt sensitive macroinvertebrates hence their presence may be indicative of no salinity stress. Baetidae were recorded at all the sites regardless of salinity levels and/or season. Since these are salt sensitive it is therefore unlikely that they were affected by salinity (Hart *et al*., 1991; Short *et al.*, 1991; Williams and Williams, 1998 and Kefford *et al.*, 2003). In addition, Marshall and Bailey (2004) reported a decline in Baetidae when continuously exposed to salinity levels of about 1500 mg/L. Salinity levels in the Kat River catchment were significantly less than this value during the study (maximum 1222mg/L).

An attempt was made to investigate a direct relationship between the total SASS scores and salinity. There was a general trend on the main stem of the Kat is that SASS scores did not show a general decrease in response to the salinity profile. As an example SASS scores in sites 1 and 2 are comparable to the lower catchment sites. It is therefore clear that there is no relationship between SASS scores and salinity as also mentioned by Chutter (1998). The same observation was made by Marshall and Bailey (2004) in south-eastern Australia where they investigated a relation between a similar biotic index and salinity. Although statistical methods (correlation) suggested there was a marginal correlation between salinity and macroinvetebrate abundances, these proved to be statistically insignificant (p-values greater than 0.05).

There is however a need to use salinity tolerances to give a causal relationship between ecological condition and salinity. In the subsequent section, a brief introduction to ecotoxicolgy is given, followed by criteria for selecting national and international salinity tolerances. The final part is a discussion on the set benchmarks according to SSDs.

4.6 Ecotoxicology

Whilst bioassessments provide a real time integration of ecosystem health, and can indicate impairement, they cannot provide information of any cause-effect relationships. Ecotoxicology is the experimental linkage between biotic responses and chemical concentration. It provides the explanatory data that assists with interpreting and understanding bioassessments data. Aquatic toxicology tests are seen as initial tools that provide qualitative and quantitative data on the adverse effects of chemicals and other toxicants on aquatic organisms (Rand, 1995). These results can be used to assess the potential salinity hazard and degree of damage to the aquatic ecosystem. Toxicity tests are applied worldwide as versatile and cost-effective in managing water resources and preventing further deterioration of resource quality (Warne, 1998).

The sole important aim of these guidelines is to ensure toxicant levels are not too high for a proportion of the species in the aquatic ecosystem to allow their sustainable functioning as discussed earlier in the first chapter (Roux *et al*., 1996 and Wheeler *et al*., 2002). In order to achieve these, either short term (acute) or long term (chronic) tests are carried out in the field or the laboratory (Rand, 1995). Although field toxicity tests have more realism compared to laboratory tests, they are perceived as being very difficult to conduct (Warne, 1998). In addition both chronic and multi species tests are unpopular due to their high costs and the durations needed to perform them. It is therefore easier to conduct acute single species tests as they are easily reproduced and standardised (Schudoma, 1994). Generally criticism directed to toxicity tests is that they over-simplify the situation in the real world by disregarding interactions between species (Warne, 1998). Despite this they are still the dominant tools in setting water quality guidelines (ANZECC and ARMCANZ, 2000 and Warne, 2001).

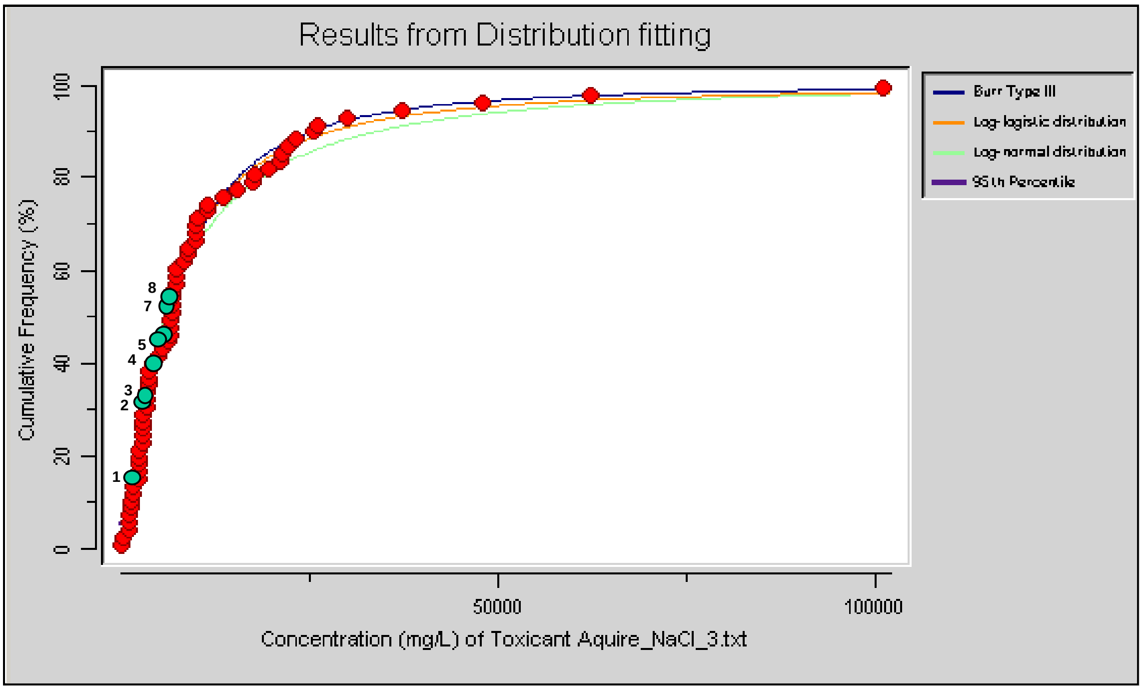
In their earliest development water quality guidelines were set by dividing reported toxicity by a safety factor set guidelines. The factor was set according to the perceived toxicity of the toxicant in question and the representation of the tested organism with regards to the wider ecosystem. This approach was abandoned in favour of more statistically robust methods that employ a whole range of tolerances of organisms in the ecosystems (Forbes and Forbes, 1993). Moreover the need for risk-based approaches as opposed to hazard based ones made the assessment factor approach irrelevant.

4.6.1 Species Sensitivity Distributions (SSDs)

One of the most recent approaches in ecosystem management that satisfies the above criteria is that of species sensitivities distributions (SSDs). Essentially, the method involves ranking of the sensitivity of organisms (LC_{50} or No Effect Concentration) to a specific toxicant and plotting these ranks against chemical concentrations (Wheeler *et al*., 2002). Statistical distributions (such as lognormal, log-logistic or Burr Type III) are then fitted to the toxicity data for different species. Shao (2000) has recommended the use of Burr type III distributions in constructing SSDs as these best fits toxicological data. An SSD allows for the determination of different toxicant concentration and their associated percentage species protection (Wheeler *et al*., 2002 and Von der Ohe and Liess, 2004). The more the data used in the derivation of the SSD, the broader the taxonomic representation of the data and the more likely it will represent 95% of the species of the ecosystem (Aldenberg and Jaworsk, 2000). This approach has already been applied in countries such as Australia and New Zealand (ANZECC and ARMCANZ, 2000 and Warne, 2001). In South Africa, the concept has not yet been incorporated in the setting of salinity guidelines although their inclusion is being proposed by Palmer *et al.* (in press). For the Natural/Good boundary, proposed percentage species protected is 95 %, similar to a proposition by Aldenberg and Slob (1993) and Palmer *et al.* (in press). The proposed boundary for Good/Fair is 90% species protection and 80% for the Fair/Poor boundary (Palmer *et al*., in press). The success in the use of SSDs in water quality protection has been highlighted by a number of authors (Schudoma, 1994, Van Straalen, 2002 and Wheeler *et al*., 2002).

4.6.2 Derivation of species sensitivities distribution boundaries

As is the case with most parts of South Africa, there was insufficient salinity toxicological data specific to the Kat River catchment. The SSD used therefore comprises both local and international data to derive percentage species boundaries. Most of the data used in this study was derived mainly from the AQUIRE ecotoxicological database (USEPA, 2004).



1 – *Baetis harrisoni*

2 – *Demoreptus natalensis*

3 – *Burnupia stenochorias*

4 – *Oligoneuropsis lawrencei*

5 – *Planaria sp.*

6 – *Afronurus barnardi*

7 – *Euthraulus elegans*

8 – *Tricorythus discolor*

Figure 4.23: An SSD derived from AQUIRE and Kat River macrinvertebrates with regard to sodium chloride (Browne, in press).

A few macroinvertebrate species from the Kat river catchment, that were available in the IWR database, were added to the AQUIRE database derived SSD. *Baetis harrisona, Demoreptus natalensis, Burnurpia stenochorias, Oligoneuropensis lawrencei, Afronurus barnardi*, *Euthraulus elegans* and unidentified *planaria* species data from the Kat River catchment was sourced from the UCEWQ database comprised of sodium chloride LC_{50}, values at which concentrations at which half of the population would die from increased sodium chloride concentrations. Only data with confidence limits were pooled from the database (Browne, in press). The resultant SSD is shown in Figure 4.23 above.

The SSD was derived using a statistical software called BurrliOZ (Campbell *et al.*, 2000). The software uses the maximum likelihood to determine which particular member of Burr Type III statistical distributions best fits toxicity data. The main advantages of these distributions over other common ones is that it provides more accurate results than for example the log-logistic approach, it is very flexible and can give good approximations of many commonly used distributions and it makes use of bootstrapping resampling technique which makes it useful for small sample sizes (Shao, 2000).

The 95%, 90% and 80% species protection sodium chloride concentrations from the SSD correspond to the Natural, Good and Poor ecological class boundaries (Browne, in press) and are summarised in Table 4.6 below.

Table 4.6 Showing percentage species protection and sodium chloride categories derived from an SSD (Browne, in press) in Figure 4.23 above

% species protected	NaCl (mg/L)	Category
95	10	N
90	39	G
80	148	F

Table 4.7 below shows the different sodium chloride classes derived from different water quality reaches and an SSD shown in Figure 4.23. The 95th percentiles for sodium chloride PES for each water quality monitoring point (Table 3.5, chapter 3) were used to derive the percentage species protections. Since there are only four DWAF water quality monitoring points in the catchment, the river had to be divided into water quality reaches to include the rest of the biomonitoring sites.

The Kat dam water quality monitoring point was taken to be under the same water quality reach with sites 3, 5, 9, 10, 11, 12 and 15 along the Kat River. Other water quality monitoring points, the Balfour and Blinkwater tributaries represented salt ecological conditions at sites 6, 7 and 8 and 13 and 14 respectively. The lower catchment sites (16, 17, 18 and 19) were taken to be in the same reach as the Fort Beaufort monitoring water quality monitoring point.

Table 4.7 Showing sodium chloride classes in different sites

Sites	%Species Protected	Class
3	90	G
5	90	G
6	90	G
7	90	G
8	90	G
9	90	G
10	90	G
11	90	G
12	90	G
13	<80	P
14	<80	P
15	<80	P
16	<80	P
17	<80	P
18	<80	P
19	<80	P

4.7 Integrating SSDs, salt concentrations and bioassessments

The first section of this chapter dealt with bioassessments and ecological conditions at different selected sites. The derivation of sodium chloride boundaries from a combined international and local SSD was then discussed. This section deals with the use of salt classes derived in chapter 3 (Table 4.8), SSD derived classes (Table 4.6) and the ecological condition classes (Table 4.9). In integrating the three sources of data sets, a method proposed by Sherman *et al.* (2003) was followed. Where there were discrepancies in the ecological classes according to sodium chloride SSD derived classes, IHAS and physical water quality variables were interrogated to give an explanation to the observed ecological classes. In cases where bioassessments ecological classes were worse than the TIMS salt classes and the underlying factor could not be identified, there is a possibility of salt toxicity. On the other hand, in cases where ASPT derived classes were better than TIMS salt classes, the latter boundaries were adjusted to conform to the former. The reason for this is that toxicity based boundaries are derived using a few species whilst bioassessments give the actual condition of the aquatic ecosystem (Sherman *et al.*, 2003).

Table 4.8 Sodium Chloride PES classes boundaries based on TIMS (taken from chapter 3)

Weir	Sample size	NaCl	
		(mg/L)	category
Kat dam	60	24	N
Balfour	59	33	N
Blinkwater	54	168	N
Fort-Beaufort	82	209	G

The delineated water quality reaches comprised of sites 3, 5, 9, 10, 11, 12 and 15 within the Kat dam water quality monitoring point reach. Sites 6, 7, 8 and 13 and 14 fall on the Balfour and Blinkwater reach respectively. The rest of the lower catchment sites; 16, 17, 18 and 19 are within the Fort Beaufort water quality monitoring point reach. This approach of identifying water quality reaches has in the past been used in water quality reserve determinations in the Olifants, Mpumalanga (DWAF, 2000). The sodium chloride classes are taken to be the same in these reaches. Table 4.8 shows a summary of sodium chloride PES salts generated from water quality records from the respective water quality monitoring points in chapter 3. These are compared to classes that were derived from an SSD. The classes were set at 95%, 90% and 80% protection corresponding to Natural, Good and Poor classes as proposed by Palmer *et al.* (in press). The sodium chloride classes are shown in Table 4.7 above. These classes are compared to ecological classes in Table 4.4. A summary of the PES and SSD classes are presented in Table 4.9 below.

Table 4.9 Ecological conditions and associated percentage species protected at different water quality monitoring points

Weir	NaCl (mg/L)	Species protected	category
Kat dam	24	90-95%	G
Balfour	33	90-95%	G
Blinkwater	168	< 80%	P
Fort-Beaufort	209	< 80%	P

The classes were derived on an SSD from international and Kat River salinity tolerance data (Browne, in press). Sites in the upper catchment (3 to 12) were categorised as Good. Sites 6, 7, and 8 on the Balfour were also categorised as Good. The rest of the catchment sites (13 and 14) on the Blinkwater and downstream of Fort Beaufort (16 to

19) were all categorised as Poor according to SSD derived sodium chloride boundaries (Table 4.9). This suggests that there is likely to be minimal impact due to sodium chloride at sites 3 to 12. On the other hand there is concern on the Poor conditions in sites 13 and 14 and 16 to 19. The likelihood of sodium chloride impacting some of the species is high noting that only less than 80% of the species are protected from sodium chloride.

In order to ascertain whether the above analysis represented the true condition of the aquatic ecosystem, classes in Table 4.4 classes were compared to those in Table 4.5. The first hurdle in comparing the two classes was that whilst there was only one class derived from species protected, the ecological class at different sites was variable from season to season. However for the most part, there was a predominant ecological class so that comparisons could be made. There was a general agreement between the SSD derived classes and ecological condition classes in the upper catchment, especially sites 3, 5 and 9 although the ecological class dropped to Fair at sites 5 and 9 in Spring. However there was a discrepancy between sites 3 and 10 in Summer where the ecological state is Natural whilst the other class is categorised as Good. General agreement in the two classes was realised at sites 6, 7 and 8 along the Balfour River. The same can be said about the trend at sites 10 and 11. This is confirmation that the aquatic ecosystem at these sites is well protected with regards to sodium chloride and SSD derived boundaries can be used to protect the aquatic ecosystem adequately.

Along the Blinkwater, sites 13 and 14 generally classified as Poor whilst the ecological condition is generally Fair. There was however total agreement on the Poor conditions at sites 16 and 17 from both SSD derived salt classes and ecological state. This suggests that salinisation may have impacted the aquatic ecosystem in relation to sodium chloride. As indicated in chapter 3, the sewage outfall, Fort Beaufort town and flow regulation are some of the factors ascribed to this salinisation. Catchment management strategies should focus on reduction of salinisation sources around Fort Beaufort. The rest of the sites (15, 18 and 19) were categorised as Poor with regards to salt boundaries whilst the ecological classes indicated Good to Fair conditions. The ecosystem can be easily protected because macroinvertebrates have mechanisms that allow them to tolerate steady salinity increases. In this case they will be able to survive at higher salinity levels than indicated by the salinity classes. It was therefore important to adjust salinity classes with the ecological classes because the former represent the present condition of the aquatic ecosystem.

4.8 Discussion

In this chapter several sources of data have been used to assess whether or not salinity is a driver of ecological condition. Bioassessements, salt concentrations (from chapter 3) and macroinvertebrate salinity tolerances were used. Each of these provides unique inside and addresses specific information needs necessary in assessing salinity impacts to the aquatic ecosystem. The first part of the chapter dealt with bioassessements (SASS) and implications about the ecological condition. Results revealed that the Kat River catchment was generally in a Good ecological condition throughout the four seasons. Ecological conditions were however Poor at some lower catchment (site 16 and 17) throughout. Site 16 is directly downstream of Fort Beaufort town and the sewage treatment works and site 17 is located few kilometres directly downstream. The ecological condition seemed to improve at sites 18 and 19. These were in agreement with the salinity profile that was described in chapter 3. However other factors had to be considered in deciding whether or not Poor ecological conditions were indeed a result of high salinities. Measured pH, DO and the temperature were within normal range and did not seem to be impacting on the aquatic ecosystem throughout the biomonitoring period. It was established that Fair ecological conditions at the Blinkwater River were a result of degraded habitat and not salinity as such. Site 16 and 17 were however considered possibly degraded with respect to high river salinities.

An attempt was also made to assess the impact of salinity on selected macroinvertebrates families that according to literature had a range of salinity tolerances. With regards to the family abundances, there was no evidence that salinity is impacting on the aquatic ecosystem. Baetidae, which are regarded highly salt-sensitive (Kefford *et al.*, 2004), were recorded at all biomonitoring sites throughout the four seasons, suggesting salinity was an unlikely driver of community structure. It was however suspected that macroinverterbrate distribution of some families was determined by flow condition. Distributions of filter-feeders such as Tricorythidae were highest in the upper reaches where there are usually fast flowing conditions as opposed to reduced abundances in the lower reaches where flow is usually slow. This concept was investigated by Palmer *et al.*, (1991) in the Buffalo River, Eastern Cape. This could only be ascertained by the use of comparing the salt concentrations and salt tolerances of biota. Results from the TIMS model at the different water quality monitoring points in chapter 3 were taken to represent salt concentrations at different reaches. The model is however based on international data. In addition extrapolations had to be made on the data to allow for comparisons to be made. However the application of the model was found appropriate since it is based on the concept that inorganic salts are differentially toxic (Jooste and Rossouw, 2002). Results yielded from the use of the TIMS model are more realistic compared to the use of TDS in defining ecological Reserve classes with respect to salts. The method has also been used in the past in ecological Reserve determinations with regards to inorganic salts (DWAF, 2000).

Salinity tolerances data of biota from the Kat River catchment were limited; therefore additional data were sourced from an international ecotoxicological (AQUIRE) database (USEPA, 2004). It was interesting to note that Kat River salinity tolerances fitted very well with the AQUIRE database data (Figure 4.23). This may suggest that the use of international data is sufficient in referring to local biota's salinity tolerances. The approach that was employed in the use of salinity tolerances was that of SSDs. The approach is being applied world wide and has been approached by Palmer *et al*. (in press). Only sodium chloride data were used to derive an SSD, which is a new development in water quality management (Browne, in press). Ecological management classes were then defined according to different percentage protection levels (Palmer *et al*., in press). Protection of ninety five percent of the biota was assigned to the Natural class, ninety to Good and eighty to the Poor class. These provided a basis for assigning management classes based sodium chloride concentration classes and the percentage species protected.

The final part of the work in this chapter was then to compare these classes to ecological classes using criteria defined in Scherman *et al*., (2003). SSD sodium chloride derived classes were related to ecological condition classes from bioassessment. Where there were discrepancies, other parameters were investigated for being possibly responsible. In cases where SSD classes suggested better ecological condition, the ecological condition was decided on bioassessment results. The reasoning behind is that SSD classes are largely based on lab-reared animals whilst bioassessments represent the real condition in the aquatic ecosystem. Sodium chloride was considered a driver of ecological condition in cases where SSD derived classes and ecological condition classes indicated degraded conditions. This was found true only at biomonitoring sites 16 and 17 downstream of Fort Beaufort. Although EWQ was employed for only sodium chloride, it was concluded that salinity is not a major driver of ecological condition in the Kat River catchment. It would have however been interesting to apply EWQ with respect to magnesium sulphate as this is much more toxic than sodium chloride.

CHAPTER 5: CONCLUDING DISCUSSION

5.1 General

This study evaluated the role of salinity on the aquatic ecosystem in a rural agricultural catchment, in line with the principles of the new water law. The catchment is vulnerable to river salinisation since the southern parts of the catchment are semi-arid and the Karoo geology of mainly shales and mudstones that are impregnated with salts. Furthermore, the citrus irrigation that is predominantly in the upper to middle reaches, and has been practiced for over a century, is a potential salinisation source to the Kat River system. For this reasons the Kat River valley was considered a river vulnerable to salinisation and associated impacts on the aquatic ecosystem.

5.2 Salinisation from Landuse

The first part of the study involved monthly salt loads monitoring at selected sites along the main river and tributaries. This provided a basis for evaluating relative salinity sources from different land uses and tributaries. Additional daily mean salt load records were computed from DWAF salinity and mean daily flow records during the monthly monitoring schedule (July 2003 to June 2004). Although there were extensive flow records at the Kat Dam water quality monitoring point, it was not possible to compute daily mean salt loads at this site due to missing salinity data. Daily mean salt loads were therefore only computed at the Balfour, Blinkwater and Fort Beaufort water quality monitoring points. Results revealed that Fairbain, Balfour and Blinkwater Rivers contribute relatively little salt compared to the magnitudes transported by the Kat River. The KATCO and Riverside citrus farms just upstream of Fort Beaufort water quality monitoring point were identified as being possible sources of salinity. The dynamics through which this happens have been covered in the first chapter. Salinity levels between site 3 and 4 doubled probably due to Amherst citrus farms (Figure 3.1). However there was no evidence of irrigation-induced salinisation around Upsher citrus plantations. The different methods of irrigation played a trivial part in the salt movement in the catchment. Earlier, it was stated that different irrigation methods imply varying degrees of river salinisation (Lei *et al.*, 2003). It is possible that the scale of irrigation in the upper catchment is significantly smaller compared to the middle reaches. It was not possible to ascertain the salinisation impacts from citrus irrigation from the natural salinity profile. However, there is some evidence of irrigation salinisation in the middle reaches. The main source of salinisation is the Fort Beaufort town and the sewage outfall. Throughout the salinity monitoring period, maximum salinities were recorded at a site directly downstream of the sewage treatment works. This salinisation may also be a combined effect from activities within the Fort Beaufort town.

Generally salt loads decreased from the Fort Beaufort site proving that there were possible salt sinks along the river. According to Hughes and Moolman (1986), salts can be stored in alluvial deposits on riverbanks and this may be a possible sink in the Kat River catchment. The rest of the salt probably finds its way to the groundwater through recharge. These can only be ascertained through site-specific studies with regards to salt dynamics. Nonetheless, monthly salt loads were able to identify landuse practices associated with salinity in the Kat River catchment. The main error in the estimation of salt loads came from flow measurements (Jain, 2001). However, the aim of the exercise was identify salinising land uses. The monthly sampling schedule may have missed first rainfall events that transports and dissolve salts from the surface. Daily mean salt load trends were always consistent between sites, suggesting the chosen methodology was enough to identify salinising landuses.

Since salinity management needs to be practised on a wide catchment scale, the implications may be to the wider catchment scale. Although during the study, there was little evidence for salinisation, it should be borne in mind that salinisation from irrigation can take a long time before it manifests itself (Beresford *et al.*, 2001). The current KATCO salinity monitoring network should therefore continue and the data kept electronically. It was realised that some valuable salinity data was lost at KATCO offices and this could have given a better picture of the historical salinity profile of the river and possible impacts on the aquatic ecosystem.

5.3 Salinity Threat to the Aquatic Ecosystem

Historical salinity and ionic compositions were however available for the four DWAF monitoring water quality monitoring points; Kat Dam, Balfour, Blinkwater and Fort Beaufort water quality monitoring points. Trends in EC, calcium, sodium, chloride, magnesium, sulphate and potassium were assessed at each water quality monitoring point in the light of past landuse history, hydrological regime and possible soil-water interaction processes. Generally, potassium levels remained constant at all the water quality monitoring points throughout the years and were independent of both historical landuse and the hydrological regime. EC, calcium, sodium and chloride seemed to be affected by these factors. High concentrations in the 1980s coincided with dry periods in the study area. This suggests that a constant amount of each is discharged into the river and the concentration depends on how much flow is available for dilution. It is understood that during drought situations, the bulk of river flow is base flow driven (Parsons, 2003). Major ion concentrations in the groundwater are high because of the long residence time that allows for more ions being dissolved. Rainfall and surface runoff on the other hand are characterised by lower concentrations due to the short contact time with the geology (Parsons, 2003). During the rainy season, major ion concentrations are therefore diluted by runoff. Sources for sodium include weathering of feldspars, evaporates and clays that are common in the area. Igneous rocks provide natural sources of sodium, magnesium and calcium (Dallas and Day, 2004). Of these, magnesium is the most highly soluble hence one would expect high concentrations. Chloride concentrations remain the same in the river because it is very conservative ion. The sulphate concentrations at the Kat Dam water quality monitoring point showed a steady increase between 1970 and 2001. Although sulphates at this particular water quality monitoring point are expected to be sourced from weathering of gypsum, this trend indicates that there is sulphate build up in the Kat Dam. This may be attributed to organic decomposition of accumulating plant materials in the dam. Unlike at the Kat Dam water quality monitoring point sulphate concentrations at the Balfour and Blinkwater water quality monitoring points remained constant over the duration of the water quality data. However trend analysis for the different ions should be made in the light that there are possibilities of analytical errors and different methods used for analysis as the years progressed.

In line with assessing the salinity impact on the aquatic ecosystem, ionic compositions were considered. Salinity influences are not only dependent on the overall salinity but more importantly on individual proportions of ions (Mount *et al*., 1997). It has been proven that different salts pose varying threats to the aquatic ecosystem. Jooste and Rossouw (2002) acknowledge that salts in water dissociate into different ions and ionic proportions are most important with regards to toxicity. They developed a model that makes use of ionic data to simulate Toxicologically Important Major Salts (TIMS).

The TIMS results revealed salt concentrations for magnesium sulphate, sodium sulphate, magnesium chloride, calcium chloride, sodium chloride and calcium sulphate in different water quality reaches. Only magnesium sulphate and sodium chloride were the most likely salts to have an impact on the aquatic ecosystem at the four water quality monitoring points. It is important to point out that magnesium sulphate is far more toxic than sodium chloride so that the former posed the main threat (Goetsch and Palmer, 1997). Issues with the TIMS model as already highlighted in chapter3 are that only international toxicological data (some of which was extrapolated) were used in setting of ecological classes. This was not considered a major drawback since it has been shown that there are no major disparities between local and international data (Kefford *et al*., 2003). The model was therefore taken to have yielded realistic results. Furthermore it takes into cognisance the fact that different salt pose varying hazards to the aquatic ecosystem (Mount *et al*., 1997). The toxicity of different salts to the aquatic ecosystem was determined by comparing Present Ecological State (PES) to Reference Condition (RC).

According to the Jooste and Rossouw (2002) method, 95th percentiles of the earliest records and the most recent are calculated to represent RC and PES respectively. RC defines the protected state in which the ecosystem is able to function normally. PES on the other hand represents the current state, so that inferences can be made on the need for management initiatives. Preceding the comparison between RC and PES default benchmarks, there was a need to evaluate default benchmarks for calibration. Since default salt benchmarks were derived on lab-reared organisms and based on some that may not necessarily exist in the field, there was a need to adjust benchmarks to attain greater realism with the local conditions (Jooste and Rossouw, 2002). In this study, default boundary conditions for sodium chloride were adjusted at the Balfour, Blinkwater and Beaufort water quality monitoring points. Additional adjustments were made with regards to magnesium sulphate at the Blinkwater and the Fort Beaufort water quality monitoring points. At these sites, biota are considered well adapted to higher sodium chloride and magnesium sulphate concentrations than default benchmarks. However, sodium chloride is the most predominant salt that is normally associated with irrigation-induced salinisation. Magnesium sulphate is the second most predominant salt in the catchment. The rest of the salts are not of particular concern to the ecological ecosystem. The hazard of salinisation was largely based on sodium chloride, due to the fact that irrigation is the most-widely practiced land use. There were no readily recognisable land use impacts that may result in magnesium sulphate salinisation and therefore this salt was probably geologically driven.

The decision on whether or not salts are a hazard on the aquatic ecosystem was attained by comparing RC and the PES. Contrary to expectation, salt classes at different water quality monitoring points were either categorised as Natural or Good. Throughout, sodium sulphate, magnesium chloride, calcium chloride and calcium sulphate were categorised as Natural. However there was a mixed picture with regards to magnesium sulphate and sodium chloride. For magnesium sulphate, at both the Balfour and Blinkwater water quality monitoring points, the aquatic ecosystem categorised as Natural. The aquatic ecosystem at the Kat Dam and Fort Beaufort water quality monitoring points were in Good ecological class and had been slightly impacted with regards to magnesium sulphate. In the case of sodium chloride the aquatic ecosystem class for the Kat Dam, Balfour and Blinkwater water quality monitoring points was categorised as Natural with the exception of the Fort Beaufort water quality monitoring point. At this water quality monitoring point the aquatic ecosystem was classified as Good. The above classifications imply that there was no impact from most toxicologically major salts.

However such conclusions should be made in the light of hydrological conditions and landuse under which the RC and PES were set. In this case RC were set under relatively average rainfall (1973 and 1974) although 1975 was wetter. During this period there was there was extensive tobacco and citrus farming in the upper catchment. Although there is still some citrus irrigation farming and vegetable farming in these parts activities have been greatly reduced since 1980. The RC for the Kat dam, Balfour and Blinkwater water quality monitoring points therefore seem to represent impacted ecosystem conditions although the hydrological regime was quite normal. However DWAF data were the only available source that could represent conditions under least impact. The RC at the Kat Dam and Fort Beaufort water quality monitoring point are likely to be affected by dam releases after commissioning of the dam in 1969. In addition RC for the Fort Beaufort water quality monitoring point was determined using early 1990s data which may be far of from the true reference conditions. The water quality monitoring point is also downstream of extensive citrus irrigation, which is highly likely to have contributed to salinity at the site as discussed earlier.

Equally important to assessment of land use and the hydrological regime under which RC and PES are derived is the determination of confidence in the data set. This is important because it can be used to determine the level of data validity of the data used in determining PES. One of the ways in which this can be assessed is by calculating the power of the data set (Jooste and Rossouw, 2003). The mean, standard deviation and sample size are used in the determination of power. In this study, confidences for magnesium sulphate and sodium chloride salts for the PES were determined through the program G-POWER (Faul and Erdfelder, 2002). Results revealed good confidences for both salts at the Kat Dam water quality monitoring point and sodium chloride at the Balfour water quality monitoring point. There was medium confidence for magnesium sulphate at the Blinkwater water quality monitoring point, otherwise the rest of the data yielded poor confidences. The reasons behind the poor confidence in the data may be to do with the small sample size. This down weighs the importance of management implications in terms of the relationship between the real conditions with regards to major salts. Nonetheless information provided by the analysis of major salts and their associated classes is invaluable in the protection of the aquatic ecosystem against salinity. The two main questions that may arise from the use of the Jooste and Rossouw (2002) method is that only international data was used in the derivation of ecological classes and some of the ecotoxicological data had to be extrapolated to allow for comparisons. However the use of international data should not be a major draw back since macroinvertebrates are affected the same way in different parts of the world (Kefford *et al.*, 2003). The method also take cognisance that major salts are differentially toxic and is therefore more practical than assessing impacts due to EC. Presently the method has been accepted for use in the ecological Reserve determinations and it’s use is therefore considered sufficient and relevant in the evaluation of salinity impacts in this study.

This approach only attempted to assess the salt hazard posed by different salts given the different major ion concentration. There is however a shift from a hazard-based approach to a risk-based one in water resources management (Jooste *et al.*, 2000). This is largely based on assessing the likelihood of a water resource to be under salinity stress. It has long been recognised that salt concentration can be largely influenced by a flow regime (lack of dilution). The discharge may therefore be indirectly linked to salinity risk to the aquatic ecosystem. One advantage of applying such an assessment is that it can be used to cover a wider time scale compared to spot salt concentration readings. Since flow records are much more continuous than major ion concentrations, the use of flow derived salt concentration series is beneficial. This can be applied to assess the likelihood of aquatic ecosystems being classified under different management classes.

In this study an attempt was made to find flow sodium chloride relationships at the four water quality sub-units represented by the four DWAF water quality monitoring sites. Although both magnesium sulphate and sodium chloride were considered a threat to the aquatic ecosystem, simple flow concentration regression relationships were only derived for sodium chloride because there was available toxicological data for comparisons. The power function was found to be the most suitable fit to the simulated and original sodium chloride concentrations in all analysis. However, only the Blinkwater and Balfour water quality monitoring point exhibited good correlation coefficients (above 0.5) to warrant further investigations in terms of risk to the aquatic ecosystem. Both the Kat dam and the Fort Beaufort water quality monitoring points exhibit very poor flow sodium chloride concentration relationships (correlation coefficients of less than 0.5). Analysis of the role of salinity on the four sub-units was therefore restricted to the Blinkwater and Balfour. It is however important to point out that the relationship was only derived from monthly mean flows and mean monthly sodium chloride concentrations. Reasoning for this approach was to permit for comparison with other studies and a further test on methods proposed by Malan and Day (2002). The concentration time series is therefore a further approximation of conditions in the field (Malan and Day, 2003). The approach is however considered to give first hand approximation to salinity impacts to the aquatic ecosystem.

In order to simulate the sodium chloride time series, the derived flow concentration were applied on discharge records at respective water quality monitoring points in T-SOFT (Hughes *et al*., 2000). These records were compared with the original concentrations to verify their accuracy to the real situation in the field. From this, the probability of a site equalling or exceeding sodium chloride concentrations was then simulated in T-SOFT (Hughes *et al*., 2000). This frequency of occurrences were then analysed in terms of the set sodium chloride benchmarks for the respective water quality monitoring points. Results revealed that the aquatic ecosystem at the Balfour and the Blinkwater water quality monitoring points were under fair/poor boundary most of the time. In the management perspective, the Natural and Good categories are considered acceptable and the aquatic ecosystem is protected in terms of salinity (Figure 1.1). Under such conditions the aquatic ecosystem is able to offer all if not most of the goods and services (Palmer *et al*., 2002). It is also important to note that it is impossible to keep the ecosystem completely protected (Natural) especially when the water resource is the main source. Resource managers may in such cases choose to manage the aquatic ecosystem for Good or Fair ecological classes. Under the Fair ecological classes, there is some deterioration in the ecosystem condition. The Poor ecological classes is however unacceptable in terms of management (DWAF, 2004a). In this study sodium chloride was in a Poor state for a negligent period at the Balfour and Blinkwater water quality monitoring points respectively and therefore not considered a risk to the aquatic ecosystem.

It is a difficult task to evaluate the role of salinity on the aquatic ecosystem using salinity levels and salinity tolerances in isolation (Blinn and Bailey, 2001). Aquatic ecosystems are complex and have many interactions between the different components that are not well understood (Petts and Muddock, 1994). The assessment of the condition of the aquatic ecosystem should therefore be inclusive of bioassessments, which indicate the condition of the aquatic ecosystem. Unlike salinity concentration records, different components of bioassessments can be used to directly assess its integrity. Macroinvertebrates are widely used because they have a wide range of salinity tolerances, hence they can depict instream salinity impacts. A new approach in assessing salinity impacts on the aquatic ecosystem is then to combine salinity levels, bioassessments and salt tolerances. In this study an SSD derived from international and a few tested local species salinity tolerance data was utilised to derive sodium chloride boundaries. The boundaries coincided with proposed species protection percentages, which are 95%, 90% and 80% for natural, good and fair respectively (Palmer *et al*., in press). It was interesting to note that salinity tolerances of a few tested species in the Kat River catchment fitted very well with AQUIRE database data (Figure 4.22). This may suggest that salinity tolerances are not site specific and the data can be applied widely.

On this basis, the SSD was considered representative of species in the Kat River catchment. Salt classes were then derived to show percentage species protected under the PES at different water quality monitoring points.

5.4 Environmental Water Quality Approach

The three approaches complement each other and have already been used with some success in South Africa (Malan and Day, 2003 and Sherman *et al.*, 2003). This new approach has been termed the Environmental Water Quality (EWQ) approach (Palmer *et al.*, 2003). Bioassessments in terms of SASS5 protocol were undertaken at different sites over four seasons. There were no sites found to be in an ideal natural state, therefore the upper most site in Balfour was selected as a reference site. However results showed that the site was impacted even more than some of the monitoring sites. Ecological condition classes were therefore adopted from DWAF (2004b). Since water quality analysis is site specific, the resultant classes may not be indicative of the true ecological condition. The ecological condition seemed to generally vary with season and was also affected by habitat quality. At some sites therefore the ecological condition were degraded because of habitat not salinity. Different sites in the catchment are under different ecological conditions; the upper catchment is generally in a good state whilst the Blinkwater and lower Kat River have poor ecological conditions. However there is a need to define reference conditions in the catchment so that site-specific resources categories are developed. At the time of the study, there were insufficient data to determine the reference ecological condition. Protocols of adjusting the benchmark category boundaries are presented in Palmer *et al.* (2004a). The determination of reference state requires the use of boundary values set for the wider Ecoregion on which the catchment falls (Palmer *et al.*, 2004a). Where these conditions are not yet defined through the River Health Programme (RHP), at least 3 unimpaired sites are sampled during low flows for high confidence assessments. Reference ecological conditions in the Kat River catchment were difficult to define because there are practically no unimpacted sites throughout the catchment. Although it would have been more meaningful to use adjusted ecological benchmarks that are more site-specific, default benchmarks were used to define ecological conditions. This may have improved realism, but there was not enough data for adjusting the salt benchmarks.

The bioassessment ecological condition classes were now used to verify both the Jooste and Rossouw (2002) method and the SSD derived classes. Most of the upper catchment sites were not under salinity stress. This is borne out in the agreement between the salinity and ecological classes. However, there were cases where these methods are overprotective to the aquatic ecosystem. The main reason behind this trend is the salinity acclimation of some Kat River macroinvertebrates. Under such situations, ecological condition remains in good conditions even though there is inherent salinisation (e.g. Blinkwater stream).

Salinity is the main driver of ecosystem condition in this river segment with regards to preset Jooste and Rossouw (2002) salt categories. To identify river reaches, a multilevel hierarchical framework has been developed to characterise rivers from landscape-level templates, through hydrological regime to localised channel attributes. In order to assess salinity hazard the four water quality monitoring points were utilised to divide the catchment into four salinity segments. The Kat River was divided into two segments the first being between the Kat Dam and Fort Beaufort water quality monitoring points and the rest (downstream of Fort Beaufort water quality monitoring point) of the river designated as a different salinity reach. The other two reaches were the Balfour and Blinkwater tributaries on which the respective water quality monitoring points represented conditions in the individual rivers. These classification layers are used to delineate sites in which salinity and ionic compositions are thought to be similar.

There is however enough evidence to show that salinity is a major driver of ecological conditions in sites immediately downstream of Fort-Beaufort. Poor salinity classes and ecological conditions suggest that sodium chloride has had a major role on the macroinvertebrates. Although there are some salt intolerant species that still inhabit these sites, there appears to be a shift towards a Chironmiidae and Simuliidae dominated community structure compared to the rest of the catchment. Similar observations were made for the Blinkwater, although deterioration there may also be attributed to poor habitat quality.

It is important to note that salinity impacts are site specific. Methods that were employed depended heavily on the four DWAF water quality monitoring sites as the defining factor for water quality segments. This is a simplification of the true situation in the real world. Secondly there is a need to attempt to define ecological reference conditions, so that assessments can be made more meaningful.

5.5 General Conclusions and Recommendations

This study has shown that contrary to expectation, salinity is not a major water quality concern to the Kat River ecosystem. The findings are in line with earlier work at the UCEWQ, that salinity does not affect aquatic ecosystem at levels that were originally thought. The fact that salinisation is not yet pronounced is no reason for catchment managers to be complacent. Irrigation induced salinisation can take a long time before it manifests as a problem to the aquatic ecosystem. This is likely to happen in the Kat River catchment where citrus irrigation has been practiced for over a century and there is present expansion of citrus orchards along the river banks especially around Fort Beaufort. Another possibility is the expansion of the town in union with the inclusion of newly built RDP houses in Fort Beaufort and the subsequent increases in volumes of sewage disposal into the Kat River. The situation calls for urgent attention on the salinity of the treated sewage. According to Rose (2002), there are three basic interventions that need to be considered namely prevention, dilution and segregation. Dilution is the most established of the three, and might be feasible in the Kat River catchment. According to (Katco, 1990 and 1991), dam releases have been observed to improve downstream salinities in the past. However, since the Kat River dam is the main source of water supply in the catchment, there is a high possibility that this solution may not be sustainable although there are simple dam operational models that have been tested elsewhere in the country (Deksissa *et al*., 2003). Segregation requires the treatment of the sewage effluent from the end of the pipe before discharging into the river (Rose, 2002). This option might prove too costly to implement in the Kat River catchment and prevention might be a more feasible solution. Prevention and occasional dilution from the Kat Dam may be the optimal solution to the salinity problem in the catchment. With lower salinity sewage disposed into the Kat River, salt levels downstream of Fort Beaufort are likely to improve so that the salinity risk is reduced. The catchment should be managed in order to meet requirements of all the citizens, therefore the deterioration of ecological conditions downstream of Fort Beaufort should not be taken lightly.

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APPENDIX A: A BRIEF HISTORICAL BACKROUND OF THE STUDY AREA

1.0 The Historical context of the study Area

Besides the present biophysical characteristics of the catchment, the rich history of the area has played a major in the present land use patterns and associated water quality management issues. The history goes as back as the early 1800's, when the first European settlers arrived in the area. This proved to be the beginning of tensions that transgressed between these settlers and the Xhosa chiefs who were already leaving in the area right up to the end of the 1900's (Motteux, 1999). The area has been contested between the Xhosa, 'coloreds' and the Dutch and the British. The Xhosa were a number of times driven out of the area by the white settlers and were therefore dissatisfied with the new inhabitants. On the other hand the settlers persistently complained about stock theft and part of their crop harvest from the fields. Later the colored people were given land in between these two groups as a barrier to alleviate tension and threat from theft (Hill and Nel, 2000). They also fought on the side of the settlers during battles and wars against the Xhosa. The following section is aimed at highlighting events that let to the present land use patterns in the area.

The present economic and environmental status in the Kat River catchment has been largely to do with its history. Through historical times the area has been used to support agricultural activities. According to earlier reports, "it's fertile and soils and reliable supply of water" has attracted a landscape of human settlements line along the river banks and its tributaries (Hill and Nel, 2000). These areas along the river frontage were intensively farmed and since the 1970's the mid and lower regions have continued to be irrigated by citrus farmers. However farming in the area has been taking place long before this period as early as 1800's (Hill and Nel, 2002).

1.1 Early settlements in the Kat River area

The Xhosa chief Maqoma and his followers has inhabited the Kat river catchment as early as 1829. He was however forced out of the area following a sequence of clashes with the British colonial government of the time (Hill and Nel, 2000). The area was designated to the 'coloured' people who were predominantly Khoi-san and some freed slaves. They started planting sorghum and fruit trees upon their arrival (Logie, 1997).

The decision to designate the area to the coloured people was a strategic one. They were to provide a buffer zone between the Xhosa and the white farmers (Logie, 1997; Nel, 1998). This was necessary because the Xhosa were still dissatisfied with the fact that they were driven out of the area and were persistently a source of discomfort to the farmers. The buffer zone lied between the Fish and the Keiskamma Rivers (Hill and Nel, 2000). The conflict continued through out the nineteenth and was central to the formation of the Ciskei homeland.

The level of stock theft in the area also dissatisfied the British and the Dutch. They accorded the blame to the neighboring Xhosa people (Hill and Nel, 2000). Despite efforts to curb this theft by building military posts and compulsory military training for all men, the problem persisted. From the Xhosa's perspective, the settling of the British and the Dutch in the Kat River valley drove the feud. They were determined to get back to the area they occupied earlier. Slowly they came back, by encroaching near the frontier. In 1833, Sir Lowry Cole successfully evicted the Xhosa.

However this solution proved to be short-lived; as the following year, war erupted. A series of wars followed afterwards, 'War of the axe' in 1845 and the 'Kat River rebellion' in 1851. The latter is considered South Africa's second longest war and saw many of the Kat River 'coloreds' turning against the British and sitting with the Xhosa (Hill and Nel, 2000). This time the Xhosa and the coloreds were able to launch an attack on Fort White, stormed Fort-Beaufort, targeted Fort Hare and then occupied Fort Armstrong. They were only able to occupy these areas for a month as British forces regrouped and soon hit back. The British won back the Forts, captured 220 prisoners and also managed to burn Xhosa and colored houses in the process. Both sides suffered heavy losses because the Xhosa and the coloreds were either jailed or put on death row. On the other hand the farmers crops failed and they suffered heavy losses in terms of sheep and cattle deaths (Logie, 1997 and Nel, 1998). Having betrayed and lost the war, the 'coloreds' were no longer welcome to stay along the Kat River Banks. Half of them were displaced as punishment for participating in the rebellion (Motteux, 1999). It was during this time that 'white' settlers began to dominate in the Kat River catchment. Land was later confiscated from the coloreds irrespective of their involvement in the rebellion. Those that were jailed or absent lost their land through failure to reclaim back their land. The friction still continued between the coloreds and the whites and the accusations of theft went on. Some Xhosa people came back to settle in the area, but only as farm workers in the early twentieth century. Very few were able to retain their title deeds to land.

Things settled out a bit after the 1850's and the white settlers were able to claim and purchase land. A piece of legislation that was passed in 1905 enabled more land to be acquired. Under the Boedel Erven Act the white settlers were entitled to claiming land on condition that they have occupied it between 1836 and 1865. This subsequently resulted in a shift from small scale farming to larger scale farming. More coloreds were evicted from their land besides those in Tamboekiesvlei. These were allowed to stay as a gesture of appreciation for their loyalty during the rebellion.

1.2 The Creation of the Ciskei

Subsequent to the Boedel Erven Act, other two acts were passed by parliament. The first is the Land Act, which was passed by parliament in 1913. Under the act, 7 % of the land was to be apportioned among the 'non-white' citizens. It's sister legislation was passed twenty-three years later and under this act the land apportionment to the natives was increased to 13 %. Certain parts of the old Cape colony were to be occupied exclusively by Africans. However both acts did not affect land allocation in the Kat River catchment in any way.

In the early, 1970's there was a new government policy that divided the country into 'homelands' and old South Africa. This meant people who were staying in parts of South Africa especially urban centres were to relocate to the newly created homelands according to their ethnic group. Under this policy part of the Kat River catchment now fell under the newly created Ciskei homeland. This emanated in the migration of almost all white and colored populations who were inhabiting the upper and parts of the middle catchment. Xhosa speaking people from other parts of South Africa were forcefully relocated to the northern part of the catchment.

This yielded serious negative impacts on the socio-economic conditions of the area. The outcomes of the policy are still evident up to this day. Numerous fields and infrastructure that once used to be productive now lie fallow and unutilized. The labourers who remained on the farms were left without jobs and they heavily depend on state grants and pensions. An area that was once renowned of its tobacco and citrus through the whole country, just lays fallow. Rusting old tobacco drying sheds is still evident in the Fairbain area. Once a sign of vibrant economic activity in the study area, the railway line that passed the area has stopped operating. Land that once used to produce tobacco, potatoes and mostly citrus was no longer productive. The only activity that remained was keeping of livestock.

The Ciskei government bought some of the farms that still remained in some white farmers hands in the upper to middle reaches of the Kat River catchment. Although, the Ciskei was given autonomy, it failed to satisfactorily deal with the socio-economic situation. The lack of clear policy on land possession in the Ciskei government resulted in local people not given access to land for farming. Instead some land was allocated to some politicians and their followers not necessarily on the merit of being able to produce.

