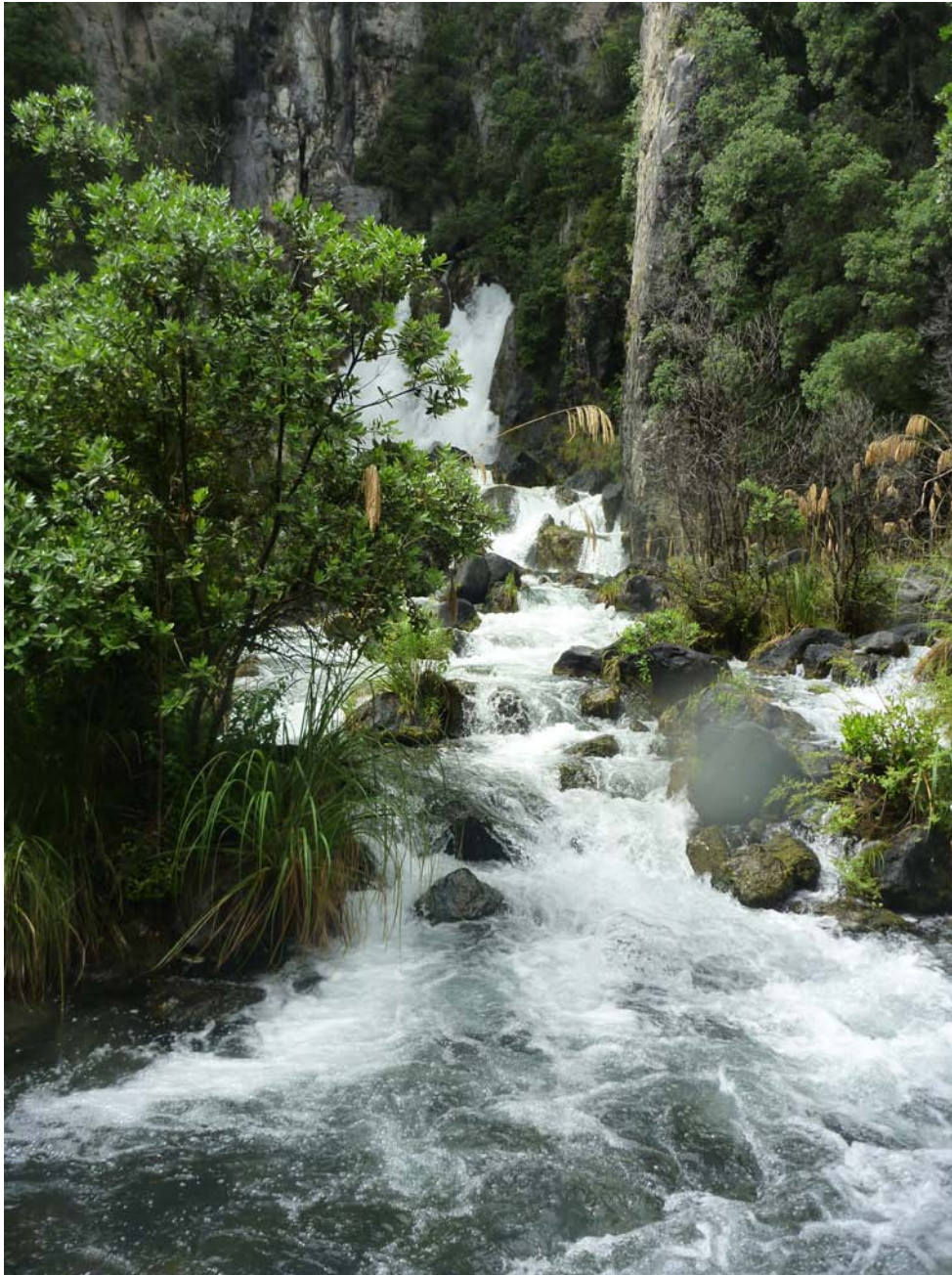

Water Quality of the Tarawera River:
A Pollutant Input Analysis of the Tasman Pulp and Paper Mill