The Ciskei government efforts were however soon recognized through the formation of Ciskei Agricultural Corporation (ULIMCOR), a government parastatal. Through this initiative, part of the ex-white farms were targeted and taken up for production. The aim was to give assistance to interested black farmers in the Kat River catchment (Motteux, 1999). Most these were ex-labourers of the white farmers who stayed on the farms even after the white owners left the area.

By 1984, ULIMCOR occupied most of the citrus farms in the upper catchment area. The land was then divided into plots of 16.8 to 36 hectares and were farmed with the vision of that black farmers would ultimately take up ULIMCOR with time. The criteria for selecting farmers were that they had to have practical agricultural experience and training from the agricultural college. In addition to this these, they had to have to draw business plans showing how much they would need and projected profits. To the successful candidates loans were secured from the Development Bank of South Africa through the Ciskei government as a guarantor. The government also leased the land for short periods of five years. The expectation was that the emerging farmers would be self-sufficient and able to buy the land as their own after this period.

However land rights have never been transferred to the black emerging farmers up to this day although many still remain on the farms. A few farm managers were able to get farming rights in areas such as Lorraine, Klipvlei, Dumrae, Oakdene and Gonzana (Hill and Nel, 2000). Some of the land that was not taken up by ULIMCOR was simply just given to supporters and followers of the Ciskei government. In addition some acquired land was left fallow. Currently most of this land has no defined land tenure and is therefore used opportunistically by some villagers (Hill and Nel, 2000). Members of local communities from Tamboekiesvlei, Hertzog and Fairbairn got permission to farm the land from the government through the Agricultural department. A small group of farmers who hold title deeds to the farms can be found around Fairbain.

1.4 Formation of agricultural cooperatives

Unlike parts of the middle and lower reaches that have long been producing citrus, the agricultural activities in the former Ciskei remained paralyzed. Just like the rest of the catchment, soils and water were recognized as having soil and topography with a high irrigation potential between 1950 and 1970 (Hill and Nel, 2000). At this time farmers practiced a combination of intensive, irrigated farming as well as livestock production. The colored and Xhosa people densely populated the area. The Kat River and its tributaries provided irrigation water and became a focal point for settlement in the area. It has been intensively farmed since 1829 (Motteux, 1999).

With the coming of the new democracy in South Africa in 1994, people were instilled with some hope that the socio-economic status would improve. However like most rural areas, there was no direct conversion of democracy to better life. Lack of basic services and economic activity, remained a harsh reality. Dwellers in the upper catchment decided to be pro-active and not wait for government intervention by engaging in agricultural activities. They were still leaving in an area considered as one of the few productive ‘ex-homelands’. With their neglect and lack of service, in the upper catchment, an initiative against poverty was taken in the form of another co-operative in the Fairbain and Hertzog areas. In 1993, some members in this area formed a community based cooperative by the name of Hertzog Agricultural Co-operation (HACOP). This was encouraged by the farming skills of some ex-farm laborers.

1.4.1 HACOP

By 1996, only 83 plots of land could be cultivated because of shortage of irrigation pumps, piping, diesel for the tractor and ploughs. Although the land was leased until 2007, by the Agricultural department, agricultural inputs remained a big challenge for HACOP (Motteux, 1999). Some members of the community still acknowledge d the input and influence HACOP makes in their lives. It offered some sort of employment and earning additional income. Although majority of residents support HACOP, the cooperation still faces challenges in terms of financial and agricultural inputs. The irrigation equipment has to be moved the members fields each day to ensure irrigation of all fields. In addition extreme weather sometimes threatens the production of vegetables. Frost and heavy rainfall have been reported in the past has having negatively impacted on production. Vegetables are sometimes left on they until the rot because of lack of transport to the market. These emerging farmers are solely dependent on people who buy fresh vegetables directly from their fields. Some Non Governmental Organizations (NGO’s) came on board and some of the problems were solved (Motteux, 1999). This ensured supply for seeds, irrigation pipes and at later stage administrative support for members. The upper catchment up to this day is dominated by emerging farmers.

1.4.2 ULIMCOR

Poverty-stricken Xhosa communities populate parts of the middle to upper reaches of the Kat River catchment (Tamboekiesvlei, Upsher, Paradise and Parcardy). Some of the former ULIMCOR farms were bought back by some white farmers (Hill and Nel, 2000). The dominant land use here is citrus irrigation. These farms extend from Upsher right down to Gonzana. Places such as Armherst and White have vibrant citrus irrigation activities. However, a legacy of the past is still eminent around Tidbury’s Toll and Oakdene area, where citrus trees where left abandoned (McMaster, 2002). In this area a more efficient method of irrigation is employed; drip irrigation instead of sprinkler irrigation that is predominant in the upper catchment. Some citrus irrigation can be found in the lower Blinkwater stream. Water is pumped directly from the river and impounded by water quality monitoring points that are that are a common feature in the catchment. Some off-channel storage dams have also been built in some areas to supplement river flow.

1.4.3 KATCO

A much more economically viable co-operative that is operational in the middle and to some extent the lower reaches is that of Kat River Citrus Co-operatives (KATCO). KATCO serves a number of farmers who specialize in various types of citrus. Some of the world's best citrus is produced in these parts of the catchment. Produce is mainly exported to the European Union retail markets. This obliges the farms to uphold sound environmentally friendly ways of production in line with international standards. Some farms that fall under KATCO's due restriction are ISO 14000 compliant, allowing them to sell to worldwide markets. Farm operations in Riverside for instance are more advanced as opposed to those in most parts of the catchment. Here a more strict irrigation scheduling is implemented to control salt concentration in the soil. The amount of irrigation required depends on the moisture already in the soil. This is measured by means of lysimeters to guard against over irrigation. KATCO recognizes the danger of salinity to the citrus trees; hence they have initiated a monthly salinity-monitoring scheme around their farms as early as mid-80's. The programme Paradise, Lorraine, Baddaford, Riverside, Winterberg, Pakamila, Sulphur Bath, Lemon dam Drummond and Ernest farms. According some historical technical reports (Katco, 1990 and 1991), salinity is in fact a problem for farmers downstream of Fort Beaufort. KATCO operations are most important for offering employment to the many people living in the catchment in and around the orchards.

APPENDIX B: BIOMONITORING SITES VISITED DURING SITE SELECTION

Site 1 (32° 31’ 3.4” S, 26° 47’ 16” E)

The site is on the Eyre tributary at Riverside farm and is upstream of a bridge. Types of habitat found consist of riffles, marginal vegetation and pools. The site is in the proximity of few settlements and there is limited livestock activity around. Shallow fields around signify the nature of agricultural activities as subsistence. There is a small dry tributary, impact of which is unknown. The site seems to be a good site for Biomonitoring. However the stream has more canopy cover, which is not representative of the whole catchment. The site is shown on plate 1 below.

Plate 1: Eyre tributary upstream site

Site 2 (32° 31’ 48.1” S, 26° 47’ 29” E)

The site is also on the Eyre and is downstream of the first site. The substrate upstream is bedrock with riffles, marginal vegetation and pools also present. Deep pools and no canopy cover characterize the site, which is representative of the catchment. It seems to be a good site for monitoring and is shown on plate 2.

Plate 2: Eyre downstream of site 1

Site 3 (32° 33’ 22.4” S, 26° 48’ 45.3” E)

This is the upper most site on the Elands tributary and is on the road to Mooistroom. Types of habitats are riffles, limited marginal vegetation and pools that are a result of a culvert. The site may dry up during Winter although there is not much human impact around the site. The site was selected as the first biomonitoring site (plate 3).

Plate 3: Elands tributary site

Site 4 (32° 36’ 58.5” S, 26° 49’ 1.9” E)

This is the uppermost site on the Lushington River, upstream of the Kat River dam. Riffles, pools and limited marginal vegetation are present. Not much human impact on the site. The site is invaded by wattle trees. There is marginal flow in the stream. A picture of site is shown on plate 4. This site was identified as the second Biomonitoring site (Figure 4.1).

Plate 4: Lushington site

Site 5 (32° 34’ 40.4” S, 26° 45’ 20.4” E)

This is downstream of the Kat river dam wall. The site dominated by bedrock with limited riffles, marginal vegetation and pools. The site may be largely impacted by dam releases. The limited riffles may be washed away and this makes the site unfavourable for biomonitoring. Other observations include turbid water, algal growth at the edges, limited sand and mud and fast flowing water (plate5).

Plate 5: Downstream of Kat dam site

Site 6 (32° 34’ 38.5” S, 26° 43’ 49.3” E)

Situated downstream of site5. Pools, canopy cover and riffles are present. The site seems to be next to abandoned fields and therefore no real agricultural impacts can be envisaged. There are some surges and reeds present with the site being shown on (plate 6). This was identified as the third biomonitoring site (Figure 4.1).

Plate 6: Second site downstream Kat River dam

Site 7 (32° 32’ 21.6” S, 26° 42’ 30.6” E)

The site is on the Fairbain River a few hundred metres before it joins the Kat. Riffles, pools and very limited marginal vegetation are present at the site. Unstable banks are evident on the site and there are lots of fallow fields, which may suggest intensive farming. The site is open, with limited canopy cover and shown in plate 7. This was considered the fourth biomonitoring site (Figure 4.1).

Plate 7: The downstream Fairbain site

Site 8 (32° 31’ 33.5” S, 26° 42’ 18.1” E)

This is the upper Fairbairn site. The site is characterized by a wide channel, unstable banks, pool upstream of bridge, riffles downstream, mud, lots of canopy downstream and limited marginal vegetation. There is limited agricultural activity as there are fallow fields evident (plate 8).

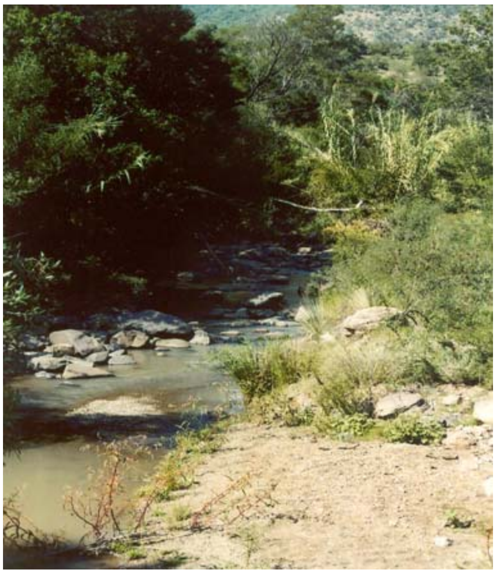


Plate 8: Upper Fairbain site

Site 9 (32° 31’ 39.7” S, 26° 42’ 43.8” E)

Situated on the Kat River upstream of confluence with Fairbain; the site is situated next to a newly build bridge. There is washing site, settlements and a bit of subsistence farming with irrigation. Habitats present are riffles, pools upstream and lots of riparian trees. The site is on an open canopy with banks unfairly stable. Algal blooms were also evident (plate 9).

Plate 9: Kat River upstream of confluence with Fairbain

Site 10 (32° 33’ 20.5” S, 26° 41’ 22.7” E)

There are riffles, reeds, marginal vegetation and pools just downstream of an old bridge. The site is along the Kat River upstream of Upsher and situated in the vicinity of a small rural community. This is a water collection site for the nearby village as well. This was designated biomonitoring site 5 (Figure 4.1).

Plate 10: Kat River upstream of Upsher

Site 11 (32° 30’ 49,0” S, 26° 40’ 31,2” E)

This site is located along the Balfour stream and is a collecting site for macroinvertebrates for ecotoxicological experiments. There are riffles, pool and marginal vegetation all present. There is small agriculture around the site. Other factors evident are stable banks (70%), and reeds. People are drinking directly from the stream, which may suggest good water quality. The site was chosen as a possible a reference site (biomonitoring site6) and shown on plate 11 below.

Plate 11: Balfour reference site

Site 12 (32° 33’ 15,4” S, 26° 40’ 16,7” E)

This site is situated downstream of the DWAF water quality monitoring water quality monitoring point. There are riffles and marginal vegetation at the site. It is very much an open system with low flow. The site would allow for comparison of biomonitoring data and long-term water quality data and hence is an obvious selection. The photo of the site is shown on plate 12. The site was designated biomonitoring site 7 (Figure 4.1).

Plate 12: Balfour water quality monitoring point site

Site 13 (32° 33’ 46,6”S, 26° 40’ 30,3” E)

The site is situated along the Balfour River and is under an old railway bridge. This is the last site a few tens of metres before the confluence with the Kat river. There is some citrus plantation on the opposite bank of the confluence. There is also some riffles and riparian vegetation. The site is shown in plate 13 and was chosen as biomonitoring site 8 (location shown in Figure 4.1).

Plate 13: Balfour upstream of confluence with Kat River

Site 14 (32° 33’ 51” S, 26° 40’ 36.5” E)

This site is situated downstream of the Kat and Balfour River’s confluence. There are riffles and pools at the site. Sand mining and domestic animals drinking from the river may impact the site. Marginal vegetation in reeds and trees is also evident. The site is on an open system, with no canopy cover. The site is shown on plate 14.

Plate 14: Kat downstream of confluence with Balfour

Site 15 (32° 44’ 31.8” S, 26° 45’ 45.9” E)

The site is located at Henhill and is a potential reference site for irrigation. Habitats present at the site are riffles, sand, pools and marginal vegetation. The site is typical of the rest of the Kat. The site is downstream of site 14 and may be used as a reference compared to it. One observation is that the banks are unstable. The site is shown on plate 15.

Plate 15: Kat River at Henhill

Site 16 (32° 33’ 20.5” S, 26° 41’ 22.7” E)

The site is downstream of site 15 and is below a bridge on the main R67 road. It has nice pools and riffles with some marginal vegetation, which are suitable for biomonitoring sampling. There some abandoned citrus trees upstream. It is more open and representative of the Kat. The site is shown on plate 16 and was biomonitoring site 9.

Plate 16: Kat River downstream Henhill

Site 17 (32° 38' 28.4" S, 26° 41' 17.1" E)

This is a macroinvertebrate collecting site for toxicity tests at Amherst. Riffles, pools and marginal vegetation are all present at the site. There is little or no impact visible around the site although the site is not representative of the Kat. Other observations are that people drink directly from the river and banks are unstable (Plate 17).

Plate 17: Kat River at Amherst

Site 18 (32° 38’ 35.2” S, 26° 39’ 47” E)

This site is downstream of a road bridge on the way to Amherst. There are riffles, pools and marginal vegetation. Upstream of the site is a water quality monitoring point and there are trees on the edges. The site may be good for assessing the impact of citrus irrigation round the bend (plate 18).

Plate 18: Kat River downstream Amherst

Site 19 (32° 39’ 1.6” S, 26° 39’ 7.9” E)

The site is at Tidbury’s Toll. There is limited riffle, pool upstream and marginal vegetation in the form of reeds. The site may not be impacted by irrigation because there are only abundant fields in the vicinity. The site is more or less typical of the Kat and has unstable banks evident (plate 19). This site was included in the biomonitoring as site 10 (Figure 4.1).

Plate 19: Kat River at Tidbury's Toll

Site 20 (32° 41' 30.1" S, 26° 36' 46.4" E)

The site is situated on the way to Gonzana and has considerable flow. There is a large water quality monitoring point upstream and the banks are relatively stable. Marginal vegetation downstream of the water quality monitoring point includes reeds and willow trees. There is a good riparian zone that might buffer irrigation impacts next to the water quality monitoring point. This is therefore included as the eleventh biomonitoring site (plate 20).

Plate 20: Kat River at Gonzana

Site 21 (32° 42’ 56.8” S, 26° 35’ 17.0” E)

Large boulders from a tributary characterize the site, even though there is not much impact around. There are riffles, mud and marginal vegetation as habitats. There is also not so much impact visible around the area. The amount of water at the site has dropped considerably from an upstream site, which suggests the might be some impoundment of some sought or abstraction. The banks are relatively stable with the right hand bank having more vegetation (plate 21). The site was selected as biomonitoring site 12.

Plate 21: Kat River downstream of confluence with Blinkwater

Site 22 (32° 35’ 40.9” S, 26° 34’ 22.8” E)

This is a site on the upper Blinkwater and is situated in Mpofu game Reserve. The flow is very low and there are lots of Arcasias. There are riffles and pools with limited marginal vegetation. The site appears to be relatively unimpacted with regard to citrus irrigation.

Plate 22: Upper Blinkwater at Mpofu Game Reserve

Site 23 (32° 36’ 54.9” S, 26° 33’ 33.3” E)

The site is on the Blinkwater at Kleenplautic inside the Mpofu Reserve. The site is characterized by low flow, unstable banks and not typical of the Kat. There is bedrock, downstream of the bridge. However riffles, pools and pools are evident (plate 23). The site was included in the broader biomonitoring programme as site 14 (Figure 4.1).

Plate 23: Middle Blinkwater

Site 24 (32° 41’ 16.1” S, 26° 33’ 57.3” E)

The site is also on the Blinkwater River a road crossing on the way to Mpofu Game Reserve. Although there are riffles and pools, it is not typical of the Kat Rover sites. There is limited marginal vegetation, some canopy cover with algal enrichment on the edges. The site is downstream of some citrus irrigation and it is not clear where the farmers get all the water since there are low flows (plate 24).

Plate 24: Blinkwater at the lower Blinkwater

Site 25 (32° 42’ 7.5” S, 26° 34’ 33.1” E)

This is a DWAF water quality monitoring sites on the Blinkwater. There are considerable algal blooms. The site is downstream of some citrus irrigation with some intensive farming downstream of the site. There are no reeds or canopy and the substrate is made up of large boulders. However the site formed part of selected biomonitoring sites (site 13). The site is shown on plate 25.

Plate 25: Blinkwater at DWAF water quality monitoring sites

Site 26 (32° 42’ 31.6” S, 26° 34’ 42.3” E)

The site is on the Blinkwater next to a railway. There are algal blooms apparent with unstable banks. There is limited marginal vegetation and a bit of riffles downstream. The flow is low but there is considerable riparian vegetation. The site is not so good for monitoring because of low quality of habitat (plate 26)

Plate 26: Blinkwater upstream of confluence with Kat River.

Site 27 (32° 42’ 53.2” S, 26° 35’ 12.2” E)

The site is on the Kat after Blinkwater joins. It is upstream of site 21 and has lots of water. There is riparian vegetation, marginal vegetation pools, large boulders for riffles and unstable banks. This may be a good monitoring site (plate 27).

Plate 27: Kat River upstream of site 21

Site 28 (32° 45’ 58.0” S, 26° 36’ 21.7” E)

The site is upstream of Fort Beaufort and is downstream of extensive citrus irrigation. There is considerable marginal vegetation with reeds, little riffles and big pools. The banks are also unstable downstream. This was considered for biomonitoring because it is downstream of extensive citrus irrigation farming (plate 28) (biomonitoring site 15).

Plate 28: Kat River at Riverside citrus estate

Site 29 (32° 47’ 10.9” S, 26° 39’ 2.3” E)

The site is downstream of Fort Beaufort and the Sewage treatment works. There are riffles, pools and marginal vegetation. There is a sewage treatment pipe that discharge treated sewage into the river upstream of the site. There is also some small-scale sand mining. The river has some considerable flow (plate 29).

Plate 29: Kat River at the Fort Beaufort sewage treatment works

Site 30 (32° 50’ 20.4” S, 26° 40’ 17.6” E)

The site is at the Highlands farm and downstream of a water quality monitoring point. There are riffles, reeds and pools as habitats. There was considerable flow and some riparian vegetation. This was selected as biomonitoring site 17 (plate 30).

Plate 30: Kat River at Highlands farm

Site 31 (32° 53’ 26.4” S, 26° 41’ 0.41” E)

The site is on Howsepost farm. There is water seeping through the base of the water quality monitoring point. There are riffles, marginal vegetation, pools, sand and mud and lots of canopy cover. This site seemed like a good biomonitoring site and was numbered 18.

Plate 31: Kat at Howsepost farm

Site 32 (32° 58’ 7.6” S, 26° 44’ 59.8” E)

The site is at Sam Knott and is the lowest site before the Kat joins the Fish River. There are pools, limited riffles and lots of water. It may be possible to find indigenous vegetation. The site is typical of the rest of the Kat. The only impact at this site may be wild animals. The site is shown on plate 32 below and was selected as the last biomonitoring site.

Plate 32: Kat River at Sam Knott Game Reserve

APPENDIX C: MONTHLY SALINITY MONITORING RESULTS BETWEEN JUNE 2003 AND JULY, 2004

Electrical Conductivity (mS/m) Summary table from June 2003 to July 2004

	Sites									
	4	5	9	10	11	12	16	17	18	19
July	15.6	17.7	19.9	30	N/A	33.7	92.7	74.2	69.1	54.4
August	17.27	27.3	22.9	41.8	N/A	44.7	151.6	69.5	68.8	51.3
September	11.37	19.5	17.5	26.1	21.5	25.8	101.9	87	115.1	61.5
October	17.1	22	7.73	26.7	23.6	34.9	108	84.4	109	56.4
November	12.01	21	13.85	32.4	27.6	27.8	170.9	84.4	109.4	76.4
December	11.6	25.4	16.1	30	31.9	38.1	188	102	140	N/A
January	9.31	15.2	12.7	21.2	23.2	25.2	98.9	157	N/A	N/A
February	7.04	9.01	8.71	12.28	13.18	15.1	30.3	24.5	64	N/A
March	7.16	8.19	9.91	19.97	15.87	19.72	30.3	29.1	33.1	55.4
April	9.81	16	12.26	22.2	15.5	21.9	57	36.1	37.4	55.4
May	11.62	21.2	17.5	35.1	26.5	33	122.5	41.4	N/A	N/A
June	14.73	19.1	18.4	23.8	20	22.7	111.7	45.1	52.4	55.7

N/A denotes where meausurements were not taken due to no flows or floods

Flow (m3/S) summary table from June 2003 to July 2004

	Sites									
	4	5	9	10	11	12	16	17	18	19
July	0.015	0.291	0.305	0.328	N/A	0.087	0.126	0.064	0.213	0.037
August	0.024	0.095	0.069	0.014	N/A	0.059	0.011	0.017	0.01	0.019
September	0.0275	0.1372	0.2858	0.1223	0.0922	0.042	0.0104	0.0631	0.0436	0.1108
October	0.0031	0.0362	0.1212	0.0553	0.09082	0.0448	0.0323	0.0021	0.0157	0.0592
November	0.029	0.108	0.216	0.042	0.0456	0.022	0.039	0.013	N/A	N/A
December	0.03	0.07	0.16	0.06	0.0488	0.01	0.03	N/A	N/A	N/A
January	0.062	0.078	0.192	0.192	0.1561	0.063	0.042	0.031	N/A	N/A
February	0.211	0.312	0.554	1.171	1.6122	0.886	1.56	0.918	1.691	N/A
March	0.45	0.56	1.03	1.74	1.6094	0.98	2.36	0.71	0.85	0.53
April	0.4461	0.5584	1.0311	1.7358	0.12457	0.9774	2.3594	0.7108	0.8499	0.5339
May	0.037	0.0611	0.178	0.0475	0.0961	0.0105	0.0302	0.0072	N/A	N/A
June	0.038942	0.091126	0.247706	0.163678	0.120081	0.070552	0.097463	0.133659	0.162293	0.005792

N/A denotes where meausurements were not taken due to no flows or floods

Salt loads (Kg/day) summary table from June 2003 to July 2004

	Sites									
	4	5	9	10	11	12	16	17	18	19
July	135	2932	3453	5618	N/A	1664	6675	2707	8390	1143
August	232	1472	902	344	N/A	1516	917	676	390	549
September	179	1526	2852	1820	1131	618	606	3131	2863	3886
October	30	454	534	842	1222	891	1988	103	983	1905
November	197	1295	1709	780	718	348	3759	627	N/A	N/A
December	208	1029	1426	1089	888	300	2961	N/A	N/A	N/A
January	331	676	1397	2325	2065	901	2360	N/A	N/A	N/A
February	847	1602	2751	8200	12117	7630	26947	12825	61724	N/A
March	1821	2608	5827	19766	14564	10991	40767	11794	16042	16866
April	62	120	301	260	167	164	850	416	471	797
May	37	112	269	144	220	30	319	259	N/A	N/A
June	315	957	2560	2142	1321	881	6114	3385	467	177

N/A denotes where meausurements were not taken due to no flows or floods

APPENDIX D: IONIC CONCENTRATIONS IN THE KAT RIVER CATCHMENT

Ionic data from the Kat Dam weir used in the determination of the most likely salts

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1977/10/28	14.9	6	2	16.3	2.26	10.7
1977/11/25	15.7	5.6	5.3	14.4	1.88	11.3
1977/12/30	15.2	5.3	2	14.7	1.57	13.4
1978/01/27	15	5.7	2	15.1	1.44	12.9
1978/02/28	14.9	7.3	2	12.3	1.6	11.1
1978/04/28	14.7	6.2	2	12.9	2.22	12.9
1978/05/26	15.5	6.4	2	14.9	2.54	14
1978/06/30	13.9	5.6	2	14.1	1.77	12.4
1978/07/28	15.2	6.2	2	14	2.05	10.3
1978/09/28	14.6	6.2	2	14.4	2.16	13.3
1978/10/30	15.2	5.9	2	12	1.89	12.2
1978/11/30	15.7	5.8	14.3	15.8	2.1	11.9
1978/12/31	15.3	6.2	2	16	1.99	12.2
1979/04/30	14.6	6.3	5.7	16.9	2.33	13.2
1979/05/25	17	6.4	2	15.7	2.59	14.4
1979/11/30	14.5	5.7	23.2	13	2.07	9.7
1979/12/31	13.1	4.8	10.9	15.7	2.96	10.9
1980/01/31	11.3	5.7	7.2	14.4	1.78	11
1980/02/29	10.7	5.5	8.3	13.4	1.83	11
1980/03/31	14.5	4.7	2	14.1	2.32	11.8
1980/04/30	14.2	5.1	2	14.7	2.14	13
1980/05/30	16	4.6	7.2	14.1	2.25	12.3
1980/06/06	15.6	4.5	6.2	14.5	2.25	12.3
1980/06/13	14.8	5.4	2	16.2	2.56	11.8
1980/06/20	14.3	4.5	4.8	17.1	2.04	12.3
1980/08/01	15.8	6.2	5.8	15.8	2.4	11.5
1980/07/25	15.3	5.9	5.8	15.3	2.12	10.9
1980/08/08	14.7	6.9	2	16.1	1.99	21.5
1980/08/15	15.1	6.4	2	14.9	1.99	12.1
1980/08/22	16.7	5.9	5	16.6	2.28	11.9
1980/08/29	14.7	5.7	5	15.1	1.55	12
1980/09/05	14.7	5.7	4.3	15	1.72	12.5
1980/09/12	15.4	6.6	9.9	15.8	2.24	13.1
1980/09/19	15.4	6	9.3	16.2	2.12	12.3
1980/09/26	17.5	6	2	17.1	2.13	13.7
1980/10/03	16.4	6	2	17	2.49	14.1
1980/10/10	16.1	6.5	5.4	19.6	2.14	12.7
1980/10/17	15.7	6.3	4.8	18.9	2.33	12.5
1980/10/24	15.5	5.9	2	10.4	2	12.4
1980/10/31	15.1	6	2	10.7	2.31	13.2
1980/11/07	15.4	5.8	6.5	16.3	2.03	12.4
1980/11/14	15.4	6.1	8.5	16.3	2.22	12.6
1980/11/21	17	6	5.6	17.1	2.19	12.4
1980/11/28	16.9	6	4.9	17.4	2.3	12
1980/12/26	16.6	6.6	2	17	2.21	13.3
1981/01/02	15.4	6.9	8	17.1	2.55	13.3
1981/01/09	15.7	6.7	11.2	18.2	2.29	12.9
1981/01/16	16.1	6.7	12.2	17	2.49	13.5
1981/01/23	16.3	6.2	4.6	16.4	2.11	12.8
1981/02/06	14.5	5.3	16.2	16.7	2.27	11
1981/01/30	17.5	6.7	11.4	18.7	2.41	14.8

APPENDIX D: IONIC CONCENTRATIONS IN THE KAT RIVER CATCHMENT

Ionic data from the Kat Dam weir used in the determination of the most likely salts

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1977/10/28	14.9	6	2	16.3	2.26	10.7
1977/11/25	15.7	5.6	5.3	14.4	1.88	11.3
1977/12/30	15.2	5.3	2	14.7	1.57	13.4
1978/01/27	15	5.7	2	15.1	1.44	12.9
1978/02/28	14.9	7.3	2	12.3	1.6	11.1
1978/04/28	14.7	6.2	2	12.9	2.22	12.9
1978/05/26	15.5	6.4	2	14.9	2.54	14
1978/06/30	13.9	5.6	2	14.1	1.77	12.4
1978/07/28	15.2	6.2	2	14	2.05	10.3
1978/09/28	14.6	6.2	2	14.4	2.16	13.3
1978/10/30	15.2	5.9	2	12	1.89	12.2
1978/11/30	15.7	5.8	14.3	15.8	2.1	11.9
1978/12/31	15.3	6.2	2	16	1.99	12.2
1979/04/30	14.6	6.3	5.7	16.9	2.33	13.2
1979/05/25	17	6.4	2	15.7	2.59	14.4
1979/11/30	14.5	5.7	23.2	13	2.07	9.7
1979/12/31	13.1	4.8	10.9	15.7	2.96	10.9
1980/01/31	11.3	5.7	7.2	14.4	1.78	11
1980/02/29	10.7	5.5	8.3	13.4	1.83	11
1980/03/31	14.5	4.7	2	14.1	2.32	11.8
1980/04/30	14.2	5.1	2	14.7	2.14	13
1980/05/30	16	4.6	7.2	14.1	2.25	12.3
1980/06/06	15.6	4.5	6.2	14.5	2.25	12.3
1980/06/13	14.8	5.4	2	16.2	2.56	11.8
1980/06/20	14.3	4.5	4.8	17.1	2.04	12.3
1980/08/01	15.8	6.2	5.8	15.8	2.4	11.5
1980/07/25	15.3	5.9	5.8	15.3	2.12	10.9
1980/08/08	14.7	6.9	2	16.1	1.99	21.5
1980/08/15	15.1	6.4	2	14.9	1.99	12.1
1980/08/22	16.7	5.9	5	16.6	2.28	11.9
1980/08/29	14.7	5.7	5	15.1	1.55	12
1980/09/05	14.7	5.7	4.3	15	1.72	12.5
1980/09/12	15.4	6.6	9.9	15.8	2.24	13.1
1980/09/19	15.4	6	9.3	16.2	2.12	12.3
1980/09/26	17.5	6	2	17.1	2.13	13.7
1980/10/03	16.4	6	2	17	2.49	14.1
1980/10/10	16.1	6.5	5.4	19.6	2.14	12.7
1980/10/17	15.7	6.3	4.8	18.9	2.33	12.5
1980/10/24	15.5	5.9	2	10.4	2	12.4
1980/10/31	15.1	6	2	10.7	2.31	13.2
1980/11/07	15.4	5.8	6.5	16.3	2.03	12.4
1980/11/14	15.4	6.1	8.5	16.3	2.22	12.6
1980/11/21	17	6	5.6	17.1	2.19	12.4
1980/11/28	16.9	6	4.9	17.4	2.3	12
1980/12/26	16.6	6.6	2	17	2.21	13.3
1981/01/02	15.4	6.9	8	17.1	2.55	13.3
1981/01/09	15.7	6.7	11.2	18.2	2.29	12.9
1981/01/16	16.1	6.7	12.2	17	2.49	13.5
1981/01/23	16.3	6.2	4.6	16.4	2.11	12.8
1981/02/06	14.5	5.3	16.2	16.7	2.27	11
1981/01/30	17.5	6.7	11.4	18.7	2.41	14.8

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1981/02/13	14	5.5	5.3	14.7	2.15	10.9
1981/02/20	14.1	5	4.7	15.8	2.27	11.4
1981/02/27	13.6	5.3	4.2	16.1	2.03	11.9
1981/03/06	12.9	5	4.1	17.3	2.23	11.1
1981/03/13	13.9	5.4	6.9	17.2	2.43	11.2
1981/03/20	14.5	5.3	2	16.9	2.68	11
1981/03/27	13.5	4.9	2	16.3	2.77	11.3
1981/04/03	12.2	4.8	5.1	15.7	2.41	18.5
1981/04/10	12.8	4.6	2	14.3	2.45	9.4
1981/04/17	14	4.8	2	15	2.66	8.7
1981/05/01	12.9	5.1	2	16.3	2.77	10.5
1981/04/24	11.8	5.1	2	14.3	2.41	10.3
1981/05/08	14.1	4.8	2	15.4	2.45	9.9
1981/05/15	14.3	5.4	2	15.4	2.29	10.3
1981/05/22	12.1	5.6	5.6	16.8	2.45	10.6
1981/05/29	12.4	5.3	2	13.1	2.59	11.3
1981/06/05	15.1	6	2	17.3	3.04	11.7
1981/06/12	15.7	5.8	5.3	16.8	3.19	11.2
1981/06/19	13.5	4.7	5.5	16.9	2.56	10.3
1981/06/26	11.6	4.7	9.7	15.2	2.32	8.3
1981/07/03	10.9	4.6	9.5	14.7	2.31	8.7
1981/07/10	12	4.3	9.6	14.1	2.45	9
1981/07/17	12.3	4.9	6.1	14.4	2.44	9.4
1981/07/31	12.4	4.7	14.7	13.6	2.29	17.1
1981/08/07	12.4	4.9	14.1	14	2.54	13.6
1981/08/14	14.4	4.7	10.2	15.2	2.35	9.5
1981/08/21	13.9	5.1	6	15.3	2.68	10.9
1981/08/28	13.4	5.4	6.5	14.9	2.35	23.8
1981/09/04	15.3	5.1	6.5	17.3	2.53	11.2
1981/09/11	14.5	5.1	5.9	16.5	2.59	12
1981/09/18	14.4	4.3	12.5	17.3	2.53	9.5
1981/09/25	14.3	4.3	11.7	15.4	2.53	9.5
1981/10/02	13.3	5.8	9.7	14.4	1.83	12
1981/10/09	13.1	5	8.6	16.1	1.81	8.4
1981/10/16	11.6	4.5	5.8	13.1	2.4	9.8
1981/10/23	11.9	5	5.8	13	2.39	9.8
1981/10/30	11.8	4.7	7.9	15.9	2.31	8.9
1981/11/06	12.6	5.2	11	16.7	2.36	8.7
1981/11/13	12.8	4.9	7.5	15.3	2.21	9.7
1981/11/20	12.4	4.5	7.8	16.4	2.07	8.4
1981/12/11	13.5	4.6	2	17.2	2.26	10.2
1981/12/18	13.5	4.8	2	17.1	2.33	10.3
1982/01/01	13.4	4.8	2	19.9	2.18	9.9
1982/01/08	13	4.9	2	18.8	2.25	9.9
1982/01/15	13.5	5.1	2	17.5	2.4	9.5
1982/01/22	13.4	5.1	2	16.8	2.26	9.7
1982/01/29	13.4	5.1	2	18.4	2.31	10.3
1982/02/05	12.6	5.1	2	18.8	2.23	10.3
1982/02/12	13.5	4.2	2	19.7	2.25	10.9
1982/02/19	14.7	4.3	2	19.6	2.44	11.1
1982/02/26	14.9	5.1	12.1	17.9	2.26	10.2
1982/03/05	14.1	5.6	4.2	15.7	2.25	11
1982/03/12	12.8	5.4	2	15.8	2.39	10.1

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1982/03/19	13.9	5.8	5.9	17.8	2.4	9.9
1982/03/26	14.6	4.4	2	15.6	2.39	11.1
1982/04/02	13.8	4.2	2	14.9	2.33	11.1
1982/04/09	13.7	5.2	2	15.4	2.76	7.2
1982/04/16	15.1	5.3	2	17.8	2.82	10.9
1982/04/23	13.6	5.8	2	14.8	2.53	10.2
1982/04/30	13.2	5.4	2	15.1	2.46	10.6
1982/05/07	15	5.8	2	15.7	2.65	11.4
1982/05/14	14.9	5.8	2	16	2.76	11.2
1982/05/21	14.7	5.2	2	16.6	2.27	13
1982/05/28	13.2	5.2	2	16.8	1.96	12.5
1982/06/04	15.4	5.4	2	17.1	2.92	12
1982/06/15	16.2	6.3	2	20.4	2.69	12.8
1982/06/25	15.5	6.3	2	18.5	2.86	12.6
1982/07/02	14.7	5	2	15.8	2.71	12.7
1982/07/09	13.6	3.7	2	16.5	2.39	9.8
1982/07/16	14.9	5.4	2	19.1	2.32	10.4
1982/07/23	6.8	5.6	2	15.6	2.11	11
1982/07/30	16.3	5.7	2	17.5	3	11.4
1982/08/06	16.6	5.9	2	17	2.94	12.4
1982/08/20	15	5.3	2	14.1	2.54	12.3
1982/08/13	14.9	5.4	2	13.5	2.53	12.5
1982/08/27	14.9	5.6	2	15.5	2.1	12
1982/09/03	14.2	6.1	2	16.5	2.34	15.8
1982/09/10	14.2	6.2	2	17	2.7	13.2
1982/09/17	15.7	6	2	15.2	2.51	11.7
1982/09/24	14.9	6	2	15.9	2.58	12.1
1982/10/01	15.5	6	2	16.9	2.26	11.4
1982/11/19	15.4	5.5	6	15.3	2.13	12.4
1982/11/26	15	5.7	4.6	17.1	2.2	12.7
1982/12/31	18.5	6	10.7	21.7	2.82	13.7
1983/01/14	16.6	6	9	19.3	2.09	14.3
1983/01/21	17.3	6	10	19.2	2.39	14.7
1983/01/28	16.3	5.4	9.3	15.2	2.3	10.5
1983/02/04	19	7.2	9.6	16.9	2.65	15.7
1983/02/25	21.9	6.9	9.4	21.3	2.57	16.5
1983/03/04	20.3	6.9	8.3	18.8	2.44	17.2
1983/03/11	20.3	6.9	8	17.5	2.25	18.2
1983/03/18	20.2	6.9	7.8	18.3	2.43	18.2
1983/03/25	26.4	9.7	17.2	27.7	2.91	16.6
1983/04/01	17.7	8	16.7	17.8	2.29	18
1983/04/08	19.3	7.3	14.5	65.7	2.22	14.9
1983/04/15	21.3	7.8	18.3	20.4	2.42	16
1983/04/22	21.4	8.3	11.6	22.9	2.73	16
1983/04/29	20.2	8.2	11.1	22.9	2.66	16.8
1983/05/06	20.6	8.4	11.4	22.9	2.81	16.6
1983/05/13	21	8.8	10.5	23.3	2.68	17.2
1983/05/20	19.6	7.7	12.3	23	2.23	18.4
1983/05/27	22	7.7	11.8	22.5	2.36	18.6
1983/06/03	22.8	7.9	12.1	25.1	2.08	18.6
1983/06/10	23.2	8.1	12.5	24.2	2	19.3
1983/06/17	20.5	7.2	11.3	19.8	2.08	16.1
1983/06/24	22	8.6	11.2	21.4	2.26	18.7

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1983/07/01	20.8	8.3	10.9	22.2	2.45	18.5
1983/07/08	21.6	7.7	11.2	22.1	2.51	15.5
1983/07/15	23.9	8.1	2	23.5	2.45	15.2
1983/07/22	24.4	8.4	6.1	24	2.38	16.8
1983/07/29	21.2	7.3	5.6	19.6	2.32	15.2
1983/08/05	21.7	8.4	7.3	22.2	1.91	17.9
1983/08/12	20.7	9	7.8	25.3	2.34	18.7
1983/08/19	22.2	8.9	10.6	24.5	2.08	19.7
1983/08/26	22.2	9.2	16.6	25.9	2.55	20.5
1983/09/02	22.3	8.9	18.2	27.4	2.34	18.6
1983/09/09	24	10.3	19	29.1	2.34	21.5
1983/09/16	24	10.2	19	29.1	2.34	21.5
1983/09/23	21.6	9	17.4	26.6	2.34	19.5
1983/10/07	20.9	8.6	14.3	23.2	2.16	17.4
1983/10/14	21.6	8	13.7	22.8	1.98	14.1
1983/10/21	21.2	8.5	15.6	24.1	1.98	16.1
1983/10/28	20.5	8.2	15.5	22.8	1.85	16.6
1983/11/04	22.7	8.7	16.1	24	2.32	19.7
1983/11/11	22.3	8.3	15.2	22.7	2.39	18.9
1983/11/18	23.2	8.5	15.1	24.1	2.6	20.4
1983/11/25	18.2	7.4	12.6	18.9	2.26	18.2
1983/12/09	20.1	8.3	11.3	17.9	2.32	19.3
1983/12/16	18.3	7.3	2	16	2.24	17.4
1983/12/23	16.9	6.3	11.4	18.5	2.47	16.3
1984/01/06	16.4	6.2	13	18.4	2.25	15.9
1984/01/13	16.4	6.2	11.4	18.4	2.32	15.9
1984/01/20	16.8	6.2	9.1	21.3	2.45	15.9
1984/01/27	17.8	6.6	8.8	19.2	2.04	15
1984/02/03	18.2	6.8	7.8	18.4	1.77	16.2
1984/02/10	17.8	6.6	7.8	17.9	2.03	15
1984/02/17	19	7.1	8.9	19.1	1.88	15.9
1984/03/16	14.4	6.1	6.2	16.6	1.71	15.3
1984/04/13	15.3	6.1	14.9	15.9	2	12.4
1984/03/23	17.4	6.4	13.5	17.6	1.9	12.5
1984/03/30	16.7	6.4	13.3	16.1	1.77	12.5
1984/04/06	16.7	6.4	13.1	16.1	2.1	12.5
1984/05/11	13.4	5	16.2	12.9	1.68	9.9
1984/06/08	12.6	4.7	14.3	13.9	1.7	9.9
1984/07/06	14.5	3.9	12.4	13.3	1.89	10.9
1984/08/03	14.9	5.5	10.2	12.5	1.53	11.7
1984/10/05	8.6	5.7	9	12.8	1.61	9.5
1984/11/02	13	6.3	6.7	13.9	1.71	13.9
1984/11/30	14.5	5.8	6.4	11.5	1.58	11.1
1984/12/28	15.9	6.5	6.9	13.9	1.72	13.2
1985/01/25	13.8	5.3	2	12.5	2.11	11.8
1985/03/22	16.5	6.3	10.9	16.4	2.51	14
1985/05/17	13	4.1	7.8	12.6	1.85	8.4
1985/06/14	13.2	5.6	11	14.9	2.25	10.5
1985/07/05	14	5.1	8.8	10.1	2.11	10.3
1985/07/12	13.6	5	7.9	11	2.09	10.6
1985/09/06	14.4	5.1	9.5	15.2	1.88	11.5
1985/10/04	15.7	5.5	6.1	13.6	2.23	11.6
1985/11/01	13.9	5.1	8.4	12	2.17	11.3

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1985/11/29	14.9	6.1	18.4	16.5	3.17	10.7
1985/12/27	16.4	3.6	18.5	89.4	73.32	6.9
1986/01/29	11.6	4.3	2	11.8	2.33	23.1
1986/02/21	10	4.4	4.9	11.6	2.47	9.5
1986/03/21	9.2	4.2	4.5	13.6	2.19	9.3
1986/04/25	15	5.5	6.6	16.6	2.76	10.7
1986/05/23	11.4	5.4	5.9	19.1	2.82	11.3
1986/08/15	13.7	6	4.7	19	2.89	12
1986/09/12	10.8	4.2	2	14.1	2.42	9.6
1986/10/10	14	6.2	2	18.5	2.46	12.7
1986/11/07	10.4	4.3	5.8	15.6	3.33	9.6
1987/02/06	9.8	4.8	5.9	14.7	2.25	10.1
1987/03/06	10.8	5.1	8.4	15.1	2.42	10.9
1987/01/16	9.5	4.2	2	16	1.87	9.2
1987/04/24	8.9	4.5	2	13.8	2.08	10.2
1987/05/22	12.8	5.7	2	16.5	2.62	15.5
1987/06/26	12.6	5.1	10.6	17.3	2.65	10.7
1987/07/24	13.2	5.6	9.3	17.8	2.56	12.6
1987/08/21	14.4	6.2	7.4	16.7	2.4	13
1987/09/18	11.2	4.7	2	14.6	2.19	10.6
1987/10/16	12.1	5.7	14.2	18.5	2.28	11.8
1987/11/13	15.4	6	6.9	18.3	2.63	12.2
1987/12/11	10.6	4.5	2	18.1	2.08	10.2
1988/01/22	11.5	4.9	2	17.6	2.15	10.5
1988/02/19	11.7	4.8	6.1	15.1	2.33	9.6
1988/03/18	11.6	5.2	4.7	17.7	2.27	12.4
1988/04/15	11.4	5.3	2	13.7	2.05	11.9
1988/05/13	11.1	5	2	17.7	2.11	10.8
1988/06/15	13.1	5.9	2	16.9	2.07	12.6
1988/07/11	16.1	7.3	6.5	19.5	2.23	14.9
1988/08/08	18.5	7.9	4.4	20.5	2.45	16
1988/09/05	14.9	6	2	15.6	2.55	12.1
1988/10/03	17.6	7.5	2	20.2	2.58	14.4
1988/10/31	17.7	6.5	2	19.6	2.77	14.6
1988/11/28	13.3	5.5	2	16.2	2.33	10.2
1988/12/06	11.5	5.5	2	18.6	1.79	12.3
1989/01/23	11.3	4.9	2	14.8	1.9	11.8
1989/02/27	13.5	5.4	5.8	16.7	2.59	11.8
1989/04/03	13.4	5.4	2	16.4	2.39	11.8
1989/05/29	15.4	6.1	2	14.7	2.36	12.4
1989/05/01	19.1	8.5	6.6	22.7	2.77	18.7
1989/06/26	21.1	9	4.7	19.4	2.38	17.6
1989/07/24	12.7	5.5	2	15.5	1.92	10.6
1989/08/21	14.9	5.9	5.8	17.3	2.19	11.7
1989/09/18	18.5	8.9	2	23.9	2.62	15.2
1989/10/16	24.2	8.8	5.1	23.4	2.43	19.4
1989/11/13	12.1	4.7	9.1	18.4	2.06	9.8
1989/12/11	10	3.3	2	18.5	2	7.5
1990/05/14	10.5	4.6	2	13.6	2.17	10.4
1990/10/01	11.1	6.5	8.2	9	1.76	9
1990/10/08	9.9	4	11.5	10.2	1.68	8.7
1990/10/15	10.4	4	14.1	10.5	1.84	9.6