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Abstract

Pulp and paper mills generate a significant amount of both solid and liquid wastes, creating significant disposal concerns. The most common repositories for these waste products are nearby landfills. One such area of concern is the waste disposal site of the Tasman Pulp and Paper Mill, in Kawerau, New Zealand. Studies have been conducted analyzing the contamination of the waste site itself, including solid waste and groundwater. In February 2010, water samples were taken from three regions of the Tarawera River, upstream of the mill waste site, on or adjacent to the mill and further downstream of the mill, to determine to what extent contaminants may be migrating into the river. Samples were analyzed via Atomic Absorption Spectroscopy (AAS) and Ion Chromatography (IC) to determine concentrations of a variety of inorganic species, both cations and anions. It was hypothesized that the samples taken closest to the mill discharge outlet into the river would have the highest level of contamination, but this was not supported by the data collected. Little variation was noted between data collected in February of 2008, 2009 and 2010. Concentrations of all species were well below ANZECC guidelines for allowable limits and did not vary significantly between samples collected in all three regions. Because of this, the study concluded that mill waste discharging into the river is not contributing an appreciable amount of inorganic pollutants into the Tarawera River. A Mauri Model assessment concluded that the mauri, or life sustaining potential, of the river has improved with the implementation of the waste treatment plant, but is still declining, suggesting further improvements are necessary.

I. Introduction

The Norske Skog Tasman Pulp and Paper Mill is located in Kawerau, New Zealand (see Figure 1) on land owned by a local Maori trust. Prior to 1964, the land was home to a healthy body of water, Lake Rotoitipaku. In 1964 the Maori trust was given the option to either sell or lease the land to Norske Skog to be used as a disposal site for waste from the mill (Tull & Vengosh, 2008). Not wanting to lose the land entirely, they chose to lease the land, a lease that expires soon in 2013. For the past 25 years, the mill has been dumping solid waste into Lake Rotoitipaku and the surrounding land, so much so that the lake no longer exists; It has been entirely filled in with waste sludge. Many are concerned with what impact this contamination may have on the surrounding areas as well. The mill is located only a few hundred meters from the Tarawera River and once leached into the groundwater, contaminants have the capability to migrate into both the river and other areas nearby. Several risk assessments have been done previously, but most have focused on the solid waste site, neglecting to collect valuable data from surface water sampling. This data is essential to understanding what contaminants are present and how they may be migrating from the waste site into the Tarawera River.

This study seeks to help answer these questions of contaminant migration. Surface water was collected from eleven locations in three main regions: upstream of the waste disposal site, on or directly adjacent to the waste site and downstream of waste discharge into the river. The samples were analyzed for a variety of species including both cations and anions. This year's data was compared with existing data from 2008 and 2009 to assess temporal changes. It was hypothesized that the samples taken upstream of the mill would have lower concentration of toxic species that those taken near or downstream of the disposal site. Samples taken closest to where the solid waste site is located adjacent to the river were expected to have the highest levels of contaminants, with concentration decreasing with distance from the mill due to natural dilution. It was also hypothesized that values would not change significantly between 2008 and 2010 since the waste output has not changed drastically within that time frame. If the waste dumped on the disposal site is leaching out of the ground into the river, an increase in toxic species downstream over the site would be expected over time. It is unclear to what extent this is occurring, however, so there is not enough to background data to warrant this hypothesis.

II. Background

Site Background

The Tasman Pulp and Paper mill is located in the Bay of Plenty region in New Zealand in the town of Kawerau (see Figure 1).

The mill itself sits only 300 meters from the Tarawera River. When the mill was first established, the untreated waste was dumped directly into the river. In 1964, the mill gained access to land owned by a local Maori trust (A8 land-block, see Figure 2) to be used as a waste disposal site through the Tasman Pulp and Paper Enabling Act (Tull & Vengosh, 2008). Since then, sludge has completely inundated Lake Rotoitipaku, leaving a toxic waste site in its place (see



Figure 1. Map of Bay of Plenty Region. Kawerau, labeled on the map, is located in the central region of the Bay of Plenty. (www.localcouncils.govt.nz)

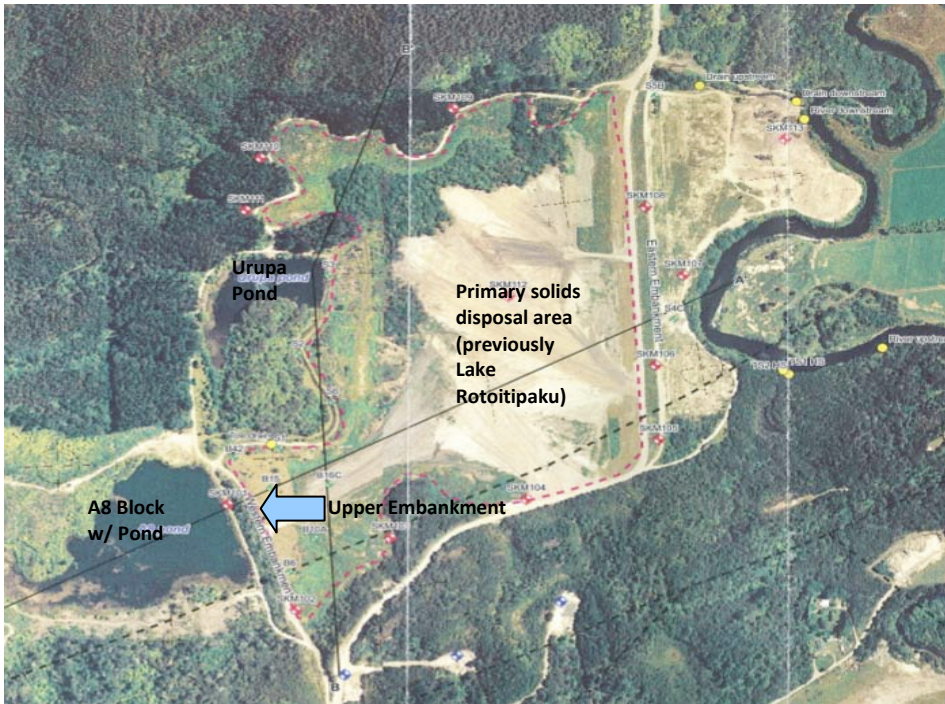


Figure 2. Mill Waste Disposal Site. Previously the site of Lake Rotoitipaku, this aerial photograph shows the current status of the waste disposal site.

Figure 2).

In a site description of a 2004 risk assessment, the landfill is situated on “one of the worst locations one could contrive for a waste disposal site” (GRLM, 2004). The ground contains highly permeable rocks with a high groundwater table and sits on top active

faults (Tull & Vengosh, 2008). The hydrology of the area is such that contamination migration to the nearby Tarawera River is extremely likely (SKM, 2007).

Pulp and Paper Industrial Processes

For a complete picture of the contaminants entering the disposal site, the industrial processes involving the conversion of pulp to paper must be understood. The three primary steps in this process are pulping, pulp processing (including bleaching) and papermaking (EPA, 2002).

Pulping

The first step, pulping, involves preparing the wood for further processing. The pulping process is responsible for the majority of pulp and paper industry environmental impacts. Logs on site are mechanically broken down (i.e. sent through chipping machines) to provide smaller pieces for chemical processing. Wood chips are then dissolved into fibers by a variety of chemical, semi-chemical or mechanical methods. The process used depends on the desired end product.

1. Chemical Methods

Most pulping plants use chemical methods, which typically yield the strongest and highest quality fibrous pulp. Chemical pulping involves breaking the bonds between the cellulose fibers by digesting the wood at very high temperatures and pressures. Sulfites and hydroxides are two

commonly used chemicals in this process. The most popular method is kraft pulping, which is in use at the Tasman mill, where a solution of sodium sulfide and sodium hydroxide is used to digest the wood. This method is popular because it yields very strong pulp that can be used for a variety of finished products. The chemicals can also be easily recovered, which gives this method the potential of having a smaller environmental impact. Another less common method is sulfite pulping, which uses sulfurous acid and bisulfite ions to perform the digestion (EPA, 2002).