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1990/11/12	10.1	4.4	4	11.8	1.62	8.7
1990/12/10	11.9	5.1	8.9	13.2	2.06	11.4
1991/02/04	12.2	6.4	7.7	12.7	2.08	12.2
1991/03/04	10.9	5.2	9.2	11.4	2.13	9.4
1991/04/01	11.2	4.6	4.8	11.8	2.13	10.3
1991/05/13	10.4	4.5	6.1	10.8	1.9	9.8
1991/06/10	11.4	5.9	8.2	13.6	1.86	12.9
1991/07/08	13.3	6.5	7.2	14.9	2.01	13.2
1991/08/05	12.5	5.9	6.3	13.9	2.27	12.1
1991/09/02	10.8	4.7	12.4	12.5	2.33	10.5
1991/09/30	10.7	5.9	4.7	14.1	2.05	10
1991/10/28	10.7	5.7	7.5	13.6	2.02	9.9
1991/11/25	8.3	4.2	2	9.3	1.8	9.5
1991/12/23	9.1	4.2	4.7	10.3	1.87	9
1992/01/06	10.1	4.4	2	13.4	1.83	9.4
1992/02/03	8.4	4.4	11.4	7.8	1.85	9.3
1992/03/02	8.7	4.5	7.4	13	2.04	10.1
1992/04/13	11.8	6.2	6.3	8.7	2.07	13
1992/05/04	9.5	5.1	11.2	10.8	1.96	11.2
1992/04/20	12.4	6.4	6.4	11.6	2.16	15
1992/05/12	11.2	5.7	15.5	11.6	2.04	13
1992/04/27	13.5	7.4	14	11.4	2.2	16
1992/05/25	9.1	4.4	7.4	8.3	1.91	9.4
1992/05/18	9.5	5.6	9.8	9.9	2.22	13.5
1992/06/01	9	4.9	6	9.4	1.93	11.3
1992/06/08	8.7	4.4	8.9	9.1	1.74	9.3
1992/06/29	9	4.7	7.7	9.4	1.82	10
1992/07/06	9.4	4.8	9.7	10.1	1.9	10.5
1992/06/22	9.1	4.7	10.7	8.1	1.83	10.9
1992/06/15	9.2	4.5	10.3	10.1	1.8	10.3
1992/07/13	10.7	4.7	8.4	7.7	1.83	10.3
1992/08/03	9.9	4.8	13.6	7.4	1.88	9.5
1992/07/27	10.9	5.4	12.8	9.2	2.09	10.2
1992/07/20	10.6	4.4	11	7.4	1.94	10
1992/09/07	11.1	5.1	10	9.3	1.8	10.2
1992/09/14	12.2	5.2	8.8	13	1.92	11.5
1992/08/17	11.3	5.1	8	10.2	1.88	10.9
1992/08/10	11.3	5.3	9.6	11.6	1.68	10.3
1992/09/30	10.8	5.1	9	11.5	1.75	9.7
1992/08/24	11.2	5.2	8.7	12	1.8	10
1992/09/21	10.7	4.3	6.9	10.5	1.72	10.1
1992/10/05	11	4.5	7.2	10.7	1.72	9.8
1992/09/28	11.6	4.8	8.1	11.4	1.79	11.3
1992/10/19	12.9	5.6	7.2	12.6	2.01	12.2
1992/10/12	11.5	5.4	9	12.1	1.9	10.9
1992/10/26	11	4.5	7.5	9.8	1.63	10
1992/10/21	12.9	5.3	9.5	11.3	1.79	10.3
1992/11/09	10.1	4.7	11.2	10	2.02	9.4
1992/11/16	12.3	5.1	11.6	10.3	2.04	12.1
1992/11/30	10.5	4.4	19.2	11.1	2.02	9
1992/12/09	11	5	22	10.5	2.42	11
1992/12/15	11.2	4.5	17.7	8.3	2.18	10
1992/12/21	11.5	4.1	10.7	15.6	2.17	9.7

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1992/12/28	11.3	4.6	19	10.2	2.16	9.2
1993/01/04	11.5	4.5	13.2	8.2	2.12	10.4
1993/01/11	11.7	4.8	8	8.7	1.92	9.9
1993/01/18	11.6	4.4	11.6	9.4	2.01	9.1
1993/02/01	10.5	4.9	14.8	7.9	2.03	11.8
1993/01/25	11.1	4.9	24	8.9	1.98	10.6
1993/02/08	10.1	4.6	14.4	7.4	2.01	11
1993/02/15	10.9	5.7	18.9	8.7	2.24	11.3
1993/02/22	11.2	5.2	19	10	3	11.2
1993/03/01	12.6	5.6	14.6	13.6	2.42	11.1
1993/03/15	11.2	5.5	12.3	11.1	2.48	11.5
1993/03/22	9.6	6.8	16.7	10.1	2.4	11.7
1993/04/05	11.1	4.7	10.5	10.6	2.02	10.8
1993/04/19	11.6	5.5	10.3	11	2.03	13.7
1993/04/26	11.4	5.6	9.8	10	2.11	13.2
1993/05/03	8.9	6	11.6	10.4	2.43	12.6
1993/05/10	11	6	8.1	16	2.02	15.8
1993/05/17	11.6	6.2	9.9	12.8	2.07	13.5
1993/05/24	12.6	6.8	9.8	12.6	2.18	16.1
1993/06/14	7.8	3.5	4.6	7.3	1.59	8.9
1993/06/21	11.7	5.3	7.5	7.9	1.88	10.7
1993/06/28	12.4	6	8.9	10.3	2.12	13.8
1993/07/05	12.8	6.3	9.2	11.5	1.98	14
1993/07/12	12.1	5.4	11.5	8.5	2.33	10.7
1993/07/19	11.2	6.6	7	9.7	2.13	9.7
1993/07/26	10.9	5.4	12.5	9.2	2.16	12.7
1993/08/02	12.8	5.9	14.3	11.8	2.3	13.8
1993/08/09	11.3	5.4	15.4	8.9	2.25	12.1
1993/08/16	11.2	5.6	6.2	9.3	2.01	13.5
1993/08/30	10.5	5.2	9.5	8.7	2.18	10.9
1993/08/23	11	5.5	14.8	11.8	2.37	12.8
1993/09/13	11.6	4.8	9	11.7	1.96	10.7
1993/09/20	11.2	5.1	13	11.1	2.22	10.9
1993/09/27	10.1	5.1	17.7	11.5	2	12.8
1993/10/04	11	5.5	11.5	11.6	2.24	11.8
1993/10/11	11.5	5	12.9	11.1	2.45	11.7
1993/10/18	11.8	5.4	6.7	11.1	1.98	11.1
1993/10/25	11.2	4.9	10.6	10.3	2.25	12.3
1993/11/01	12.4	5.3	7.6	9.6	1.91	11
1993/11/08	11	5.1	9.7	9.1	2.14	10.7
1993/11/15	12	5.2	7.3	9.5	2.09	12.7
1993/11/22	11.7	5.7	8.3	9.5	2.2	15.2
1993/12/01	12.1	4.2	16	9.1	2.28	12.2
1993/12/06	11	5.7	13.4	6.3	1.97	13.3
1993/12/13	14.5	6.6	10.6	12.7	2.11	14.9
1993/12/27	11.6	5.5	11.9	8.6	2.15	14.4
1993/12/19	11.3	5.6	6.7	9.1	2.14	11.6
1994/01/03	11.3	6	11.3	9.7	2.29	15.9
1994/01/10	10.7	5.9	9.1	9.3	2.18	12.7
1994/01/17	12.2	5.8	4.4	11.5	2.38	13.6
1994/01/24	10.4	4.9	8.5	8.6	2.26	11.4
1994/01/31	11.1	6.1	9.2	11.8	2.19	13
1994/02/07	10.5	6.2	14.3	9.6	2.07	11.9

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1994/02/14	12.2	6.5	6.1	10.9	2.4	15.3
1994/03/07	11.7	5.6	15.3	10.8	2.81	12.5
1994/02/28	11.3	5.2	18.1	9.8	2.8	11
1994/02/21	13.7	6.4	8.5	10.4	2.87	14.9
1994/03/21	11.7	5.1	16	10.1	2.72	12.4
1994/03/28	11.9	5.8	16.4	10	2.91	14.5
1994/03/14	13.6	6.5	8.8	9.1	2.81	15
1994/04/11	11.7	5.3	5.2	8.6	2.73	11.3
1994/04/04	11.4	6	13.6	10.4	2.81	12.1
1994/05/09	11.1	6	11.5	12.3	2.66	11.6
1994/05/16	11.2	6.2	12.8	8.9	2.88	12
1994/05/02	13	6.7	17.7	10.8	3	12.7
1994/05/23	11.6	5.7	7	14.5	2.8	12.3
1994/06/06	10.8	5	11.4	8.1	2.85	10.1
1994/05/30	9.4	4.1	11.7	5	2.61	8.4
1994/06/22	11.7	6.2	15	10	2.77	12.4
1994/07/18	9.5	4.5	19.8	8.4	3.01	9.7
1994/08/01	10.7	5.7	11.2	9.6	2.78	12.4
1994/07/25	9.3	5.2	11.2	8.8	2.78	11.6
1994/08/22	13	6.2	6.8	10.2	3.08	13.9
1994/08/29	14	6.6	9.3	9.5	2.86	15.3
1994/08/15	13.6	6.5	14.3	12.5	2.87	13.8
1994/08/08	11.9	6.4	5.6	11.7	2.88	12.9
1994/09/26	11.5	5.8	7.6	13.1	3.02	12.7
1994/10/03	12.3	6.1	5.1	12.7	2.99	12.8
1994/10/10	9.8	4	7.8	12.3	2.82	9.9
1994/10/17	10.8	4.9	10.5	13.8	2.76	11.2
1994/10/24	11.8	5.1	5.3	13.1	3.05	12
1994/10/31	13.7	6	4.4	12.9	3	13.3
1994/11/07	14.3	6.5	5.7	13.1	3.25	13.5
1994/11/14	11.3	3.9	6.3	12	2.92	10.7
1994/11/21	11.1	4.7	10.7	12.1	2.81	12.3
1994/11/28	11.5	4.8	14.7	12.4	2.78	10.5
1994/12/05	11.8	5.4	11.4	12.8	3.12	12.4
1994/12/19	12.3	4.2	12.4	11.4	3.04	12.2
1994/12/26	9.5	4.3	8.8	11.2	2.85	9.9
1995/01/09	12.3	6.1	11	12	3.11	13.3
1995/01/16	13.4	5.7	22	11.3	3.26	11.2
1995/02/13	10.9	4.7	9.8	10.5	2.9	11.1
1995/02/06	11.3	5.2	7.3	10.5	3.18	11.6
1995/01/30	15.2	6.8	10	6.8	3.24	17.1
1995/02/20	10.2	5.1	13.2	9.2	2.89	10.3
1995/02/27	10.5	5.5	11.9	10.3	3.15	11.7
1995/01/23	12	5.9	5.5	8.2	3.15	11.9
1995/03/06	10.1	5.2	7.1	9	3.07	9.7
1995/03/13	10.6	4.6	9.8	9	3.06	11
1995/03/27	10	5.1	9.7	7.5	3.19	13
1995/03/20	10.3	5.1	11.7	8.8	3.27	11.6
1995/04/03	10.4	5	6.8	8.8	3.05	11.8
1995/04/10	10.7	5.1	6.5	13.1	3.03	12.7
1995/04/17	10.4	5.2	2	9.5	3.12	12.3
1995/05/15	10.1	5.3	7.6	8	3.17	14.3
1995/04/24	10.8	5.4	4.3	7	3.15	11.4

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1995/05/01	10.6	5.1	7.4	6.5	3.07	10.6
1995/05/03	9.9	5.4	8.5	8.3	3.18	13.7
1995/05/22	6.8	5.3	5.2	6.2	2.88	12.8
1995/06/12	11.4	4.6	11	8.2	3.02	9.8
1995/06/05	11.4	5.3	10.6	6.7	3.18	10.9
1995/05/29	9.6	5.5	12.7	7.6	3.21	12.5
1995/06/19	10.9	4.9	10.8	5.3	3.11	10.8
1995/06/26	11.2	4.5	8.5	5.9	3.01	10.1
1995/07/03	11.6	5	7.2	7.1	3.03	15.3
1995/08/16	11.7	4.4	6.7	9.7	3.23	10
1995/07/31	10	4.4	19	7.8	3.24	9.9
1995/08/14	11.7	4.9	16.2	10.9	2.61	11.1
1995/08/21	10.7	5	8.3	8.3	3.05	10.3
1995/09/04	10.1	5	6.9	8.1	3.09	11.8
1995/09/11	10.3	4.2	13.1	8.2	3.28	13
1995/09/25	11.6	4.2	7.7	9	2.98	9.5
1995/10/09	13	6.6	6.2	9.2	3.23	12.5
1995/11/06	14.2	5.5	11.3	10.9	3.4	12.9
1995/11/20	11.7	4.4	13.6	8	3.46	9.5
1995/12/18	11.2	5.4	10.2	10.2	3.2	11
1996/01/15	20.6	7.6	7.5	13.6	3.73	17.3
1996/01/29	5.4	3.9	10.7	9.3	2.61	8
1996/02/12	8.9	3.6	9.3	9.2	2.85	8.2
1996/02/26	10.2	3.5	11.9	10.4	3.1	7.8
1996/03/11	9.8	4.6	14.9	8	2.83	9.5
1996/04/22	8.2	3.5	5.7	7.1	2.63	7.2
1996/05/06	8.8	3.6	12.2	8.3	2.81	8.1
1996/06/17	12.5	4.8	12.9	8.8	3.03	10
1996/06/03	8.7	4	10.7	9.3	2.98	8.9
1996/05/20	8.5	4.1	11.2	9.2	2.88	8.3
1996/07/15	9	4.8	8	9.5	2.95	10.2
1996/08/12	15.5	6.3	7.2	11.3	3.2	11.3
1996/09/23	10.8	4.5	14.8	7.7	3.37	8.8
1996/08/26	10.5	4.4	2	11.6	1.74	9.6
1996/10/21	9.2	4.4	27.1	9.8	2.18	9.2
1996/10/07	10	4.5	19.8	9.5	2.24	9
1996/12/02	9.6	3.7	9.9	7.8	1.57	9
1996/12/17	10	4.3	18.1	9.5	2	9.9
1996/12/30	9.9	3.8	9.2	8.1	1.97	9
1997/01/27	9.2	4	2	7.2	1.64	9.4
1997/02/10	10.4	3.9	19.2	8.7	2.11	9.8
1997/03/17	9.4	3.6	10.8	8.5	1.74	8.9
1997/03/03	9.6	3.8	8.1	8.6	1.71	9.6
1997/03/31	9.9	4	14.1	7.3	1.72	8.7
1997/09/29	9.6	3.7	13.5	10.2	1.52	8.4
1997/11/03	12.6	4.4	14.1	10.1	1.91	11.6
1997/11/17	8.4	3.4	21.2	8.4	1.76	7.2
1997/12/29	9.2	3.5	17	9.2	1.5	9.6
1997/12/15	10.3	4.4	18.6	10.8	1.92	15
1998/02/02	9.2	3.3	6.7	7.7	1.45	10
1998/01/13	8.8	3.5	14.2	8.6	1.68	7.9
1998/02/23	10.9	3.5	15.7	8.3	1.56	10.9
1998/02/16	9.8	5.1	13.7	8.9	1.46	8.9

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1998/03/30	13.4	4.6	12.7	9.5	1.81	12.2
1998/03/16	12.9	4.7	11.5	11.1	1.63	12.4
1998/04/13	14.4	4.7	12.2	10.4	1.77	11.3
1998/05/11	8.5	4.2	18.7	8.2	1.42	9.9
1998/04/07	10.5	4.9	18.1	9	1.86	9.8
1998/06/15	10.7	4.1	7.8	8.1	1.53	9.2
1998/06/22	11.3	4.7	12.7	8.9	1.58	9.9
1998/08/24	9.8	3.2	12.2	11.9	1.58	8.1
1998/08/24	11.2	4.1	20.7	11.1	1.66	9.5
1998/09/07	11.1	4.4	13.7	11.9	1.59	9.3
1998/10/17	10.7	5	14.6	13.3	1.76	10.6
1998/12/28	10.1	4.2	11	10.5	1.68	9.2
1999/09/13	11.956	3.845	2	12.759	1.461	10.259
1999/10/04	12.074	4.727	6.633	15.468	1.392	10.491
1999/11/29	12.662	4.416	11.625	13.012	1.638	11.606
1999/11/15	14.303	5.243	7.158	14.855	2.168	13.21
1999/11/08	14.265	5.166	8.983	17.271	2.424	13.592
1999/12/20	11.29	4.51	7.148	13.359	1.719	11.126
1999/04/12	11.862	4.429	8.773	11.235	1.512	9.685
1999/08/16	13.422	4.728	7.063	13.004	1.435	10.393
1999/08/23	12.086	4.404	8.249	12.483	1.566	9.769
1999/09/09	13.331	4.645	9.98	12.847	1.45	10.53
1999/10/18	12.367	4.493	6.736	13.774	1.52	10.204
1999/10/11	13.487	4.748	8.123	15.931	2.082	10.293
1999/01/18	10.6	4.2	14.4	11.7	1.8	10.6
1999/03/01	11.3	4.6	9	13.3	1.75	12
1999/03/15	10.5	4.4	6.2	12.1	1.62	10.5
1999/03/29	10.5	4.4	10.1	11.6	1.57	10.6
1999/02/15	11.1	4.3	9.7	11.8	1.41	9.9
1999/04/26	10	4.5	9.7	11.6	1.47	9.3
1999/04/13	10.2	4.3	11.5	11.7	1.55	9.7
1999/05/10	10.3	5.2	8.8	11.8	1.49	10
1999/05/31	11.4	5.3	16.4	13.1	1.53	11.5
1999/06/28	11.1	4.8	9.4	12.3	1.49	9.6
1999/05/17	11	4.9	6.3	13.1	1.65	9.5
1999/06/14	12.9	5.2	11.7	11.9	1.95	10.7
1999/06/07	11.4	5.2	8.5	14.9	1.49	10.5
1999/05/24	11.1	4.2	16.9	11	1.56	9.7
1999/06/21	11.4	4.9	12.6	13.6	1.84	10.5
1999/07/26	11.7	4.6	16.9	11.7	1.73	9
1999/07/05	11.5	4.4	12.2	12.1	1.45	9.3
1999/07/12	12.2	4.3	18.5	13.1	1.63	8.8
1999/07/19	12.4	4.7	14.9	4.5	1.48	9.6
1999/09/06	11.7	4.7	6.4	12.3	1.4	10.5
1999/08/09	12.7	4.9	8.6	11.2	1.16	9.5
1999/08/02	12.1	4.9	7.6	11.4	1.55	9.7
1999/08/02	13.7	5.2	6.4	11.4	1.52	10.4
1999/08/30	11.6	4.5	5.6	13.4	1.53	10.1
2000/01/17	12.413	4.928	13.185	11.068	2.198	10.398
2000/02/07	12.554	5.266	16.427	12.584	2.376	9.977
2000/02/21	11.11	4.312	13.665	12.218	2.196	10.393
2000/03/06	11.981	5.115	10.401	12.397	1.905	10.105
2000/03/29	9.959	6.979	21.955	11.421	2.164	6.966

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2000/04/11	12.198	2.88	10.433	11.144	2.201	8.843
2000/05/17	10.855	3.621	10.501	12.19	1.859	9.353
2000/05/02	10.55	3.486	22.036	12.351	2.312	7.906
2000/05/29	11.318	3.573	16.677	11.214	2.141	8.297
2000/06/26	11.321	2.588	6.463	12.844	2.46	10.492
2000/07/10	12.219	3.097	12.518	10.8	1.85	9.005
2000/08/14	10.455	5.231	11.683	12.399	1.797	10.126
2000/08/28	11.438	4.599	24.166	11.481	2.308	11.25
2000/09/04	12.488	5.147	22.065	11.577	2.531	11.808
2000/10/02	10.376	4.771	20.889	11.743	2.052	11.93
2000/11/09	10.818	4.272	18.057	11.229	1.945	10.114
2001/05/21	10.936	4.589	38.129	13.322	2.695	10.491
2001/05/14	11.438	4.216	13.617	11.065	1.965	10.403
2001/05/28	11.405	4.143	9.054	13.681	1.765	10.022
2001/04/23	11.002	4.081	18.015	10.222	2.019	11.483
2001/06/04	11.137	4.45	9.618	12.825	2.381	9.889
2001/11/12	9.964	4.23	9.259	14.68	1.748	8.992
2001/11/12	10.258	4.287	9.922	13.421	1.797	8.919

Ionic data from the Balfour weir used in the determination of the most likely salts

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1972/09/15	48	14	15	45	2	28
1974/05/30	17.3	5.7	5.5	21.2	1.49	11.5
1977/10/07	17.7	8	4	21.9	0.99	17.7
1977/10/14	20.9	8.9	4.7	25.3	1.07	19.1
1977/10/21	23	9.9	4.8	26.4	1.15	21.4
1977/10/28	12.3	5.6		13.6	0.88	10
1977/11/04	9.1	2.7		7.3	0.88	3.7
1977/11/11	12.4	3.4		8.2	0.75	6.9
1977/11/18	15.5	5	5.9	12.9	0.85	11.3
1977/11/25	20.5	7.1	6.2	16.5	1.08	15.9
1977/12/02	8.5	3		9.1		4.4
1977/12/09	12.7	4.7		13.8		9.1
1977/12/15	13.7	5.6		15.1		28.4
1977/12/23	17.9	6.9	4.6	19.4		15.1
1977/12/30	19	8.6	4.8	23		17.3
1978/01/06	9.1	3.6		12.9		8.5
1978/01/13	8.5	3.6		13.2		8.6
1978/01/20	13	5.4	4.3	16.8		11.7
1978/01/27	19.1	8.5		18.1	1.32	15.2
1978/02/03	17.8	7.1		16.1	0.76	15.4
1978/02/10	18.7	7.4		17.3	0.86	15.6
1978/02/16	19.2	7.1		16.5	0.56	15
1978/02/23	19.7	12.2		20.8	0.97	18.1
1978/03/03	29.1	14.2	5	31.9	1.12	27.3
1978/03/10	17.3	9.2		17.3	0.84	17.1
1978/03/17	23.6	11	4.4	24.1	0.99	22.5
1978/03/24	13.9	6.4		15.9	1.23	15.5
1978/03/31	24.2	10.5	5.3	30.1	1.65	25.9
1978/04/07	19.9	10.1	4	25.1	1.08	21.5
1978/04/11	15.4	7.2		20.8	0.94	14
1978/05/03	7.9	2.8		6.8	1.23	5.5
1978/05/10	12.7	5.7		12.1	0.7	10.4
1978/05/16	15.6	6.4		15.8	0.69	13.4
1978/05/24	18.6	7.8		20.1	0.8	16.7
1978/06/14	16.4	7.6		18.5	3.1	17.8
1978/06/21	22.6	10.1		23.8	1.25	21
1978/06/28	24	9.8	4.8	27.7	1.37	21.9
1978/07/12	27.4	11.4	5.7	32.2	1.5	23.9
1978/07/19	28	12	5.3	36.8	1.65	26.2
1978/07/26	32.4	12.6	8.2	40.6	1.47	30.9
1978/08/02	38	14	6.1	44.6	1.49	32
1978/08/09	50.7	17.3	9.7	61.7	1.5	38.5
1978/08/16	57.8	21	11.8	76.6	1.8	47.3
1978/08/23	20.6	8.5		27.5	2.18	20.9
1978/08/30	40.2	16.2	6.6	49.3	1.69	35.7
1978/09/06	47	18.9	15.4	60.5	1.84	44.3
1978/09/13	34.8	14.5	10	41.9	2.03	31.8
1978/09/20	14.5	5.7	4.3	14.1	1.57	12.6
1978/09/27	23.6	10.1	5.4	28.2	1.36	21.4
1978/10/04	32.9	13.6	7.7	40.3	1.8	29.8
1978/10/11	15.6	6.4		16.3	0.7	14.8

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1978/10/18	12.1	5.6		12	0.63	11.2
1978/10/25	8.9	4.3		8.1	1.22	6.3
1978/11/01	16.3	8	6.1	16.6	0.91	14.3
1978/11/08	8.7	4.3		7.2	0.66	22.2
1978/11/15	13.6	5.9	7.9	12.6	0.79	12.8
1978/11/22	17.7	7.5	7.9	17.4	0.94	15.9
1978/11/29	21.1	8.3	10.1	22.5	1.38	19.6
1978/12/06	26.6	12.2		27.7	1.3	23.7
1978/12/13	8.6	4.2	6.9	8.6	0.94	6.9
1978/12/20	15.2	6.2		15	0.9	14.3
1978/12/27	9	3.5		8.7	0.82	8.6
1979/01/03	7.4	3		7.3	2.18	6.1
1979/01/10	11.3	4.4		9.4	0.75	10.6
1979/04/25	18.4	7.7		19.6	2.2	16
1979/05/02	21.3	9.2	7.4	22	1.16	20.6
1979/05/09	19.7	8.6	6.2	20.1	1.17	18
1979/05/16	26.1	10	8.3	24.2	1.03	23.6
1979/05/23	28.9	11.3	5.6	31	1.29	25.4
1979/05/30	21.5	9.4	4.1	23	1.35	20.4
1979/06/06	24.9	10.4	6.7	24.3	1.12	24.4
1979/06/13	27.2	12	5.4	30.2	1.22	26.9
1979/06/20	26.1	10.7	4.8	28.6	1.01	24.9
1979/06/27	35.8	13.2	8	42.7	1.48	29
1979/07/11	46.5	17.8	9.1	52.1	1.68	40.8
1979/10/10	20.7	6.6	5.7	22.7	1.79	19
1979/10/17	20.2	7.7	4.6	21.9	1.26	16.7
1979/11/14	13.6	6	12	16	6.88	11.7
1979/11/28	17.8	6.9		16.6	1.48	15.3
1979/12/05	26	12.3	25.3	24.5	2.04	23.4
1979/12/12	33.8	14.6	9.6	37.7	1.87	31.4
1979/12/19	40.4	17.2	6.2	40.9	2.31	39.2
1979/12/26	38.8	14.4	10.1	34.9	2.85	33.4
1980/01/02	33.1	14	22.1	36	2.5	33.1
1980/01/16	19.3	7.2	20.3	20.5	2.26	18.5
1980/01/23	32.1	13.4	8.1	30.9	1.54	31.5
1980/01/30	16.8	7.4		16.8	1.3	9
1980/02/06	28.7	11.2	5.6	33.6	1.79	26.1
1980/02/13	30.7	12.1	6.1	43.9	1.6	27.1
1980/02/20	40.4	16.8	7.8	39	1.28	33.9
1980/02/27	14.7	7.4	7	25.6	1.89	16.3
1980/03/05	12.2	4.9	4.5	16.1	1.26	10.7
1980/03/12	17.1	7.4		18.1	1.04	16
1980/03/19	10.9	4.6		12.4	0.88	10.2
1980/03/26	16	7.4		19.7	0.95	13.9
1980/04/02	21.9	8.4	7.3	29.8	1.45	20
1980/04/09	32.1	10.8	10.2	38.2	1.33	27.4
1980/04/16	31.5	11.7	6.5	38.4	1.61	24
1980/04/23	37.2	14.6	8.5	42.3	1.49	35.1
1980/04/30	42	15.6	9.4	43.5	1.5	35.8
1980/05/07	40.9	17.1	9.1	39.6	1.33	37.4
1980/05/14	41.1	16.9	11.3	37.9	1.7	39.5
1980/05/21	41	18.8	14.6	40.9	1.3	37.9
1980/06/03	62.5	22.4	14.7	68.3	2.08	48.3

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1980/06/11	50.1	18.1	13.2	61.3	1.54	44.4
1980/06/18	47.4	18.5	12.1	49.3	1.42	37.4
1980/07/15	41	17.8	13.3	41.8	1.1	36.4
1980/07/22	37.5	17	10.1	35.5	1.03	37.2
1980/07/29	52.1	20	15.7	56.3	0.84	35.5
1980/08/12	43.2	17.9	15.4	44.3	0.82	32
1980/08/19	42	18.6	12.9	44.8	0.74	31.9
1980/08/26	45.8	17.7	7	45.4	1.02	28.5
1980/09/09	63.6	20.2	16.4	78.2	3.01	37.3
1980/09/02	46.8	18.6	10.7	44.7	1.29	32.6
1980/09/16	72.3	20.4	14.8	82.7	2.04	23.3
1980/09/23	49.2	19.4	12.8	54.7	1.78	36.2
1980/09/30	11.5	4.6	15.7	13.8	1.85	10.1
1980/10/07	33.8	11.4	10.7	38.2	1.95	30
1980/10/14	44.2	16.1	16.3	55.7	2.12	36.1
1980/10/21	11.1	4.7	7.5	11.3	1.34	9.9
1980/10/28	25.2	10	9	28.4	1.32	23
1980/11/04	39.3	13.5	9.5	40.3	1.67	30.4
1980/11/11	38	14.4	13.8	41.7	1.7	34.8
1980/11/18	43.8	16.8	13.2	47.8	0.98	33.8
1980/11/25	45.2	20.3	9.8	52.3	0.88	36
1980/12/02	13.6	4.7		10.4	1.42	11.5
1980/12/23	32.9	11.7		28.3	1.55	30
1980/12/30	10.2	3.6		9.4	1.61	8.7
1981/01/06	16.2	6.2	7.8	15.9	1.41	15.4
1981/01/13	9.9	3.1		9.6	1.55	8.8
1981/01/20	15.1	4.5	4.9	9.8	1.15	13.1
1981/01/28	7.9	3.3		7.2	1.03	7.1
1981/02/03	8.3	2.9	4.3	6.2	1.14	5.8
1981/02/10	9.2	3.5	7.2	6.4	0.95	7.2
1981/02/17	6	6.3	12.6	12.1	13.36	8
1981/02/24	8.8	3.8	20.7	8.6	3.85	8.9
1981/03/03	9.4	3.6		8.8	1.1	8
1981/03/31	9.1	3.7		8.9	0.68	8.8
1981/04/28	18.7	7	51.2	14.9	1.54	15.9
1981/05/26	18.2	8.1		16	1.18	15.5
1981/06/23	17.6	6.6	12.6	14.7	1.17	16
1981/08/19	43.3	16.3	13.2	44.2	1.37	36.4
1981/09/16	16.7	6.9		16.7	0.9	16.3
1981/10/14	32.5	13	13.2	30.8	1.03	28.3
1981/11/11	19.5	7.1	12.2	18.7	1.17	17.5
1982/01/05	19.5	7.6	8.2	21.1	1.27	19.4
1982/02/02	41.8	16	12.3	41.5	1.99	42.5
1982/03/02	28.3	10.5	9.4	30.2	1.44	24.9
1982/05/05	17.7	7.5	4.4	17.1	1.64	15.5
1982/06/02	39.1	14.2	5.8	38.5	1.61	35.5
1982/07/07	14.2	6.1		18.1	1.39	23.8
1982/08/04	30.3	11.7	15.6	30.1	1.07	26.9
1982/09/08	26.3	10.3		28.7	1.58	26.3
1983/11/02	35.1	14	59.3	43	1.78	35
1983/12/28	13.6	5.3	11.7	17.1	1	18.6
1984/01/04	9	3.1	7.8	16.1	1.35	7.8
1984/02/08	18.7	6.6	12.7	22	1.11	18

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1984/04/04	13.2	5.2	10.5	13.8	0.64	10.1
1984/04/09	6.8	2.6	15.2	5.8	2.04	4.7
1984/05/02	19.5	7.9	10.6	18.6	1.49	16.7
1984/07/04	27.6	10.3	12	27.6	0.89	26.3
1984/11/06	26.5	9.6	10.2	28.8	1.56	23.8
1984/12/05	10.6	4.6	5.3	14.6	1.04	9.7
1985/01/02	22.6	9.9	5.4	20.1	1.22	21.6
1985/03/06	12.6	5.4	8.7	12.8	0.8	11.4
1985/04/03	28.4	12.6	9.6	24.9	1.52	30.9
1985/05/08	36.6	14.6	11	30.8	1.34	31.9
1985/06/05	32.5	12.9	11.7	30.7	1.2	32.7
1985/07/03	34.5	12.4	9.7	39.2	1.57	28.9
1985/08/07	35.6	13.7	10.9	50.4	1.02	29.4
1985/09/04	49.2	15.7	9.9	44.1	1.75	35.1
1985/10/02	35.9	16.5	6.3	41.8	1.01	35.9
1985/11/06	9.7	3.5	10.7	19.6	1.66	7.8
1985/12/04	9.5	3	11.7	17.9	2.33	6.7
1986/01/08	11.4	4.3	9.6	17.2	0.96	9.2
1986/02/05	13.2	4.6	5.4	21.3	1.39	10.6
1986/03/05	14.6	5.3	8.2	17.8	0.98	11.8
1986/04/02	15.7	6.5	7.6	19.9	1.06	14.9
1986/05/07	19.7	8	368.2	356.8	0.96	18.2
1986/06/04	36.4	12	11.8	45.2	1.33	29.9
1986/07/02	40.6	15.5	13.8	54.9	1.33	35.6
1986/08/06	46.7	16	14.2	62.7	1.37	37.3
1986/09/03	40.9	14.2	9.6	45.1	1.67	29.8
1986/10/06	9.2	3.8		13.8	2.64	8.3
1986/11/05	10	3.3		12.5	0.84	5.9
1986/12/03	12.1	4.9		13.2	0.85	11.2
1987/01/07	15.1	5.9		15.8	0.88	14.2
1987/02/03	14.9	5.3	5.9	15.1	0.83	13.4
1987/03/07	9.9	4		14	1.31	8.8
1987/04/08	15.6	5.9	4.5	13.5	1.01	12.9
1987/05/06	22.4	8.3	6.8	20.8	1.05	18.9
1987/06/03	30.7	11.2	9.6	29.6	1.28	25.8
1987/07/08	41.1	15.2	11.2	44.5	1.58	35.6
1987/08/05	44	14.9	11.7	56.2	1.17	34.5
1987/09/09	29.5	10.8	5.8	31.1	1.26	27.1
1987/10/07	16.3	5.8	7.4	17.5	0.97	14.3
1987/11/04	27	9.8	5.5	26.1	1.16	21.2
1987/12/02	19	7.6	5	20.3	1.34	11.5
1988/01/06	32.7	11.9	5.2	30.2	1.35	26.5
1988/02/02	37.3	14.4	4.2	38.2	1.24	31.7
1988/03/02	11.7	5		13.4	1.02	11.4
1988/04/06	16.1	6.6		16.1	1.11	15.2
1988/06/08	22.7	8.9	6.4	21.3	1.3	22
1988/07/06	27.5	11	8.7	24.7	1.48	23.6
1988/05/04	27.4	10.6	4.3	25.2	1.1	24.9
1988/08/03	36.8	13.5	7.5	32	1.13	31.2
1988/09/07	34.6	13.1	8.7	38.4	1.47	29.5
1988/10/05	38.9	14.6	4.9	36.8	1.12	29.7
1988/11/02	29.1	11	4.3	26.5	1.12	22.2
1988/12/07	7.7	2.6		10.7	0.97	5.5

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1989/01/04	22.9	3.1	13.7	33.1	5.12	7.5
1989/03/08	13.6	4.9	9.1	11.1	1.05	12.3
1989/04/04	14.7	5.3		13.5	1.03	15.1
1989/05/02	10.1	3.7		11.7	0.99	8.6
1989/06/06	15.2	6.8	4.4	18.3	0.87	17.7
1989/07/04	18.9	7.7	8.5	22.2	0.82	19.3
1989/08/01	25.8	10.7	7.5	29	1.35	21.4
1989/09/05	37	14.4	17.9	42.5	1.24	31.6
1989/10/03	9.3	3.3	5.3	18	2.61	9.5
1989/11/07	7.6	3.2		14.4	0.75	8.9
1989/12/05	9.7	3.8		15.8	1.07	8.7
1990/05/01	11.2	4.7	6.6	15	1	10.5
1991/03/05	10.2	4.8		13.8	1.03	9.7
1991/04/02	13.8	5.6		12.7	0.76	11.9
1991/06/04	27.8	10.3	8.7	28.8	1.05	25.1
1991/07/02	32.2	11.4	7.7	30.4	1.34	25
1991/08/06	40.9	14.6	8.2	40.6	1.27	30.5
1991/09/03	34.5	14	8.4	39.3	1.17	30.2
1991/10/01	38.2	14.3	6.7	40.1	1.67	35.4
1991/11/05	9	4	4.9	9.5	0.82	8.6
1991/12/03	14.6	5.7	4.6	13.3	0.84	14.4
1992/01/07	17.9	7.5	4.2	17.1	1.05	18.9
1992/02/04	16.7	8.4	5.4	16.3	0.94	18.7
1992/03/03	11.4	5.8	4.9	14	1.02	15
1992/04/07	17.3	7.6	7.9	13.1	1.4	17.5
1992/05/05	21.3	9.6	8.9	17.2	1.21	20.9
1992/06/02	31.5	12.9	12.8	29.3	1.67	30.7
1992/07/07	34.4	13.7	12.6	30.3	1.58	31.4
1992/08/11	18.2	7.8	11.8	18.7	2.1	19.6
1992/09/01	36.2	13.1	9	35.4	1.54	31.7
1992/10/06	37.2	14.2	9.7	34.3	1.53	32.1
1992/11/03	31.9	12.1	11	28	1.38	27.6
1992/12/01	16.9	6.7	9.1	12.7	2.02	17.1
1993/01/05	16.4	6.3	7.6	11.9	1.79	17.4
1993/02/02	7.2	3	8.9	5.3	1.13	6.2
1993/03/02	12.6	6.1	7.9	9	1.45	12.4
1993/04/06	6	2.6	4.5	5.5	0.78	4.9
1993/05/03	11.1	5	8.7	9	0.99	11
1993/06/01	21.6	9.3	7.2	21.2	1.54	20
1993/08/03	33.4	11.6	8.2	25.6	1.6	29.4
1993/09/07	39	13	8.6	35.5	1.63	30.3
1993/10/05	8.5	4.5	9.3	10	1.03	9.3
1993/11/02	11.6	5.3	10.4	8.8	1.08	11.7
1993/11/30	9.8	4.8	9.4	8.6	1.11	10.1
1994/01/04	7.1	2.6	8	7.9	0.74	6.3
1994/02/01	7.5	3.5	6.4	7	1.58	6.3
1994/03/01	9.9	3.5	8.6	9.5	0.84	7.8
1994/04/05	12.4	5.3	7.3	10.1	0.77	10.8
1994/05/03	18.4	7.6	13	17.2	1.73	16.3
1994/05/31	18.4	7.7	5.6	17.4	1.8	16.6
1994/07/05	24.4	9.5	12.8	20.2	2.21	23.1
1994/08/29	18.7	8.1	12.9	12.1	1.93	18
1994/08/02	24.2	8.5	10	26	2.22	21.4

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1994/09/05	21	8.7	4.7	18.7	2.07	19.2
1994/09/19	22.2	8.9	7.6	20.6	2.23	21.7
1994/10/03	27.4	10.8	6.6	23.9	2.62	23.8
1994/09/26	25.6	9.8	6.1	21.7	2.68	22.6
1994/10/10	10.3	3.6	15.2	9	2.83	8.5
1994/10/17	12.3	5.1	6.4	11.3	2.19	11.5
1994/10/31	17.8	6.7	5.1	14.4	2.19	15.7
1994/10/14	13.9	5.6	6.1	12.2	2.13	12.6
1994/11/07	16	6.2	5.7	13.2	2.58	14
1994/11/21	22.8	9	9.3	21.3	2.38	19.4
1994/11/14	20.1	7.6	9.7	17.8	2.55	18.7
1994/12/12	6.3	2.2	7.8	7.6	1.86	5.1
1994/11/28	26.3	8.2	9.2	22.2	2.6	19.1
1994/12/26	6.9	2.5	11.6	9.7	2.04	11.6
1994/12/19	13.6	4.7	6.9	11	2.19	11.3
1995/01/02	7.7	2.1		9.2	1.58	6.1
1995/01/16	8.4	4.2	11.4	10.5	2.12	12.6
1995/01/30	7.7	3.2	4.9	7.2	1.38	7.6
1995/02/13	9.3	4.5		6.7	1.7	10
1995/02/06	8.8	3.4	8.7	4	1.75	8.3
1995/02/20	8.8	4.1	4.1	7.4	1.7	9.1
1995/01/09	7.1	2	8.2	6.9	1.83	6.7
1995/02/27	26.9	8.8	9.5	38.7	2.81	15.8
1995/01/23	7.6	3.2		7.8	2.1	6.9
1995/03/06	7.7	2.9	9.8	6.9	1.9	6.3
1995/03/20	6.5	3.3	7.4	6.7	1.52	8
1995/03/13	16.7	5.2	11.3	21.7	2.26	9.1
1995/03/27	8.2	3.6	9.5	6.5	2.11	8.4
1995/04/03	7.8	3.1	4.4	5.8	1.61	7.1
1995/04/10	5.4	2	6.3	5.4	1.84	5.3
1995/04/17	7.7	3.3	7.3	7.4	1.53	7.4
1995/04/24	7.4	3.2		4.1	1.37	5.9
1995/05/01	8.6	3.8		3	1.6	8.9
1995/05/15	11.8	3.9	7.3	7.1	2.35	10.3
1995/05/22	13.7	5.2	7.1	6.9	2.47	10.4
1995/06/12	12.7	5.6	5	8.5	2.18	13.4
1995/06/05	12.7	6	6.5	7.2	2.39	12.1
1995/06/19	9.7	4.6	11.5	5	2.47	10.2
1995/06/26	12.8	6	6.2	7.6	2.13	12.9
1995/07/07	15.1	6.8	5.7	9.7	2.42	13.4
1995/07/24	17.9	8	4.8	13.4	2.37	18
1995/08/07	19.2	8.4	6.4	13.2	2.49	18.8
1995/08/21	21.3	8.9	10.4	17.9	2.59	20.8
1995/09/04	25.6	9.7	12.7	21.9	2.75	24.2
1995/09/18	31.1	12.7	7.3	28.3	3.15	24.9
1995/10/02	24.9	9.5	7	22.8	3	20.5
1995/10/23	16.7	4.1	11.4	12.1	3.12	10
1995/10/30	17.7	6.3	7.1	12.6	3.04	10.6
1995/11/13	15.3	5.8	4.7	7.5	2.76	12.1
1995/11/27	8.5	3	9.2	5.5	2.54	6.4
1995/12/25	14.2	5.5	11	8.4	3.6	12.5
1995/12/11	9.6	4.3	8.4	7.9	2.52	7.9
1996/01/08	9.3	3.7	6.3	8.4	2.41	7

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1996/01/22	8.7	2.5	5.6	8	2.6	5.6
1996/02/05	7.1	3.1	5.9	7.5	1.81	6.7
1996/02/19	5.8	2.2		6.6	1.71	5.8
1996/03/04	8.4	2.3	15.6	11.1	2.69	5.8
1996/03/18	10.9	3.8	5.2	6.3	1.61	8.2
1996/04/01	9.4	3.8		8.1	1.74	8.3
1996/04/15	9	4	6.2	9.8	1.41	8.9
1996/04/29	9.4	4.2		7	1.71	9.9
1996/05/13	9.6	4.7	6.6	7.8	1.93	10.4
1996/06/10	15.4	6.1	6.4	12.2	2.6	13.5
1996/05/27	24.5	7.3	14.4	26.8	2.92	13
1996/06/24	15.3	6.7	13	14.9	2.46	14.8
1996/07/08	16.7	7.7	8.2	15.8	2.72	16.2
1996/07/22	19.9	8.9	13.9	20	2.47	20.6
1996/08/05	23.1	8.8	7.4	30.4	2.69	20.4
1996/08/19	29.1	9.2	6.5	20.6	2.62	20.9
1996/09/02	27.6	10.5	5	27.2	1.43	24.1
1996/09/16	21.9	9.1	11.2	18.7	1.48	20.5
1996/09/30	29	10.9	10.4	27.8	1.71	25.2
1996/10/28	20.7	8.5	9.1	19.6	1.85	21.5
1996/10/14	32.1	12.3	5.9	29.2	1.96	26.8
1996/12/23	12.7	5.2	7.4	10.2	1.13	12.2
1996/11/25	10	2.3	6	5.8	1.3	7.2
1996/12/09	11.7	4.6		9	1.9	11.3
1997/01/06	10.1	4.6	7.2	5.7	0.98	10.8
1997/02/03	8.6	3.2	4.9	6.1	1.07	7.4
1997/03/17	10.5	3.2	18.5	8.5	1.11	7.4
1997/03/31	5.3	1.9	6.3	6.4	0.57	4.2
1997/04/14	9	2.9	10.7	7.4	1.07	6.9
1997/04/28	9.1	3.6	7.5	7	1.04	8.1
1997/05/12	11.7	4.6	6.8	6.8	0.81	10
1997/05/26	12.3	5.2	7.2	10.6	0.99	12.2
1997/05/27	274.3	46.2	144.9	317.5	3.56	53.7
1997/06/09	13.6	5.8	6.3	12.6	1.17	13.5
1997/06/23	9.4	4	7.3	7.5	0.87	10.1
1997/07/07	11.4	4.9		8.7	0.86	10.7
1997/07/21	13.4	5.3	8.8	9	0.87	12.2
1997/08/04	15.5	6.5	8.4	12.3	0.94	14.1
1997/09/01	19.9	7.9	7.2	17.4	1.33	19.1
1997/09/29	23.4	8.8	14.6	21.8	1.43	19.1
1997/08/18	16.8	7.1	7.1	14.5	0.98	17.6
1997/10/13	25.8	10.1	12.3	26.1	1.53	24.7
1997/09/15	22.2	8.3	7.8	19.4	1.21	23.1
1997/10/27	10.8	5	10.5	8.6	1.39	11.8
1997/11/10	21.1	6.6	9.5	13.6	1.09	17.4
1997/12/08	10.4	3.9	6.4	8.8	1.03	9
1997/12/22	11.3	4.9	7.2	8.9	1	12
1997/02/17	10.4	4	5	7.5	1.2	10.3
1997/03/03	9.1	3.4	11	5.6	1.5	9.9
1997/03/17	10.2	3.1	6	4.7	4	7.3
1997/01/06	10.1	4.3	2	7.4	1.6	10
1997/01/20	9.7	3	6	6.1	2.1	9
1998/01/05	13.2	5	7.1	7.2	1.08	12.4

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1998/02/02	8.3	3.4	4.8	5.7	1.09	8.6
1998/03/16	8.7	3.1	8.5	6.4	0.87	7
1998/02/16	9.5	3.2	7.4	5.6	1.03	9.4
1998/03/02	4.8	1.5	9	4.9	0.81	3.7
1998/03/30	10.8	3.2	6.1	7.9	0.82	9.1
1998/04/13	10.5	3.4	5.2	7.2	0.87	10.6
1998/05/11	11.5	4.6		8.3	0.89	11.5
1998/04/27	10.7	4.5	15.2	7.5	1.18	9.4
1998/05/25	13	5.8	8.2	9.9	0.98	13.1
1998/06/22	16.9	7.2	11.8	16.3	1.2	17.8
1998/07/06	20.1	7.6	7.1	16.1	1.25	23.6
1998/06/08	13.2	8.5	6.7	12.8	1.04	12.7
1998/08/03	18.6	7.2	7.2	18.1	1.17	17.1
1998/08/31	13.7	6	6.1	14.4	1.14	14.2
1998/07/20	20.6	7.9	6.5	19.8	1.26	20.1
1998/09/14	10.1	3.9	5.9	9.8	0.91	10
1998/09/28	12.8	5.7	8.4	13	0.96	14.4
1998/10/12	14.4	6.5	6.1	15.8	1.18	15.2
1998/10/26	10.7	4.7	6.6	12.6	1.19	11.6
1998/11/09	14.3	6.1	9.5	13.9	1.05	16.3
1998/11/23	13.2	5.8	10.2	14.3	1.52	15.9
1998/12/21	8.7	4.1	8.1	8.3	0.94	9.5
1998/12/07	7.3	2.8		7	0.85	6.3
1999/09/22	40.379	15.891	9.215	53.386	1.665	31.757
1999/10/25	7.953	3.502	10.827	12.006	1.179	7.297
1999/11/03	14.495	5.359	8.901	15.129	1.467	13.8
1999/11/29	8.361	3.613	7.168	10.147	1.409	9.34
1999/11/17	8.862	3.072			1.981	7.826
1999/12/21	6.726	2.265	8.035		1.241	6.16
1999/10/20	9.924	4.167	9.664	11.11	1.413	10.157
1999/04/22	8.916	4.008			0.849	10.145
1999/10/06	21.5	8.808	9.12	23.398	1.609	21.613
1999/09/06	30.439	11.498	11.974	30.106	1.513	24.623
1999/01/04	10.2	4.6	5.8	8.5	0.97	10.9
1999/01/18	10	5.2	5.5	9.6	1.05	10.5
1999/02/01	9.9	4.3	6.3	10.5	1.19	9.6
1999/02/08	7.5	3.2	4	5.6	0.73	6.6
1999/02/16	6.9	3	4.5	7.4	0.96	7.4
1999/03/08	9.5	4.2	4.2	10.6	1.18	10.3
1999/02/22	7.1	3.1	5.5	8.2	1.15	7.8
1999/03/22	6.4	2.6	7.7	7.5	1.07	6.5
1999/04/07	10.2	4.2	4.9	10.1	0.88	11.5
1999/05/05	10.6	4.9		9.9	0.87	11
1999/05/03	10.2	4.6	4.6	8.9	0.79	10.5
1999/06/16	16.8	7.1	9.8	16.4	1.54	16.6
1999/06/30	16.7	7.7	5.6	16.8	1.27	16.4
1999/05/19	11.9	5.9	6.9	12.3	1.37	12.8
1999/06/01	14.1	6.5	8.7	13.2	0.91	13.5
1999/07/28	15.4	6.6	10.4	15.1	1.75	17.1
1999/07/16	22.2	9	4.8	21.1	1.61	22.4
1999/09/08	30.1	12.5	9.4	31.1	1.5	26.5
1999/08/02	13.8	6.5	10.9	14.4	1.25	14.8
1999/08/11	20.7	8.6	7.7	21.4	1.35	19.4