2. Semi-chemical Methods

These methods use lower temperatures and more dilute solutions for the chemical digestion, along with mechanical processes to separate the fibers. Semi-chemical methods do not remove as much lignin from the wood as chemical methods, which makes bleaching more difficult (EPA, 2002).

3. Mechanical Methods

These methods are only used to prepare pulp for low quality paper production, like newsprint. Physical pressure rather than chemical digestion is responsible for separating fibers. Sometimes a minimal amount of chemicals is used to soften the wood before mechanically processing it. Pulp yields can be as high as 95% (compared to ~45% yield from chemical methods) but the pulp is a much lower quality (EPA, 2002).

Pulp Processing

Once the wood has been converted to pulp, impurities need to be removed via pulp processing. Steps here involve screening, difibering and deknottting. Residual chemicals from the pulping process are washed from the pulp using brown stock washers before the pulp can be bleached. This is necessary because the chemicals involved in the digestion from the previous step readily consume bleaching chemicals, increasing consumption and cost. These chemicals are recovered so they can be reprocessed and reused, saving costs and minimizing the environmental impact. Recovery methods vary based on pulping method. For the kraft method, residual weak black liquor is collected and concentrated via evaporation, then burned in a recovery boiler to generate energy for the pulp and paper plant. Chemicals that can't be combusted ("smelt") pass out of the boiler and are recausticized with a variety of additional chemicals. Through a series of chemical reactions, sodium hydroxide and sodium sulfide can be recovered and reused as these are two of the main ingredients for pulping digestion (EPA, 2002).

Bleaching

Processed pulps are then typically bleached to increase brightness and softness. Since 1990, plants have stopped using elemental chlorine due to environmental concerns about dioxins, which are also known to have negative impacts on wildlife and human health. Some of these chemicals may be present in waste dumped prior to 1990, however. Chemical bleaching involves submerging the pulp in an acidic solution to whiten the lignin in the pulp, followed by an alkaline solution which removes reaction by-products generated in the acidic step. Up to 18% of pulp can be lost during this process due to harsh conditions (EPA, 2002).

Paper Manufacture

After processing, the pulp is ready to be turned into paper. This involves forming the pulp into sheets which are then dried. The waste water collected from the drying process is filtered and the contaminants are concentrated into a sludge, which is then disposed of in a landfill. Potential water pollutants from these processes include solids, BOD (biochemical oxygen demand), chlorinated organic compounds and water with a high concentration of suspended particles.

Previous Site Assessments

2004 & 2007 Risk Assessment

In 2004, Gulf Resource Management Ltd (GRML) was hired by Norske Skog Tasman to assess the risk of contamination of the A8 block, including the upper embankment and the primary solids waste disposal areas (see Figure 2).

According to their analysis, all 19 of the 19 samples taken exceeded ANECC allowable levels for at least one chemical in the primary solids disposal site. The primary contaminants included dioxins, arsenic, boron, mercury, and lead. Groundwater samples were also taken from the primary solids waste area. Of the nine samples taken, seven exceeded the ANZECC guidelines for nitrogen and all nine exceeded the safe level of manganese in drinking water (GRML, 2004).

The second part of the risk assessment covered the general mill waste site. 45 boreholes were sampled and analyzed for pH, conductivity and anions. These tests revealed that groundwater quality on the waste site was extremely poor, with every sample exceeding the allowable concentration for at least one parameter. This degradation was determined to be due to the waste disposal since baseline monitoring indicated only elevated zinc concentrations and low pH, which would not explain the other contaminants found (GRML, 2004).