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1999/08/25	29	10.6	9	31.9	1.32	24.1
2000/01/17	7.423	3.026			1.001	7.414
2000/01/26	11.299	4.466	5.626	10.692	1.394	9.319
2000/02/09	9.164	3.563	5.708	11.187	1.211	8.223
2000/02/23	9.673	3.932			1.031	8.386
2000/03/08	7.593	2.967			0.706	7.186
2000/03/22	9.223	3.146	6.118	10.505	1.335	7.744
2000/04/19	14.096	4.784	10.68	16.706	1.266	13.38
2000/04/11	11.558	3.896	4.653	14.756	0.887	11.07
2000/05/03	16.2	5.33	8.233	17.49	1.069	14.511
2000/05/17	15.543	5.807	7.735	17.065	1.024	11.972
2000/05/31	17.419	5.847	7.243	18.253	0.878	13.772
2000/06/14	20.049	5.545	7.192	20.898	1.356	18.511
2000/06/28	18.617	5.694	6.87	20.876	1.124	19.345
2000/07/12	21.785	6.999	8.898	24.211	1.409	21.289
2000/08/23	30.051	12.021	10.062	33.497	1.696	25.893
2000/09/06	32.352	13.111	10.094	37.63	1.64	29.46
2000/09/20	9.431	3.425	13.856	12.902	1.541	10.578
2000/10/04	17.848	7.215	8.942	19.716	1.401	18.308
2000/10/18	14.759	5.478	13.184	13.955	1.165	12.905
2000/11/01	9.649	3.157	17.071		1.128	7.239
2000/11/15	8.851	3.19	6.384		1.563	7.854
2000/12/13	10.235	3.932	7.374	12.552	0.78	8.634
2000/12/27	12.165	4.297	9.46	13.304	0.907	11.298
2001/01/10	12.211	5.149	6.932	14.097	0.949	11.994
2001/01/24	10.198	4.73	5.009	12.202	0.997	10.709
2001/02/07	11.61	4.284	4.513	12.387	1.011	10.677
2001/02/21	8.649	3.138	8.985		1.038	9.329
2001/03/07	11.019	4.347	17.819	10.135	1.062	11.981
2001/03/21	7.092	2.626	11.568		0.965	6.986
2001/04/18	9.587	4.149	14.147	10.98	0.759	10.333
2001/04/04	10.46	3.468	10.757	11.269	1.722	8.538
2001/05/02	11.155	4.379	4.645	12.036	0.889	9.636
2001/05/17	12.758	5.142	6.417	15.095	0.79	16.027
2001/05/30	13.254	5.245	6.027	15.166	1.196	12.609
2001/04/24	11.55	3.815	9.956	10.711	0.991	9.809
2001/06/13	15.267	6.432	8.669	17.586	1.08	15.688
2001/06/27	15.509	6.853	4.743	19.224	1.024	16.291
2001/07/11	17.728	7.702	8.335	22.61	1.318	18.249
2001/07/25	15.165	6.193	5.06	17.338	1.551	13.571
2001/08/08	19.734	7.762	6.277	19.914	1.522	22.466
2001/08/22	20.867	8.916	7.935	22.976	1.243	23.151
2001/09/05	18.621	13.273	8.078	20.734	1.942	9.451
2001/09/19	9.839	4.124	9.123	12.449	1.483	9.68
2001/10/03	11.663	4.532	9.554	12.313	1.064	10.933
2001/10/17	11.316	5.402		14.541	1.248	12.505
2001/10/31	12.642	6.065		16.032	1.347	15.602
2001/11/28	6.444	2.987	12.742		0.874	7.116
2001/12/12	6.925	3.027	7.344	10.518	1.134	7.673
2001/12/27	7.663	3.684	6.113	11.562	1.243	8.871
2002/01/24	8.611	4.38		12.11	0.858	11.03
2002/01/09	8.95	3.458		10.05	1.174	8.541
2002/02/06	7.955	3.418			0.818	8.683

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L)	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2002/02/20	8.182	3.892	5.451	10.124	0.852	9.554
2002/02/07	6.523	3.062	12.89		1.734	7.615
2002/03/20	7.012	3.617	4.555	11.94	0.904	9.293
2002/04/01	11.865	4.728	8.202	15.216	1.44	12.776
2002/04/29	11.572	5.259	8.332	16.364	1.025	14.408
2002/05/27	13.43	7.603	7.694	16.774	1.246	15.285
2002/06/24	14.132	7.189	5.465	18.962	1.158	15.639
2002/07/22	8.529	4.07	6.774	11.661	1.239	10.022
2002/08/19	6.466	3.333	6.928	10.469	1.413	7.479
2002/09/16	7.113	3.033	5.798	10.865	0.991	7.415
2002/10/14	10.554	4.974	5.165	15.445	0.875	12.646
2002/11/11	10.147	5.878	7.711	14.591	1.1	13.857
2002/12/10	6.247	2.667	8.051		1.162	5.881
2003/01/06	7.494	3.149	10.692	10.496	1.324	9.206
2003/02/03	8.349	4.481	4.397	11.494	1.038	10.83
2003/03/03	8.011	4.543	6.109	11.801	1.037	11.202
2003/03/31	7.628	3.884		10.805	1.001	9.677
2003/04/28	8.54	3.703	4.465		0.943	11.36
2003/05/28	8.325	3.746	7.969		0.92	12.708
2003/06/25	10.959	4.608	7.562	13.552	0.875	11.959
2003/07/21	15.547	5.667	4.901	15.22	1.098	15.552
2003/08/18	15.124	7.11		14.806	1.238	13.232
2003/09/15	6.755	3.5	5.414	10.298	1.885	9.115
2003/10/13	13.907	5.892		15.302	1.559	14.78
2003/11/10	7.296	3.071		7.282	1.217	7.974
2003/12/08	8.908	3.888		11.991	1.501	9.461
2004/01/12	7.009	2.532		9.499	1.155	7.038
2004/01/26	8.121	3.387		7.868	1.13	11.199
2004/03/08	7.868	2.92		7.803	1.047	8.438
2004/04/05	8.368	2.939		6.409	0.955	7.393
2004/05/18	9.191	4.554	6.503	9.116	0.872	9.822

Ionic data from the Blinkwater weir used in the determination of the most likely salts

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1971/08/30	77	19	27	109		31
1971/11/08	48.6	12.8	18.4	86.5		24.5
1972/04/10	72	20.2	18.7	97.5		23.8
1972/09/15	119	36	36	163	2	41
1974/05/30	64	17.2	16.3	80.1	1.74	32.2
1977/10/06	127.8	40.6	35.5	151	1.54	63.5
1977/10/13	130	43.4	36.7	160.1	1.46	66.2
1977/10/20	127.7	40.3	36.6	157.7	1.11	54
1977/10/28	97.7	30.1	24.5	110.3	1.65	47.3
1977/11/03	29.5	7.8		34.6	3.7	13.5
1977/11/10	42.3	12	8.6	49.6	2.09	20.5
1977/11/17	93	27.8	24.1	99.1		47.7
1977/11/24	129.6	38.1	34.8	158	0.46	61.2
1977/12/01	50.5	14.2	13.2	53.7		25.8
1977/12/08	104.5	28.8	26.5	118.9		48.9
1977/12/15	114.1	37.5	32	137.3		58.5
1977/12/22	122.1	39.6	34.5	147.2	0.34	61.6
1977/12/29	126.3	41.6	36.2	158.7		65.1
1977/04/07	127.6	35.4	41	158.3	2.13	53.6
1977/04/14	130.2	36.6	41.1	160.5	2.15	58.9
1977/04/21	137.3	38.4	42.1	170.5	2.01	60.6
1977/04/28	86.2	24.4	24.3	103.3	1.88	43.2
1977/05/05	103.9	33.5	28.9	121	2	52
1977/05/12	63.1	17.8	17.2	76.9	2.6	28
1977/05/20	86.5	27.5	24.1	101.7	1.98	44.4
1977/05/26	97.2	32.4	28.2	118.8	1.6	51
1977/06/03	115.3	33.4	32.7	133.2	1.62	59.1
1977/06/09	119.9	36.1	34.4	140	1.71	62.2
1977/06/16	125.4	39.5	36.8	149.2	1.55	63.7
1977/06/23	127.8	39.1	38.8	154.2	1.69	63.6
1977/06/30	126	40.2	36.2	161.2	1.98	62.6
1977/07/07	128	40.2	37.6	160.7	1.56	51.3
1977/07/14	131.4	42.3	39.3	164.3	1.59	63.4
1977/07/21	129.8	41.4	36.4	168.7	1.61	58.4
1977/07/28	5.1			9.2		4.1
1977/08/04	6.6	1.2	4	12.5	0.43	22.6
1977/08/11	4.2			9.3		2.8
1977/08/18	27.7	5.2	20.1	44.5	1.04	15.2
1977/08/25	141	41	38	161	2.61	47
1977/09/01	141	41	37	162	2.61	46
1977/09/08	148	38	37	162	1.5	41
1977/09/15	131.3	43.2	37.1	161.6	1.7	67.7
1977/09/22	129.6	42.8	36.1	158.8	1.39	67.7
1977/09/29	67.3	20.8	17.8	73.5	1.41	36.2
1978/01/05	31.9	10		38.7	3.01	14.5
1978/01/12	83	26	17	97	1.45	43
1978/01/19	96	32	23	113	1.31	54
1978/01/26	110	37	28	130	1.3	60
1978/02/02	99	35	25	115	1.01	57
1978/02/09	94.3	31.7	23.9	109.1	1.2	49.2
1978/02/16	110.5	37.9	30.7	132.1	1.2	58.6

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1978/02/23	117.9	40.9	33.2	145.7	1.33	60.6
1978/03/02	119	42.4	33.2	145.6	1.2	61
1978/03/09	124.6	41	37.4	150.9	0.94	62.2
1978/03/16	126.3	40.9	38.3	155.8	0.94	61.1
1978/04/06	120.9	39.6	36.3	153.6	1.08	60.9
1978/04/12	119.2	39.2	35.4	150.7	1.21	63.2
1978/05/17	113.5	37.4	33.2	132.2	1.37	57.5
1978/06/14	123.5	41	39.5	148.5	3.61	67.2
1978/07/05	143	39.7	40.1	167.5	2.78	57.6
1978/08/02	127	39.5	32.8	151.4	1.39	64.2
1978/08/30	118.6	39.1	38.3	142.7	1.45	65
1978/09/27	130.9	43.2	38.6	157.1	1.48	69.7
1978/10/25	133.3	39.6	27.8	160.9	1.67	48.7
1978/11/22	129.8	30.1	21.3	156.3	2.19	34.1
1979/05/16	148.1	45.8	45.3	172.8	2.15	29.3
1979/06/13	116.6	42.7	35.5	145	1.07	46.7
1979/10/10	120.9	27.5	43	142.9	1.72	54.6
1979/10/17	116.5	34.4	42.8	143	1.43	50
1979/11/14	124.3	36	40.1	159	1.88	59.4
1979/12/05	130.7	37.2	40.6	153.9	1.75	60.6
1979/12/12	126.5	37.6	27.8	158	1.88	58.4
1979/12/19	134.1	37.3	28.6	161.7	2.65	56.4
1979/12/26	120.2	34.9	24.5	145.3	2.56	59.1
1980/01/16	63.7	18	20.4	71.9	4	33.1
1980/01/02	122.1	37.4	44.5	141.7	2.46	56.8
1980/01/23	114.1	32.7	26.6	133.6	2.01	54.7
1980/01/30	117.8	39.7	33.6	137.5	1.74	36
1980/02/06	126.4	39	30.3	153.4	1.59	48.4
1980/02/13	123.1	36.4	34.9	147.2	1.83	47.9
1980/02/20	129.7	38.8	30.3	152.6	1.8	48.3
1980/02/27	125.8	37.4	30.9	155.1	2.29	48.2
1980/03/05	126.6	35.9	29.2	151.1	2.14	49.6
1980/03/12	106.3	30.3	22	111.8	1.86	47.4
1980/03/19	108.1	33	24.5	126.5	1.64	41.4
1980/03/26	112.2	36.8	28.4	128.6	1.88	50.3
1980/04/02	120.5	36.9	24.6	138	1.77	49.3
1980/04/09	120.6	31.1	32.2	140.8	1.69	45.9
1980/04/16	117.9	35.7	25.7	138.4	1.75	53.6
1980/04/23	114.4	37.3	27.7	135.3	1.76	50.2
1980/04/30	202.3	50.6		251.6	7.94	45.8
1980/05/07	196.2	49.1		243.2	7.36	40.8
1980/05/14	124.9	37.2	31.9	143.1	1.83	55.2
1980/05/21	124	40.1	36.1	142.5	1.69	53.1
1980/05/28	122.4	38.9	26.6	141.9	1.7	64.4
1980/06/04	128.9	39.5	44.3	139.5	1.67	56.4
1980/06/11	112.5	36.4	35.9	140.1	1.28	58.6
1980/06/18	123.1	38.2	36.4	139.1	1.29	56.9
1980/06/25	122.8	40	35.5	139.6	1.47	58.5
1980/07/16	120.9	38.8	38	141.2	1.81	54.8
1980/07/23	129.7	41.8	41.9	145.6	1.66	61.5
1980/08/20	129.4	40.6	28.9	149.5	1.69	55.1
1980/08/27	124.8	38.6	30.5	148.9	1.66	53.3
1980/09/10	129.9	39.5	29.3	153.7	1.97	53.5

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1980/09/17	140.5	42	34.5	159.4	1.84	54
1980/10/01	132.5	38.6	31.9	153.4	1.91	56.5
1980/10/08	139.2	41.5	25.6	154.8	1.96	57.1
1981/02/04	112.2	32.7	43.3	113.8	2.87	42.4
1981/02/18	108.2	33.8	23.5	116	2.88	46.7
1981/02/25	32.8	11	14.2	31.9	2.59	29.9
1981/03/04	50.3	18.6	16.1	58.4	2.42	37.5
1981/04/29	121.7	38.3	48	147	2.3	60
1981/05/27	113.8	37.4	36.4	129.5	3.16	57
1981/06/24	101	31.6	37.2	100.2	1.7	52.6
1981/07/22	21.6	6.8	9.3	21.6	0.83	11.5
1981/08/19	151.5	44.5	57.4	174.3	2.25	46.5
1981/09/16	100.4	31.1	31.6	105.6	1.26	50
1981/11/11	123.2	38.2	21.8	139	1.23	46.1
1981/12/15	129.6	33.2	28.7	149.4	1.43	16
1982/07/07	101.2	42	36.4	142.1	2.23	44.8
1982/08/04	120.3	40.5	43.8	148.7	1.96	46.7
1982/09/08	112.8	38.6	38.3	143.8	1.2	46.7
1984/01/04	20.4	6.4		29.3	5.01	15.6
1985/11/06	42.9	13.2	47.5	60.8	4.3	25.2
1985/12/04	31.4	7.7	27.3	47.7	4.89	16.7
1986/01/08	52.2	13.5	27.1	67.8	2.89	25.5
1986/01/15	76.6	21.3	35.1	103.6	2.64	38.6
1986/02/05	55.7	14.9	25.7	68.3	2.42	26.8
1986/03/05	104.8	32.6	49.9	130	1.67	53.9
1986/04/02	107.3	35.7	54.4	138.2	1.67	61.3
1986/05/01	112.2	37.4	60.1	138.4	1.87	63.2
1986/05/28	118.1	36.9	62.1	147.8	1.39	64.5
1986/06/04	121	37.1	62	147.9	1.33	65.9
1986/06/30	124.4	39.3	61.3	138.9	1.38	64.1
1986/07/02	123	38.9	64.2	142.6	2.17	63.1
1986/07/23	126	38.2	66.4	134	1.31	63.5
1986/08/06	127	37.3	66.6	132.5	1.31	63.9
1986/08/13	126.5	34.6	63.7	138.3	1.48	61.4
1986/08/20	130.6	35.5	63.3	140.9	1.65	62.1
1986/09/03	125.9	38	62.6	134.6	1.61	53.2
1986/09/23	132.3	38.7	61	135.7	1.52	55.8
1986/09/30	124	38.2	58.7	134.2	1.81	54.2
1986/10/07	121.2	37.2	53.1	124.3	2.04	56.5
1986/10/16	95.9	28.3	33	96.5	2.11	49.3
1986/11/05	57.3	17.1	23.9	64.7	1.8	30.4
1986/11/19	94.9	31.8	42.7	106.9	1.7	49.9
1986/11/26	90.3	25.9	34	100	2.63	43.2
1986/12/03	99.5	30.9	37.8	100.1	1.35	49.8
1986/12/10	107.1	32.8	47.1	114.5	1.22	52
1986/12/31	107.2	32.9	39.2	117	1.02	53.1
1987/01/14	106	33.5	30.3	116.9	1.23	53
1987/02/03	113.7	35.1	36.8	123.4	1.47	55.6
1987/01/28	114.6	35.5	40.3	130	1.58	55.6
1987/03/04	115.5	34.6	39.7	140.5	1.26	56.5
1987/03/11	115.8	36.1	38.5	125.3	1.36	53.8
1987/03/18	115.6	35.7	38	135.9	1.89	56.1
1987/03/25	110.8	36.2	39.9	115.7	1.28	56.2

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1987/04/01	115.7	37.7	41.5	119.9	1.39	59
1987/04/08	118	38.5	40.2	123.8	1.52	54.9
1987/04/22	117.6	38.6	42.3	119.1	2	57.1
1987/04/29	119.4	39.5	41.8	121.4	1.26	56.1
1987/04/15	113.4	36	36.4	131.8	1.6	53.5
1987/05/06	120.9	38.3	41	136.9	1.38	50.4
1987/05/13	114.4	37.6	42.5	131.8	1.77	53.5
1987/05/20	124.1	39	47.1	139.5	1.9	60.5
1987/05/27	120.5	37.1	46.8	126.5	1.5	60
1987/06/03	122.3	37.7	44.8	125	1.5	59.8
1987/06/10	124.3	38.4	46.7	126.2	1.68	61.7
1987/06/18	123.3	38.9	44.9	126.2	1.4	61.5
1987/06/24	124.3	38.7	44.8	126.2	1.63	62.3
1987/07/02	126.7	38.7	47.2	133.6	1.94	64.4
1987/07/08	124.8	39.2	46.5	133.1	1.41	65.8
1987/07/15	128.6	39.6	53.9	129	1.38	61.5
1987/07/22	123	37.1	48.5	135.8	1.66	62.9
1987/07/29	123.9	37.7	49	137.9	1.55	63.6
1987/08/05	121.7	37.1	47.5	135.2	1.28	62.9
1987/08/12	125.2	37.8	43.9	126.6	1.45	60.5
1987/08/19	128.5	39.5	43.8	124.1	1.15	62.1
1987/08/26	128.4	37	45.1	134.7	1.68	61.3
1987/09/02	126.9	39.7	43.3	133.3	1.47	60.6
1987/09/09	129.3	36.7	38.4	130.7	1.27	56.4
1987/10/07	124.2	36.4	39	122.8	1.45	47
1987/10/28	130.8	36.4	41.6	136.2	1.37	42.4
1987/11/18	135.9	38	39.9	145.1	1.53	27.7
1987/11/04	140	37.1	40.7	152.1	1.07	20.4
1987/12/02	146.8	36.3	32.9	166.1	1.49	16.6
1987/11/11	133.8	38.9	35.1	148.8	1.26	26.7
1988/03/02	51.2	18.3	31.2	54	2.92	39.8
1988/03/09	34.8	10.6	14.3	39.7	2.44	21
1988/03/16	108.4	36.8	49.9	122.1	1.79	60.6
1988/02/24	31.9	10.4	24.1	35.7	2.89	24.5
1988/03/23	114.4	38.3	52.4	122.3	1.48	56.1
1988/03/30	111.2	37.1	45.7	113	1.42	54.4
1988/04/06	105	33.6	40.2	103.3	1.31	51.9
1988/04/13	112.7	34.6	41.4	109.8	2.21	55.8
1988/04/20	106.1	33.8	38	98.4	1.26	54.9
1988/04/27	108.7	34.6	41	99	1.26	53.6
1988/05/11	103.5	32.1	39	90.3	1.3	52.3
1988/05/25	105.8	33.6	41.1	96.8	1.19	52.7
1988/06/01	102.6	32.6	39.3	92.7	1.24	52.3
1988/06/08	108.9	34.7	40.9	104	1.13	56.7
1988/05/18	108.1	34	44.8	102.5	1.17	55.1
1988/06/15	110.4	35.7	44.8	102.4	1.25	54.2
1988/06/22	120	36.3	45.9	111.8	1.11	54.6
1988/06/29	115.1	36.1	52.1	108.4	1.14	57.5
1988/05/04	104.9	33.8	44	99.8	1.03	54
1988/07/06	116	36.9	45.7	110.2	1.2	56.5
1988/07/13	117.9	37.5	45.7	113.3	1.32	58.3
1988/07/20	129.7	38.4	57.7	136.6	5.96	54.9
1988/07/27	122.1	38.9	52.4	119	1.19	57

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1992/02/04	100.5	33.2	18.5	91.2	1.29	24.2
1992/04/07	77.2	24.3	23.6	68.8	3.65	33.5
1992/05/05	83.3	28.3	22.6	74.4	2.12	28.9
1992/09/01	111.4	36.9	65.8	114.4	2.72	42.1
1993/12/28	19.4	10.9	49	15.3	5.27	23.1
1994/01/04	44.3	18.7	61.9	37.2	2.95	38.4
1994/02/01	66.5	27.2	59.2	53.2	1.57	50.9
1994/03/01	75.4	25.7	39.6	63.3	2.05	44
1994/04/04	80.1	28.6	48.5	64.2	1.89	52.9
1994/05/03	80.1	31	54.1	74.6	2.14	53.1
1994/05/31	84.4	30.7	57.4	72	2.02	56.1
1994/08/02	93.2	32.3	75	75.3	2.31	58.7
1994/06/05	88.8	32.5	71.5	77.9	2.07	58.1
1994/09/05	101.6	35.5	79.7	78.8	2.22	53.3
1994/10/03	108.4	34.3	73.1	78.9	2.02	52.1
1994/10/17	97.6	32.3	68.3	74.9	2.29	49.5
1995/02/06	98.6	30	52.5	85.2	2.64	49.6
1995/01/16	70.2	23.3	41.8	61.5	3.75	32.7
1995/01/23	82.7	23.6	41.6	78.8	3.45	42.9
1995/03/06	62.9	17.7	35.4	52.5	3.59	35.6
1995/03/20	86.2	24.7	38.7	76.9	3	44.8
1995/04/06	74.7	22.6	39.6	63.5	2.99	43
1995/04/19	67.2	20.4	28.7	49.8	2.65	37.5
1995/05/04	93.7	29.8	57.6	69.8	2.54	52.1
1995/05/18	96.9	32	61.3	71.3	3.07	60.6
1995/06/15	102.9	29.7	54.1	75.9	2.94	59.1
1995/07/13	104.1	31.5	51.7	82.8	2.75	52.9
1995/06/29	105.9	34.5	54.1	77.7	2.73	57
1995/07/27	108.5	34.4	61.5	79.5	3.12	56.5
1995/06/01	92.7	31.1	55.3	73.7	2.88	62.4
1995/08/24	108.8	34	48.9	80.5	2.68	56
1995/09/07	107.5	33.2	48.3	71.5	2.59	52.9
1995/09/21	114	34.1	48.5	81.7	2.99	57.1
1995/10/05	112.7	32.6	41.1	85.9	2.79	56.3
1995/10/25	100.6	31.3	37.2	85	2.45	39.1
1995/10/31	18.6	11.3	17.7	9.4	1.19	19.9
1995/12/27	35.1	9.9	23	27.6	3.96	20.3
1996/01/10	86	24	32.7	93.5	4.69	44.5
1996/01/24	22.6	5.1	21.8	22.9	3.97	11
1996/02/07	70	18.8	21.3	59	3.28	33.7
1996/02/21	72.9	20.7	21.9	55.4	2.74	37.6
1996/03/06	38.1	8.6	17	39.2	3.5	18.1
1996/03/20	69.3	19.9	19.1	61	2.3	33.4
1996/04/03	32.1	8.1	16.4	25.2	2.77	15.9
1996/05/01	78	25.8	24.2	63.2	2.88	44.4
1996/04/17	70.8	22.1	20.6	55.5	2.53	36.6
1996/05/15	84.4	27.8	27.8	63.9	2.1	48.1
1996/05/29	84.7	26.3	27.2	65.4	2.63	43.2
1996/06/12	89.5	27.2	28	64.7	2.8	47.9
1996/06/26	86.7	30.6	34.1	69.9	2.6	47.9
1996/07/10	89.9	29.4	28.4	68.7	2.46	51
1996/07/24	87.5	26.9	32.4	64.6	2.68	51.6
1996/08/07	91	30	29.7	64.9	2.82	46.1

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1996/08/21	90.6	29.5	30.1	70.4	0.94	53.9
1996/09/04	101.9	31.1	30.5	71.8	1.31	48.6
1996/09/18	102.7	32.2	29.6	74.4	1.46	50.7
1996/10/02	95.7	30	24.9	74.9	1.42	44.3
1996/10/30	100.4	30.1	28.8	70.6	1.28	42.8
1996/10/16	97.6	30.4	28.2	78	1.14	47.5
1996/12/25	86	28.3	26.5	73.1	1.49	47.8
1996/11/13	94.8	22.5	18	61.3	2.8	54.5
1996/11/27	50.2	12.3	9	47.2	4.5	32.5
1996/12/11	60.9	16.4	22	53.3	3.7	31.5
1997/02/05	52.6	18.2	18.5	42.4	2.67	35
1997/03/19	83.9	27.2	23.5	62.9	1.32	45.5
1997/04/02	49.2	14.9	18.8	37.9	1.83	27.5
1997/04/16	56.9	16.6	25.9	42.8	1.92	30.8
1997/04/30	52.7	14.8	25.5	45.2	2.16	28.8
1997/05/14	72.7	22.7	14.8	64.5	1.62	41.9
1997/05/28	80.2	25.4	18	72.6	1.76	44.2
1997/06/11	81	24.6	23.5	69.3	1.71	48.5
1997/06/26	66.6	16.8	23	54	1.95	33.9
1997/07/09	68.7	19	21.6	60.3	1.62	34.1
1997/07/23	79.8	23.6	24.5	64.9	1.59	39.7
1997/08/06	86.9	24.8	23.3	72.7	1.58	44.8
1997/09/03	102.9	31.3	30.4	91	1.57	48.9
1997/09/17	101.1	31.3	27.4	86.5	1.54	50.5
1997/10/01	101.9	30.2	25.8	86.5	1.37	50.3
1997/08/20	91.4	26.5	30.1	85.6	1.71	45
1997/10/29	90.5	28.9	26.4	71.8	1.35	44.7
1997/10/15	97.4	29.8	29.8	81.1	1.37	51.3
1997/11/12	96.8	30.1	26.3	82.6	1.46	50.2
1997/11/26	95.3	29.7	30.4	76.7	0.99	49.6
1997/12/10	95.7	28.6	26.8	74.7	1.15	46.3
1997/12/24	99.6	30.3	26	83.7	1.34	45.8
1997/02/19	81.4	22.8	17	61.3	2.2	45.2
1997/03/05	82.3	24.2	29	57.6	1.8	44.7
1997/03/19	89.1	25.6	26	61.6	1.4	43.1
1997/01/08	89.6	25.2	19	76.2	2.4	49.3
1997/01/22	48.4	15.5	13	37.7	3	27.1
1998/01/07	102.4	29	21.3	87.7	1.66	39.3
1998/01/21	97.9	30	28.6	90.5	1.34	38.7
1998/02/04	99.1	29.5	25.7	79.9	1.58	47.3
1998/02/18	98.2	29.2	24.7	82.4	1.87	47.8
1998/03/04	32.3	6.5	21.1	20.3	1.65	15.7
1998/03/18	81	24.6	25.1	59.6	1.52	43.4
1998/04/15	85.3	30.1	23.1	71.1	1.11	49.4
1998/05/13	88.8	30.8	31.1	75.6	1.18	48.5
1998/04/29	78.7	30.1	22.5	68.3	1.15	49.2
1998/05/27	92.8	28.8	26.4	75.4	1.36	54.3
1998/07/08	96.9	30.6	26.3	73.7	1.95	55.1
1998/06/24	95.6	33.4	28.1	78.2	1.32	53.4
1998/06/10	91.8	30	41	69.3	1.25	51.6
1998/07/22	93.9	31	24.8	72.5	1.6	51.7
1998/08/19	97	31	26.9	74.6	1.22	55.7
1998/09/02	91.2	29.8	14.2	69.8	1.04	50.9

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1998/08/06	83.7	31.2	56	62.4	2.32	49.1
1998/09/16	94.1	30.7	19.9	74.8	1.11	51.8
1998/09/30	100.6	31.3	29.2	77	0.98	52.4
1998/10/14	87.4	27.8	19.2	72.5	1.37	48.4
1998/11/11	105.1	30.5	23.3	83	0.75	26.8
1998/11/25	97.1	27.7	19.9	81.7	1.5	48
1998/12/23	68.6	20.5	18	49.9	1.52	32.5
1998/12/09	56	16.3	18.7	40.1	1.75	31.5
1999/09/22	101.712	32.233	19.364	83.79	2.091	29.886
1999/10/06	99.174	31.918	17.179	75.173	1.229	39.441
1999/04/22	72.48	30.08	22.922	45.734	1.293	50.576
1999/09/06	99.652	33.289	25.918	73.156	1.118	47.445
1999/01/06	90.4	30.3	17.7	68.9	1.27	47
1999/01/20	85.3	29	19.7	66	1.28	47.4
1999/01/18	86.4	27.9	24.6	66.7	1.34	47.3
1999/02/03	97.4	32.6	21.4	84.2	1.92	52.8
1999/03/10	88.2	28.8	16.2	74.8	2.42	51.9
1999/03/24	70.6	25.1	16.6	54.5	1.52	42.6
1999/02/24	42.8	13.4	15.2	33.6	2.97	26.8
1999/04/07	77.5	30.1	20.9	57.5	1.13	51.4
1999/05/05	71.1	29.3	18.1	53.7	1.13	44
1999/06/30	86.1	31.3	20.3	64.9	1.5	49.5
1999/05/19	75.4	29	19.1	56.8	1.16	48.4
1999/06/16	83.3	30.6	21.4	60	1.33	48.8
1999/06/01	81.4	31.6	18.8	64.9	1.15	50.5
1999/07/16	88.3	31	19.4	70.4	1.62	53.9
1999/08/11	88.4	30.8	22.6	67.9	1.08	52.7
1999/07/28	88.3	30	26.8	67.8	2.25	49.7
1999/09/08	93.1	32.9	21.9	74.1	0.96	43.8
1999/08/02	81.6	29.6	19.9	59.9	1.69	42.2
1999/08/25	90.5	30.6	24.4	70	1.14	48.4
2000/01/17	24.409	6.52	23.733	21.072	2.668	16.264
2000/02/09	66.542	23.479	24.98	57.118	2.022	44.225
2000/01/26	57.729	16.729	21.382	37.117	2.345	36.754
2000/02/23	51.819	19.288	15.052	32.665	1.468	35.33
2000/03/08	30.37	11.474	10.66	22.818	1.764	24.871
2000/03/22	32.421	9.159	18.247	27.333	1.903	20.503
2000/04/05	27.831	5.996	12.757	16.924	3.474	13.821
2000/04/19	57.776	15.712	24.62	66.304	2.966	32.551
2000/05/17	72.196	25.389	27.641	74.109	3.57	52.857
2000/05/03	59.496	17.505	24.661	63.904	2.102	36.367
2000/05/31	91.077	28.157	34.602	86.543	2.05	50.369
2000/06/14	102.535	33.535	42.143	97.465	1.792	57.025
2000/06/28	93.624	34.265	42.759	106.765	1.564	59.007
2000/07/12	97.664	36.57	45.474	102.997	1.606	61.457
2000/07/26	108.001	38.345	45.476	102.773	1.648	59.931
2000/08/09	108.14	34.83	39.02	99.331	1.593	42.826
2000/08/23	109.883	33.302	36.596	101.857	1.738	60.569
2000/09/06	100.621	33.29	45.142	99.585	1.563	56.168
2000/09/20	43.267	11.929	39.636	48.608	2.937	24.57
2000/10/04	102.997	31.943	39.313	94.41	1.475	55.33
2000/10/18	97.365	33.683	30.616	96.435	1.486	55.431
2000/11/01	101.627	32.151	43.218	87.658	1.316	56.572

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2000/11/15	34.031	7.208	34.329	30.79	3.052	15.301
2000/11/29	11.72	3.93	12.554	15.849	1.618	10.643
2000/12/27	88.769	26.92	28.564	79.922	2.03	48.089
2000/12/13	56.074	15.469	14.572	53.97	1.672	29.473
2001/01/10	94.695	31.178	28.149	88.833	1.861	45.214
2001/01/24	88.446	29.806	25.674	83.526	1.611	53.811
2001/02/07	87.658	30.763	27.523	84.398	1.412	47.155
2001/02/21	75.418	22.74	18.693	67.14	1.748	40.597
2001/03/07	91.693	31.597	27.491	91.23	1.474	51.051
2001/03/21	55.33	16.09	16.845	50.039	1.952	29.409
2001/04/18	47.35	12.09	17.215	53.121	2.728	24.4
2001/04/04	28.113	8.144	17.662	29.363	2.549	16.787
2001/05/02	65.018	19.449	18.94	58.139	1.564	37.275
2001/05/17	84.793	26.748	22.657	72.492	1.488	51.525
2001/05/30	86.441	28.849	27.367	77.214	1.514	49.548
2001/04/23	51.758	11.912	15.53	45.005	3.393	24.667
2001/06/13	84.766	30.013	31.907	80.999	1.327	52.084
2001/06/27	90.68	29.743	27.7	79.301	1.353	55.039
2001/07/11	88.908	31.609	31.576	85.998	1.274	53.737
2001/07/25	90.544	31.344	28.192	76.649	1.342	47.271
2001/08/08	94.336	31.244	25.971	79.842	1.47	56.619
2001/08/22	92.939	31.427	29.557	83.896	1.197	56.28
2001/09/05	97.966	30.127	24.617	79.269	1.319	52.154
2001/09/19	91.64	30.468	30.525	76.233	1.455	51.086
2001/10/03	100.106	33.088	25.793	84.401	1.292	41.979
2001/10/17	87.104	30.726	22.724	79.453	1.366	52.178
2001/10/31	89.92	30.171	25.757	82.217	1.368	57.557
2001/11/14	101.853	29.402	31.115	83.18	1.237	47.893
2001/11/28	39.179	12.958	18.81	41.907	1.916	23.303
2001/12/12	32.623	8.679	18.39	37.561	2.929	18.974
2001/12/27	61.61	19.039	17.357	61.908	1.866	37.667
2002/01/24	84.819	28.375	22.45	75.269	1.636	50.728
2002/01/09	41.493	12.474	13.241	39.721	1.878	26.161
2002/02/06	70.344	22.999	20.58	61.687	1.688	41.625
2002/02/20	73.765	26.919	15.069	65.618	1.404	47.768
2002/04/01	80.793	29.772	23.275	66.327	1.502	50.357
2002/04/29	89.602	30.783	24.926	66.791	1.375	53.051
2002/05/27	90.396	32.838	28.393	77.704	1.59	55.933
2002/06/24	90.442	31.8	18.793	75.114	1.47	56.68
2002/07/22	79.728	27.683	23.192	70.494	1.471	49.057
2002/08/19	72.125	27.684	17.894	67.002	2.503	47.98
2002/09/16	47.341	12.207	19.872	56.632	2.659	21.489
2002/10/14	89.109	27.531	28.659	82.763	1.664	50.297
2002/11/11	81.465	29.462	27.847	83.722	1.312	50.6
2002/12/10	89.457	35.564	24.162	94.196	1.641	55.546
2003/01/06	82.142	27.677	30.002	81.263	1.753	50.122
2003/02/03	97.31	33.974	30.579	120.211	2.248	60.593
2003/03/03	84.468	29.087	28.673	85.102	2.67	54.273
2003/03/31	53.627	19.225	16.971	53.543	1.843	34.88
2003/04/28	92.644	28.907	21.602	76.722	1.564	51.128
2003/05/26	94.379	29.501	34.243	80.729	1.47	51.966
2003/06/25	98.195	31.507	34.642	79.465	1.296	54.469
2003/07/21	97.494	35.559	24.411	90.616	1.417	53.43

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2003/08/18	108.8	33.532	31.245	81.858	1.502	51.549
2003/09/17	95.847	31.705	28.576	88.599	1.584	59.511
2003/10/13	111.079	36.367	30.015	106.871	1.877	54.07
2003/11/10	101.771	30.636	27.597	97.221	2.081	46.462
2004/01/26	36.209	12.323	15.903	40.596	4.968	31.757
2004/02/23	96.519	37.605	22.888	131.548	4.943	72.973

Ionic data from the Fort Beaufort weir used in the determination of the most likely salts

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1992/12/29	36.8	10.6	17.8	43.3	2.92	22.3
1993/01/26	22.6	7.3	21.1	19.6	2.89	16
1993/04/06	46.3	14.6	14.3	49.7	2.49	28
1993/04/06	43.4	12	13.7	52	2.55	25.8
1993/06/29	76	17.8	26.1	88.5	4.02	41.2
1993/09/07	83.8	23.5	31	106.5	2.68	37.1
1993/11/02	74.7	22.9	22.4	78.2	2.87	35.4
1993/11/02	74.9	22.2	21.9	79.6	2.8	32.9
1993/11/16	11.8	3.8	12.6	12.4	1.96	8.5
1993/11/30	18.3	5.8	16.9	20.8	2.24	11.8
1993/12/14	18.4	5.6	12.1	22.3	1.82	10.6
1993/12/28	12.9	4.2	12.3	11.6	1.46	8.6
1994/01/25	23.7	7.3	5	26.2	2.11	15.3
1994/01/11	13.8	5.3	19.3	14.2	1.91	10.2
1994/02/08	13.1	3.7	16	12.4	1.86	7.7
1994/02/22	15.7	5.2	13.1	14.3	2.4	9.5
1994/03/08	31	9.8	14.5	29.9	2.44	18
1994/03/22	33.9	10.5	14.7	37.8	2.61	21
1994/04/05	44.7	13	17.2	49	2.5	26
1994/05/31	112.5	31	38.3	126.7	2.85	49.7
1994/07/26	91.3	24.3	34.9	113.9	3.44	40.7
1994/08/09	89.4	23.8	27.5	107.3	3.21	38.4
1994/10/17	19.5	7.6	18	16.9	2.97	15
1994/11/28	55.5	14.9	25.4	64.7	3.1	27.1
1994/12/26	74.7	18.5	25.3	94.1	3.36	31.9
1995/02/06	34.1	8.8	11.1	31.5	2.52	19.8
1995/01/09	21.4	5.3	15.1	22.7	4	14.3
1995/01/23	17.6	5.4	7.9	15	2.7	9.9
1995/03/06	60.7	16.5	21.2	62.7	2.95	30.8
1995/04/05	42.5	12.8	15	41.9	2.82	23.9
1995/04/03	47.6	14.1	22.1	45.6	2.92	24.1
1995/04/19	27.8	8.4	10.6	25.8	2.57	15.6
1995/05/03	46.1	12.4	15.6	42.8	2.46	22.1
1995/05/17	52.9	14.5	19.1	55.4	2.76	28
1995/09/20	88.3	22.8	36.2	102.9	3.62	33.9
1995/11/29	43.4	11.5	13.6	41.2	3.59	21.1
1995/12/13	26	5.6	15.3	22.5	3.02	11.8
1996/01/10	26.9	6.3	17.8	30.5	4.34	13.8
1996/02/07	24.7	7.3	12.4	22.7	2.55	19.2
1996/02/21	18.3	5.4	11.8	16.2	2.8	11.5
1996/03/06	17	4.9	18.9	13.7	3.1	9.7
1996/03/20	34.2	9.4	13.3	32.3	2.72	18.5
1996/04/03	23.3	8.2	10	18.6	2.66	16.1
1996/05/01	37.7	11.7	9.7	37.5	2.7	21.1
1996/04/17	35.1	10.4	10.3	33.3	2.7	19.2
1996/05/29	66.7	16.5	21.2	73.9	3.11	27.5
1996/06/26	110.7	26.6	39.6	138	3.25	42.8
1996/08/21	108	31.1	38.4	131.7	2.84	49
1996/11/13	67.1	16.7	22.5	77.3	2.79	29.2
1996/12/25	48.3	12.3	21.7	49.4	2.46	25.3
1996/11/13	79.3	17.3	18	77.2	3.3	38

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
1996/11/27	23.9	6.8	25	7	3	14.3
1996/12/11	32.6	8.9	8	32.8	3.9	20.5
1997/02/05	34	9	16.3	28.5	1.76	18.3
1997/03/19	27	8.4	15.4	23.4	1.67	17.3
1997/04/02	37.2	10.3	23.4	36.7	1.7	18.6
1997/04/16	21.9	5.9	16.6	17.6	1.8	14.4
1997/04/30	20.5	6.6	20.4	17.6	1.79	13.4
1997/05/14	31	9.1	11.9	27.1	1.42	16.2
1997/05/28	49.8	10.4	19.6	48.2	1.66	24.4
1997/06/11	37.4	10.3	19.4	38.3	1.49	20.1
1997/07/09	29.3	9	23	28.6	2.06	18.7
1997/06/25	27.7	8.2	21	25.2	1.91	15.5
1997/07/23	42.9	11.6	20.4	43.1	1.58	21.6
1997/08/06	54.5	16	22.4	58.2	1.74	26.5
1997/08/20	63	16.2	18.8	62.9	1.77	31.6
1997/09/03	79.6	22.4	27.9	96.3	1.96	38
1997/10/29	24.8	7.7	10.8	22	1.7	14.5
1997/10/15	134.1	30.2	50.1	165.6	2.33	53.4
1997/11/26	101.8	26.4	36.8	124.8	2.39	41.1
1997/02/19	23.5	5.2		20.7	4.7	12
1997/03/05	19	5.5	18	15.3	2.8	12.2
1997/03/19	28.7	8.6	15	24.8	2.3	18.7
1997/01/08	53.7	17.5	13	50.4	3.1	34.2
1997/01/22	34.8	12	20	27.9	3.3	23.2
1998/02/04	27	8	13.8	24.1	1.92	18.1
1998/02/18	38.8	8.9	22.6	45.6	1.54	19.5
1998/03/04	11.6	2.2	14.6	8.2	1	6.2
1998/03/18	21.9	5.5	14.3	18.8	1.37	11.8
1998/04/01	37.7	10.1	16.8	31.7	1.49	19.2
1998/04/15	35.6	10.4	14.9	36.1	1.72	21.1
1998/05/13	51.8	9	14.4	45.8	1.55	27.5
1998/04/29	56.1	16.3	20.4	56.1	1.66	26.9
1998/07/22	84	21.2	32	104.7	2.1	34.5
1998/09/19	70.6	23.7	25.2	71.4	1.97	39.3
1998/09/16	46.6	14.5	12.9	48.6	1.78	25.4
1998/12/09	17.2	5.5	14	18.1	1.63	11.4
1998/12/23	20.4	5.8	13.6	22.8	1.73	11.7
1999/08/25	69.452	16.425	24.836	95.113	1.986	25.936
1999/09/22	80.923	20.546	25.72	97.327	2.206	34.833
1999/12/21	52.317	11.384	23.01	74.948	2.967	23.129
1999/04/22	56.227	15.827	21.111	57.637	2.092	29.835
1999/03/24	75.114	18.203	27.874	91.597	2.209	31.938
1999/01/20	61.8	15.5	22.8	76.8	2.05	27.5
1999/01/21	66.9	16.6	24.3	81.1	2.06	28.8
1999/02/24	45.6	12.6	19.1	53.9	2.08	23.4
1999/07/28	42.8	14.6	15	41.3	2.04	25.7
2000/01/12	16.517	4.605	11.03	16.798	2.61	11.681
2000/01/26	22.33	6.213	12.411	28.544	1.929	14.034
2000/02/23	20.712	6.629	21.823	23.293	11.056	14.724
2000/02/14	10.208	2.918	14.223		2.16	6.816
2000/03/08	18.797	4.723	11.882	18.564	1.45	9.741
2000/03/22	13.843	3.862	8.06	14.168	1.521	8.844
2000/04/10	22.875	5.364	11.892	24.69	1.872	15.05

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2000/04/19	26.016	7.205	17.775	30.515	2.127	18.272
2000/05/04	31.808	9.001	19.075	37.495	2.126	20.467
2000/05/17	42.449	12.843	16.564	50.414	1.88	26.443
2000/05/31	54.726	15.389	20.078	67.524	1.813	28.293
2000/06/14	69.944	18.215	26.212	85.759	1.967	36.743
2000/06/28	81.546	22.779	28.203	97.361	1.875	41.043
2000/07/12	82.939	23.851	29.627	111.186	2.125	39.378
2000/08/23	15.151	5.13	14.676	18.191	2.093	13.991
2000/09/20	53.02	17.611	23.989	57.25	2.729	32.668
2000/10/04	48.445	12.713	24.517	61.465	2.285	26.034
2000/10/18	86.13	22.418	35.39	117.579	2.045	39.916
2000/11/01	83.928	23.866	37.336	101.873	2.182	42.143
2000/11/15	13.635	4.157	39.085	16.007	2.431	15.324
2000/11/29	15.962	4.874	26.436	16.818	3.71	11.147
2000/12/27	48.014	12.129	18.346	61.318	1.79	24.279
2000/12/13	24.198	6.461	18.655	24.544	1.719	15.26
2001/01/10	46.016	13.61	15.374	52.977	1.826	25.411
2001/01/24	36.048	10.163	15.158	44.154	1.886	18.676
2001/02/07	37.32	11.591	17.963	47.896	1.915	23.189
2001/02/21	27.187	7.648	16.847	25.861	1.976	18.02
2001/03/07	35.552	10.954	17.229	47.338	1.471	19.916
2001/03/21	13.378	4.271	12.607	16.167	1.662	9.169
2001/04/18	20.694	5.67	13.841	22.314	1.797	12.272
2001/04/04	16.946	4.819	14.738	17.057	2.617	11.835
2001/05/02	40.892	11.693	15.28	45.948	2.06	24.071
2001/05/17	55.712	15.683	24.675	71.014	2.226	28.999
2001/05/30	74.493	21.73	25.827	95.188	1.857	37.164
2001/04/23	24.902	7.222	14.494	25.257	1.843	15.213
2001/06/13	83.664	24.984	31.527	118.142	1.884	40.444
2001/06/27	110.939	28.06	34.39	134.978	2.152	44.745
2001/07/11	108.172	31.914	35.887	147.674	1.995	49.26
2001/07/25	128.234	35.721	42.31	168.529	2.193	46.889
2001/08/08	80.087	25.501	23.519	102.421	2.095	43.4
2001/08/22	53.808	19.1	20.072	70.587	1.941	31.027
2001/09/05	77.378	20.891	30.742	85.207	1.895	36.13
2001/09/19	79.753	26.189	28.312	92.829	1.968	33.082
2001/10/03	16.62	6.619	10.998	26.694	2.053	13.898
2001/10/17	40.521	13.893	14.378	57.857	1.889	23.678
2001/10/31	62.251	18.432	25.305	92.192	1.668	34.638
2001/11/14	65.748	18.669	29.729	75.707	1.978	33.331
2001/11/28	18.23	6.799	10.502	22.537	1.776	14.209
2001/12/12	12.401	4.307	14.37	15.097	2.119	9.259
2001/12/27	27.79	9.212	14.988	35.064	1.51	20.998
2002/01/23	37.23	11.762	12.738	50.01	1.714	23.963
2002/01/09	14.795	4.573	26.362	18.171	2.184	12.827
2002/02/06	31.981	10.732	14.541	40.95	1.683	19.765
2002/02/20	46.427	13.108	15.07	55.189	1.603	23.611
2002/03/06	63.832	18.064	22.941	83.035	2.068	29.365
2002/04/01	58.925	15.547	26.254	83.481	1.807	28.394
2002/04/29	76.622	17.241	32.421	90.119	1.869	36.718
2002/06/10	108.443	29.508	43.723	162.777	2.136	44.09
2002/06/24	91.643	27.832	18.793	123.889	2.053	46.482
2002/07/22	16.726	5.187	13.942	18.679	2.01	12.145