GRLM's final assessment concluded that there is a high risk of contaminant migration to the surrounding environment, as well as a high risk to the mauri of the area. Mauri is pervasive in Maori culture and is a concept of life force or capacity of something to sustain life (Morgan, 2006). Mauri is discussed in more detail in Chapter 5. Later site reports by Sinclair Knight Merz (2007) confirmed these findings (SKM, 2007). Those assessments focused on the landfill and groundwater right on site. Detailed analysis was not performed on surface water bodies located adjacent to the landfill.

2008 Water Quality Testing of Surface Water Bodies

In 2008, Kristen Tull, a masters student at Duke University performed further testing of the site. Attention was also paid to distinguishing the inputs from both geothermal and anthropogenic sources, a key issue. Via isotopic fingerprinting, she was able to determine that geothermal waters have not mixed with A8 or Urupa pond (see Figure 2), meaning that elevated levels of inorganic compounds cannot be attributed to natural input (Tull & Vengosh, 2008). However, the evidence suggests that the higher concentrations of iron and manganese are due to dissolved sediments from reducing conditions rather than direct anthropogenic input. Further study of organic contaminants is needed to fully understand this relationship (Tull & Vengosh, 2008).

2009 Water Quality Testing

Last year, additional water quality testing was performed, adding to the growing body of data. Samples were taken from 45 bore holes on the waste disposal site and analyzed for both cations and anions. The primary aims of the study were to determine if concentrations varied seasonally, spatially and with depth (Wolfe, unpublished). Overall, analysis showed little seasonal variation, but significant variation spatially and with depth. Ion concentrations were higher on the eastern border of the landfill, potentially due to contaminant migration down slope. Chloride concentration typically increased with depth, possibly due to geothermal input. Increased concentration of metals at lower depths is likely due to the reducing conditions created by high amounts of organic content (Tull & Vengosh, 2008). The only species that consistently exceeded ANZECC guidelines was zinc; all other species were below allowable limits. This study concluded that concentrations had not changed significantly since 2006, but points out that further testing is needed to accurately reflect variation over time. Although surface water was sampled, the 2009 study chose to focus on groundwater. The present study has picked up where last year's study left

off and worked to help fill this gap by focusing on surface water contamination of the Tarawera River.

III. Methods

Field Work

Water samples were collected from eleven sites in three regions to assess spatial variation in relation to proximity to the mill (see Figure 3). Three surface water samples were taken from location 1 (upstream of the mill) four surface water sites and two groundwater sites at location 2 (directly adjacent to the mill) and three surface water sites from location 3 (well downstream of the mill). One sample was taken straight from the discharge flow, and another was taken further downstream of where the waste water enters the river. All the samples were taken over the course of the week of February 12th, 2010.



Figure 3. Map of Water Sampling Locations. Samples were taken from three regions: upstream of the waste site (1), on or directly adjacent to the waste site (2) and further downstream of the where the waste discharges into the river (3).

Samples taken from the Tarawera River were collected by hand using a 1 L high-density polyethylene (HDPE) bottle. All bottles were rinsed with water from the collection site to ensure

the samples were not contaminated. The bottles containing samples intended for cation and anion analysis were acidified with trace amounts of nitric acid and put on ice shortly after collection. The exact procedure can be found in the Frontiers Abroad 2010 field course curriculum, Appendix A: Water Sampling Background Information (Frontiers Abroad, 2010).

While samples were collected for laboratory analysis, on site testing took place as well. Measurements for percent dissolved oxygen (DO), pH, temperature, conductivity and flow rate (if applicable) were taken on site. Lastly, field conditions were recorded at each site, including time of collection, weather conditions and a description of the sampling location. The exact location of the samples was recorded using a handheld GPS unit.