Date	Na (mg/L)	Mg (mg/L)	SO4 (mg/L	Cl (mg/L)	K (mg/L)	Ca (mg/L)
2002/08/19	31.022	13.879	10.997	42.543	1.893	25.424
2002/09/16	20.385	5.902	15.09	26.323	1.989	13.663
2002/10/14	60.744	16.369	21.668	81.15	2.053	31.906
2002/11/11	103.513	25.38	42.277	141.653	2.602	47.65
2002/12/09	57.417	17.506	23.004	80.357	2.325	31.611
2003/01/06	48.683	11.106	21.956	50.596	2.413	23.304
2003/02/03	39.904	11.189	16.664	64.136	2.021	23.259
2003/03/03	43.265	13.258	22.185	62.433	4.327	25.118
2003/03/31	38.604	11.713	17.962	53.495	1.694	23.404
2003/04/28	42.393	12.094	16.44	53.19	1.886	24.622
2003/05/29	39.577	10.308	21.888	49.693	1.598	18.706
2003/06/25	54.765	14.946	19.961	69.75	1.587	26.515
2003/07/21	63.849	20.186	23.843	85.979	1.845	30.061
2003/11/10	85.882	22.438	30.816	119.285	2.548	43.276
2004/01/26	38.402	10.795	15.002	43.714	2.348	23.149
2004/03/08	30.834	8.869	11.4	32.748	2.013	17.177
2004/04/05	23.869	7.776	9.819	28.834	1.583	15.712

APPENDIX E: TIMS OUTPUT RESULTS AT DIFFERENT WATER QUALITY MONITORING POINTS

Table showing output salt concentrations from the TIMS model at the Kat Dam weir

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
10/28/1977	2.51	0	0	0	26.86	0
11/25/1977	6.64	0	0	0	23.73	0
12/30/1977	2.51	0	0	0	24.22	0
01/27/1978	2.51	0	0	0	24.88	0
02/28/1978	2.51	0	0	0	20.27	0
04/28/1978	2.51	0	0	0	21.26	0
05/26/1978	2.51	0	0	0	24.55	0
06/30/1978	2.51	0	0	0	23.24	0
07/28/1978	2.51	0	0	0	23.07	0
09/28/1978	2.51	0	0	0	23.73	0
10/30/1978	2.51	0	0	0	19.77	0
11/30/1978	17.92	0	0	0	26.04	0
12/31/1978	2.51	0	0	0	26.37	0
04/30/1979	7.14	0	0	0	27.85	0
05/25/1979	2.51	0	0	0	25.87	0
11/30/1979	28.22	1.01	0.68	0	21.42	0
12/31/1979	13.66	0	0	0	25.87	0
01/31/1980	9.02	0	0	0	23.73	0
02/29/1980	10.40	0	0	0	22.08	0
03/31/1980	2.51	0	0	0	23.24	0
04/30/1980	2.51	0	0	0	24.22	0
05/30/1980	9.02	0	0	0	23.24	0
06/06/1980	7.77	0	0	0	23.89	0
06/13/1980	2.51	0	0	0	26.70	0
06/20/1980	6.02	0	0	0	28.18	0
08/01/1980	7.27	0	0	0	26.04	0
07/25/1980	7.27	0	0	0	25.21	0
08/08/1980	2.51	0	0	0	26.53	0
08/15/1980	2.51	0	0	0	24.55	0
08/22/1980	6.27	0	0	0	27.35	0
08/29/1980	6.27	0	0	0	24.88	0
09/05/1980	5.39	0	0	0	24.72	0
09/12/1980	12.41	0	0	0	26.04	0
09/19/1980	11.65	0	0	0	26.70	0
09/26/1980	2.51	0	0	0	28.18	0
10/03/1980	2.51	0	0	0	28.01	0
10/10/1980	6.77	0	0	0	32.30	0
10/17/1980	6.02	0	0	0	31.15	0
10/24/1980	2.51	0	0	0	17.14	0
10/31/1980	2.51	0	0	0	17.63	0
11/07/1980	8.15	0	0	0	26.86	0
11/14/1980	10.65	0	0	0	26.86	0
11/21/1980	7.02	0	0	0	28.18	0
11/28/1980	6.14	0	0	0	28.67	0
12/26/1980	2.51	0	0	0	28.01	0
01/02/1981	10.03	0	0	0	28.18	0
01/09/1981	14.04	0	0	0	29.99	0
01/16/1981	15.29	0	0	0	28.01	0
01/23/1981	5.76	0	0	0	27.03	0
02/06/1981	20.30	0	0	0	27.52	0
01/30/1981	14.29	0	0	0	30.82	0
02/13/1981	6.64	0	0	0	24.22	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
03/26/1982	2.51	0	0	0	25.71	0
04/02/1982	2.51	0	0	0	24.55	0
04/09/1982	2.51	0	0	0	25.38	0
04/16/1982	2.51	0	0	0	29.33	0
04/23/1982	2.51	0	0	0	24.39	0
04/30/1982	2.51	0	0	0	24.88	0
05/07/1982	2.51	0	0	0	25.87	0
05/14/1982	2.51	0	0	0	26.37	0
05/21/1982	2.51	0	0	0	27.35	0
05/28/1982	2.51	0	0	0	27.68	0
06/04/1982	2.51	0	0	0	28.18	0
06/15/1982	2.51	0	0	0	33.62	0
06/25/1982	2.51	0	0	0	30.49	0
07/02/1982	2.51	0	0	0	26.04	0
07/09/1982	2.51	0	0	0	27.19	0
07/16/1982	2.51	0	0	0	31.47	0
07/23/1982	2.51	0	0	0	17.30	0
07/30/1982	2.51	0	0	0	28.84	0
08/06/1982	2.51	0	0	0	28.01	0
08/20/1982	2.51	0	0	0	23.24	0
08/13/1982	2.51	0	0	0	22.25	0
08/27/1982	2.51	0	0	0	25.54	0
09/03/1982	2.51	0	0	0	27.19	0
09/10/1982	2.51	0	0	0	28.01	0
09/17/1982	2.51	0	0	0	25.05	0
09/24/1982	2.51	0	0	0	26.20	0
10/01/1982	2.51	0	0	0	27.85	0
11/19/1982	7.52	0	0	0	25.21	0
11/26/1982	5.76	0	0	0	28.18	0
12/31/1982	13.41	0	0	0	35.76	0
01/14/1983	11.28	0	0	0	31.80	0
01/21/1983	12.53	0	0	0	31.64	0
01/28/1983	11.65	0	0	0	25.05	0
02/04/1983	12.03	0	0	0	27.85	0
02/25/1983	11.78	0	0	0	35.10	0
03/04/1983	10.40	0	0	0	30.98	0
03/11/1983	10.03	0	0	0	28.84	0
03/18/1983	9.77	0	0	0	30.16	0
03/25/1983	21.55	0	0	0	45.65	0
04/01/1983	20.93	0	0	0	29.33	0
04/08/1983	18.17	0	0	41.24	49.09	0
04/15/1983	22.93	0	0	0	33.62	0
04/22/1983	14.54	0	0	0	37.74	0
04/29/1983	13.91	0	0	0	37.74	0
05/06/1983	14.29	0	0	0	37.74	0
05/13/1983	13.16	0	0	0	38.40	0
05/20/1983	15.41	0	0	0	37.90	0
05/27/1983	14.79	0	0	0	37.08	0
06/03/1983	15.16	0	0	0	41.36	0
06/10/1983	15.66	0	0	0	39.88	0
06/17/1983	14.16	0	0	0	32.63	0
06/24/1983	14.04	0	0	0	35.26	0
07/01/1983	13.66	0	0	0	36.58	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/20/1981	5.89	0	0	0	26.04	0
02/27/1981	5.26	0	0	0	26.53	0
03/06/1981	5.14	0	0	0	28.51	0
03/13/1981	8.65	0	0	0	28.34	0
03/20/1981	2.51	0	0	0	27.85	0
03/27/1981	2.51	0	0	0	26.86	0
04/03/1981	6.39	0	0	0	25.87	0
04/10/1981	2.51	0	0	0	23.56	0
04/17/1981	2.51	0	0	0	24.72	0
05/01/1981	2.51	0	0	0	26.86	0
04/24/1981	2.51	0	0	0	23.56	0
05/08/1981	2.51	0	0	0	25.38	0
05/15/1981	2.51	0	0	0	25.38	0
05/22/1981	7.02	0	0	0	27.68	0
05/29/1981	2.51	0	0	0	21.59	0
06/05/1981	2.51	0	0	0	28.51	0
06/12/1981	6.64	0	0	0	27.68	0
06/19/1981	6.89	0	0	0	27.85	0
06/26/1981	12.16	0	0	0	25.05	0
07/03/1981	11.90	0	0	0	24.22	0
07/10/1981	12.03	0	0	0	23.24	0
07/17/1981	7.64	0	0	0	23.73	0
07/31/1981	18.42	0	0	0	22.41	0
08/07/1981	17.67	0	0	0	23.07	0
08/14/1981	12.78	0	0	0	25.05	0
08/21/1981	7.52	0	0	0	25.21	0
08/28/1981	8.15	0	0	0	24.55	0
09/04/1981	8.15	0	0	0	28.51	0
09/11/1981	7.39	0	0	0	27.19	0
09/18/1981	15.66	0	0	0	28.51	0
09/25/1981	14.66	0	0	0	25.38	0
10/02/1981	12.16	0	0	0	23.73	0
10/09/1981	10.78	0	0	0	26.53	0
10/16/1981	7.27	0	0	0	21.59	0
10/23/1981	7.27	0	0	0	21.42	0
10/30/1981	9.90	0	0	0	26.20	0
11/06/1981	13.78	0	0	0	27.52	0
11/13/1981	9.40	0	0	0	25.21	0
11/20/1981	9.77	0	0	0	27.03	0
12/11/1981	2.51	0	0	0	28.34	0
12/18/1981	2.51	0	0	0	28.18	0
01/01/1982	2.51	0	0	0	32.79	0
01/08/1982	2.51	0	0	0	30.98	0
01/15/1982	2.51	0	0	0	28.84	0
01/22/1982	2.51	0	0	0	27.68	0
01/29/1982	2.51	0	0	0	30.32	0
02/05/1982	2.51	0	0	0	30.98	0
02/12/1982	2.51	0	0	0	32.46	0
02/19/1982	2.51	0	0	0	32.30	0
02/26/1982	15.16	0	0	0	29.50	0
03/05/1982	5.26	0	0	0	25.87	0
03/12/1982	2.51	0	0	0	26.04	0
03/19/1982	7.39	0	0	0	29.33	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
07/08/1983	14.04	0	0	0	36.42	0
07/15/1983	2.51	0	0	0	38.73	0
07/22/1983	7.64	0	0	0	39.55	0
07/29/1983	7.02	0	0	0	32.30	0
08/05/1983	9.15	0	0	0	36.58	0
08/12/1983	9.77	0	0	0	41.69	0
08/19/1983	13.28	0	0	0	40.37	0
08/26/1983	20.80	0	0	0	42.68	0
09/02/1983	22.81	0	0	0	45.15	0
09/09/1983	23.81	0	0	0	47.95	0
09/16/1983	23.81	0	0	0	47.95	0
09/23/1983	21.80	0	0	0	43.83	0
10/07/1983	17.92	0	0	0	38.23	0
10/14/1983	17.17	0	0	0	37.57	0
10/21/1983	19.55	0	0	0	39.71	0
10/28/1983	19.42	0	0	0	37.57	0
11/04/1983	20.18	0	0	0	39.55	0
11/11/1983	19.05	0	0	0	37.41	0
11/18/1983	18.92	0	0	0	39.71	0
11/25/1983	15.79	0	0	0	31.15	0
12/09/1983	14.16	0	0	0	29.50	0
12/16/1983	2.51	0	0	0	26.37	0
12/23/1983	14.29	0	0	0	30.49	0
01/06/1984	16.29	0	0	0	30.32	0
01/13/1984	14.29	0	0	0	30.32	0
01/20/1984	11.40	0	0	0	35.10	0
01/27/1984	11.03	0	0	0	31.64	0
02/03/1984	9.77	0	0	0	30.32	0
02/10/1984	9.77	0	0	0	29.50	0
02/17/1984	11.15	0	0	0	31.47	0
03/16/1984	7.77	0	0	0	27.35	0
04/13/1984	18.67	0	0	0	26.20	0
03/23/1984	16.92	0	0	0	29.00	0
03/30/1984	16.67	0	0	0	26.53	0
04/06/1984	16.42	0	0	0	26.53	0
05/11/1984	20.30	0	0	0	21.26	0
06/08/1984	17.92	0	0	0	22.91	0
07/06/1984	15.54	0	0	0	21.92	0
08/03/1984	12.78	0	0	0	20.60	0
10/05/1984	11.28	0	0	0	21.09	0
11/02/1984	8.40	0	0	0	22.91	0
11/30/1984	8.02	0	0	0	18.95	0
12/28/1984	8.65	0	0	0	22.91	0
01/25/1985	2.51	0	0	0	20.60	0
03/22/1985	13.66	0	0	0	27.03	0
05/17/1985	9.77	0	0	0	20.76	0
06/14/1985	13.78	0	0	0	24.55	0
07/05/1985	11.03	0	0	0	16.64	0
07/12/1985	9.90	0	0	0	18.13	0
09/06/1985	11.90	0	0	0	25.05	0
10/04/1985	7.64	0	0	0	22.41	0
11/01/1985	10.53	0	0	0	19.77	0
11/29/1985	23.06	0	0	0	27.19	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/04/1991	9.65	0	0	0	20.93	0
03/04/1991	11.53	0	0	0	18.79	0
04/01/1991	6.02	0	0	0	19.45	0
05/13/1991	7.64	0	0	0	17.80	0
06/10/1991	10.28	0	0	0	22.41	0
07/08/1991	9.02	0	0	0	24.55	0
08/05/1991	7.89	0	0	0	22.91	0
09/02/1991	15.54	0	0	0	20.60	0
09/30/1991	5.89	0	0	0	23.24	0
10/28/1991	9.40	0	0	0	22.41	0
11/25/1991	2.51	0	0	0	15.33	0
12/23/1991	5.89	0	0	0	16.97	0
01/06/1992	2.51	0	0	0	22.08	0
02/03/1992	14.29	0	0	0	12.85	0
03/02/1992	9.27	0	0	0	21.42	0
04/13/1992	7.89	0	0	0	14.34	0
05/04/1992	14.04	0	0	0	17.80	0
04/20/1992	8.02	0	0	0	19.12	0
05/12/1992	19.42	0	0	0	19.12	0
04/27/1992	17.54	0	0	0	18.79	0
05/25/1992	9.27	0	0	0	13.68	0
05/18/1992	12.28	0	0	0	16.31	0
06/01/1992	7.52	0	0	0	15.49	0
06/08/1992	11.15	0	0	0	15.00	0
06/29/1992	9.65	0	0	0	15.49	0
07/06/1992	12.16	0	0	0	16.64	0
06/22/1992	13.41	0	0	0	13.35	0
06/15/1992	12.91	0	0	0	16.64	0
07/13/1992	10.53	0	0	0	12.69	0
08/03/1992	17.04	0	0	0	12.19	0
07/27/1992	16.04	0	0	0	15.16	0
07/20/1992	13.78	0	0	0	12.19	0
09/07/1992	12.53	0	0	0	15.33	0
09/14/1992	11.03	0	0	0	21.42	0
08/17/1992	10.03	0	0	0	16.81	0
08/10/1992	12.03	0	0	0	19.12	0
09/30/1992	11.28	0	0	0	18.95	0
08/24/1992	10.90	0	0	0	19.77	0
09/21/1992	8.65	0	0	0	17.30	0
10/05/1992	9.02	0	0	0	17.63	0
09/28/1992	10.15	0	0	0	18.79	0
10/19/1992	9.02	0	0	0	20.76	0
10/12/1992	11.28	0	0	0	19.94	0
10/26/1992	9.40	0	0	0	16.15	0
10/21/1992	11.90	0	0	0	18.62	0
11/09/1992	14.04	0	0	0	16.48	0
11/16/1992	14.54	0	0	0	16.97	0
11/30/1992	21.78	2.69	1.80	0	18.29	0
12/09/1992	24.75	3.32	2.23	0	17.30	0
12/15/1992	22.18	0	0	0	13.68	0
12/21/1992	13.41	0	0	0	25.71	0
12/28/1992	22.77	1.22	0.82	0	16.81	0
01/04/1993	16.54	0	0	0	13.51	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
12/27/1985	0.00	0	0	19.10	41.71	0
01/29/1986	2.51	0	0	0	19.45	0
02/21/1986	6.14	0	0	0	19.12	0
03/21/1986	5.64	0	0	0	22.41	0
04/25/1986	8.27	0	0	0	27.35	0
05/23/1986	7.39	0	0	0	29.00	0
08/15/1986	5.89	0	0	0	31.31	0
09/12/1986	2.51	0	0	0	23.24	0
10/10/1986	2.51	0	0	0	30.49	0
11/07/1986	7.27	0	0	0	25.71	0
02/06/1987	7.39	0	0	0	24.22	0
03/06/1987	10.53	0	0	0	24.88	0
01/16/1987	2.51	0	0	0	24.16	0
04/24/1987	2.51	0	0	0	22.64	0
05/22/1987	2.51	0	0	0	27.19	0
06/26/1987	13.28	0	0	0	28.51	0
07/24/1987	11.65	0	0	0	29.33	0
08/21/1987	9.27	0	0	0	27.52	0
09/18/1987	2.51	0	0	0	24.06	0
10/16/1987	17.79	0	0	0	30.49	0
11/13/1987	8.65	0	0	0	30.16	0
12/11/1987	2.51	0	0	0	26.96	0
01/22/1988	2.51	0	0	0	29.00	0
02/19/1988	7.64	0	0	0	24.88	0
03/18/1988	5.89	0	0	0	29.17	0
04/15/1988	2.51	0	0	0	22.58	0
05/13/1988	2.51	0	0	0	28.23	0
06/15/1988	2.51	0	0	0	27.85	0
07/11/1988	8.15	0	0	0	32.13	0
08/08/1988	5.51	0	0	0	33.78	0
09/05/1988	2.51	0	0	0	25.71	0
10/03/1988	2.51	0	0	0	33.29	0
10/31/1988	2.51	0	0	0	32.30	0
11/28/1988	2.51	0	0	0	26.70	0
12/06/1988	2.51	0	0	0	29.25	0
01/23/1989	2.51	0	0	0	24.39	0
02/27/1989	7.27	0	0	0	27.52	0
04/03/1989	2.51	0	0	0	27.03	0
05/29/1989	2.51	0	0	0	24.22	0
05/01/1989	8.27	0	0	0	37.41	0
06/26/1989	5.89	0	0	0	31.97	0
07/24/1989	2.51	0	0	0	25.54	0
08/21/1989	7.27	0	0	0	28.51	0
09/18/1989	2.51	0	0	0	39.38	0
10/16/1989	6.39	0	0	0	38.56	0
11/13/1989	11.40	0	0	0	30.32	0
12/11/1989	2.51	0	0	0	25.43	0
05/14/1990	2.51	0	0	0	22.41	0
10/01/1990	10.28	0	0	0	14.83	0
10/08/1990	14.41	0	0	0	16.81	0
10/15/1990	17.67	0	0	0	17.30	0
11/12/1990	5.01	0	0	0	19.45	0
12/10/1990	11.15	0	0	0	21.75	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
01/11/1993	10.03	0	0	0	14.34	0
01/18/1993	14.54	0	0	0	15.49	0
02/01/1993	18.55	0	0	0	13.02	0
01/25/1993	24.26	6.87	4.61	0	14.67	0
02/08/1993	18.05	0	0	0	12.19	0
02/15/1993	23.68	0	0	0	14.34	0
02/22/1993	23.81	0	0	0	16.48	0
03/01/1993	18.30	0	0	0	22.41	0
03/15/1993	15.41	0	0	0	18.29	0
03/22/1993	20.93	0	0	0	16.64	0
04/05/1993	13.16	0	0	0	17.47	0
04/19/1993	12.91	0	0	0	18.13	0
04/26/1993	12.28	0	0	0	16.48	0
05/03/1993	14.54	0	0	0	17.14	0
05/10/1993	10.15	0	0	0	26.37	0
05/17/1993	12.41	0	0	0	21.09	0
05/24/1993	12.28	0	0	0	20.76	0
06/14/1993	5.76	0	0	0	12.03	0
06/21/1993	9.40	0	0	0	13.02	0
06/28/1993	11.15	0	0	0	16.97	0
07/05/1993	11.53	0	0	0	18.95	0
07/12/1993	14.41	0	0	0	14.01	0
07/19/1993	8.77	0	0	0	15.98	0
07/26/1993	15.66	0	0	0	15.16	0
08/02/1993	17.92	0	0	0	19.45	0
08/09/1993	19.30	0	0	0	14.67	0
08/16/1993	7.77	0	0	0	15.33	0
08/30/1993	11.90	0	0	0	14.34	0
08/23/1993	18.55	0	0	0	19.45	0
09/13/1993	11.28	0	0	0	19.28	0
09/20/1993	16.29	0	0	0	18.29	0
09/27/1993	22.18	0	0	0	18.95	0
10/04/1993	14.41	0	0	0	19.12	0
10/11/1993	16.17	0	0	0	18.29	0
10/18/1993	8.40	0	0	0	18.29	0
10/25/1993	13.28	0	0	0	16.97	0
11/01/1993	9.52	0	0	0	15.82	0
11/08/1993	12.16	0	0	0	15.00	0
11/15/1993	9.15	0	0	0	15.65	0
11/22/1993	10.40	0	0	0	15.65	0
12/01/1993	20.05	0	0	0	15.00	0
12/06/1993	16.79	0	0	0	10.38	0
12/13/1993	13.28	0	0	0	20.93	0
12/27/1993	14.91	0	0	0	14.17	0
12/19/1993	8.40	0	0	0	15.00	0
01/03/1994	14.16	0	0	0	15.98	0
01/10/1994	11.40	0	0	0	15.33	0
01/17/1994	5.51	0	0	0	18.95	0
01/24/1994	10.65	0	0	0	14.17	0
01/31/1994	11.53	0	0	0	19.45	0
02/07/1994	17.92	0	0	0	15.82	0
02/14/1994	7.64	0	0	0	17.96	0
03/07/1994	19.17	0	0	0	17.80	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/28/1994	22.68	0	0	0	16.15	0
02/21/1994	10.65	0	0	0	17.14	0
03/21/1994	20.05	0	0	0	16.64	0
03/28/1994	20.55	0	0	0	16.48	0
03/14/1994	11.03	0	0	0	15.00	0
04/11/1994	6.52	0	0	0	14.17	0
04/04/1994	17.04	0	0	0	17.14	0
05/09/1994	14.41	0	0	0	20.27	0
05/16/1994	16.04	0	0	0	14.67	0
05/02/1994	22.18	0	0	0	17.80	0
05/23/1994	8.77	0	0	0	23.89	0
06/06/1994	14.29	0	0	0	13.35	0
05/30/1994	14.66	0	0	0	8.24	0
06/22/1994	18.80	0	0	0	16.48	0
07/18/1994	22.28	2.99	2.01	0	13.84	0
08/01/1994	14.04	0	0	0	15.82	0
07/25/1994	14.04	0	0	0	14.50	0
08/22/1994	8.52	0	0	0	16.81	0
08/29/1994	11.65	0	0	0	15.65	0
08/15/1994	17.92	0	0	0	20.60	0
08/08/1994	7.02	0	0	0	19.28	0
09/26/1994	9.52	0	0	0	21.59	0
10/03/1994	6.39	0	0	0	20.93	0
10/10/1994	9.77	0	0	0	20.27	0
10/17/1994	13.16	0	0	0	22.74	0
10/24/1994	6.64	0	0	0	21.59	0
10/31/1994	5.51	0	0	0	21.26	0
11/07/1994	7.14	0	0	0	21.59	0
11/14/1994	7.89	0	0	0	19.77	0
11/21/1994	13.41	0	0	0	19.94	0
11/28/1994	18.42	0	0	0	20.43	0
12/05/1994	14.29	0	0	0	21.09	0
12/19/1994	15.54	0	0	0	18.79	0
12/26/1994	11.03	0	0	0	18.46	0
01/09/1995	13.78	0	0	0	19.77	0
01/16/1995	27.57	0	0	0	18.62	0
02/13/1995	12.28	0	0	0	17.30	0
02/06/1995	9.15	0	0	0	17.30	0
01/30/1995	12.53	0	0	0	11.21	0
02/20/1995	16.54	0	0	0	15.16	0
02/27/1995	14.91	0	0	0	16.97	0
01/23/1995	6.89	0	0	0	13.51	0
03/06/1995	8.90	0	0	0	14.83	0
03/13/1995	12.28	0	0	0	14.83	0
03/27/1995	12.16	0	0	0	12.36	0
03/20/1995	14.66	0	0	0	14.50	0
04/03/1995	8.52	0	0	0	14.50	0
04/10/1995	8.15	0	0	0	21.59	0
04/17/1995	2.51	0	0	0	15.65	0
05/15/1995	9.52	0	0	0	13.18	0
04/24/1995	5.39	0	0	0	11.54	0
05/01/1995	9.27	0	0	0	10.71	0
05/03/1995	10.65	0	0	0	13.68	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
03/16/1998	15.29	0	0	0	17.14	0
04/13/1998	20.79	3.12	2.09	0	13.51	0
05/11/1998	22.68	0	0	0	14.83	0
04/07/1998	9.77	0	0	0	13.35	0
06/15/1998	15.91	0	0	0	14.67	0
06/22/1998	15.29	0	0	0	19.61	0
08/24/1998	20.30	6.66	4.47	0	18.29	0
08/24/1998	17.17	0	0	0	19.61	0
09/07/1998	18.30	0	0	0	21.92	0
10/17/1998	13.78	0	0	0	17.30	0
12/28/1998	2.51	0	0	0	21.03	0
09/13/1999	8.31	0	0	0	25.49	0
10/04/1999	14.57	0	0	0	21.44	0
11/29/1999	8.97	0	0	0	24.48	0
11/15/1999	11.26	0	0	0	28.46	0
11/08/1999	8.96	0	0	0	22.01	0
12/20/1999	10.99	0	0	0	18.51	0
04/12/1999	8.85	0	0	0	21.43	0
08/16/1999	10.34	0	0	0	20.57	0
08/23/1999	12.51	0	0	0	21.17	0
09/09/1999	8.44	0	0	0	22.70	0
10/18/1999	10.18	0	0	0	26.25	0
10/11/1999	18.05	0	0	0	19.28	0
01/18/1999	11.28	0	0	0	21.92	0
03/01/1999	7.77	0	0	0	19.94	0
03/15/1999	12.66	0	0	0	19.12	0
03/29/1999	12.16	0	0	0	19.45	0
02/15/1999	12.16	0	0	0	19.12	0
04/26/1999	14.41	0	0	0	19.28	0
04/13/1999	11.03	0	0	0	19.45	0
05/10/1999	20.55	0	0	0	21.59	0
05/31/1999	11.78	0	0	0	20.27	0
06/28/1999	7.89	0	0	0	21.59	0
05/17/1999	14.66	0	0	0	19.61	0
06/14/1999	10.65	0	0	0	24.55	0
06/07/1999	20.79	0.45	0.31	0	18.13	0
05/24/1999	15.79	0	0	0	22.41	0
06/21/1999	21.18	0	0	0	19.28	0
07/26/1999	15.29	0	0	0	19.94	0
07/05/1999	13.47	11.46	7.69	0	21.59	0
07/12/1999	18.67	0	0	0	7.42	0
07/19/1999	8.02	0	0	0	20.27	0
09/06/1999	10.78	0	0	0	18.46	0
08/09/1999	9.52	0	0	0	18.79	0
08/02/1999	8.02	0	0	0	18.79	0
08/02/1999	8.02	0	0	0	18.79	0
01/17/2000	16.52	0	0	0	18.24	0
02/07/2000	20.59	0	0	0	20.74	0
02/21/2000	17.12	0	0	0	20.13	0
03/06/2000	13.03	0	0	0	20.43	0
03/29/2000	27.51	0	0	0	18.82	0
04/11/2000	13.07	0	0	0	18.36	0
05/17/2000	13.16	0	0	0	20.09	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
05/22/1995	6.52	0	0	0	10.22	0
06/12/1995	13.78	0	0	0	13.51	0
06/05/1995	13.28	0	0	0	11.04	0
05/29/1995	15.91	0	0	0	12.52	0
06/19/1995	13.53	0	0	0	8.73	0
06/26/1995	10.65	0	0	0	9.72	0
07/03/1995	9.02	0	0	0	11.70	0
08/16/1995	8.40	0	0	0	15.98	0
07/31/1995	21.78	2.39	1.61	0	12.85	0
08/14/1995	20.30	0	0	0	17.96	0
08/21/1995	10.40	0	0	0	13.68	0
09/04/1995	8.65	0	0	0	13.35	0
09/11/1995	16.42	0	0	0	13.51	0
09/25/1995	9.65	0	0	0	14.83	0
10/09/1995	7.77	0	0	0	15.16	0
11/06/1995	14.16	0	0	0	17.96	0
11/20/1995	17.04	0	0	0	13.18	0
12/18/1995	12.78	0	0	0	16.81	0
01/15/1996	9.40	0	0	0	22.41	0
01/29/1996	13.41	0	0	0	13.73	0
02/12/1996	11.65	0	0	0	15.16	0
02/26/1996	14.91	0	0	0	17.14	0
03/11/1996	18.67	0	0	0	13.18	0
04/22/1996	7.14	0	0	0	11.70	0
05/06/1996	15.29	0	0	0	13.68	0
04/08/1996	16.17	0	0	0	14.50	0
06/17/1996	13.41	0	0	0	15.33	0
06/03/1996	14.04	0	0	0	15.16	0
05/20/1996	10.03	0	0	0	15.65	0
07/15/1996	9.02	0	0	0	18.62	0
08/12/1996	18.55	0	0	0	12.69	0
09/23/1996	2.51	0	0	0	19.12	0
08/26/1996	21.78	8.80	5.91	0	16.15	5.34
10/21/1996	22.28	2.99	2.01	0	15.65	0
10/07/1996	12.41	0	0	0	12.85	0
12/02/1996	21.29	1.65	1.10	0	15.65	0
12/17/1996	11.53	0	0	0	13.35	0
12/30/1996	2.51	0	0	0	11.86	0
01/27/1997	19.31	5.61	3.76	0	14.34	0
02/10/1997	13.53	0	0	0	14.01	0
03/17/1997	10.15	0	0	0	14.17	0
03/03/1997	17.67	0	0	0	12.03	0
03/31/1997	16.92	0	0	0	16.81	0
09/29/1997	17.67	0	0	0	16.64	0
11/03/1997	16.83	9.13	6.13	0	13.84	2.26
11/17/1997	17.33	4.69	3.15	0	15.16	0
12/29/1997	21.78	1.80	1.21	0	17.80	0
12/15/1997	8.40	0	0	0	12.69	0
02/02/1998	17.33	0.55	0.37	0	14.17	0
01/13/1998	17.33	2.77	1.86	0	13.68	0
02/23/1998	17.17	0	0	0	14.67	0
02/16/1998	15.91	0	0	0	15.65	0
03/30/1998	14.41	0	0	0	18.29	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
05/02/2000	17.26	7.87	5.28	0	20.35	4.17
05/29/2000	10.30	12.51	8.40	0	18.48	0
06/26/2000	8.10	0	0	0	21.17	0
07/10/2000	2.03	16.12	10.82	0	17.80	0
08/14/2000	14.64	0	0	0	20.43	0
08/28/2000	22.77	8.87	5.95	0	18.92	0
09/04/2000	25.48	2.56	1.72	0	19.08	0
10/02/2000	23.62	3.02	2.03	0	19.35	0
11/09/2000	21.15	1.75	1.17	0	18.50	0
05/21/2001	22.72	7.11	4.78	0	21.95	21.52
05/14/2001	17.06	0	0	0	18.23	0
05/28/2001	11.35	0	0	0	22.54	0
04/23/2001	20.20	2.80	1.88	0	16.84	0
06/04/2001	12.05	0	0	0	21.13	0
11/12/2001	11.60	0	0	0	24.19	0
11/12/2001	12.43	0	0	0	22.12	0

(All concentrations measured in mg/L)

Table showing Output salt concentrations from the TIMS model at the Balfour weir

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
10/07/1977	5.01	0	0	0	36.09	0
10/14/1977	5.89	0	0	0	41.69	0
10/21/1977	6.02	0	0	0	43.50	0
10/28/1977	2.51	0	0	0	22.41	0
11/04/1977	2.51	0	0	0	12.03	0
11/11/1977	2.51	0	0	0	13.51	0
11/18/1977	7.39	0	0	0	21.26	0
11/25/1977	7.77	0	0	0	27.19	0
12/02/1977	2.51	0	0	0	15.00	0
12/09/1977	2.51	0	0	0	22.74	0
12/15/1977	2.51	0	0	0	24.88	0
12/23/1977	5.76	0	0	0	31.97	0
12/30/1977	6.02	0	0	0	37.90	0
01/06/1978	2.51	0	0	0	21.26	0
01/13/1978	2.51	0	0.11	0	21.62	0
01/20/1978	5.39	0	0	0	27.68	0
01/27/1978	2.51	0	0	0	29.83	0
02/03/1978	2.51	0	0	0	26.53	0
02/10/1978	2.51	0	0	0	28.51	0
02/16/1978	2.51	0	0	0	27.19	0
02/23/1978	2.51	0	0	0	34.28	0
03/03/1978	6.27	0	0	0	52.57	0
03/10/1978	2.51	0	0	0	28.51	0
03/17/1978	5.51	0	0	0	39.71	0
03/24/1978	2.51	0	0	0	26.20	0
03/31/1978	6.64	0	0	0	49.60	0
04/07/1978	5.01	0	0	0	41.36	0
04/11/1978	2.51	0	0	0	34.28	0
05/03/1978	2.51	0	0	0	11.21	0
05/10/1978	2.51	0	0	0	19.94	0
05/16/1978	2.51	0	0	0	26.04	0
05/24/1978	2.51	0	0	0	33.12	0
06/14/1978	2.51	0	0	0	30.49	0
06/21/1978	2.51	0	0	0	39.22	0
06/28/1978	6.02	0	0	0	45.65	0
07/12/1978	7.14	0	0	0	53.06	0
07/19/1978	6.64	0	0	0	60.64	0
07/26/1978	10.28	0	0	0	66.90	0
08/02/1978	7.64	0	0	0	73.50	0
08/09/1978	12.16	0	0	0	101.67	0
08/16/1978	14.79	0	0	0	126.23	0
08/23/1978	2.51	0	0	0	45.32	0
08/30/1978	8.27	0	0	0	81.24	0
09/06/1978	19.30	0	0	0	99.70	0
09/13/1978	12.53	0	0	0	69.05	0
09/20/1978	5.39	0	0	0	23.24	0
09/27/1978	6.77	0	0	0	46.47	0
10/04/1978	9.65	0	0	0	66.41	0
10/11/1978	2.51	0	0	0	26.86	0
10/18/1978	2.51	0	0	0	19.77	0
10/25/1978	2.51	0	0	0	13.35	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
11/01/1978	7.64	0	0	0	27.35	0
11/08/1978	2.51	0	0	0	11.86	0
11/15/1978	9.90	0	0	0	20.76	0
11/22/1978	9.90	0	0	0	28.67	0
11/29/1978	12.66	0	0	0	37.08	0
12/06/1978	2.51	0	0	0	45.65	0
12/13/1978	8.65	0	0	0	14.17	0
12/20/1978	2.51	0	0	0	24.72	0
12/27/1978	2.51	0	0	0	14.34	0
01/03/1979	2.51	0	0	0	12.03	0
01/10/1979	2.51	0	0	0	15.49	0
04/25/1979	2.51	0	0	0	32.30	0
05/02/1979	9.27	0	0	0	36.25	0
05/09/1979	7.77	0	0	0	33.12	0
05/16/1979	10.40	0	0	0	39.88	0
05/23/1979	7.02	0	0	0	51.08	0
05/30/1979	5.14	0	0	0	37.90	0
06/06/1979	8.40	0	0	0	40.04	0
06/13/1979	6.77	0	0	0	49.77	0
06/20/1979	6.02	0	0	0	47.13	0
06/27/1979	10.03	0	0	0	70.36	0
07/11/1979	11.40	0	0	0	85.85	0
10/10/1979	7.14	0	0	0	37.41	0
10/17/1979	5.76	0	0	0	36.09	0
11/14/1979	15.04	0	0	0	26.37	0
11/28/1979	2.51	0	0	0	27.35	0
12/05/1979	31.70	0	0	0	40.37	0
12/12/1979	12.03	0	0	0	62.13	0
12/19/1979	7.77	0	0	0	67.40	0
12/26/1979	12.66	0	0	0	57.51	0
01/02/1980	27.69	0	0	0	59.32	0
01/16/1980	25.44	0	0	0	33.78	0
01/23/1980	10.15	0	0	0	50.92	0
01/30/1980	2.51	0	0	0	27.68	0
02/06/1980	7.02	0	0	0	55.37	0
02/13/1980	7.64	0	0	0	72.34	0
02/20/1980	9.77	0	0	0	64.27	0
02/27/1980	8.77	0	3.91	0	37.39	0
03/05/1980	5.64	0	0	0	26.53	0
03/12/1980	2.51	0	0	0	29.83	0
03/19/1980	2.51	0	0	0	20.43	0
03/26/1980	2.51	0	0	0	32.46	0
04/02/1980	9.15	0	0	0	49.11	0
04/09/1980	12.78	0	0	0	62.95	0
04/16/1980	8.15	0	0	0	63.28	0
04/23/1980	10.65	0	0	0	69.71	0
04/30/1980	11.78	0	0	0	71.68	0
05/07/1980	11.40	0	0	0	65.26	0
05/14/1980	14.16	0	0	0	62.45	0
05/21/1980	18.30	0	0	0	67.40	0
06/03/1980	18.42	0	0	0	112.55	0
06/11/1980	16.54	0	0	0	101.02	0
06/18/1980	15.16	0	0	0	81.24	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
07/15/1980	16.67	0	0	0	68.88	0
07/22/1980	12.66	0	0	0	58.50	0
07/29/1980	19.67	0	0	0	92.78	0
08/12/1980	19.30	0	0	0	73.00	0
08/19/1980	16.17	0	0	0	73.83	0
08/26/1980	8.77	0	0	0	74.81	0
09/09/1980	20.55	0	0	0	128.86	0
09/02/1980	13.41	0	0	0	73.66	0
09/16/1980	18.55	0	0	0	136.28	0
09/23/1980	16.04	0	0	0	90.14	0
09/30/1980	19.67	0	0	0	22.74	0
10/07/1980	13.41	0	0	0	62.95	0
10/14/1980	20.43	0	0	0	91.79	0
10/21/1980	9.40	0	0	0	18.62	0
10/28/1980	11.28	0	0	0	46.80	0
11/04/1980	11.90	0	0	0	66.41	0
11/11/1980	17.29	0	0	0	68.72	0
11/18/1980	16.54	0	0	0	78.77	0
11/25/1980	12.28	0	0	0	86.18	0
12/02/1980	2.51	0	0	0	17.14	0
12/23/1980	2.51	0	0	0	46.64	0
12/30/1980	2.51	0	0	0	15.49	0
01/06/1981	9.77	0	0	0	26.20	0
01/13/1981	2.51	0	0	0	15.82	0
01/20/1981	6.14	0	0	0	16.15	0
01/28/1981	2.51	0	0	0	11.86	0
02/03/1981	5.39	0	0	0	10.22	0
02/10/1981	9.02	0	0	0	10.55	0
02/17/1981	15.79	0	3.81	0	15.26	0
02/24/1981	18.81	8.41	0	0	14.17	0
03/03/1981	2.51	0	0	0	14.50	0
03/31/1981	2.51	0	0	0	14.67	0
04/28/1981	34.65	27.93	0	0	24.55	6.61
05/26/1981	2.51	0	0	0	26.37	0
06/23/1981	15.79	0	0	0	24.22	0
08/19/1981	16.54	0	0	0	72.84	0
09/16/1981	2.51	0	0	0	27.52	0
10/14/1981	16.54	0	0	0	50.75	0
11/11/1981	15.29	0	0	0	30.82	0
01/05/1982	10.28	0	0	0	34.77	0
02/02/1982	15.41	0	0	0	68.39	0
03/02/1982	11.78	0	0	0	49.77	0
05/05/1982	5.51	0	0	0	28.18	0
06/02/1982	7.27	0	0	0	63.44	0
07/07/1982	2.51	0	0	0	29.83	0
08/04/1982	19.55	0	0	0	49.60	0
09/08/1982	2.51	0	0	0	47.29	0
11/02/1983	55.37	22.35	0	0	70.86	0
12/28/1983	14.66	0	0	0	28.18	0
01/04/1984	9.77	0	2.96	0	22.89	0
02/08/1984	15.91	0	0	0	36.25	0
04/04/1984	13.16	0	0	0	22.74	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
04/09/1984	12.87	7.29	0	0	9.56	0
05/02/1984	13.28	0	0	0	30.65	0
07/04/1984	15.04	0	0	0	45.48	0
11/06/1984	12.78	0	0	0	47.46	0
12/05/1984	6.64	0	0	0	24.06	0
01/02/1985	6.77	0	0	0	33.12	0
03/06/1985	10.90	0	0	0	21.09	0
04/03/1985	12.03	0	0	0	41.03	0
05/08/1985	13.78	0	0	0	50.75	0
06/05/1985	14.66	0	0	0	50.59	0
07/03/1985	12.16	0	0	0	64.60	0
08/07/1985	13.66	0	0	0	83.05	0
09/04/1985	12.41	0	0	0	72.67	0
10/02/1985	7.89	0	0	0	68.88	0
11/06/1985	13.41	0	3.10	3.62	24.67	0
12/04/1985	14.66	0	0.15	4.89	24.16	0
01/08/1986	12.03	0	0	0	28.34	0
02/05/1986	6.77	0	1.24	0	33.57	0
03/05/1986	10.28	0	0	0	29.33	0
04/02/1986	9.52	0	0	0	32.79	0
05/07/1986	39.60	0	0	50.38	50.11	0
06/04/1986	14.79	0	0	0	74.48	0
07/02/1986	17.29	0	0	0	90.47	0
08/06/1986	17.79	0	0	0	103.32	0
09/03/1986	12.03	0	0	0	74.32	0
10/06/1986	2.51	0	0	0	22.74	0
11/05/1986	2.51	0	0	0	20.60	0
12/03/1986	2.51	0	0	0	21.75	0
01/07/1987	2.51	0	0	0	26.04	0
02/03/1987	7.39	0	0	0	24.88	0
03/07/1987	2.51	0	0	0	23.07	0
04/08/1987	5.64	0	0	0	22.25	0
05/06/1987	8.52	0	0	0	34.28	0
06/03/1987	12.03	0	0	0	48.78	0
07/08/1987	14.04	0	0	0	73.33	0
08/05/1987	14.66	0	0	0	92.61	0
09/09/1987	7.27	0	0	0	51.25	0
10/07/1987	9.27	0	0	0	28.84	0
11/04/1987	6.89	0	0	0	43.01	0
12/02/1987	6.27	0	0	0	33.45	0
01/06/1988	6.52	0	0	0	49.77	0
02/02/1988	5.26	0	0	0	62.95	0
03/02/1988	2.51	0	0	0	22.08	0
04/06/1988	2.51	0	0	0	26.53	0
06/08/1988	8.02	0	0	0	35.10	0
07/06/1988	10.90	0	0	0	40.70	0
05/04/1988	5.39	0	0	0	41.53	0
08/03/1988	9.40	0	0	0	52.73	0
09/07/1988	10.90	0	0	0	63.28	0
10/05/1988	6.14	0	0	0	60.64	0
11/02/1988	5.39	0	0	0	43.67	0
12/07/1988	2.51	0	0	0	17.63	0
01/04/1989	13.36	4.49	0	0	54.55	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
03/08/1989	11.40	0	0	0	18.29	0
04/04/1989	2.51	0	0	0	22.25	0
05/02/1989	2.51	0	0	0	19.28	0
06/06/1989	5.51	0	0	0	30.16	0
07/04/1989	10.65	0	0	0	36.58	0
08/01/1989	9.40	0	0	0	47.79	0
09/05/1989	22.43	0	0	0	70.04	0
10/03/1989	6.64	0	4.89	0	23.65	0
11/07/1989	2.51	0	3.58	0	19.33	0
12/05/1989	2.51	0	1.11	0	24.67	0
05/01/1990	8.27	0	0	0	24.72	0
03/05/1991	2.51	0	0	0	22.74	0
04/02/1991	2.51	0	0	0	20.93	0
06/04/1991	10.90	0	0	0	47.46	0
07/02/1991	9.65	0	0	0	50.10	0
08/06/1991	10.28	0	0	0	66.90	0
09/03/1991	10.53	0	0	0	64.76	0
10/01/1991	8.40	0	0	0	66.08	0
11/05/1991	6.14	0	0	0	15.65	0
12/03/1991	5.76	0	0	0	21.92	0
01/07/1992	5.26	0	0	0	28.18	0
02/04/1992	6.77	0	0	0	26.86	0
03/03/1992	6.14	0	0	0	23.07	0
04/07/1992	9.90	0	0	0	21.59	0
05/05/1992	11.15	0	0	0	28.34	0
06/02/1992	16.04	0	0	0	48.28	0
07/07/1992	15.79	0	0	0	49.93	0
08/11/1992	14.79	0	0	0	30.82	0
09/01/1992	11.28	0	0	0	58.34	0
10/06/1992	12.16	0	0	0	56.52	0
11/03/1992	13.78	0	0	0	46.14	0
12/01/1992	11.40	0	0	0	20.93	0
01/05/1993	9.52	0	0	0	19.61	0
02/02/1993	11.15	0	0	0	8.73	0
03/02/1993	9.90	0	0	0	14.83	0
04/06/1993	5.64	0	0	0	9.06	0
05/03/1993	10.90	0	0	0	14.83	0
06/01/1993	9.02	0	0	0	34.94	0
08/03/1993	10.28	0	0	0	42.19	0
09/07/1993	10.78	0	0	0	58.50	0
10/05/1993	11.65	0	0	0	16.48	0
11/02/1993	13.03	0	0	0	14.50	0
11/30/1993	11.78	0	0	0	14.17	0
01/04/1994	10.03	0	0	0	13.02	0
02/01/1994	8.02	0	0	0	11.54	0
03/01/1994	10.78	0	0	0	15.65	0
04/05/1994	9.15	0	0	0	16.64	0
05/03/1994	16.29	0	0	0	28.34	0
05/31/1994	7.02	0	0	0	28.67	0
07/05/1994	16.04	0	0	0	33.29	0
08/29/1994	16.17	0	0	0	19.94	0
08/02/1994	12.53	0	0	0	42.85	0
09/05/1994	5.89	0	0	0	30.82	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
09/19/1994	9.52	0	0	0	33.95	0
10/03/1994	8.27	0	0	0	39.38	0
09/26/1994	7.64	0	0	0	35.76	0
10/10/1994	17.82	1.45	0	0	14.83	0
10/17/1994	8.02	0	0	0	18.62	0
10/31/1994	6.39	0	0	0	23.73	0
10/14/1994	7.64	0	0	0	20.10	0
11/07/1994	7.14	0	0	0	21.75	0
11/21/1994	11.65	0	0	0	35.10	0
11/14/1994	12.16	0	0	0	29.33	0
12/12/1994	9.77	0	0	0	12.52	0
11/28/1994	11.53	0	0	0	36.58	0
12/26/1994	12.38	1.9	0	0	15.98	0.62
12/19/1994	8.65	0	0	0	18.13	0
01/02/1995	2.51	0	0	0	15.16	0
01/16/1995	14.29	0	0	0	17.30	0
01/30/1995	6.14	0	0	0	11.86	0
02/13/1995	2.51	0	0	0	11.04	0
02/06/1995	10.90	0	0	0	6.59	0
02/20/1995	5.14	0	0	0	12.19	0
01/09/1995	3.40	8.12	0	0	11.37	0
02/27/1995	11.90	0	0	0	63.77	0
01/23/1995	2.51	0	0	0	12.85	0
03/06/1995	12.28	0	0	0	11.37	0
03/20/1995	9.27	0	0	0	11.04	0
03/13/1995	14.16	0	0	0	35.76	0
03/27/1995	11.90	0	0	0	10.71	0
04/03/1995	5.51	0	0	0	9.56	0
04/10/1995	7.89	0	0	0	8.90	0
04/17/1995	9.15	0	0	0	12.19	0
04/24/1995	2.51	0	0	0	6.76	0
05/01/1995	2.51	0	0	0	4.94	0
05/15/1995	9.15	0	0	0	11.70	0
05/22/1995	8.90	0	0	0	11.37	0
06/12/1995	6.27	0	0	0	14.01	0
06/05/1995	8.15	0	0	0	11.86	0
06/19/1995	14.41	0	0	0	8.24	0
06/26/1995	7.77	0	0	0	12.52	0
07/07/1995	7.14	0	0	0	15.98	0
07/24/1995	6.02	0	0	0	22.08	0
08/07/1995	8.02	0	0	0	21.75	0
08/21/1995	13.03	0	0	0	29.50	0
09/04/1995	15.91	0	0	0	36.09	0
09/18/1995	9.15	0	0	0	46.64	0
10/02/1995	8.77	0	0	0	37.57	0
10/23/1995	14.29	0	0	0	19.94	0
10/30/1995	8.90	0	0	0	20.76	0
11/13/1995	5.89	0	0	0	12.36	0
11/27/1995	11.53	0	0	0	9.06	0
12/25/1995	13.78	0	0	0	13.84	0
12/11/1995	10.53	0	0	0	13.02	0
01/08/1996	7.89	0	0	0	13.84	0
01/22/1996	7.02	0	0	0	13.18	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/05/1996	7.39	0	0	0	12.36	0
02/19/1996	2.51	0	0	0	10.88	0
03/04/1996	11.39	3.73	0	0	18.29	5.65
03/18/1996	6.52	0	0	0	10.38	0
04/01/1996	2.51	0	0	0	13.35	0
04/15/1996	7.77	0	0	0	16.15	0
04/29/1996	2.51	0	0	0	11.54	0
05/13/1996	8.27	0	0	0	12.85	0
06/10/1996	8.02	0	0	0	20.10	0
05/27/1996	18.05	0	0	0	44.16	0
06/24/1996	16.29	0	0	0	24.55	0
07/08/1996	10.28	0	0	0	26.04	0
07/22/1996	17.42	0	0	0	32.96	0
08/05/1996	9.27	0	0	0	50.10	0
08/19/1996	8.15	0	0	0	33.95	0
09/02/1996	6.27	0	0	0	44.82	0
09/16/1996	14.04	0	0	0	30.82	0
09/30/1996	13.03	0	0	0	45.81	0
10/28/1996	11.40	0	0	0	32.30	0
10/14/1996	7.39	0	0	0	48.12	0
12/23/1996	9.27	0	0	0	16.81	0
11/25/1996	7.52	0	0	0	9.56	0
12/09/1996	0.63	0	0	0	14.83	0
01/06/1997	9.02	0	0	0	9.39	0
02/03/1997	6.14	0	0	0	10.05	0
03/17/1997	15.84	8.66	0	0	14.01	0
03/31/1997	7.89	0	0	0	10.55	0
04/14/1997	13.41	0	0	0	12.19	0
04/28/1997	9.40	0	0	0	11.54	0
05/12/1997	8.52	0	0	0	11.21	0
05/26/1997	9.02	0	0	0	17.47	0
05/27/1997	181.58	0	0	0	523.20	0
06/09/1997	7.89	0	0	0	20.76	0
06/23/1997	9.15	0	0	0	12.36	0
07/07/1997	2.51	0	0	0	14.34	0
07/21/1997	11.03	0	0	0	14.83	0
08/04/1997	10.53	0	0	0	20.27	0
09/01/1997	9.02	0	0	0	28.67	0
09/29/1997	18.30	0	0	0	35.92	0
08/18/1997	8.90	0	0	0	23.89	0
10/13/1997	15.41	0	0	0	43.01	0
09/15/1997	9.77	0	0	0	31.97	0
10/27/1997	13.16	0	0	0	14.17	0
11/10/1997	11.90	0	0	0	22.41	0
12/08/1997	8.02	0	0	0	14.50	0
12/22/1997	9.02	0	0	0	14.67	0
02/17/1997	6.27	0	0	0	12.36	0
03/03/1997	13.78	0	0	0	9.23	0
03/17/1997	7.52	0	0	0	7.75	0
01/06/1997	2.51	0	0	0	12.19	0
01/20/1997	7.52	0	0	0	10.05	0
01/05/1998	8.90	0	0	0	11.86	0
02/02/1998	6.02	0	0	0	9.39	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
03/16/1998	10.65	0	0	0	10.55	0
02/16/1998	9.27	0	0	0	9.23	0
03/02/1998	7.03	5.02	0	0	8.07	0
03/30/1998	7.64	0	0	0	13.02	0
04/13/1998	6.52	0	0	0	11.86	0
05/11/1998	2.51	0	0	0	13.68	0
04/27/1998	19.05	0	0	0	12.36	0
05/25/1998	10.28	0	0	0	16.31	0
06/22/1998	14.79	0	0	0	26.86	0
07/06/1998	8.90	0	0	0	26.53	0
06/08/1998	8.40	0	0	0	21.09	0
08/03/1998	9.02	0	0	0	29.83	0
08/31/1998	7.64	0	0	0	23.73	0
07/20/1998	8.15	0	0	0	32.63	0
09/14/1998	7.39	0	0	0	16.15	0
09/28/1998	10.53	0	0	0	21.42	0
10/12/1998	7.64	0	0	0	26.04	0
10/26/1998	8.27	0	0	0	20.76	0
11/09/1998	11.90	0	0	0	22.91	0
11/23/1998	12.78	0	0	0	23.56	0
12/21/1998	10.15	0	0	0	13.68	0
12/07/1998	2.51	0	0	0	11.54	0
09/22/1999	11.55	0	0	0	87.97	0
10/25/1999	13.57	0	0	0	19.78	0
11/03/1999	11.15	0	0	0	24.93	0
11/29/1999	8.98	0	0	0	16.72	0
11/17/1999	2.51	0	0	0	8.24	0
12/21/1999	10.07	0	0	0	8.24	0
10/20/1999	12.11	0	0	0	18.31	0
04/22/1999	2.51	0	0	0	8.24	0
10/06/1999	11.43	0	0	0	38.56	0
09/06/1999	15.00	0	0	0	49.61	0
01/04/1999	7.27	0	0	0	14.01	0
01/18/1999	6.89	0	0	0	15.82	0
02/01/1999	7.89	0	0	0	17.30	0
02/08/1999	5.01	0	0	0	9.23	0
02/16/1999	5.64	0	0	0	12.19	0
03/08/1999	5.26	0	0	0	17.47	0
02/22/1999	6.89	0	0	0	13.51	0
03/22/1999	9.65	0	0	0	12.36	0
04/07/1999	6.14	0	0	0	16.64	0
05/05/1999	2.51	0	0	0	16.31	0
05/03/1999	5.76	0	0	0	14.67	0
06/16/1999	12.28	0	0	0	27.03	0
06/30/1999	7.02	0	0	0	27.68	0
05/19/1999	8.65	0	0	0	20.27	0
06/01/1999	10.90	0	0	0	21.75	0
07/28/1999	13.03	0	0	0	24.88	0
07/16/1999	6.02	0	0	0	34.77	0
09/08/1999	11.78	0	0	0	51.25	0
08/02/1999	13.66	0	0	0	23.73	0
08/11/1999	9.65	0	0	0	35.26	0
08/25/1999	11.28	0	0	0	52.57	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
01/17/2000	2.51	0	0	0	8.24	0
01/26/2000	7.05	0	0	0	17.62	0
02/09/2000	7.15	0	0	0	18.43	0
02/23/2000	2.51	0	0	0	8.24	0
03/08/2000	2.51	0	0	0	8.24	0
03/22/2000	7.67	0	0	0	17.31	0
04/19/2000	13.38	0	0	0	27.53	0
04/11/2000	5.83	0	0	0	24.32	0
05/03/2000	10.32	0	0	0	28.82	0
05/17/2000	9.69	0	0	0	28.12	0
05/31/2000	9.08	0	0	0	30.08	0
06/14/2000	9.01	0	0	0	34.44	0
06/28/2000	8.61	0	0	0	34.40	0
07/12/2000	11.15	0	0	0	39.90	0
08/23/2000	12.61	0	0	0	55.20	0
09/06/2000	12.65	0	0	0	62.01	0
09/20/2000	14.56	3.31	0	0	21.26	0
10/04/2000	11.21	0	0	0	32.49	0
10/18/2000	16.52	0	0	0	23.00	0
11/01/2000	15.63	6.80	0	0	8.24	0
11/15/2000	8.00	0	0	0	8.24	0
12/13/2000	9.24	0	0	0	20.68	0
12/27/2000	11.85	0	0	0	21.92	0
01/10/2001	8.69	0	0	0	23.23	0
01/24/2001	6.28	0	0	0	20.11	0
02/07/2001	5.66	0	0	0	20.41	0
02/21/2001	11.26	0	0	0	8.24	0
03/07/2001	21.52	0.96	0	0	16.70	0
03/21/2001	13.00	1.77	0	0	8.24	0
04/18/2001	17.73	0	0	0	18.09	0
04/04/2001	13.48	0	0	0	18.57	0
05/02/2001	5.82	0	0	0	19.83	0
05/17/2001	8.04	0	0	0	24.87	0
05/30/2001	7.55	0	0	0	24.99	0
04/24/2001	12.48	0	0	0	17.65	0
06/13/2001	10.86	0	0	0	28.98	0
06/27/2001	5.94	0	0	0	31.68	0
07/11/2001	10.44	0	0	0	37.26	0
07/25/2001	6.34	0	0	0	28.57	0
08/08/2001	7.87	0	0	0	32.82	0
08/22/2001	9.94	0	0	0	37.86	0
09/05/2001	10.12	0	0	0	34.17	0
09/19/2001	11.43	0	0	0	20.51	0
10/03/2001	11.97	0	0	0	20.29	0
10/17/2001	2.51	0	0	0	23.96	0
10/31/2001	2.51	0	0	0	26.42	0
11/28/2001	14.79	1.39	0	0	8.24	0
12/12/2001	9.20	0	0	0	17.33	0
12/27/2001	7.66	0	0	0	19.05	0
01/24/2002	2.51	0	0	0	19.96	0
01/09/2002	2.51	0	0	0	16.56	0
02/06/2002	2.51	0	0	0	8.24	0
02/20/2002	6.83	0	0	0	16.68	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/07/2002	15.16	1.17	0	0	8.24	0
03/20/2002	5.71	0	1.50	0	17.83	0
04/01/2002	10.28	0	0	0	25.07	0
04/29/2002	10.44	0	0	0	26.97	0
05/27/2002	9.64	0	0	0	27.64	0
06/24/2002	6.85	0	0	0	31.25	0
07/22/2002	8.49	0	0	0	19.22	0
08/19/2002	8.68	0	0.66	0	16.45	0
09/16/2002	7.27	0	0	0	17.90	0
10/14/2002	6.47	0	0	0	25.45	0
11/11/2002	9.66	0	0	0	24.04	0
12/10/2002	10.09	0	0	0	8.24	0
01/06/2003	13.40	0	0	0	17.30	0
02/03/2003	5.51	0	0	0	18.94	0
03/03/2003	7.66	0	0	0	19.45	0
03/31/2003	2.51	0	0	0	17.81	0
04/28/2003	5.60	0	0	0	8.24	0
05/28/2003	9.99	0	0	0	8.24	0
06/25/2003	9.48	0	0	0	22.33	0
07/21/2003	6.14	0	0	0	25.08	0
08/18/2003	2.51	0	0	0	24.40	0
09/15/2003	6.78	0	0	0	16.97	0
10/13/2003	3.76	0	0	0	25.22	0
11/10/2003	3.76	0	0	0	12.00	0
12/08/2003	3.76	0	0	0	19.76	0
01/12/2004	3.76	0	0	0	15.65	0
01/26/2004	3.76	0	0	0	12.97	0
03/08/2004	3.76	0	0	0	12.86	0
04/05/2004	3.76	0	0	0	10.56	0
05/18/2004	3.76	0	0	0	10.56	0

(All concentrations measured in mg/L)

Table showing Output salt concentrations from the TIMS model at the Blinkwater weir

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
10/06/1977	44.49	0	0	0	248.83	0
10/13/1977	45.99	0	0	0	263.83	0
10/20/1977	45.86	0	0	0	259.87	0
10/28/1977	30.70	0	0	0	181.76	0
11/03/1977	2.51	0	0	0	57.02	0
11/10/1977	10.78	0	0	0	81.74	0
11/17/1977	30.20	0	0	0	163.31	0
11/24/1977	43.61	0	0	0	260.37	0
12/01/1977	16.54	0	0	0	88.49	0
12/08/1977	33.21	0	0	0	195.93	0
12/15/1977	40.10	0	0	0	226.25	0
12/22/1977	43.23	0	0	0	242.57	0
12/29/1977	45.36	0	0	0	261.52	0
04/07/1977	51.38	0	0	0	260.86	0
04/14/1977	51.50	0	0	0	264.49	0
04/21/1977	52.76	0	0	0	280.96	0
04/28/1977	30.45	0	0	0	170.23	0
05/05/1977	36.22	0	0	0	199.39	0
05/12/1977	21.55	0	0	0	126.72	0
05/20/1977	30.20	0	0	0	167.59	0
05/26/1977	35.34	0	0	0	195.77	0
06/03/1977	40.98	0	0	0	219.50	0
06/09/1977	43.11	0	0	0	230.70	0
06/16/1977	46.11	0	0	0	245.86	0
06/23/1977	48.62	0	0	0	254.10	0
06/30/1977	45.36	0	0	0	265.64	0
07/07/1977	47.12	0	0	0	264.82	0
07/14/1977	49.25	0	0	0	270.75	0
07/21/1977	45.61	0	0	0	278.00	0
07/28/1977	2.48	0	0	2.08	12.97	0.03
08/04/1977	5.01	0	0.74	2.76	16.79	0
08/11/1977	2.48	0	0	4.40	10.68	0.03
08/18/1977	25.19	0	0	2.73	70.45	0
08/25/1977	47.62	0	0	0	265.31	0
09/01/1977	46.37	0	0	0	266.96	0
09/08/1977	46.37	0	0	0	266.96	0
09/15/1977	46.49	0	0	0	266.30	0
09/22/1977	45.24	0	0	0	261.68	0
09/29/1977	22.31	0	0	0	121.12	0
01/05/1978	2.51	0	0	0	63.77	0
01/12/1978	21.30	0	0	0	159.85	0
01/19/1978	28.82	0	0	0	186.21	0
01/26/1978	35.09	0	0	0	214.23	0
02/02/1978	31.33	0	0	0	189.51	0
02/09/1978	29.95	0	0	0	179.78	0
02/16/1978	38.47	0	0	0	217.69	0
02/23/1978	41.60	0	0	0	240.10	0
03/02/1978	41.60	0	0	0	239.93	0
03/09/1978	46.87	0	0	0	248.67	0
03/16/1978	47.99	0	0	0	256.74	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
04/06/1978	45.49	0	0	0	253.12	0
04/12/1978	44.36	0	0	0	248.34	0
05/17/1978	41.60	0	0	0	217.85	0
06/14/1978	49.50	0	0	0	244.71	0
07/05/1978	50.25	0	0	0	276.02	0
08/02/1978	41.10	0	0	0	249.49	0
08/30/1978	47.99	0	0	0	235.15	0
09/27/1978	48.37	0	0	0	258.88	0
10/25/1978	34.84	0	0	0	265.15	0
11/22/1978	26.69	0	0	0	257.56	0
05/16/1979	56.77	0	0	0	284.75	0
06/13/1979	44.49	0	0	0	238.94	0
10/10/1979	53.88	0	0	0	235.48	0
10/17/1979	53.63	0	0	0	235.65	0
11/14/1979	50.25	0	0	0	262.01	0
12/05/1979	50.88	0	0	0	253.61	0
12/12/1979	34.84	0	0	0	260.37	0
12/19/1979	35.84	0	0	0	266.46	0
12/26/1979	30.70	0	0	0	239.44	0
01/16/1980	25.56	0	0	0	118.48	0
01/02/1980	55.76	0	0	0	233.51	0
01/23/1980	33.33	0	0	0	220.16	0
01/30/1980	42.11	0	0	0	226.58	0
02/06/1980	37.97	0	0	0	252.79	0
02/13/1980	43.73	0	0	0	242.57	0
02/20/1980	37.97	0	0	0	251.47	0
02/27/1980	38.72	0	0	0	255.59	0
03/05/1980	36.59	0	0	0	249.00	0
03/12/1980	27.57	0	0	0	184.23	0
03/19/1980	30.70	0	0	0	208.46	0
03/26/1980	35.59	0	0	0	211.92	0
04/02/1980	30.83	0	0	0	227.41	0
04/09/1980	40.35	0	0	0	232.02	0
04/16/1980	32.21	0	0	0	228.07	0
04/23/1980	34.71	0	0	0	222.96	0
04/30/1980	2.51	0	0	0	414.61	0
05/07/1980	2.51	0	0	0	400.77	0
05/14/1980	39.97	0	0	0	235.81	0
05/21/1980	45.24	0	0	0	234.82	0
05/28/1980	33.33	0	0	0	233.84	0
06/04/1980	55.51	0	0	0	229.88	0
06/11/1980	44.99	0	0	0	230.87	0
06/18/1980	45.61	0	0	0	229.22	0
06/25/1980	44.49	0	0	0	230.05	0
07/16/1980	47.62	0	0	0	232.68	0
07/23/1980	52.51	0	0	0	239.93	0
08/20/1980	36.22	0	0	0	246.36	0
08/27/1980	38.22	0	0	0	245.37	0
09/10/1980	36.72	0	0	0	253.28	0
09/17/1980	43.23	0	0	0	262.67	0
10/01/1980	39.97	0	0	0	252.79	0
10/08/1980	32.08	0	0	0	255.09	0
02/04/1981	54.26	0	0	0	187.53	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
02/18/1981	29.45	0	0	0	191.15	0
02/25/1981	17.79	0	0	0	52.57	0
03/04/1981	20.18	0	0	0	96.24	0
04/29/1981	60.15	0	0	0	242.24	0
05/27/1981	45.61	0	0	0	213.40	0
06/24/1981	46.62	0	0	0	165.12	0
07/22/1981	11.65	0	0	0	35.59	0
08/19/1981	71.93	0	0	0	287.23	0
09/16/1981	39.60	0	0	0	174.02	0
11/11/1981	27.32	0	0	0	229.06	0
12/15/1981	35.96	0	0	0	246.19	0
07/07/1982	45.61	0	0	0	234.16	0
08/04/1982	54.89	0	0	0	245.04	0
09/08/1982	47.99	0	0	0	236.97	0
01/04/1984	2.51	0	0	0	48.28	0
11/06/1985	59.52	0	0	0	100.19	0
12/04/1985	34.21	0	0	0	78.60	0
01/08/1986	33.96	0	0	0	111.73	0
01/15/1986	43.98	0	0	0	170.72	0
02/05/1986	32.21	0	0	0	112.55	0
03/05/1986	62.53	0	0	0	214.23	0
04/02/1986	68.17	0	0	0	227.74	0
05/01/1986	75.31	0	0	0	228.07	0
05/28/1986	77.82	0	0	0	243.56	0
06/04/1986	77.69	0	0	0	243.72	0
06/30/1986	76.82	0	0	0	228.89	0
07/02/1986	80.45	0	0	0	234.99	0
07/23/1986	83.21	0	0	0	220.82	0
08/06/1986	83.46	0	0	0	218.35	0
08/13/1986	79.82	0	0	0	227.90	0
08/20/1986	79.32	0	0	0	232.19	0
09/03/1986	78.45	0	0	0	221.81	0
09/23/1986	76.44	0	0	0	223.62	0
09/30/1986	73.56	0	0	0	221.15	0
10/07/1986	66.54	0	0	0	204.83	0
10/16/1986	41.35	0	0	0	159.02	0
11/05/1986	29.95	0	0	0	106.62	0
11/19/1986	53.51	0	0	0	176.16	0
11/26/1986	42.61	0	0	0	164.79	0
12/03/1986	47.37	0	0	0	164.95	0
12/10/1986	59.02	0	0	0	188.68	0
12/31/1986	49.12	0	0	0	192.80	0
01/14/1987	37.97	0	0	0	192.64	0
02/03/1987	46.11	0	0	0	203.35	0
01/28/1987	50.50	0	0	0	214.23	0
03/04/1987	49.75	0	0	0	231.53	0
03/11/1987	48.25	0	0	0	206.48	0
03/18/1987	47.62	0	0	0	223.95	0
03/25/1987	50.00	0	0	0	190.66	0
04/01/1987	52.00	0	0	0	197.58	0
04/08/1987	50.38	0	0	0	204.01	0
04/22/1987	53.01	0	0	0	196.26	0
04/29/1987	52.38	0	0	0	200.05	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
04/15/1987	45.61	0	0	0	217.19	0
05/06/1987	51.38	0	0	0	225.60	0
05/13/1987	53.26	0	0	0	217.19	0
05/20/1987	59.02	0	0	0	229.88	0
05/27/1987	58.65	0	0	0	208.46	0
06/03/1987	56.14	0	0	0	205.99	0
06/10/1987	58.52	0	0	0	207.96	0
06/18/1987	56.27	0	0	0	207.96	0
06/24/1987	56.14	0	0	0	207.96	0
07/02/1987	59.15	0	0	0	220.16	0
07/08/1987	58.27	0	0	0	219.33	0
07/15/1987	67.54	0	0	0	212.58	0
07/22/1987	60.78	0	0	0	223.78	0
07/29/1987	61.40	0	0	0	227.24	0
08/05/1987	59.52	0	0	0	222.79	0
08/12/1987	55.01	0	0	0	208.62	0
08/19/1987	54.89	0	0	0	204.50	0
08/26/1987	56.52	0	0	0	221.97	0
09/02/1987	54.26	0	0	0	219.66	0
09/09/1987	48.12	0	0	0	215.38	0
10/07/1987	48.87	0	0	0	202.36	0
10/28/1987	52.13	0	0	0	224.44	0
11/18/1987	50.00	0	0	0	239.11	0
11/04/1987	51.00	0	0	0	250.64	0
12/02/1987	41.23	0	0	0	273.71	0
11/11/1987	43.98	0	0	0	245.21	0
03/02/1988	39.10	0	0	0	88.99	0
03/09/1988	17.92	0	0	0	65.42	0
03/16/1988	62.53	0	0	0	201.21	0
02/24/1988	30.20	0	0	0	58.83	0
03/23/1988	65.66	0	0	0	201.54	0
03/30/1988	57.27	0	0	0	186.21	0
04/06/1988	50.38	0	0	0	170.23	0
04/13/1988	51.88	0	0	0	180.94	0
04/20/1988	47.62	0	0	0	162.15	0
04/27/1988	51.38	0	0	0	163.14	0
05/11/1988	48.87	0	0	0	148.80	0
05/25/1988	51.50	0	0	0	159.52	0
06/01/1988	49.25	0	0	0	152.76	0
06/08/1988	51.25	0	0	0	171.38	0
05/18/1988	56.14	0	0	0	168.91	0
06/15/1988	56.14	0	0	0	168.74	0
06/22/1988	57.52	0	0	0	184.23	0
06/29/1988	65.29	0	0	0	178.63	0
05/04/1988	55.14	0	0	0	164.46	0
07/06/1988	57.27	0	0	0	181.60	0
07/13/1988	57.27	0	0	0	186.71	0
07/20/1988	72.31	0	0	0	225.10	0
07/27/1988	65.66	0	0	0	196.10	0
08/03/1988	63.78	0	0	0	194.95	0
08/10/1988	67.29	0	0	0	219.83	0
08/17/1988	67.79	0	0	0	219.83	0
08/24/1988	66.54	0	0	0	209.78	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
08/31/1988	63.78	0	0	0	218.02	0
09/07/1988	59.77	0	0	0	225.10	0
09/14/1988	59.02	0	0	0	231.69	0
09/21/1988	50.75	0	0	0	216.86	0
09/28/1988	49.12	0	0	0	189.51	0
10/05/1988	51.25	0	0	0	203.02	0
10/19/1988	49.25	0	0	0	228.73	0
10/26/1988	47.74	0	0	0	216.20	0
11/30/1988	34.46	0	0	0	95.41	0
12/07/1988	33.71	0	0	0	142.38	0
12/14/1988	50.00	0	0	0	207.47	0
12/21/1988	19.80	0	0	0	80.09	0
12/28/1988	13.03	0	0	0	69.05	0
01/04/1989	42.73	0	0	0	125.40	0
01/11/1989	9.40	0	0	0	60.31	0
01/18/1989	36.34	0	0	0	140.40	0
01/25/1989	43.61	0	0	0	160.83	0
02/01/1989	40.98	0	0	0	180.94	0
02/15/1989	39.60	0	0	0	173.36	0
02/22/1989	39.47	0	0	0	162.98	0
03/15/1989	38.60	0	0	0	185.22	0
02/08/1989	47.62	0	0	0	180.11	0
03/01/1989	43.36	0	0	0	182.09	0
03/08/1989	48.75	0	0	0	180.94	0
03/22/1989	27.32	0	0	0	108.43	0
03/28/1989	36.34	0	0	0	148.31	0
04/04/1989	48.37	0	0	0	171.71	0
04/11/1989	31.83	0	0	0	114.36	0
04/18/1989	14.79	0	0	0	59.98	0
04/25/1989	15.54	0	0	0	61.47	0
05/02/1989	12.66	0	0	0	66.74	0
06/06/1989	46.24	0	0	0	142.38	0
07/04/1989	48.87	0	0	0	149.63	0
08/01/1989	51.13	0	0	0	160.17	0
09/05/1989	57.77	0	0	0	162.98	0
10/03/1989	5.01	0	3.78	0	40.19	0
11/07/1989	14.29	0	0	0	80.91	0
12/05/1989	23.56	0	0	0	119.64	0
05/01/1990	31.58	0	0	0	130.68	0
10/02/1990	37.34	0	0	0	168.58	0
03/05/1991	33.71	0	0	0	141.06	0
04/02/1991	32.58	0	0	0	142.21	0
05/07/1991	34.71	0	0	0	160.34	0
06/04/1991	38.97	0	0	0	169.57	0
08/06/1991	41.73	0	0	0	176.82	0
10/22/1991	26.69	0	0	0	190.66	0
11/05/1991	15.66	0	0	0	72.01	0
12/03/1991	30.45	0	0	0	127.55	0
01/07/1992	20.93	0	0	0	129.19	0
02/04/1992	23.18	0	0	0	150.29	0
04/07/1992	29.57	0	0	0	113.37	0
05/05/1992	28.32	0	0	0	122.60	0
09/01/1992	82.46	0	0	0	188.52	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
12/28/1993	53.96	8.78	0	0	25.21	0
01/04/1994	77.57	0	0	0	61.30	0
02/01/1994	74.19	0	0	0	87.67	0
03/01/1994	49.62	0	0	0	104.31	0
04/04/1994	60.78	0	0	0	105.79	0
05/03/1994	67.79	0	0	0	122.93	0
05/31/1994	71.93	0	0	0	118.65	0
08/02/1994	93.98	0	0	0	124.09	0
06/05/1994	89.60	0	0	0	128.37	0
09/05/1994	99.87	0	0	0	129.85	0
10/03/1994	91.60	0	0	0	130.02	0
10/17/1994	85.59	0	0	0	123.43	0
02/06/1995	65.79	0	0	0	140.40	0
01/16/1995	52.38	0	0	0	101.35	0
01/23/1995	52.13	0	0	0	129.85	0
03/06/1995	44.36	0	0	0	86.51	0
03/20/1995	48.50	0	0	0	126.72	0
04/06/1995	49.62	0	0	0	104.64	0
04/19/1995	35.96	0	0	0	82.06	0
05/04/1995	72.18	0	0	0	115.02	0
05/18/1995	76.82	0	0	0	117.49	0
06/15/1995	67.79	0	0	0	125.07	0
07/13/1995	64.79	0	0	0	136.45	0
06/29/1995	67.79	0	0	0	128.04	0
07/27/1995	77.07	0	0	0	131.01	0
06/01/1995	69.30	0	0	0	121.45	0
08/24/1995	61.28	0	0	0	132.65	0
09/07/1995	60.53	0	0	0	117.82	0
09/21/1995	60.78	0	0	0	134.63	0
10/05/1995	51.50	0	0	0	141.55	0
10/25/1995	46.62	0	0	0	140.07	0
10/31/1995	22.18	0	0	0	15.49	0
12/27/1995	28.82	0	0	0	45.48	0
01/10/1996	40.98	0	0	0	154.08	0
01/24/1996	7.02	23.97	0	0	37.74	0
02/07/1996	26.69	0	0	0	97.23	0
02/21/1996	27.44	0	0	0	91.29	0
03/06/1996	21.30	0	0	0	64.60	0
03/20/1996	23.93	0	0	0	100.52	0
04/03/1996	20.55	0	0	0	41.53	0
05/01/1996	30.33	0	0	0	104.15	0
04/17/1996	25.81	0	0	0	91.46	0
05/15/1996	34.84	0	0	0	105.30	0
05/29/1996	34.08	0	0	0	107.77	0
06/12/1996	35.09	0	0	0	106.62	0
06/26/1996	42.73	0	0	0	115.19	0
07/10/1996	35.59	0	0	0	113.21	0
07/24/1996	40.60	0	0	0	106.45	0
08/07/1996	37.22	0	0	0	106.95	0
08/21/1996	37.72	0	0	0	116.01	0
09/04/1996	38.22	0	0	0	118.32	0
09/18/1996	37.09	0	0	0	122.60	0
10/02/1996	31.20	0	0	0	123.43	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
10/30/1996	36.09	0	0	0	116.34	0
10/16/1996	35.34	0	0	0	128.54	0
12/25/1996	33.21	0	0	0	120.46	0
11/13/1996	22.56	0	0	0	101.02	0
11/27/1996	11.28	0	0	0	77.78	0
12/11/1996	27.57	0	0	0	87.83	0
02/05/1997	23.18	0	0	0	69.87	0
03/19/1997	29.45	0	0	0	103.65	0
04/02/1997	23.56	0	0	0	62.45	0
04/16/1997	32.46	0	0	0	70.53	0
04/30/1997	31.95	0	0	0	74.48	0
05/14/1997	18.55	0	0	0	106.29	0
05/28/1997	22.56	0	0	0	119.64	0
06/11/1997	29.45	0	0	0	114.20	0
06/26/1997	28.82	0	0	0	88.99	0
07/09/1997	27.07	0	0	0	99.37	0
07/23/1997	30.70	0	0	0	106.95	0
08/06/1997	29.20	0	0	0	119.80	0
09/03/1997	38.10	0	0	0	149.96	0
09/17/1997	34.34	0	0	0	142.54	0
10/01/1997	32.33	0	0	0	142.54	0
08/20/1997	37.72	0	0	0	141.06	0
10/29/1997	33.08	0	0	0	118.32	0
10/15/1997	37.34	0	0	0	133.64	0
11/12/1997	32.96	0	0	0	136.12	0
11/26/1997	38.10	0	0	0	126.39	0
12/10/1997	33.58	0	0	0	123.10	0
12/24/1997	32.58	0	0	0	137.93	0
02/19/1997	21.30	0	0	0	101.02	0
03/05/1997	36.34	0	0	0	94.92	0
03/19/1997	32.58	0	0	0	101.51	0
01/08/1997	23.81	0	0	0	125.57	0
01/22/1997	16.29	0	0	0	62.13	0
01/07/1998	26.69	0	0	0	144.52	0
01/21/1998	35.84	0	0	0	149.13	0
02/04/1998	32.21	0	0	0	131.67	0
02/18/1998	30.95	0	0	0	135.79	0
03/04/1998	26.44	0	0	0	33.45	0
03/18/1998	31.45	0	0	0	98.21	0
04/15/1998	28.95	0	0	0	117.16	0
05/13/1998	38.97	0	0	0	124.58	0
04/29/1998	28.20	0	0	0	112.55	0
05/27/1998	33.08	0	0	0	124.25	0
07/08/1998	32.96	0	0	0	121.45	0
06/24/1998	35.21	0	0	0	128.86	0
06/10/1998	51.38	0	0	0	114.20	0
07/22/1998	31.08	0	0	0	119.47	0
08/19/1998	33.71	0	0	0	122.93	0
09/02/1998	17.79	0	0	0	115.02	0
08/06/1998	70.17	0	0	0	102.83	0
09/16/1998	24.94	0	0	0	123.26	0
09/30/1998	36.59	0	0	0	126.89	0
10/14/1998	24.06	0	0	0	119.47	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
11/11/1998	29.20	0	0	0	136.77	0
11/25/1998	24.94	0	0	0	134.63	0
12/23/1998	22.56	0	0	0	82.23	0
12/09/1998	23.43	0	0	0	66.08	0
09/22/1999	24.27	0	0	0	138.08	0
10/06/1999	21.53	0	0	0	123.88	0
04/22/1999	28.72	0	0	0	75.36	0
09/06/1999	32.48	0	0	0	120.55	0
01/06/1999	22.18	0	0	0	113.54	0
01/20/1999	24.69	0	0	0	108.76	0
01/18/1999	30.83	0	0	0	109.91	0
02/03/1999	26.82	0	0	0	138.75	0
03/10/1999	20.30	0	0	0	123.26	0
03/24/1999	20.80	0	0	0	89.81	0
02/24/1999	19.05	0	0	0	55.37	0
04/07/1999	26.19	0	0	0	94.75	0
05/05/1999	22.68	0	0	0	88.49	0
06/30/1999	25.44	0	0	0	106.95	0
05/19/1999	23.93	0	0	0	93.60	0
06/16/1999	26.82	0	0	0	98.87	0
06/01/1999	23.56	0	0	0	106.95	0
07/16/1999	24.31	0	0	0	116.01	0
08/11/1999	28.32	0	0	0	111.89	0
07/28/1999	33.58	0	0	0	111.73	0
09/08/1999	27.44	0	0	0	122.11	0
08/02/1999	24.94	0	0	0	98.71	0
08/25/1999	24.94	0	0	0	98.71	0
01/17/2000	29.74	0	0	0	34.72	0
02/09/2000	31.30	0	0	0	94.12	0
01/26/2000	26.79	0	0	0	61.16	0
02/23/2000	18.86	0	0	0	53.83	0
03/08/2000	13.36	0	0	0	37.60	0
03/22/2000	22.87	0	0	0	45.04	0
04/05/2000	15.99	0	0	0	27.89	0
04/19/2000	30.85	0	0	0	109.26	0
05/17/2000	34.64	0	0	0	122.12	0
05/03/2000	30.90	0	0	0	105.31	0
05/31/2000	43.36	0	0	0	142.61	0
06/14/2000	52.81	0	0	0	160.61	0
06/28/2000	53.58	0	0	0	175.94	0
07/12/2000	56.98	0	0	0	169.73	0
07/26/2000	56.99	0	0	0	169.36	0
08/09/2000	48.90	0	0	0	163.69	0
08/23/2000	45.86	0	0	0	167.85	0
09/06/2000	56.57	0	0	0	164.10	0
09/20/2000	49.67	0	0	0	80.10	0
10/04/2000	49.26	0	0	0	155.58	0
10/18/2000	38.37	0	0	0	158.91	0
11/01/2000	54.16	0	0	0	144.45	0
11/15/2000	6.19	43.47	0	0	50.74	0
11/29/2000	15.73	0	0	0	26.12	0
12/27/2000	35.79	0	0	0	131.70	0
12/13/2000	18.26	0	0	0	88.94	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
01/10/2001	35.27	0	0	0	146.39	0
01/24/2001	32.17	0	0	0	137.64	0
02/07/2001	34.49	0	0	0	139.08	0
02/21/2001	23.42	0	0	0	110.64	0
03/07/2001	34.45	0	0	0	150.34	0
03/21/2001	21.11	0	0	0	82.46	0
04/18/2001	21.57	0	0	0	87.54	0
04/04/2001	22.13	0	0	0	48.39	0
05/02/2001	23.73	0	0	0	95.81	0
05/17/2001	28.39	0	0	0	119.46	0
05/30/2001	34.29	0	0	0	127.24	0
04/23/2001	19.46	0	0	0	74.16	0
06/13/2001	39.98	0	0	0	133.48	0
06/27/2001	34.71	0	0	0	130.68	0
07/11/2001	39.57	0	0	0	141.72	0
07/25/2001	35.33	0	0	0	126.31	0
08/08/2001	32.54	0	0	0	131.57	0
08/22/2001	37.04	0	0	0	138.25	0
09/05/2001	30.85	0	0	0	130.63	0
09/19/2001	38.25	0	0	0	125.62	0
10/03/2001	32.32	0	0	0	139.08	0
10/17/2001	28.48	0	0	0	130.93	0
10/31/2001	32.28	0	0	0	135.48	0
11/14/2001	38.99	0	0	0	137.07	0
11/28/2001	23.57	0	0	0	69.06	0
12/12/2001	23.04	0	0	0	61.90	0
12/27/2001	21.75	0	0	0	102.02	0
01/24/2002	28.13	0	0	0	124.03	0
01/09/2002	16.59	0	0	0	65.46	0
02/06/2002	25.79	0	0	0	101.65	0
02/20/2002	18.88	0	0	0	108.13	0
04/01/2002	29.17	0	0	0	109.30	0
04/29/2002	31.24	0	0	0	110.06	0
05/27/2002	35.58	0	0	0	128.05	0
06/24/2002	23.55	0	0	0	123.78	0
07/22/2002	29.06	0	0	0	116.17	0
08/19/2002	22.42	0	0	0	110.41	0
09/16/2002	24.90	0	0	0	93.32	0
10/14/2002	35.91	0	0	0	136.38	0
11/11/2002	34.90	0	0	0	137.96	0
12/10/2002	30.28	0	0	0	155.22	0
01/06/2003	37.60	0	0	0	133.91	0
02/03/2003	38.32	0	0	0	198.09	0
03/03/2003	35.93	0	0	0	140.24	0
03/31/2003	21.27	0	0	0	88.23	0
04/28/2003	27.07	0	0	0	126.43	0
05/26/2003	42.91	0	0	0	133.03	0
06/25/2003	43.41	0	0	0	130.95	0
07/21/2003	30.59	0	0	0	149.32	0
08/18/2003	39.15	0	0	0	134.89	0
09/17/2003	35.81	0	0	0	146.00	0
10/13/2003	37.61	0	0	0	176.11	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
11/10/2003	34.58	0	0	0	160.21	0
01/26/2004	19.93	0	0	0	66.90	0
02/23/2004	28.68	0	0	0	216.78	0

(All concentrations measured in mg/L)

Table showing Output salt concentrations from the TIMS model at the Fort-Beaufort weir

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
12/29/1992	22.31	0	0	0	71.35	0
01/26/1993	26.44	0	0	0	32.30	0
04/06/1993	17.92	0	0	0	81.90	0
04/06/1993	17.17	0	0	0	85.69	0
06/29/1993	32.71	0	0	0	145.84	0
09/07/1993	38.85	0	0	0	175.50	0
11/02/1993	28.07	0	0	0	128.86	0
11/02/1993	27.44	0	0	0	131.17	0
11/16/1993	15.79	0	0	0	20.43	0
11/30/1993	21.18	0	0	0	34.28	0
12/14/1993	15.16	0	0	0	36.75	0
12/28/1993	15.41	0	0	0	19.12	0
01/25/1994	6.27	0	0	0	43.17	0
01/11/1994	24.19	0	0	0	23.40	0
02/08/1994	6.80	15.64	0	0	20.43	0
02/22/1994	16.42	0	0	0	23.56	0
03/08/1994	18.17	0	0	0	49.27	0
03/22/1994	18.42	0	0	0	62.29	0
04/05/1994	21.55	0	0	0	80.75	0
05/31/1994	47.99	0	0	0	208.79	0
07/26/1994	43.73	0	0	0	187.69	0
08/09/1994	34.46	0	0	0	176.82	0
10/17/1994	22.56	0	0	0	27.85	0
11/28/1994	31.83	0	0	0	106.62	0
12/26/1994	31.70	0	0	0	155.07	0
02/06/1995	13.91	0	0	0	51.91	0
01/09/1995	18.92	0	0	0	37.41	0
01/23/1995	9.90	0	0	0	24.72	0
03/06/1995	26.57	0	0	0	103.32	0
04/05/1995	18.80	0	0	0	69.05	0
04/03/1995	27.69	0	0	0	75.14	0
04/19/1995	13.28	0	0	0	42.52	0
05/03/1995	19.55	0	0	0	70.53	0
05/17/1995	23.93	0	0	0	91.29	0
09/20/1995	45.36	0	0	0	169.57	0
11/29/1995	17.04	0	0	0	67.89	0
12/13/1995	19.17	0	0	0	37.08	0
01/10/1996	22.31	0	0	0	50.26	0
02/07/1996	15.54	0	0	0	37.41	0
02/21/1996	14.79	0	0	0	26.70	0
03/06/1996	23.68	0	0	0	22.58	0
03/20/1996	16.67	0	0	0	53.23	0
04/03/1996	12.53	0	0	0	30.65	0
05/01/1996	12.16	0	0	0	61.80	0
04/17/1996	12.91	0	0	0	54.87	0
05/29/1996	26.57	0	0	0	121.78	0
06/26/1996	49.62	0	0	0	227.41	0
08/21/1996	48.12	0	0	0	217.03	0
11/13/1996	28.20	0	0	0	127.38	0
12/25/1996	27.19	0	0	0	81.41	0
11/13/1996	22.56	0	0	0	127.22	0
11/27/1996	31.33	0	0	0	11.54	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
12/11/1996	10.03	0	0	0	54.05	0
02/05/1997	20.43	0	0	0	46.96	0
03/19/1997	19.30	0	0	0	38.56	0
04/02/1997	29.32	0	0	0	60.48	0
04/16/1997	20.80	0	0	0	29.00	0
04/30/1997	25.56	0	0	0	29.00	0
05/14/1997	14.91	0	0	0	44.66	0
05/28/1997	24.56	0	0	0	79.43	0
06/11/1997	24.31	0	0	0	63.11	0
07/09/1997	28.82	0	0	0	47.13	0
06/25/1997	26.32	0	0	0	41.53	0
07/23/1997	25.56	0	0	0	71.02	0
08/06/1997	28.07	0	0	0	95.91	0
08/20/1997	23.56	0	0	0	103.65	0
09/03/1997	34.96	0	0	0	158.69	0
10/29/1997	13.53	0	0	0	36.25	0
10/15/1997	62.78	0	0	0	272.89	0
11/26/1997	46.11	0	0	0	205.66	0
02/19/1997	0.63	0	0	0	34.11	0
03/05/1997	22.56	0	0	0	25.21	0
03/19/1997	18.80	0	0	0	40.87	0
01/08/1997	16.29	0	0	0	83.05	0
01/22/1997	25.06	0	0	0	45.98	0
02/04/1998	17.29	0	0	0	39.71	0
02/18/1998	28.32	0	0	0	75.14	0
03/04/1998	1.85	19.41	0	0	13.51	0
03/18/1998	17.92	0	0	0	30.98	0
04/01/1998	21.05	0	0	0	52.24	0
04/15/1998	18.67	0	0	0	59.49	0
05/13/1998	18.05	0	0	0	75.47	0
04/29/1998	25.56	0	0	0	92.45	0
07/22/1998	40.10	0	0	0	172.53	0
09/19/1998	31.58	0	0	0	117.66	0
09/16/1998	16.17	0	0	0	80.09	0
12/09/1998	17.54	0	0	0	29.83	0
12/23/1998	17.04	0	0	0	37.57	0
08/25/1999	31.12	0	0	0	156.74	0
09/22/1999	32.23	0	0	0	160.38	0
12/21/1999	28.83	0	0	0	123.51	0
04/22/1999	26.45	0	0	0	94.98	0
03/24/1999	34.93	0	0	0	150.94	0
01/20/1999	28.57	0	0	0	126.56	0
01/21/1999	30.45	0	0	0	133.64	0
02/24/1999	23.93	0	0	0	88.82	0
07/28/1999	23.93	0	0	0	88.82	0
01/12/2000	13.82	0	0	0	27.68	0
01/26/2000	15.55	0	0	0	47.04	0
02/23/2000	27.35	0	0	0	38.38	0
02/14/2000	14.45	3.99	0	0	8.24	0
03/08/2000	14.89	0	0	0	30.59	0
03/22/2000	10.10	0	0	0	23.35	0
04/10/2000	14.90	0	0	0	40.69	0
04/19/2000	22.27	0	0	0	50.29	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
05/04/2000	23.90	0	0	0	61.79	0
05/17/2000	20.76	0	0	0	83.08	0
05/31/2000	25.16	0	0	0	111.27	0
06/14/2000	32.85	0	0	0	141.32	0
06/28/2000	35.34	0	0	0	160.44	0
07/12/2000	37.13	0	0	0	183.22	0
08/23/2000	18.39	0	0	0	29.98	0
09/20/2000	30.06	0	0	0	94.34	0
10/04/2000	30.72	0	0	0	101.29	0
10/18/2000	44.35	0	0	0	193.76	0
11/01/2000	46.79	0	0	0	167.88	0
11/15/2000	20.58	10.08	0	0	26.38	22.45
11/29/2000	19.88	15.64	0	0	27.71	0
12/27/2000	22.99	0	0	0	101.05	0
12/13/2000	23.38	0	0	0	40.45	0
01/10/2001	19.27	0	0	0	87.30	0
01/24/2001	18.99	0	0	0	72.76	0
02/07/2001	22.51	0	0	0	78.93	0
02/21/2001	21.11	0	0	0	42.62	0
03/07/2001	21.59	0	0	0	78.01	0
03/21/2001	15.80	0	0	0	26.64	0
04/18/2001	17.34	0	0	0	36.77	0
04/04/2001	18.47	0	0	0	28.11	0
05/02/2001	19.15	0	0	0	75.72	0
05/17/2001	30.92	0	0	0	117.02	0
05/30/2001	32.36	0	0	0	156.86	0
04/23/2001	18.16	0	0	0	41.62	0
06/13/2001	39.51	0	0	0	194.68	0
06/27/2001	43.09	0	0	0	222.43	0
07/11/2001	44.97	0	0	0	243.35	0
07/25/2001	53.02	0	0	0	277.72	0
08/08/2001	29.47	0	0	0	168.78	0
08/22/2001	25.15	0	0	0	116.32	0
09/05/2001	38.52	0	0	0	140.41	0
09/19/2001	35.48	0	0	0	152.97	0
10/03/2001	13.78	0	1.40	0	42.27	0
10/17/2001	18.02	0	0	0	95.34	0
10/31/2001	31.71	0	0	0	151.92	0
11/14/2001	37.25	0	0	0	124.76	0
11/28/2001	13.16	0	0	0	37.14	0
12/12/2001	18.01	0	0	0	24.88	0
12/27/2001	18.78	0	0	0	57.78	0
01/23/2002	15.96	0	0	0	82.41	0
01/09/2002	22.64	9.33	0	0	29.94	2.82
02/06/2002	18.22	0	0	0	67.48	0
02/20/2002	18.88	0	0	0	90.95	0
03/06/2002	28.75	0	0	0	136.83	0
04/01/2002	32.90	0	0	0	137.57	0
04/29/2002	40.63	0	0	0	148.51	0
06/10/2002	54.79	0	0	0	268.24	0
06/24/2002	23.55	0	0	0	204.16	0
07/22/2002	17.47	0	0	0	30.78	0
08/19/2002	13.78	0	0	0	70.11	0