Lab Analysis

Laboratory analysis was undertaken in the School of Environment geochemistry lab, University of Auckland. Concentrations of calcium, potassium, magnesium and sodium were obtained using atomic absorption spectroscopy (AAS). Each sample was run in triplicate to increase the validity of the measurements. AAS calculates the concentration of a particular ion by measuring how much light at a particular wavelength is absorbed by the sample. The method used in this study was flame AAS, which atomizes the sample with a hot flame. Element-specific cathode tubes are used to transmit light through the atomized sample and the amount of light transmitted is measured by the detector. By calculating how much light is absorbed by the sample and plotting this value on a calibration curve generated with absorbance values of standards, the concentration of the unknown sample can be determined. While this method is quite effective for determining concentrations of various metals, another method is needed to quantify anions, or negatively charged species (Skoog, 2007).

In this study, concentrations of four anions of interest, sulfate, chloride and nitrate, were determined using ion chromatography (IC). This method involves the injection of a sample solution into a column where the anions chemically interact with the walls of the column. These interactions are dependent on the polarity of both the sample, which vary from ion to ion, and the column. The ions separate as they move through the column, as each ion elutes at a different rate due to its unique polarity. Concentration of the anion here is a function of retention time in the column. Once again, by comparing retention time of the unknown samples to retention times of standards, the unknown concentration can be determined (Skoog, 2007).

IV. Results

A total of 11 surface water samples were analyzed from the three regions – three from region 1 and four each from regions 2 and 3. All samples fell in to one of three categories: upstream of the mill, directly adjacent to the mill, or further downstream from the mill. A variety of parameters were measured in the field (see Figure 5).

	Location	Site Description	Date Collected	T	pH	DO (%)	Conductivity (uS/cm)
Region 1	TWS1	Tarawera Outlet	14.2.10	22.6	8.21	58.6	546
	TWS2	Near Bridge	14.2.10	19.8	7.49	81.3	444
	TWS3	T. River Water Supply	14.2.10	18.3	7.54	70	224
Region 2	TWS12	T. River Downstream of EE	15.2.10	18.6	7.3	76.2	347
	TWS13	T. River Downstream of Treatment Ponds	15.2.10	20.8	6.74	57.9	360
	TWS14	Geothermal Spring T. River	15.2.10	50.4 ¹	6.76	24.9 ³	566
	TWS20	Kawerau Bridge	13.2.10	19.6	7.14	66.5	169
Region 3	TWS16	Intersection of Rd 30 & Onepu Spring Rd	13.2.10	19.3	6.98	98.8	222
	TWS17	Rd 2 to Matata	12.2.10	20.2	7.25	nd	208
	TWS18	Near Estuary Along Rd 2	12.2.10	20.1	7.07	90.6	210
	TWS23	Braemar Spring	12.2.10	16.7	6.32 ²	78.4	78

Figure 5. Surface Water Field Parameters.

Temperature remained relatively consistent at all sites, fluctuating between 16.7 and 22.9°, with the exception of a geothermal spring that was sampled¹. pH varied between slightly acidic (6.32) to slightly basic (8.45). The pH reading of 6.32 is the only measurement that falls outside ANZECC safe pH guidelines². Percent dissolved oxygen ranged from 24.9% up to 98.8%. However, most values were between 60-80%; the one measurement of 24.9% was taken from a geothermal spring near the waste site³.

Region 1: Upstream of the Tasman Pulp and Paper Mill

Calcium concentrations in region 1 ranged from 3.45-7.68 ppm. These values were all slightly higher than those obtained last year (see Figure 6). In contrast, potassium levels at the three sites in region 1 were essentially the same as they were in 2009, dropping approximately 0.2 ppm at each site (see Figure 7). Sodium levels decreased significantly, from 52 ppm to 10 ppm at TWS2 and 48 ppm to 14 ppm at TWS3 (see Figure 8).