(All concentrations measured in mg/L)

Date	$MgSO_4$	Na_2SO_4	$MgCl_2$	$CaCl_2$	NaCl	$CaSO_4$
09/16/2002	18.91	0	0	0	43.38	0
10/14/2002	27.15	0	0	0	133.73	0
11/11/2002	52.98	0	0	0	233.43	0
12/09/2002	28.83	0	0	0	132.42	0
01/06/2003	27.51	0	0	0	83.38	0
02/03/2003	20.88	0	3.42	0	101.49	0
03/03/2003	27.80	0	0	0	102.88	0
03/31/2003	22.51	0	0	0	88.15	0
04/28/2003	20.60	0	0	0	87.65	0
05/29/2003	27.43	0	0	0	81.89	0
06/25/2003	25.01	0	0	0	114.94	0
07/21/2003	29.88	0	0	0	141.68	0
11/10/2003	38.62	0	0	0	196.57	0
01/26/2004	18.80	0	0	0	72.04	0
03/08/2004	14.29	0	0	0	53.97	0
04/05/2004	12.30	0	0	0	47.52	0

(All concentrations measured in mg/L)

APPENDIX F: MEAN DAILY FLOWS FROM DWAF WATER MONITORING SITES

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
07/08/1983	0.347	12/27/1985	1.636	02/04/1991	0.012
07/15/1983	0.006	01/29/1986	0.211	03/04/1991	0.046
07/22/1983	0.006	02/21/1986	0.713	04/01/1991	0.030
07/29/1983	0.006	03/21/1986	0.220	05/13/1991	0.019
08/05/1983	0	04/25/1986	0.032	06/10/1991	0.012
08/12/1983	0	05/23/1986	0.013	07/08/1991	1.377
08/19/1983	0	08/15/1986	0.012	08/05/1991	0.008
08/26/1983	0	09/12/1986	0.012	09/02/1991	0.011
09/02/1983	0	10/10/1986	0.013	09/30/1991	1.529
09/09/1983	0	11/07/1986	1.030	10/28/1991	0.029
09/16/1983	0	02/06/1987	0.054	11/25/1991	0.273
09/23/1983	0.012	03/06/1987	0.015	12/23/1991	0.362
10/07/1983	0.012	01/16/1987	0.072	01/06/1992	0.152
10/14/1983	0.504	04/24/1987	1.649	02/03/1992	1.448
10/21/1983	0.012	05/22/1987	0.012	03/02/1992	1.189
10/28/1983	0.012	06/26/1987	0.013	04/13/1992	0.012
11/04/1983	0.012	07/24/1987	0.010	05/04/1992	0.011
11/11/1983	0.006	08/21/1987	0.064	04/20/1992	0.012
11/18/1983	0.006	09/18/1987	0.932	05/12/1992	0.009
11/25/1983	0.006	10/16/1987	0.013	04/27/1992	0.694
12/09/1983	0	11/13/1987	0.012	05/25/1992	0.581
12/16/1983	0	12/11/1987	0.138	05/18/1992	1.372
12/23/1983	0.012	01/22/1988	0.184	06/01/1992	0.028
01/06/1984	0.012	02/19/1988	2.869	06/08/1992	0.021
01/13/1984	0.006	03/18/1988	0.029	06/29/1992	0.031
01/20/1984	0.006	04/15/1988	0.137	07/06/1992	0.040
01/27/1984	0.006	05/13/1988	0.138	06/22/1992	0.030
02/03/1984	0	06/15/1988	0.000	06/15/1992	0.023
02/10/1984	0	07/11/1988	0.000	07/13/1992	0.021
02/17/1984	0.012	08/08/1988	0.012	08/03/1992	2.424
03/16/1984	0.012	09/05/1988	0.013	07/27/1992	1.665
04/13/1984	0.012	10/03/1988	1.401	07/20/1992	0.030
03/23/1984	0.012	10/31/1988	0.012	09/07/1992	0.030
03/30/1984	0.012	11/28/1988	0.139	09/14/1992	0.005
04/06/1984	0.012	12/06/1988	0.138	08/17/1992	0.030
05/11/1984	0.012	01/23/1989	0.171	08/10/1992	0.030
06/08/1984	0.012	02/27/1989	0.206	09/30/1992	0.007
07/06/1984	0.009	04/03/1989	0.205	08/24/1992	0.030
08/03/1984	0.012	05/29/1989	0.030	09/21/1992	1.666
10/05/1984	0.012	05/01/1989	0.012	10/05/1992	0.199
11/02/1984	0.012	06/26/1989	0.000	09/28/1992	0.005
11/30/1984	0.012	07/24/1989	0.013	10/19/1992	0.003
12/28/1984	0.012	08/21/1989	0.013	10/12/1992	0.005
01/25/1985	0.012	09/18/1989	0.012	10/26/1992	0.005
03/22/1985	0.012	10/16/1989	0.000	10/21/1992	0.229
05/17/1985	0.012	11/13/1989	0.107	11/09/1992	0.118
06/14/1985	0.012	12/11/1989	0.440	11/16/1992	0.004
07/05/1985	0.012	05/14/1990	0.050	11/30/1992	0.176
07/12/1985	0.012	10/01/1990	0.041	12/09/1992	1.941
09/06/1985	0.012	10/08/1990	0.041	12/15/1992	1.540
10/04/1985	0.011	10/15/1990	0.041	12/21/1992	0.006
11/01/1985	0.013	11/12/1990	0.211	12/28/1992	0.223
11/29/1985	0.011	12/10/1990	0.018	01/04/1993	0.146

Date	Flow(m3/S)	Date	Flow(m3/S)
03/16/1998	0.006	05/02/2000	0.888
04/13/1998	0.006	05/29/2000	0.146
05/11/1998	0.036	06/26/2000	0.120
04/07/1998	0.007	07/10/2000	0.042
06/15/1998	2.010	08/14/2000	1.398
06/22/1998	0.008	08/28/2000	0.001
08/24/1998	0.045	09/04/2000	0.021
08/24/1998	0.045	10/02/2000	0.015
09/07/1998	0.009	11/09/2000	3.758
10/17/1998	0.035	05/21/2001	0.100
12/28/1998	0.088	05/14/2001	0.179
09/13/1999	0.017	05/28/2001	0.083
10/04/1999	0.014	04/23/2001	1.463
11/29/1999	0.014	06/04/2001	0.100
11/15/1999	0.011	11/12/2001	0.001
11/08/1999	0.014	11/12/2001	0.001
12/20/1999	0.021		
04/12/1999	0.028		
08/16/1999	0.015		
08/23/1999	1.666		
09/09/1999	0.019		
10/18/1999	0.014		
10/11/1999	0.014		
01/18/1999	0.104		
03/01/1999	0.015		
03/15/1999	0.009		
03/29/1999	0.014		
02/15/1999	0.072		
04/26/1999	0.037		
04/13/1999	0.021		
05/10/1999	0.039		
05/31/1999	0.011		
06/28/1999	0.015		
05/17/1999	0.009		
06/14/1999	0.014		
06/07/1999	0.012		
05/24/1999	0.013		
06/21/1999	0.012		
07/26/1999	1.861		
07/05/1999	0.017		
07/12/1999	0.017		
07/19/1999	0.018		
09/06/1999	0.019		
08/09/1999	0.017		
08/02/1999	0.016		
08/02/1999	0.016		
01/17/2000	0.017		
02/07/2000	0.007		
02/21/2000	0.015		
03/06/2000	0.012		
03/29/2000	5.264		
04/11/2000	1.181		
05/17/2000	0.194		

Pooled daily mean flow records from the Balfour weir from 1977 to 2004

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
10/07/1977	0.175	11/08/1978	0.575	07/15/1980	0.005
10/14/1977	0.084	11/15/1978	0.240	07/22/1980	0.011
10/21/1977	0.242	11/22/1978	0.173	07/29/1980	0.008
10/28/1977	0.333	11/29/1978	0.061	08/12/1980	0.017
11/04/1977	2.274	12/06/1978	0.132	08/19/1980	0.013
11/11/1977	0.701	12/13/1978	0.416	08/26/1980	0.013
11/18/1977	0.299	12/20/1978	0.149	09/02/1980	0.013
11/25/1977	0.115	12/27/1978	0.338	09/09/1980	0.040
12/02/1977	0.780	01/03/1979	1.521	09/16/1980	0.025
12/09/1977	0.289	01/10/1979	0.295	09/23/1980	0.028
12/15/1977	0.301	04/25/1979	0.084	09/30/1980	0.323
12/23/1977	0.190	05/02/1979	0.050	10/07/1980	0.077
12/30/1977	4.379	05/09/1979	0.063	10/14/1980	0.019
01/06/1978	6.201	05/16/1979	0.022	10/21/1980	0.232
01/13/1978	0.562	05/23/1979	0.049	10/28/1980	0.037
01/20/1978	0.238	05/30/1979	0.060	11/04/1980	0.050
01/27/1978	0.351	06/06/1979	0.046	11/11/1980	0.029
02/03/1978	0.332	06/13/1979	0.046	11/18/1980	0.013
02/10/1978	0.217	06/20/1979	0.035	11/25/1980	0.022
02/16/1978	0.198	06/27/1979	0.019	12/02/1980	0.152
02/23/1978	0.207	07/11/1979	0.021	12/23/1980	0.005
03/03/1978	0.068	10/10/1979	0.175	12/30/1980	0.238
03/10/1978	0.160	10/17/1979	0.095	01/06/1981	0.065
03/17/1978	0.066	11/14/1979	0.209	01/13/1981	0.269
03/24/1978	0.071	11/28/1979	0.104	01/20/1981	0.099
03/31/1978	0.162	12/05/1979	0.042	01/28/1981	0.723
04/07/1978	0.109	12/12/1979	0.084	02/03/1981	1.131
04/11/1978	0.205	12/19/1979	0.037	02/10/1981	0.426
05/03/1978	1.919	12/26/1979	0.122	02/17/1981	0.798
05/10/1978	0.261	01/02/1980	0.028	02/24/1981	0.874
05/16/1978	0.157	01/16/1980	0.027	03/03/1981	0.568
05/24/1978	0.129	01/23/1980	0.155	03/31/1981	0.369
06/14/1978	0.150	01/30/1980	0.109	04/28/1981	0.061
06/21/1978	0.087	02/06/1980	0.032	05/26/1981	0.061
06/28/1978	0.061	02/13/1980	0.023	06/23/1981	0.113
07/12/1978	0.065	02/20/1980	0.036	08/19/1981	0.010
07/19/1978	0.047	02/27/1980	0.206	09/16/1981	0.093
07/26/1978	0.045	03/05/1980	0.174	10/14/1981	0.000
08/02/1978	0.021	03/12/1980	0.094	11/11/1981	0.030
08/09/1978	0.024	03/19/1980	0.185	01/05/1982	0.035
08/16/1978	0.027	03/26/1980	0.072	01/12/1982	0.140
08/23/1978	0.068	04/02/1980	0.046	03/02/1982	0.011
08/30/1978	0.033	04/09/1980	0.015	05/05/1982	0.071
09/06/1978	0.025	04/16/1980	0.028	06/02/1982	0.028
09/13/1978	0.126	04/23/1980	0.026	07/07/1982	0.137
09/20/1978	0.203	04/30/1980	0.013	08/04/1982	0.028
09/27/1978	0.075	05/07/1980	0.012	09/08/1982	0.009
10/04/1978	0.047	05/14/1980	0.004	11/02/1983	0.000
10/11/1978	0.180	05/21/1980	0.008	12/28/1983	0.000
10/18/1978	0.280	06/03/1980	0.013	01/04/1984	0.000
10/25/1978	0.640	06/11/1980	0.012	02/08/1984	0.002
11/01/1978	0.196	06/18/1980	0.008	04/04/1984	0.000

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
04/09/1984	0.000	04/04/1989	0.121	10/03/1994	0.033
05/02/1984	0.000	05/02/1989	0.031	10/10/1994	0.804
07/04/1984	0.000	06/06/1989	0.044	10/14/1994	0.168
11/06/1984	0.852	07/04/1989	0.035	10/17/1994	0.101
12/05/1984	0.055	08/01/1989	0.020	10/31/1994	0.069
01/02/1985	1.960	09/05/1989	0.029	11/07/1994	0.082
03/06/1985	0.125	10/03/1989	0.018	11/14/1994	0.076
04/03/1985	0.174	11/07/1989	0.023	11/21/1994	0.047
05/08/1985	0.098	12/05/1989	3.425	11/28/1994	0.048
06/05/1985	0.049	05/01/1990	1.056	12/12/1994	0.278
07/03/1985	0.039	03/05/1991	0.187	12/19/1994	0.028
08/07/1985	0.039	04/02/1991	0.506	12/26/1994	0.880
09/04/1985	0.019	06/04/1991	0.031	01/02/1995	0.304
10/02/1985	0.010	07/02/1991	0.024	01/09/1995	0.409
11/06/1985	0.046	08/06/1991	0.015	01/16/1995	0.898
12/04/1985	0.261	09/03/1991	0.015	01/23/1995	0.395
01/08/1986	0.026	10/01/1991	0.018	01/30/1995	0.220
02/05/1986	0.100	11/05/1991	0.371	02/06/1995	0.150
03/05/1986	0.123	12/03/1991	0.115	02/13/1995	0.093
04/02/1986	0.023	01/07/1992	0.089	02/20/1995	0.118
05/07/1986	0.012	02/04/1992	0.065	02/27/1995	0.084
06/04/1986	0.012	03/03/1992	0.109	03/06/1995	0.351
07/02/1986	0.013	04/07/1992	0.052	03/13/1995	0.392
08/06/1986	0.008	05/05/1992	0.034	03/20/1995	0.219
09/03/1986	0.005	06/02/1992	0.014	03/27/1995	0.367
10/06/1986	0.004	07/07/1992	0.015	04/03/1995	0.192
11/05/1986	0.863	08/11/1992	0.025	04/10/1995	1.393
12/03/1986	8.698	09/01/1992	0.015	04/24/1995	0.272
01/07/1987	0.803	10/06/1992	0.009	05/01/1995	0.148
02/03/1987	0.399	11/03/1992	0.004	05/15/1995	0.080
03/07/1987	0.140	12/01/1992	0.028	05/22/1995	0.110
04/08/1987	0.074	01/05/1993	0.021	06/05/1995	0.049
05/06/1987	0.052	02/02/1993	0.234	06/12/1995	0.042
06/03/1987	0.015	03/02/1993	0.094	06/19/1995	0.092
07/08/1987	0.013	04/06/1993	0.457	06/26/1995	0.047
08/05/1987	0.010	05/03/1993	0.074	07/07/1995	0.032
09/09/1987	0.013	06/01/1993	0.027	07/24/1995	0.027
10/07/1987	1.002	08/03/1993	0.110	08/07/1995	0.024
11/04/1987	0.691	09/07/1993	0.007	08/21/1995	0.011
12/02/1987	0.222	10/05/1993	0.118	09/04/1995	0.003
01/06/1988	0.095	11/02/1993	0.061	09/18/1995	0.005
02/02/1988	0.100	11/30/1993	0.102	10/02/1995	0.011
03/02/1988	0.112	01/04/1994	0.515	10/23/1995	0.280
04/06/1988	0.092	02/01/1994	0.544	10/30/1995	0.032
05/04/1988	0.031	03/01/1994	0.299	11/13/1995	0.055
06/08/1988	0.014	04/05/1994	0.289	11/27/1995	0.178
07/06/1988	0.013	05/03/1994	0.200	12/11/1995	0.153
08/03/1988	0.013	05/31/1994	0.062	12/25/1995	0.807
09/07/1988	0.013	07/05/1994	0.056	01/08/1996	0.168
10/05/1988	0.146	08/02/1994	0.049	01/22/1996	0.734
11/02/1988	0.040	08/29/1994	0.088	02/05/1996	0.366
12/07/1988	0.115	09/05/1994	0.063	02/19/1996	0.540
01/04/1989	0.034	09/19/1994	0.034	03/04/1996	6.721
03/08/1989	1.759	09/26/1994	0.027	03/18/1996	0.279

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
04/01/1996	0.303	04/27/1998	0.245	04/11/2000	0.852
04/15/1996	0.222	05/11/1998	0.109	04/19/2000	0.463
04/29/1996	0.153	05/25/1998	0.074	05/03/2000	0.290
05/13/1996	0.089	06/08/1998	0.064	05/17/2000	0.208
05/27/1996	0.094	06/22/1998	0.040	05/31/2000	0.146
06/10/1996	0.059	07/06/1998	0.037	06/14/2000	0.102
06/24/1996	0.043	07/20/1998	0.031	06/28/2000	0.098
07/08/1996	0.043	08/03/1998	0.034	07/12/2000	0.067
07/22/1996	0.033	08/31/1998	0.067	08/23/2000	0.035
08/05/1996	0.033	09/14/1998	0.128	09/06/2000	0.031
08/19/1996	0.024	09/28/1998	0.078	09/20/2000	0.670
09/02/1996	0.016	10/12/1998	0.046	10/04/2000	0.090
09/16/1996	0.032	10/26/1998	0.093	10/18/2000	0.146
09/30/1996	0.008	11/09/1998	0.044	11/01/2000	0.703
10/14/1996	0.005	11/23/1998	0.044	11/15/2000	1.483
10/28/1996	0.017	12/07/1998	0.327	12/13/2000	0.763
11/25/1996	0.711	12/21/1998	0.161	12/27/2000	0.342
12/09/1996	0.267	01/04/1999	0.084	01/10/2001	0.205
12/23/1996	0.094	01/18/1999	0.089	01/24/2001	0.243
01/06/1997	0.172	02/01/1999	0.110	02/07/2001	0.229
01/06/1997	0.131	02/08/1999	0.267	02/21/2001	0.427
01/20/1997	0.624	02/16/1999	0.249	03/07/2001	0.164
02/03/1997	0.249	02/22/1999	0.241	03/21/2001	0.570
02/17/1997	0.172	03/08/1999	0.188	04/04/2001	1.389
03/03/1997	0.323	03/22/1999	0.517	04/18/2001	0.678
03/17/1997	0.344	04/07/1999	0.088	04/24/2001	0.391
03/17/1997	0.344	04/22/1999	0.094	05/02/2001	0.254
03/31/1997	0.306	05/03/1999	0.062	05/17/2001	0.139
04/14/1997	0.626	05/05/1999	0.054	05/30/2001	0.139
04/28/1997	0.501	05/19/1999	0.043	06/13/2001	0.092
05/12/1997	0.215	06/01/1999	0.026	06/27/2001	0.079
05/26/1997	0.133	06/16/1999	0.018	07/11/2001	0.054
05/27/1997	0.136	06/30/1999	0.014	07/25/2001	0.122
06/09/1997	0.102	07/16/1999	0.007	08/08/2001	0.063
06/23/1997	0.278	07/28/1999	0.053	08/22/2001	0.044
07/07/1997	0.164	08/02/1999	0.018	09/05/2001	0.050
07/21/1997	0.139	08/11/1999	0.013	09/19/2001	0.236
08/04/1997	0.099	08/25/1999	0.006	10/03/2001	0.167
08/18/1997	0.072	09/06/1999	0.004	10/17/2001	0.112
09/01/1997	0.055	09/08/1999	0.003	10/31/2001	0.081
09/15/1997	0.039	09/22/1999	0.046	11/28/2001	0.686
09/29/1997	0.036	10/06/1999	0.008	12/12/2001	1.831
10/13/1997	0.034	10/20/1999	0.134	12/27/2001	0.406
10/27/1997	0.274	10/25/1999	0.261	01/09/2002	0.882
11/10/1997	0.042	11/03/1999	0.036	01/24/2002	0.501
12/08/1997	0.130	11/17/1999	0.281	02/06/2002	0.353
12/22/1997	0.177	11/29/1999	0.122	02/07/2002	0.559
01/05/1998	0.138	12/21/1999	1.299	02/20/2002	0.239
02/02/1998	0.200	01/17/2000	0.959	03/20/2002	0.239
02/16/1998	1.235	01/26/2000	0.289	04/01/2002	0.154
03/02/1998	4.198	02/09/2000	0.286	04/29/2002	0.107
03/16/1998	0.373	02/23/2000	0.441	05/27/2002	0.062
03/30/1998	0.272	03/08/2000	0.561	06/24/2002	0.061
04/13/1998	0.174	03/22/2000	0.929	07/22/2002	0.129

Date	Flow(m3/S)
08/19/2002	0.428
09/16/2002	0.608
10/14/2002	0.124
11/11/2002	0.088
12/10/2002	0.437
01/06/2003	0.236
02/03/2003	0.087
03/03/2003	0.108
03/31/2003	0.111
04/28/2003	0.116
05/28/2003	0.168
06/25/2003	0.079
07/21/2003	0.048
08/18/2003	0.045
09/15/2003	0.235
10/13/2003	0.039
11/10/2003	0.170
12/08/2003	0.113
01/12/2004	0.340
01/26/2004	0.127
03/08/2004	0.279
04/05/2004	0.127
05/18/2004	0.086

Pooled daily mean flow records from the Blinkwater weir from 1977 to 2004

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
04/07/1977	0.09	05/17/1978	0.03	02/25/1981	0.012
04/14/1977	0.066	06/14/1978	0.026	03/04/1981	0.006
04/21/1977	0.066	07/05/1978	0.026	04/29/1981	0.002
04/28/1977	0.12	08/02/1978	0.025	05/27/1981	0.009
05/05/1977	0.096	08/30/1978	0.02	06/24/1981	0.007
05/12/1977	0.613	09/27/1978	0.021	07/22/1981	0.01
05/20/1977	0.167	10/25/1978	0.028	08/19/1981	0.004
05/26/1977	0.136	11/22/1978	0.014	09/16/1981	0.004
06/03/1977	0.105	05/16/1979	0.016	11/11/1981	0.002
06/09/1977	0.093	06/13/1979	0.013	12/15/1981	0
06/16/1977	0.08	10/10/1979	0.05	07/07/1982	0.002
06/23/1977	0.077	10/17/1979	0.04	08/04/1982	0.004
06/30/1977	0.068	11/14/1979	0.026	09/08/1982	0.001
07/07/1977	0.07	12/05/1979	0.019	01/04/1984	0
07/14/1977	0.056	12/12/1979	0.017	11/06/1985	0.053
07/21/1977	0.054	12/19/1979	0.018	12/04/1985	8.981
07/28/1977	0.045	12/26/1979	0.025	01/08/1986	0.135
08/04/1977	0.041	01/02/1980	0.017	01/15/1986	0.176
08/11/1977	0.045	01/16/1980	0.017	02/05/1986	0.186
08/18/1977	0.032	01/23/1980	0.019	03/05/1986	0.243
08/25/1977	0.035	01/30/1980	0.013	04/02/1986	0.021
09/01/1977	0.035	02/06/1980	0.013	05/01/1986	0.021
09/08/1977	0.034	02/13/1980	0.01	05/28/1986	0.017
09/15/1977	0.035	02/20/1980	0.009	06/04/1986	0.01
09/22/1977	0.035	02/27/1980	0.012	06/30/1986	0.01
09/29/1977	0.095	03/05/1980	0.01	07/02/1986	0.01
10/06/1977	0.036	03/12/1980	0.01	07/23/1986	0.01
10/13/1977	0.035	03/19/1980	0.01	08/06/1986	0.008
10/20/1977	0.033	03/26/1980	0.01	08/13/1986	0.01
10/28/1977	0.055	04/02/1980	0.01	08/20/1986	0.01
11/03/1977	1.111	04/09/1980	0.01	09/03/1986	0.01
11/10/1977	0.402	04/16/1980	0.009	09/23/1986	0.01
11/17/1977	0.11	04/23/1980	0.006	09/30/1986	0.01
11/24/1977	0.038	04/30/1980	0.007	10/07/1986	0.013
12/01/1977	0.45	05/07/1980	0.004	10/16/1986	0.112
12/08/1977	0.134	05/14/1980	0.009	11/05/1986	0.092
12/15/1977	0.065	05/21/1980	0.006	11/19/1986	0.054
12/22/1977	0.042	05/28/1980	0.002	11/26/1986	0.113
12/29/1977	0.045	06/04/1980	0.002	12/03/1986	0.047
01/05/1978	1.072	06/11/1980	0.006	12/10/1986	0.037
01/12/1978	0.33	06/18/1980	0.004	12/31/1986	0.024
01/19/1978	0.13	06/25/1980	0.004	01/14/1987	0.017
01/26/1978	0.127	07/16/1980	0.004	01/28/1987	0.018
02/02/1978	0.107	07/23/1980	0.004	02/03/1987	0.017
02/09/1978	0.079	08/20/1980	0	03/04/1987	0.005
02/16/1978	0.052	08/27/1980	0.002	03/11/1987	0.004
02/23/1978	0.031	09/10/1980	0.002	03/18/1987	0.009
03/02/1978	0.033	09/17/1980	0.002	03/25/1987	0.006
03/09/1978	0.024	10/01/1980	0.002	04/01/1987	0.006
03/16/1978	0.026	10/08/1980	0.002	04/08/1987	0.006
04/06/1978	0.025	02/04/1981	0.01	04/15/1987	0.006
04/12/1978	0.065	02/18/1981	0.069	04/22/1987	0.006

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
02/24/1988	0.004	04/11/1989	0.014	04/06/1995	0.026
03/02/1988	0.002	04/18/1989	0.162	04/13/1995	0.007
03/09/1988	0.068	04/25/1989	0.33	04/19/1995	0.007
03/16/1988	0.013	05/02/1989	0.263	04/19/1995	0.008
03/23/1988	0.011	06/06/1989	0.021	04/27/1995	0.007
03/30/1988	0.01	07/04/1989	0.019	05/04/1995	0.007
04/06/1988	0.012	08/01/1989	0.011	06/29/1995	0.004
04/13/1988	0.006	09/05/1989	0.023	10/25/1995	0.008
04/20/1988	0.01	10/03/1989	4.509	10/31/1995	0
04/27/1988	0.006	11/07/1989	0.132	02/07/1996	0.136
05/04/1988	0.004	12/05/1989	0.439	03/06/1996	1.355
05/11/1988	0.006	05/01/1990	0.033	03/20/1996	0.128
05/18/1988	0.006	10/02/1990	0.007	04/03/1996	0.556
05/25/1988	0.005	03/05/1991	0.016	04/17/1996	0.067
06/01/1988	0.005	04/02/1991	0.01	05/01/1996	0.025
06/08/1988	0.004	05/07/1991	0.001	05/15/1996	0.02
06/15/1988	0.005	06/04/1991	0.007	05/29/1996	0.017
06/22/1988	0.005	08/06/1991	0.006	06/12/1996	0.017
06/29/1988	0.006	10/22/1991	0.005	06/26/1996	0.015
07/06/1988	0.004	11/05/1991	0.018	07/10/1996	0.017
07/13/1988	0.004	12/03/1991	0.015	07/24/1996	0.017
07/20/1988	0.004	01/07/1992	0.011	08/07/1996	0.015
07/27/1988	0.004	02/04/1992	0.002	08/21/1996	0.014
08/03/1988	0.004	04/07/1992	0.001	09/04/1996	0.014
08/10/1988	0.003	05/05/1992	0.002	09/18/1996	0.013
08/17/1988	0.002	09/01/1992	0	10/02/1996	0.01
08/24/1988	0.001	12/28/1993	0.018	10/16/1996	0.01
08/31/1988	0.003	01/04/1994	0.018	10/30/1996	0.013
09/07/1988	0.004	02/01/1994	0.057	11/13/1996	0.015
09/14/1988	0.003	03/01/1994	0.021	11/27/1996	0.008
09/28/1988	0.004	04/04/1994	0.015	12/11/1996	0.247
10/05/1988	0.003	05/03/1994	0.01	12/25/1996	0.047
10/19/1988	0.002	05/31/1994	0.013	01/08/1997	0.042
10/26/1988	0.002	06/05/1994	0.011	01/08/1997	0.042
11/30/1988	0.001	08/02/1994	0.011	01/22/1997	0.269
12/07/1988	0.002	09/05/1994	0.01	01/22/1997	0.269
12/14/1988	0.002	09/05/1994	0.01	02/19/1997	0.067
12/21/1988	0.008	09/12/1994	0.006	03/05/1997	0.038
12/28/1988	0.056	09/26/1994	0.01	03/19/1997	0.034
01/04/1989	0.194	10/03/1994	0.017	04/02/1997	0.172
01/11/1989	0.127	10/03/1994	0.01	04/16/1997	0.247
01/18/1989	0.013	10/17/1994	0.003	04/30/1997	0.338
01/25/1989	0.013	10/17/1994	0.004	05/14/1997	0.123
02/01/1989	0.006	01/16/1995	0.004	05/28/1997	0.059
02/08/1989	0.01	01/23/1995	0.004	06/11/1997	0.077
02/08/1989	0.01	02/06/1995	0.004	06/26/1997	0.174
02/15/1989	0.013	02/06/1995	0.005	07/09/1997	0.139
02/22/1989	0.012	03/06/1995	0.004	07/23/1997	0.097
03/08/1989	0.009	03/13/1995	0.005	08/06/1997	0.078
03/15/1989	0.015	03/20/1995	0.005	08/20/1997	0.056
03/22/1989	0.013	03/20/1995	0.02	09/03/1997	0.045
03/28/1989	0.013	03/30/1995	0.008	09/17/1997	0.055
04/04/1989	0.008	04/06/1995	0.008	10/01/1997	0.039

Date	Flow(m3/S)	Date	Flow(m3/S)	Date	Flow(m3/S)
10/15/1997	0.053	01/17/2000	0.197	01/09/2002	0.158
10/29/1997	0.025	01/26/2000	0.038	01/24/2002	0.337
11/12/1997	0.014	02/09/2000	0.012	02/06/2002	0.05
11/26/1997	0.012	02/23/2000	0.029	02/20/2002	0.049
12/10/1997	0.013	03/08/2000	0.183	04/01/2002	0.022
12/24/1997	0.012	03/22/2000	0.273	04/29/2002	0.024
01/07/1998	0.009	04/05/2000	6.052	05/27/2002	0.012
01/21/1998	0.005	04/19/2000	0.332	06/24/2002	0.012
02/04/1998	0.008	05/03/2000	0.174	07/22/2002	0.016
02/18/1998	0.011	05/17/2000	0.084	08/19/2002	0.025
03/04/1998	0.093	05/31/2000	0.037	09/16/2002	0.495
03/18/1998	0.014	06/14/2000	0.024	10/14/2002	0.043
04/15/1998	0.024	06/28/2000	0.018	11/11/2002	0.019
04/29/1998	0.02	07/12/2000	0.02	12/10/2002	0.014
05/13/1998	0.012	07/26/2000	0.015	01/06/2003	0.012
05/27/1998	0.011	08/09/2000	0.02	02/03/2003	0.003
06/10/1998	0.01	08/23/2000	0.015	03/03/2003	0.008
06/24/1998	0.012	09/06/2000	0.013	03/31/2003	0.015
07/08/1998	0.011	09/20/2000	0.287	04/28/2003	0.01
07/22/1998	0.015	10/04/2000	0.02	05/26/2003	0.016
08/06/1998	0.016	10/18/2000	0.012	06/25/2003	0.012
08/19/1998	0.011	11/01/2000	0.019	07/21/2003	0.01
09/02/1998	0.012	11/15/2000	0.003	08/18/2003	0.011
09/16/1998	0.012	11/29/2000	0.603	09/17/2003	0.014
09/30/1998	0.011	12/13/2000	2.025	10/13/2003	0.004
10/14/1998	0.011	12/27/2000	0.236	11/10/2003	0.004
11/11/1998	0.001	01/10/2001	0.063	01/26/2004	0
11/25/1998	0.01	01/24/2001	0.028	02/23/2004	0.004
12/09/1998	0.013	02/07/2001	0.027	10/06/1999	0.004
12/23/1998	0.017	02/21/2001	0.021	01/17/2000	0.197
01/06/1999	0.006	03/07/2001	0.049	01/26/2000	0.038
01/18/1999	0.013	03/21/2001	0.017	02/09/2000	0.012
01/20/1999	0.012	04/04/2001	0.064	02/23/2000	0.029
02/03/1999	0.013	04/18/2001	0.898	03/08/2000	0.183
02/24/1999	0.009	04/23/2001	0.696	03/22/2000	0.273
03/10/1999	0.011	05/02/2001	1.085	04/05/2000	6.052
03/24/1999	0.018	05/17/2001	0.163	04/19/2000	0.332
04/07/1999	0.011	05/30/2001	0.077	05/03/2000	0.174
04/22/1999	0.016	06/13/2001	0.051	05/17/2000	0.084
05/05/1999	0.013	06/27/2001	0.036	05/31/2000	0.037
05/19/1999	0.009	07/11/2001	0.036	06/14/2000	0.024
06/01/1999	0.009	07/25/2001	0.031	06/28/2000	0.018
06/16/1999	0.005	08/08/2001	0.032	07/12/2000	0.02
06/30/1999	0.008	08/22/2001	0.025	07/26/2000	0.015
07/16/1999	0.007	09/05/2001	0.027	08/09/2000	0.02
07/28/1999	0.015	09/19/2001	0.024	08/23/2000	0.015
08/02/1999	0.012	10/03/2001	0.027	09/06/2000	0.013
08/11/1999	0.011	10/17/2001	0.026	09/20/2000	0.287
08/25/1999	0.012	10/31/2001	0.024	10/04/2000	0.02
09/06/1999	0.008	11/14/2001	0.023	10/18/2000	0.012
09/08/1999	0.005	11/28/2001	0.852	11/01/2000	0.019
09/22/1999	0.002	12/12/2001	0.316	11/15/2000	0.003
10/06/1999	0.004	12/27/2001	1.508	11/29/2000	0.603

Date	Flow(m3/S)	Date	Flow(m3/S)
12/13/2000	2.025	11/10/2003	0.004
12/27/2000	0.236	01/26/2004	0
01/10/2001	0.063	02/23/2004	0.004
01/24/2001	0.028		
02/07/2001	0.027		
02/21/2001	0.021		
03/07/2001	0.049		
03/21/2001	0.017		
04/04/2001	0.064		
04/18/2001	0.898		
04/23/2001	0.696		
05/02/2001	1.085		
05/17/2001	0.163		
05/30/2001	0.077		
06/13/2001	0.051		
06/27/2001	0.036		
07/11/2001	0.036		
07/25/2001	0.031		
08/08/2001	0.032		
08/22/2001	0.025		
09/05/2001	0.027		
09/19/2001	0.024		
10/03/2001	0.027		
10/17/2001	0.026		
10/31/2001	0.024		
11/14/2001	0.023		
11/28/2001	0.852		
12/12/2001	0.316		
12/27/2001	1.508		
01/09/2002	0.158		
01/24/2002	0.337		
02/06/2002	0.05		
02/20/2002	0.049		
04/01/2002	0.022		
04/29/2002	0.024		
05/27/2002	0.012		
06/24/2002	0.012		
07/22/2002	0.016		
08/19/2002	0.025		
09/16/2002	0.495		
10/14/2002	0.043		
11/11/2002	0.019		
12/10/2002	0.014		
01/06/2003	0.012		
02/03/2003	0.003		
03/03/2003	0.008		
03/31/2003	0.015		
04/28/2003	0.01		
05/26/2003	0.016		
06/25/2003	0.012		
07/21/2003	0.01		
08/18/2003	0.011		
09/17/2003	0.014		
10/13/2003	0.004		

Pooled daily mean flow records from the Fort-Beaufort weir from 1992 to 2004

DATE	Flow (m3/S)	DATE	Flow (m3/S)	DATE	Flow (m3/S)
12/29/92	0.000	12/25/1996	0.010	04/19/2000	2.371
01/26/93	0.000	01/08/1997	0.065	05/04/2000	0.980
04/06/93	0.155	01/22/1997	0.741	05/17/2000	0.339
04/06/93	0.155	02/05/1997	0.394	05/31/2000	0.174
06/29/93	0.000	02/19/1997	0.157	06/14/2000	0.095
09/07/93	0.091	03/05/1997	0.386	06/28/2000	0.194
11/02/93	0.211	03/19/1997	0.509	07/12/2000	0.015
11/02/93	0.211	03/19/1997	0.509	08/23/2000	0.019
11/16/93	0.197	04/02/1997	0.799	09/20/2000	2.276
11/30/93	0.008	04/16/1997	1.654	10/04/2000	0.011
12/14/93	0.172	04/30/1997	2.947	10/18/2000	0.036
12/28/93	1.037	05/14/1997	0.684	11/01/2000	0.719
01/11/94	1.410	05/28/1997	0.168	11/15/2000	15.650
01/25/1994	0.276	06/11/1997	0.567	11/29/2000	14.850
02/08/1994	8.670	06/25/1997	1.318	12/13/2000	2.099
02/22/1994	1.425	07/09/1997	1.174	12/27/2000	0.465
03/08/1994	1.777	07/23/1997	0.343	01/10/2001	0.093
03/22/1994	0.112	08/06/1997	0.229	01/24/2001	0.087
04/05/1994	0.000	08/20/1997	0.034	02/07/2001	0.100
05/31/1994	0.421	09/03/1997	0.024	02/21/2001	2.226
07/26/1994	0.009	10/15/1997	0.888	03/07/2001	0.037
08/09/1994	0.000	10/29/1997	0.053	03/21/2001	2.349
10/17/1994	0.025	11/26/1997	0.639	04/04/2001	7.897
11/28/1994	0.003	02/04/1998	0.589	04/18/2001	3.788
12/26/1994	1.959	02/18/1998	1.201	04/23/2001	4.508
01/09/1995	0.001	03/04/1998	2.401	05/02/2001	0.739
01/23/1995	0.792	03/18/1998	0.162	05/17/2001	0.170
02/06/1995	0.007	04/01/1998	0.345	05/30/2001	0.071
03/06/1995	0.225	04/15/1998	0.071	06/13/2001	0.046
04/03/1995	0.106	04/29/1998	0.093	06/27/2001	0.064
04/05/1995	0.076	05/13/1998	0.009	07/11/2001	0.026
04/19/1995	0.098	07/22/1998	0.004	07/25/2001	0.202
05/03/1995	0.052	09/16/1998	0.019	08/08/2001	0.206
05/17/1995	0.010	09/19/1998	0.013	08/22/2001	0.053
09/20/1995	1.130	12/09/1998	0.095	09/05/2001	0.195
11/29/1995	0.060	12/23/1998	0.106	09/19/2001	0.877
12/13/1995	0.036	01/20/1999	0.449	10/03/2001	0.609
01/10/1996	0.139	01/21/1999	0.115	10/17/2001	0.087
02/07/1996	0.791	02/24/1999	0.055	10/31/2001	0.017
02/21/1996	0.728	03/24/1999	0.215	11/14/2001	0.709
03/06/1996	7.837	04/22/1999	0.001	11/28/2001	1.809
03/20/1996	0.360	07/28/1999	1.093	12/12/2001	9.717
04/03/1996	4.392	08/25/1999	0.732	12/27/2001	0.964
04/17/1996	0.182	09/22/1999	0.119	01/09/2002	4.868
05/01/1996	0.038	12/21/1999	1.820	01/23/2002	0.089
05/29/1996	0.028	01/12/2000	0.379	02/06/2002	0.240
06/26/1996	0.793	01/26/2000	0.412	02/20/2002	0.054
08/21/1996	0.514	02/14/2000	8.955	03/06/2002	1.282
11/13/1996	0.030	02/23/2000	0.228	03/20/2002	0.118
11/13/1996	0.030	03/08/2000	0.735	04/01/2002	0.078
11/27/1996	2.323	03/22/2000	3.112	04/15/2002	0.075
12/11/1996	0.652	04/10/2000	4.394	04/29/2002	0.074

DATE	Flow (m3/S)
05/14/2002	0.040
06/10/2002	0.003
06/24/2002	0.018
07/08/2002	0.017
07/22/2002	1.989
08/05/2002	0.048
08/19/2002	1.709
09/02/2002	0.415
09/16/2002	6.720
09/30/2002	0.934
10/14/2002	0.209
11/11/2002	0.177
11/25/2002	0.058
12/09/2002	0.073
12/23/2002	3.397
01/06/2003	0.277
01/20/2003	0.156
02/03/2003	0.055
02/17/2003	0.100
03/03/2003	0.074
03/17/2003	0.035

APPENDIX G: SODIUM CHLORIDE ANNUAL AND MONTHLY FREQUENCY OF OCCURRENCES AT THE BALFOUR WATER QUALITY MONITORING POINT
FROM T-SOFT

Period equalled or exceeded	Months									Annual
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
0.10%	99.865	155.709	136.739	155.709	194.43	194.43	194.43	124.699	194.43	194.43
1%	87.699	124.699	99.865	109.507	194.43	194.43	194.43	124.699	155.709	136.739
5%	66.849	92.974	85.478	92.974	104.23	124.699	116.095	92.974	81.648	96.167
10%	58.705	78.438	81.648	85.478	96.167	109.507	96.167	73.303	67.632	83.473
15%	53.846	68.455	77.015	85.478	87.699	92.974	85.478	64.049	56.246	75.692
20%	50.307	63.421	72.219	83.473	85.478	85.478	78.438	59.63	49.394	68.455
30%	45.663	57.018	62.817	71.198	79.977	77.015	61.138	51.818	43.506	57.836
40%	41.498	50.072	57.421	64.704	72.219	70.233	52.937	45.663	39.735	51.039
50%	37.943	46.151	54.163	60.618	70.233	62.817	47.565	41.078	36.195	45.196
60%	34.738	42.874	50.546	57.018	62.817	55.515	43.904	36.569	33.022	40.288
70%	31.301	38.96	46.488	54.163	57.421	48.752	39.825	31.335	29.734	35.548
80%	27.861	35.662	42.997	50.79	50.546	41.182	35.895	26.119	26.167	30.941
85%	25.63	33.766	41.078	47.014	47.378	37.23	33.148	23.434	23.989	28.29
90%	22.371	31.234	36.38	41.392	42.997	33.064	30.095	20.323	21.253	24.921
95%	17.846	24.766	29.954	34.79	35.72	27.987	25.962	16.358	17.849	19.773
99%	15.312	17.151	18.525	19.932	25.499	19.995	15.892	11.954	12.422	13.561
99.9%	11.79	11.262	14.89	14.703	15.3	12.81	11.586	7.917	9.7	9.265

SODIUM CHLORIDE ANNUAL AND MONTHLY FREQUENCY OF OCCURENCES AT THE BLINKWATER WATER QUALITY MONITORING POINT FROM T-SOFT

Period equalled or exceeded	Months												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
0.10%	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309	521.309
1%	521.309	521.309	521.309	521.309	443.778	443.778	443.778	521.309	521.309	521.309	521.309	521.309	521.309
5%	443.778	443.778	403.887	403.887	443.778	443.778	443.778	443.778	443.778	521.309	521.309	443.778	443.778
10%	403.887	377.778	358.695	358.695	377.778	377.778	403.887	443.778	443.778	443.778	443.778	403.887	403.887
15%	358.695	358.695	321.594	343.82	358.695	358.695	377.778	403.887	443.778	443.778	443.778	358.695	377.778
20%	331.726	331.726	305.348	321.594	343.82	343.82	358.695	377.778	377.778	403.887	358.695	321.594	343.82
30%	287.294	298.662	292.686	292.686	312.914	312.914	321.594	321.594	343.82	343.82	287.294	282.39	305.348
40%	263.052	269.937	269.937	273.765	292.686	298.662	305.348	305.348	305.348	305.348	269.937	263.052	287.294
50%	238.441	238.441	244.567	263.052	277.901	287.294	292.686	287.294	287.294	269.937	251.632	221.277	269.937
60%	216.432	215.305	229.791	244.567	257.006	269.937	273.765	273.765	257.006	254.244	231.39	194.303	246.805
70%	187.825	189.479	192.418	192.418	223.93	246.805	257.006	254.244	238.441	234.775	176.837	170.135	220.012
80%	165.681	154.457	155.626	145.939	191.214	226.76	238.441	234.775	206.377	218.784	140.458	146.8	183.284
85%	149.077	139.219	133.166	133.253	173.846	216.432	221.277	216.432	190.048	207.275	127.588	132.48	163.029
90%	132.228	119.766	112.85	118.561	157.05	176.837	190.048	197.677	166.523	181.442	112.28	120.521	140.806
95%	107.946	103.037	91.723	104.303	134.688	156.228	171.436	173.139	145.939	132.061	95.05	101.25	114.54
99%	81.283	74.802	57.805	79.938	95.792	125.852	137.208	85.589	115.58	90.073	67.044	65.449	78.097
99.90%	70.299	52.1	48.518	66.834	73.285	85.284	120.215	60.015	72.985	67.113	51.269	59.633	53.872

APPENDIX H: MACROIVERTEBRATES FAMILY LISTS FROM THE NINETEEN SITES OVER THE FOUR SEASONS

	Summary of Macroinvertebrates recorded during Autumn																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Turbellaria							p				p				p	p	p	p	
Oligochaeta	p					p	p	p	p	p	p		p			p		p	p
Leeches																p			
Potamonautidae	p	p			p	p		p	p	p	p	p	p				p	p	
Atyidae			p																
Hydracarina						p													
Notonemouridae		p																	
Perlidae									p	p									
Baetidae 1sp	p	p		p	p		p	p	p		p	p		p	p	p	p	p	
Baetidae 2sp			p	p			p	p	p	p			p		p		p		p
Baetidae >2sp		p				p				p	p		p					p	p
Caenidae	p	p		p	p	p			p		p		p	p	p	p			p
Heptageniidae			p	p	p			p	p	p	p	p			p			p	
Leptophlebiidae	p	p	p	p	p		p	p	p		p	p	p	p	p	p	p	p	p
Tricorythidae	p	p	p	p	p	p	p	p	p	p	p	p	p		p			p	p
Chlorocyphidae						p			p	p									p
Coenagrionidae					p		p	p	p					p	p		p	p	p
Platycnemidae		p								p				p					
Aeshinidae				p		p		p	p	p	p	p	p					p	
Gomphidae	p	p		p	p	p	p	p	p	p	p	p	p		p		p	p	p
Libellulidae				p					p	p						p			p
Belostomatidae				p	p					p					p				
Corixidae										p								p	p
Naucoridae			p	p	p		p	p	p	p	p	p	p	p					p
Notonectidae				p									p	p		p	p		p
Vellidae		p	p	p	p	p	p	p	p	p	p				p	p	p	p	
Hydropsychidae 1sp	p				p	p	p	p		p	p	p	p		p	p	p	p	
Hydropsychidae 2sp		p			p			p				p	p		p			p	p
Leptoceridae					p			p		p					p				p
Dystiscidae												p							p
Elmidae				p			p	p					p		p	p		p	
Gyrinidae				p	p	p	p			p	p				p	p	p	p	p
Hydrophilidae																			p
Psephenidae								p	p	p				p					

Athericidae			p	p	p	p			p	p	p		p		p				
Ceratopogonidae				p		p							p	p	p			p	p
Chironomidae	p			p		p							p		p	p	p	p	p
Culicidae						p							p			p			
Psychodidae		p														p	p		
Simuliidae			p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Tabanidae	p																		
Tipulidae																			
Ancylidae	p		p		p	p	p	p		p			p		p	p	p		
Lymnaeidae												p							p
Planorbinae			p	p	p				p	p	p				p				
Corbiculidae										p	p	p				p	p	p	
Sphaeriidae										p			p						

	Summary of Macroinvertebrates recorded during Winter																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Turbellaria	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Oligochaeta	p	p	p				p	p				p	p	p		p	p	p	p
Leeches																p	p		
Potamonautidae	p	p		p		p			p	p	p		p				p		
Hydracarina		p						p											
Notonemouridae	p						p												
Perlidae									p		p	p							p
Baetidae 1sp	p								p	p			p	p		p		p	p
Baetidae 2sp	p	p	p		p	p	p	p	p		p	p	p	p	p	p	p	p	p
Baetidae >2sp	p	p	p	p		p	p	p		p	p		p		p		p	p	p
Caenidae	p	p	p	p	p	p	p	p	p		p	p	p	p	p		p	p	p
Heptageniidae	p		p	p	p		p	p	p	p	p	p			p			p	
Leptophlebiidae	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p				p
Tricorythidae	p		p	p	p	p	p	p	p	p	p	p		p	p				p
Chlorocyphidae									p						p				p
Coenagrionidae	p					p	p	p	p		p				p	p			p
Platycnemidae		p												p					
Aeshinidae				p		p	p		p	p			p	p					
Gomphidae	p	p	p	p	p	p	p	p	p	p	p	p	p				p		p
Libellulidae				p			p	p		p			p		p	p			p
Naucoridae	p				p	p	p		p		p	p	p	p		p	p	p	
Notonectidae	p													p					
Vellidae	p		p		p	p		p	p					p		p		p	
Hydropsychidae 1sp	p		p			p		p			p	p			p				
Hydropsychidae 2sp	p			p	p				p	p		p			p	p	p	p	p
Hydroptilidae											p				p				
Leptoceridae							p	p		p					p			p	p
Dystiscidae							p	p						p				p	
Elmidae	p			p	p		p	p		p				p	p	p	p	p	p
Gyrinidae					p	p	p	p	p	p			p		p		p		p
Hydrophilidae							p				p	p		p			p		
Psephenidae		p		p				p	p	p									
Athericidae		p		p	p	p	p	p	p	p	p			p					p
Ceratopogonidae	p	p	p	p	p		p	p					p	p			p	p	p

Chironomidae	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Culicidae						p	p	p		p				p		p	p		p
Muscidae							p	p					p				p		
Psychodidae		p															p		
Simuliidae	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p		p	p	p
Tabanidae	p	p	p		p		p	p	p	p		p	p		p	p	p	p	p
Tipulidae		p																	
Ancylidae	p		p	p	p	p		p	p	p	p				p	p	p	p	
Lymnaeidae																p	p		p
Planorbinae																p			
Corbiculidae										p	p				p	p	p	p	p

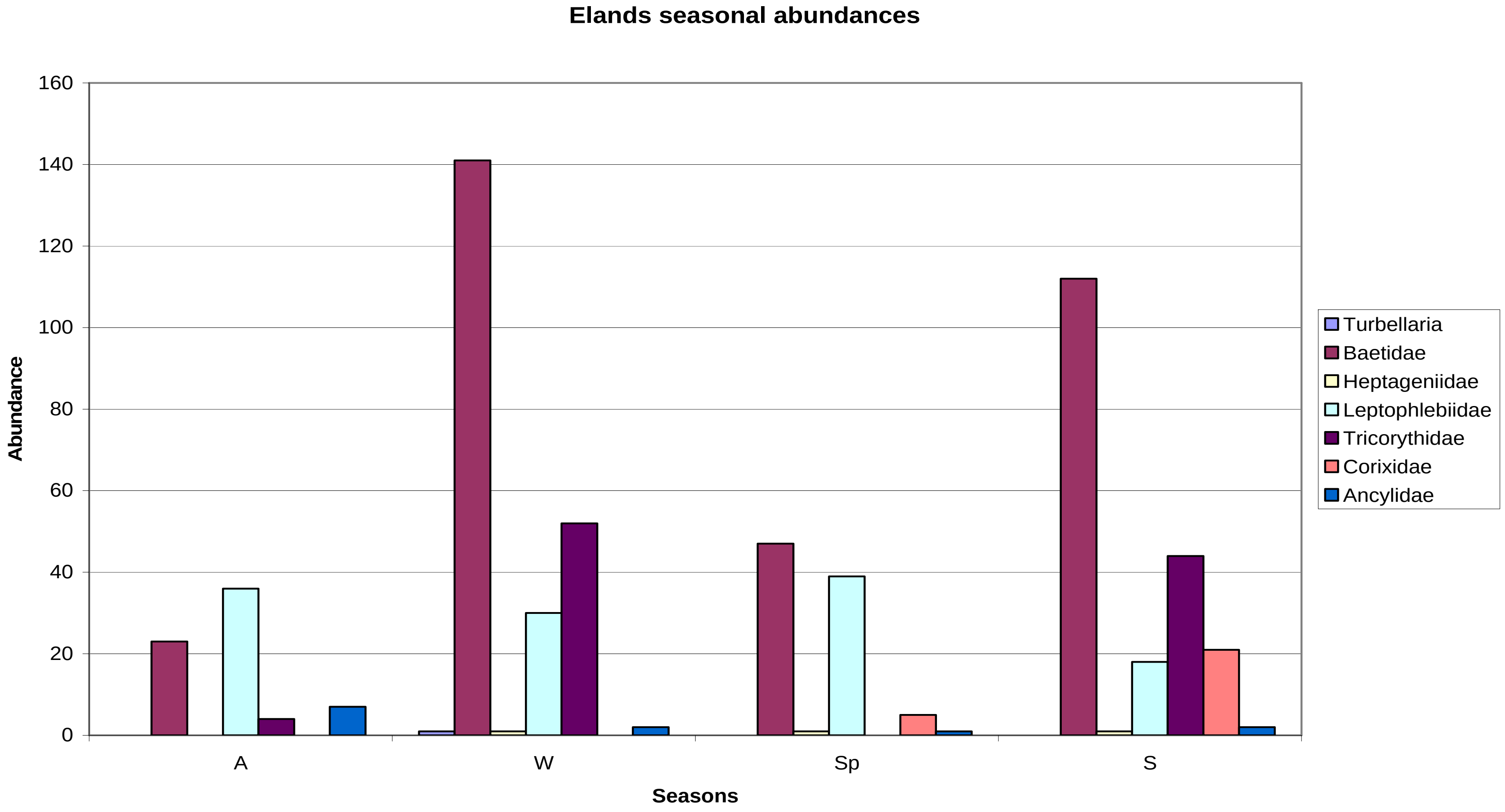
	Summary of Macroivertebrates recorded during Spring																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Turbellaria		p	p	p	p	p	p	p	p	p	p	p	p		p		p	p	p
Oligochaeta	p	p	p	p	p		p	p	p	p	p	p	p	p	p		p	p	
Leeches						p							p			p	p		
Potamonautidae	p	p	p	p	p	p			p	p	p	p	p	p				p	
Hydracarina		p	p			p	p	p											
Notonemouridae						p													
Perlidae									p	p	p	p							p
Baetidae 1sp	p								p	p		p	p		p	p	p	p	p
Baetidae 2sp		p	p	p	p			p		p			p	p			p		
Baetidae >2sp	p	p	p	p		p	p	p	p		p			p					
Caenidae	p	p	p	p	p		p	p	p	p	p	p	p	p	p	p	p	p	p
Heptageniidae	p		p	p	p		p	p	p	p	p	p			p				
Leptophlebiidae	p	p	p	p	p		p	p	p	p	p	p	p	p	p			p	p
Tricorythidae		p	p	p	p	p	p	p	p	p	p	p							
Chlorocyphidae										p	p	p			p				p
Coenagrionidae	p			p	p	p		p	p	p	p			p		p	p	p	p
Platycnemidae		p												p					
Aeshinidae			p	p			p	p		p	p	p							p
Gomphidae	p	p	p	p	p	p	p	p	p	p	p	p	p		p				
Libellulidae	p		p	p			p		p	p		p			p				p
Corixidae	p	p		p			p	p	p	p			p	p	p	p	p		p
Gerridae							p												
Naucoridae										p					p		p		p
Notonectidae	p			p			p			p			p				p		p
Pleidae	p													p	p				
Vellidae		p	p	p	p		p	p	p	p	p			p		p	p		p
Hydropsychidae 1sp								p	p		p			p					
Hydropsychidae 2sp			p				p	p	p	p		p							p
Leptoceridae	p						p	p		p				p					p
Dystiscidae				p	p		p			p	p		p	p	p		p		p
Elmidae				p		p	p	p	p					p	p	p	p	p	p
Gyrinidae					p	p	p	p	p	p	p	p		p		p			
Hydraenidae							p	p				p	p					p	
Hydrophilidae							p	p	p	p	p	p		p	p		p		

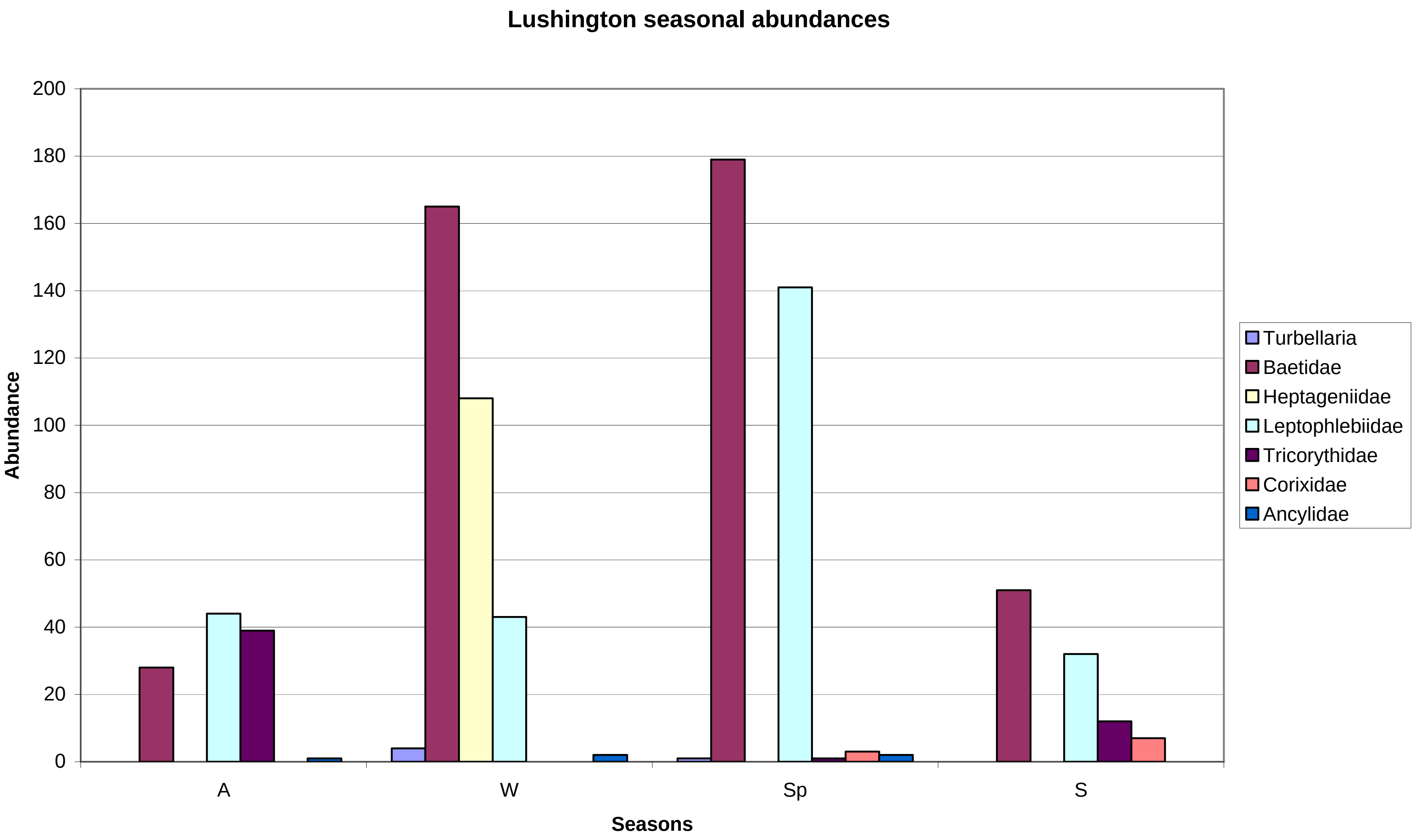
Psephenidae			p						p	p					p				
Athericidae	p	p	p	p	p	p		p	p	p		p		p					
Ceratopogonidae	p	p	p	p		p	p	p	p	p	p	p	p	p	p		p		p
Chironomidae	p		p	p	p	p	p	p	p	p	p		p	p	p	p	p	p	
Culicidae	p	p	p	p	p			p	p	p				p	p		p		p
Dixidae						p	p							p					
Ephydridae																p	p		
Muscidae								p	p										
Psychodidae		p															p		
Simuliidae		p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	
Tabanidae	p			p	p	p	p	p	p		p	p	p	p		p	p	p	
Tipulidae		p			p	p		p											
Ancylidae	p	p	p	p		p		p	p	p	p	p				p	p	p	p
Lymnaeidae							p										p		
Physidae																p			p
Planorbinae								p		p								p	
Corbiculidae												p					p	p	p
Sphaeriidae										p									

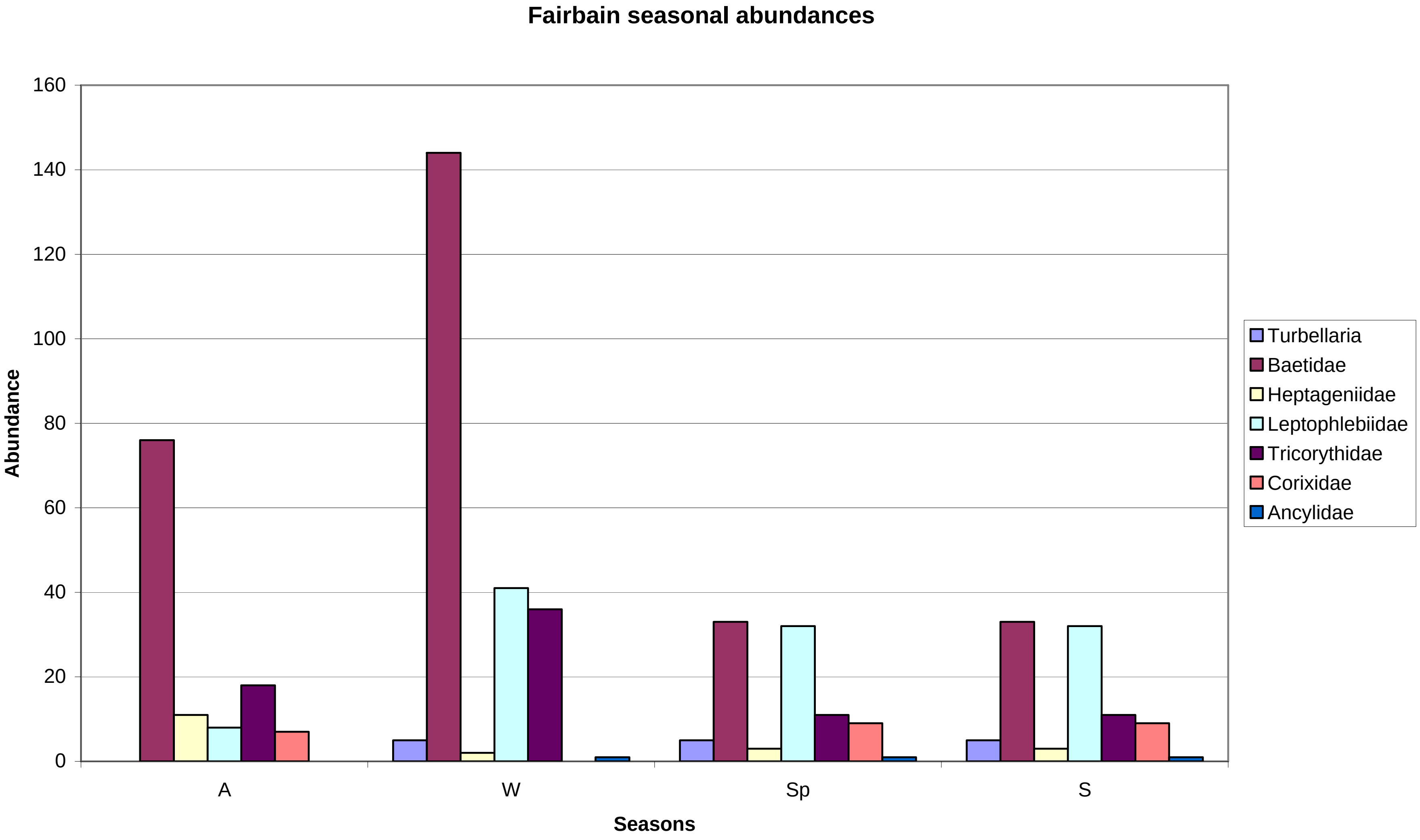
	Summary of Macroinvertebrates recoded during Summer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Turbellaria					p		p	p	p	p	p								
Oligochaeta	p	p	p			p	p	p	p		p	p	p			p	p	p	
Leeches											p				p	p	p		
Potamonautidae	p	p		p	p	p	p	p	p	p	p	p		p			p	p	
Baetidae 1sp	p			p		p	p				p	p	p	p		p	p	p	p
Baetidae 2sp	p	p	p	p	p		p	p	p	p	p	p	p	p	p			p	p
Baetidae >2sp	p		p	p	p	p	p	p										p	
Caenidae	p	p	p	p	p			p	p	p	p		p	p	p	p	p	p	p
Heptageniidae	p		p	p	p		p	p	p	p	p	p							
Leptophlebiidae	p	p	p	p	p		p	p	p	p	p	p	p		p				
Oligoneuridae								p											
Prosopistomatidae															p				
Telagonodidae															p				
Tricorythidae	p	p	p	p	p		p	p	p	p	p								
Chlorocyphidae											p		p						p
Coenagrionidae	p			p	p			p	p	p	p				p	p	p	p	p
Platycnemidae																			
Aeshinidae			p			p			p										
Gomphidae	p	p		p	p	p	p	p	p	p			p					p	
Libellulidae							p		p	p	p		p			p		p	
Belostomatidae									p	p					p	p	p		p
Corixidae	p	p		p	p			p	p	p	p	p	p	p	p	p	p	p	p
Gerridae	p		p																
Hydrometridae																			p
Naucoridae	p			p	p	p		p	p	p	p	p	p		p		p	p	p
Nepidae															p				
Notonectidae			p						p	p	p			p			p		p
Pleidae													p						p
Vellidae	p		p	p	p	p		p	p	p	p	p			p	p	p		
Hydropsychidae 1sp		p		p			p			p				p	p			p	
Hydropsychidae 2sp	p			p	p		p	p	p		p	p							
Leptoceridae			p	p	p			p	p	p	p				p				
Dystiscidae										p			p	p	p		p		
Elmidae							p			p					p	p		p	

Gyrinidae		p			p		p	p	p	p	p				p		p	p	
Hydrophilidae	p							p	p			p						p	p
Psephenidae				p	p				p	p									
Athericidae						p		p	p	p	p								
Blepharoceridae						p													
Ceratopogonidae			p	p			p	p	p					p				p	
Chironomidae	p	p		p	p	p	p	p		p	p	p		p	p	p	p	p	p
Culicidae		p									p			p			p		
Ephydridae														p					
Muscidae																			
Psychodidae																			
Simuliidae	p	p	p	p	p	p	p	p	p	p	p	p	p		p	p	p	p	
Tabanidae			p	p	p	p	p	p	p	p	p				p	p			
Tipulidae		p					p					p							
Ancylidae			p			p	p	p	p	p	p				p				
Lymnaeidae					p														
Physidae																p			
Planorbinae				p	p						p								
Corbiculidae										p	p				p				

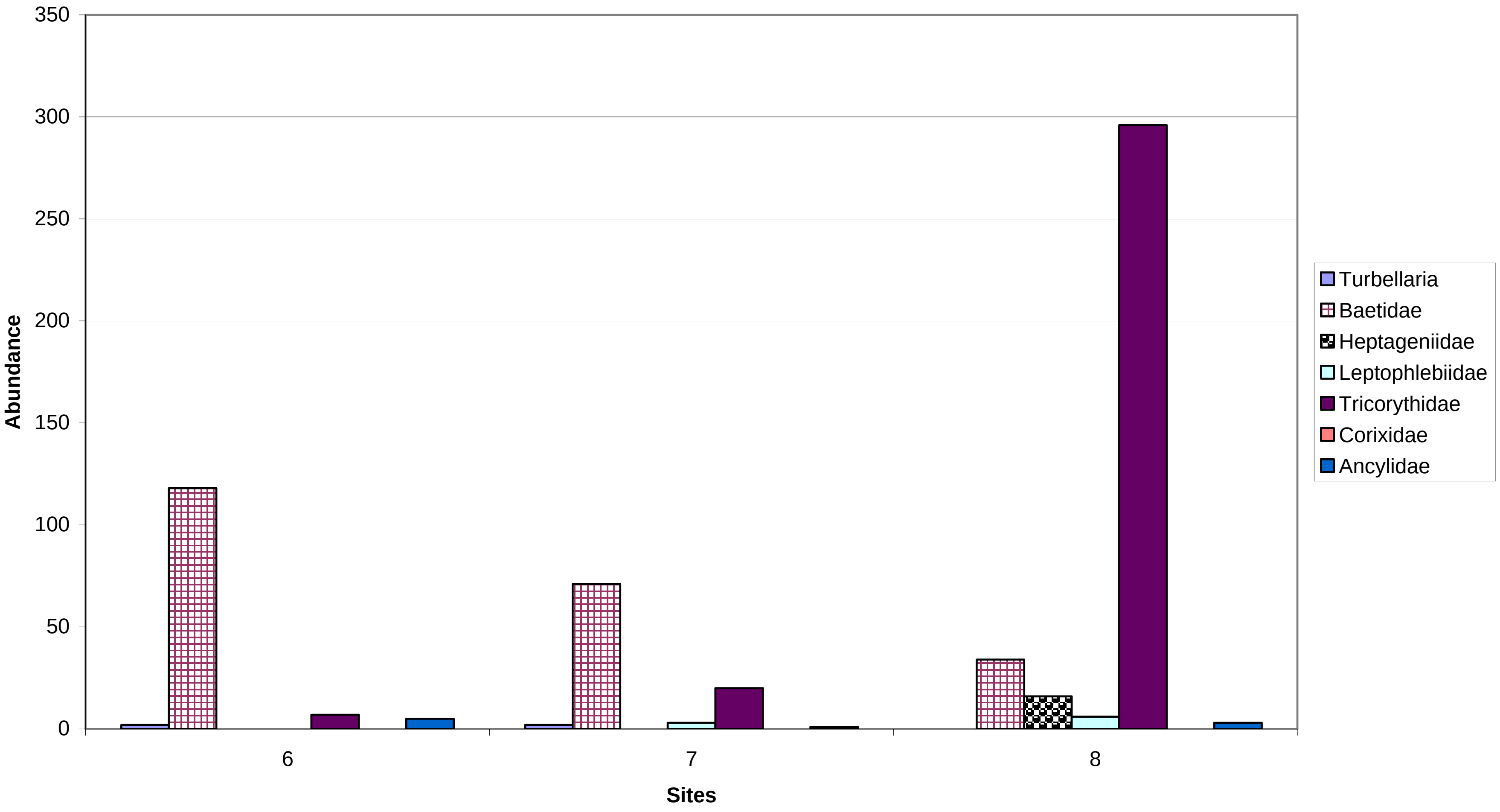
APPENDIX I: MACROINVERTEBRATE ABUNDANCES AT DIFFERENT TRIBUTARIES OVER THE FOUR SEASONS

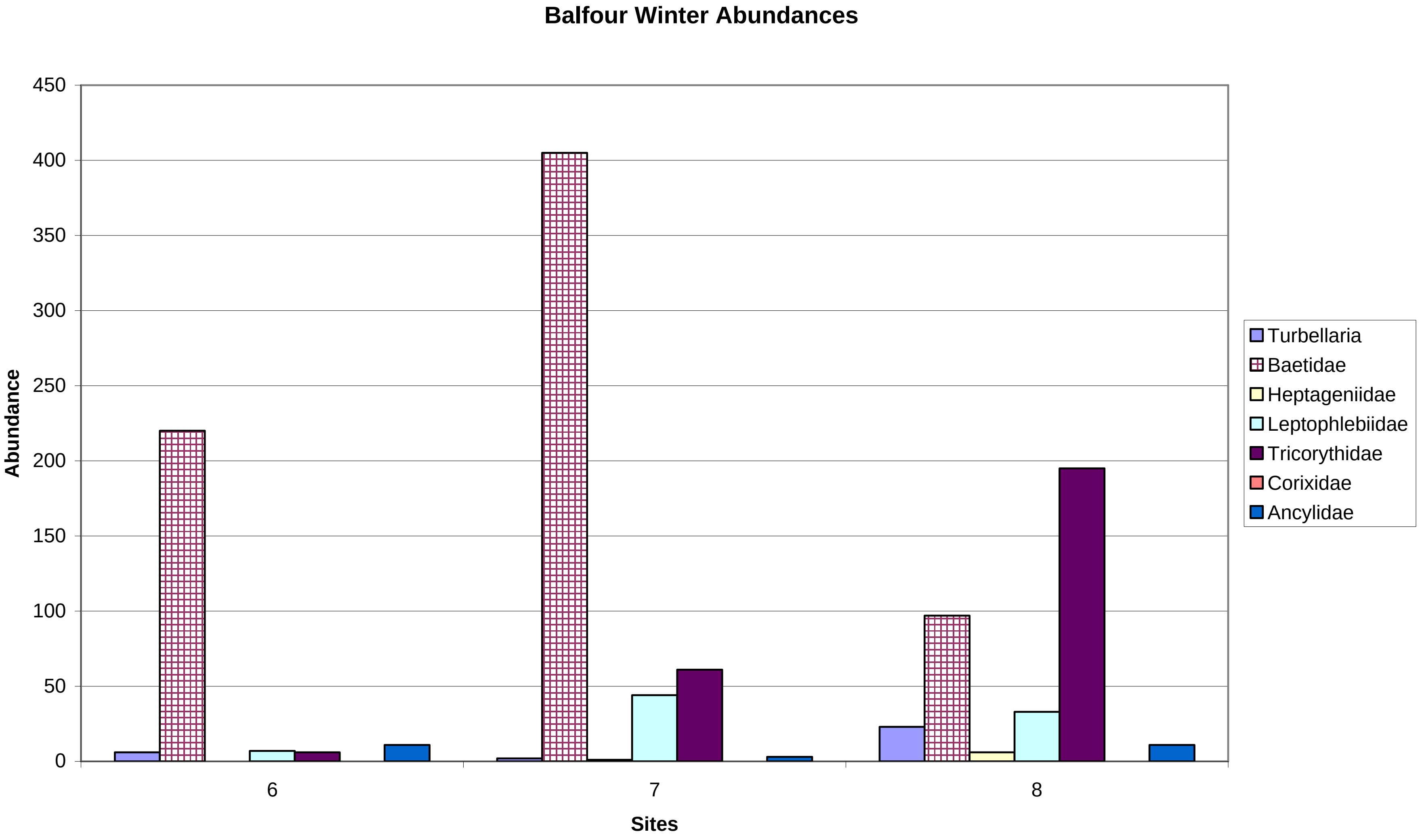



Lushington seasonal abundances
200
180
160
140
120
100
80
60
40
20
0
Abundance
A
W
Sp
S
Seasons
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae

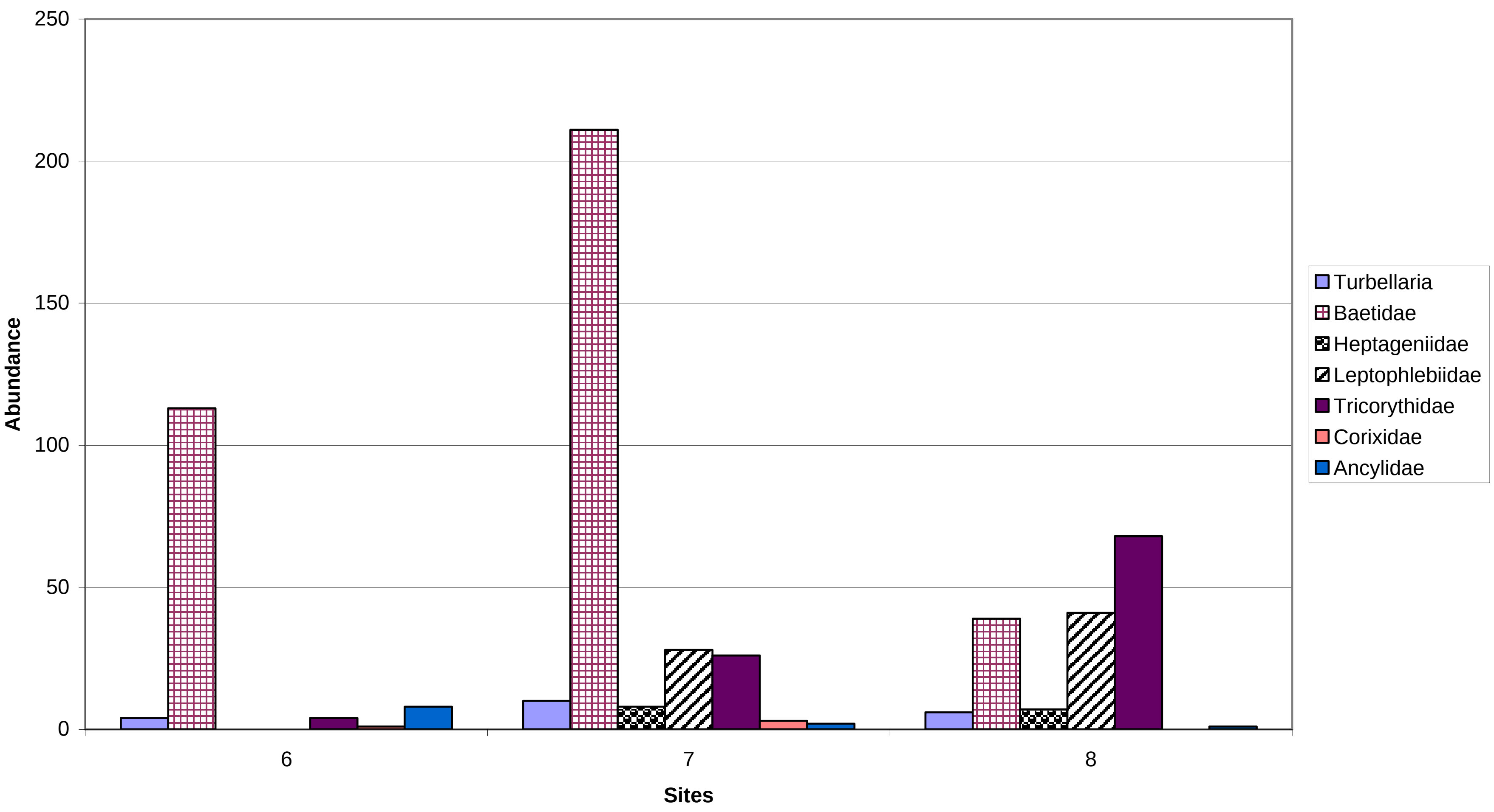

Fairbain seasonal abundances
Abundance
160
140
120
100
80
60
40
20
0
A
W
Sp
S
Seasons
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae

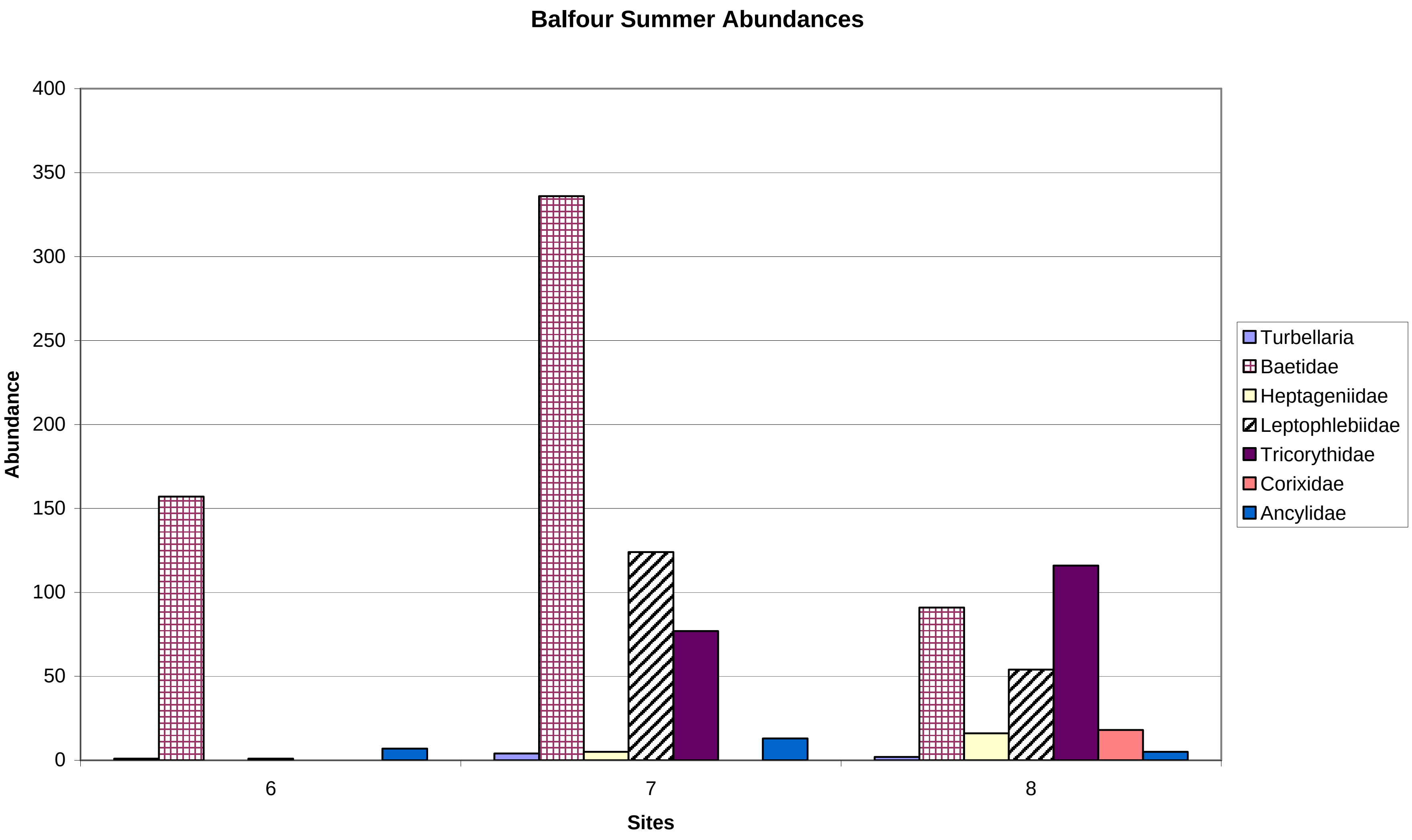
Balfour Autumn abundances

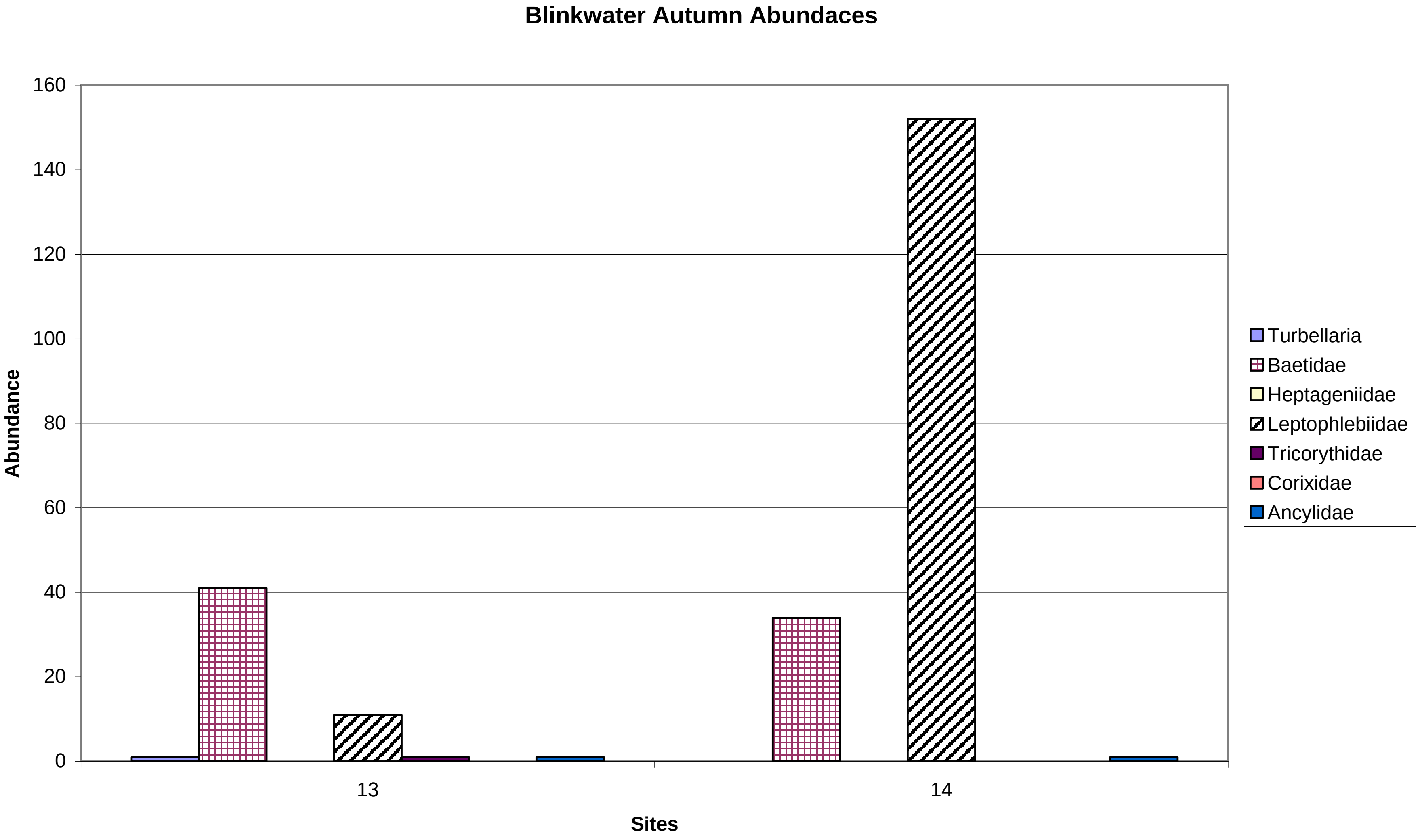


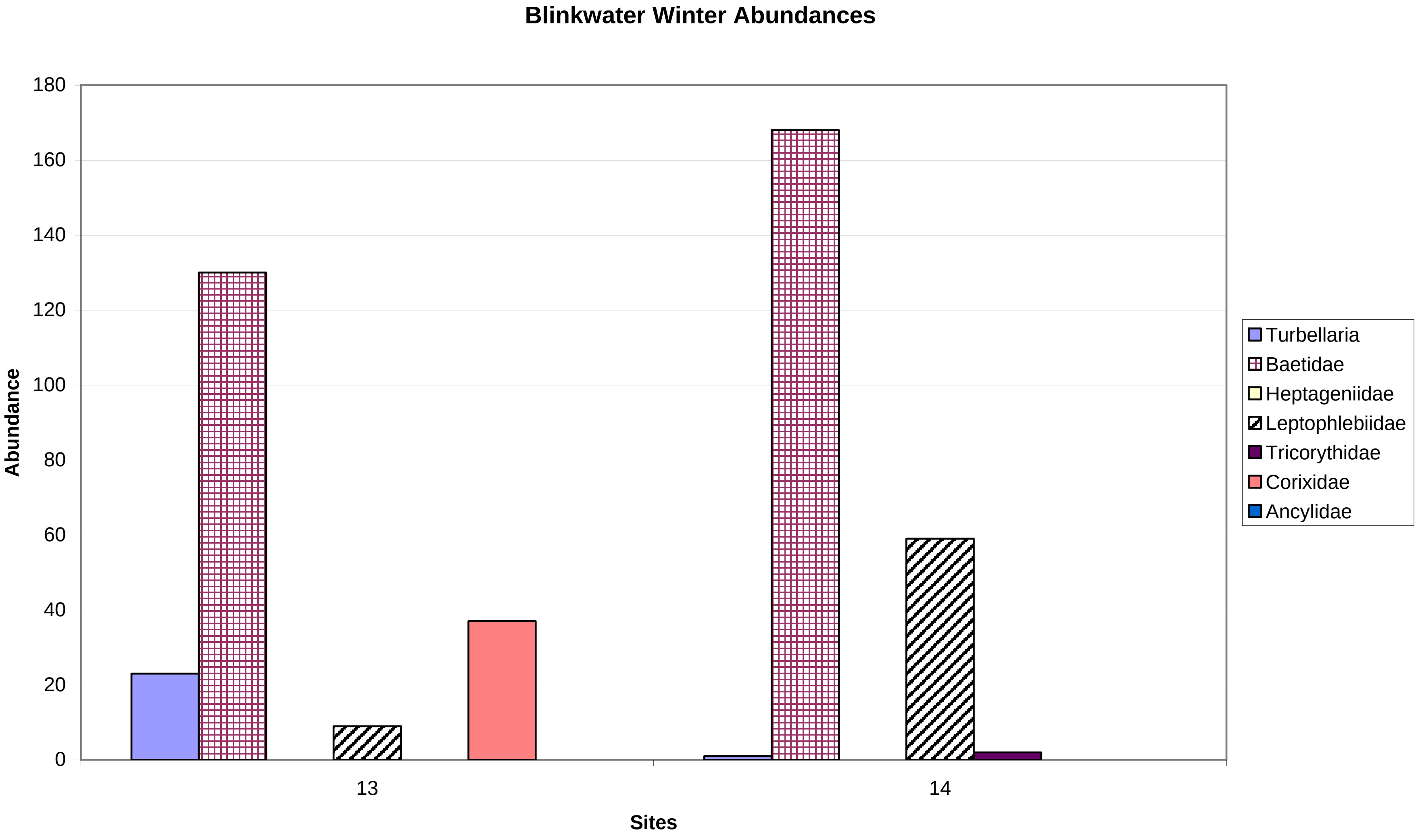

Balfour Winter Abundances
Abundance
450
400
350
300
250
200
150
100
50
0
6
7
8
Sites
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae

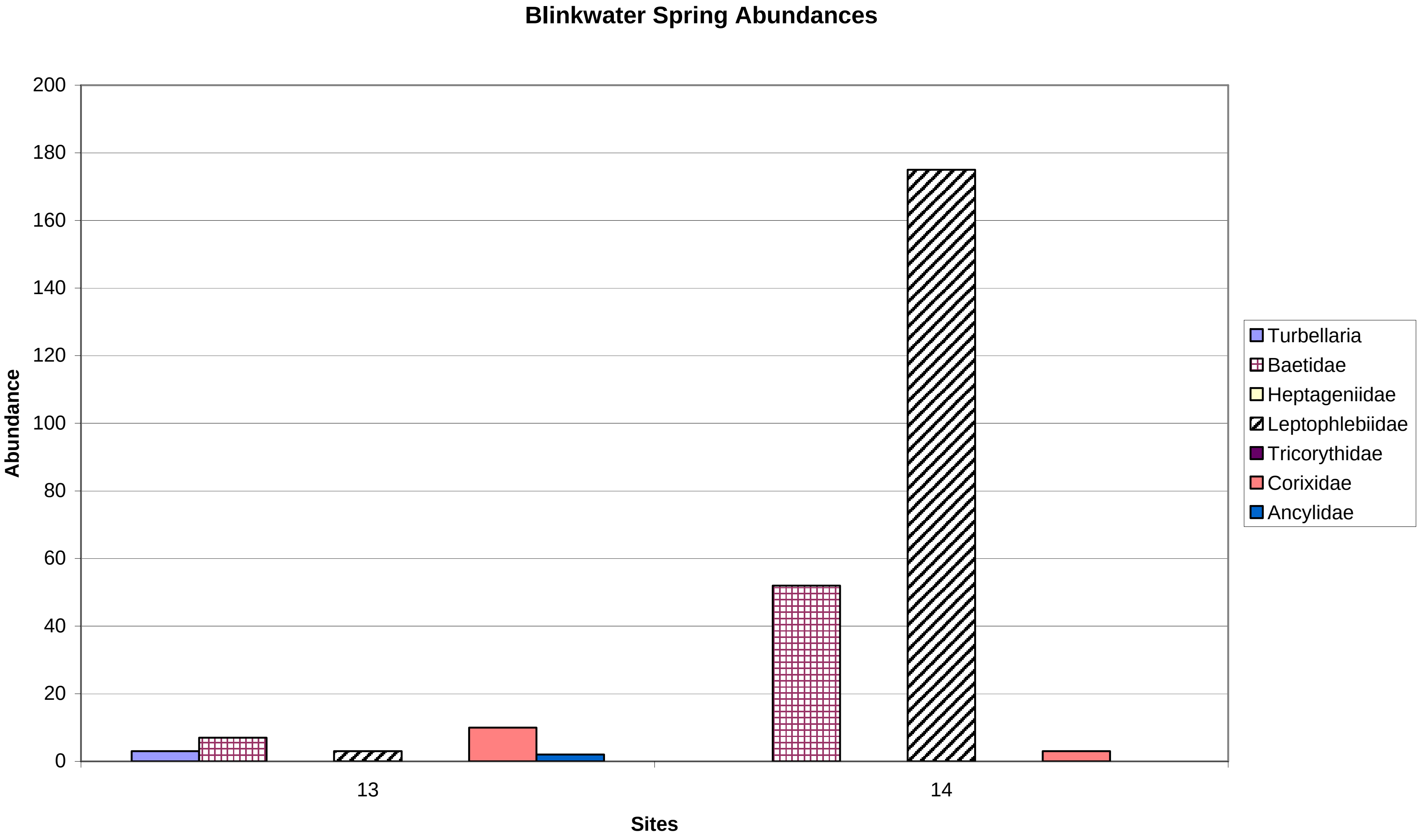
Balfour Spring Abundances




Balfour Summer Abundances
Abundance
400
350
300
250
200
150
100
50
0
6
7
8
Sites
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae


Blinkwater Autumn Abundaces
160
140
120
100
80
60
40
20
0
Abundance
13
14
Sites
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae


Blinkwater Winter Abundances
Abundance
180
160
140
120
100
80
60
40
20
0
13
14
Sites
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae


Blinkwater Spring Abundances
Abundance
200
180
160
140
120
100
80
60
40
20
0
13
14
Sites
Turbellaria
Baetidae
Heptageniidae
Leptophlebiidae
Tricorythidae
Corixidae
Ancylidae