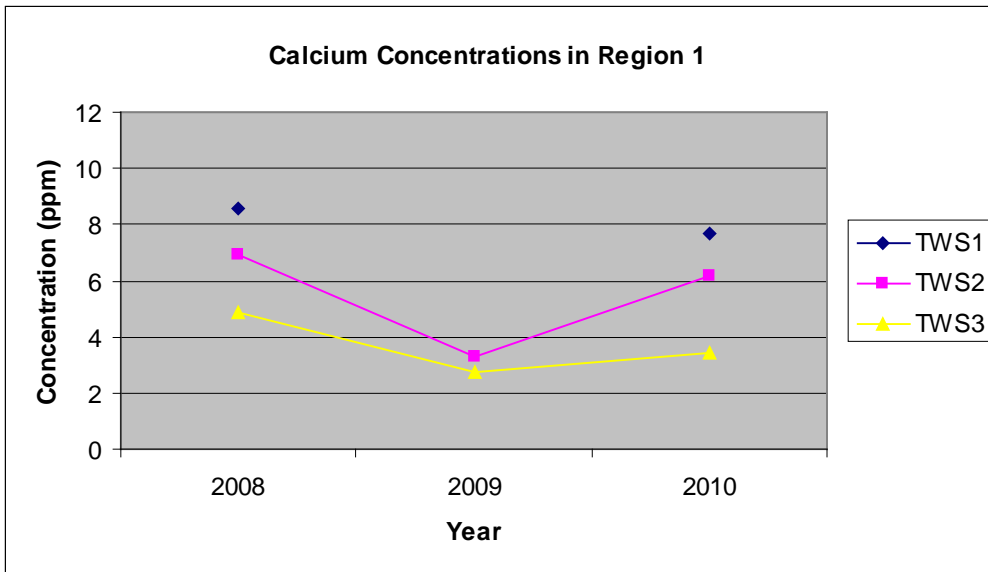


Figure 6. Calcium Concentrations from 2008-2010 in Region 1.

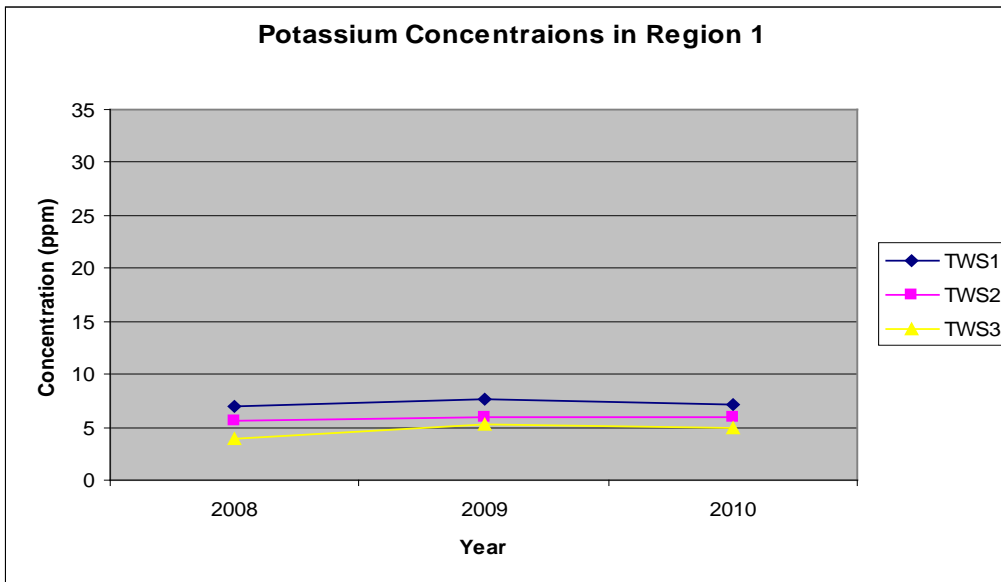


Figure 7. Potassium Concentrations from 2008-2010 in Region 1.

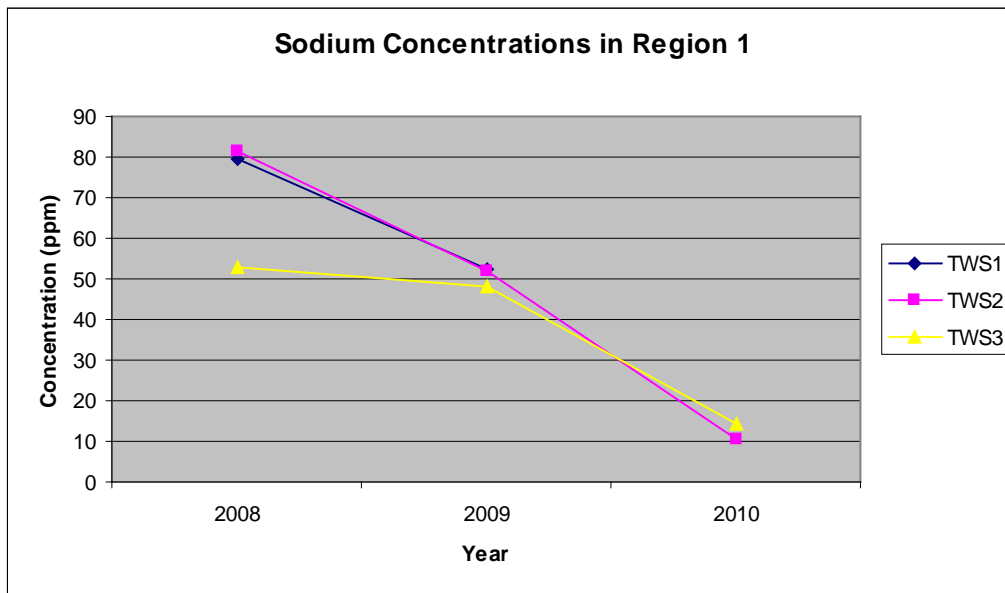


Figure 8. Sodium Concentrations from 2008-2010 in Region 1.

The concentration of the two anions, chlorine and sulfate, decreased in every case with the exception of chlorine at TWS3. Here the chlorine concentration increased from 98 ppm to 109 ppm. All other values dropped slightly. Chlorine concentrations for 2010 ranged from 109-135 ppm while sulfur levels varied between 40 ppm and 90 ppm (see Figures 9 & 10).

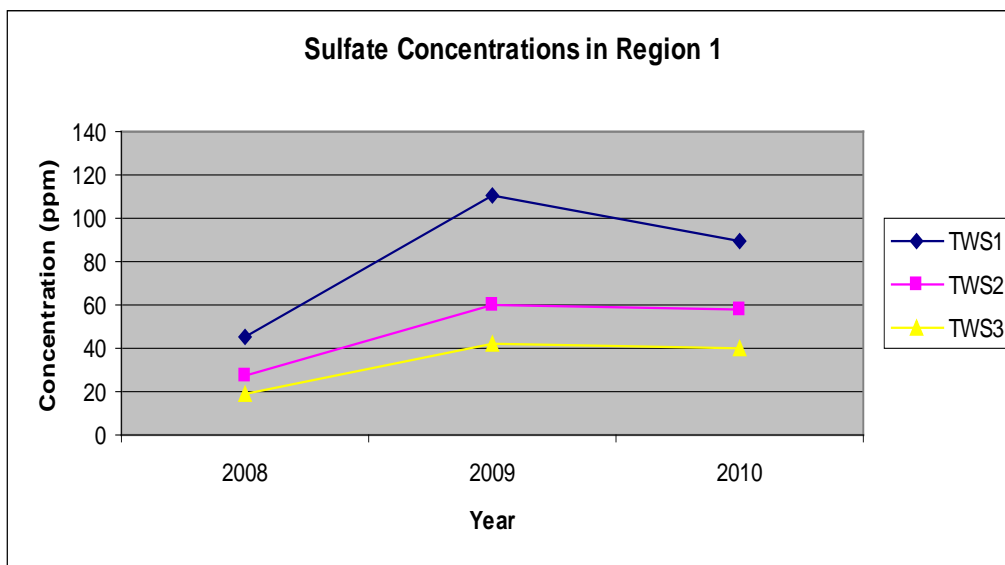


Figure 9. Sulfate Concentrations from 2008-2010 in Region 1.

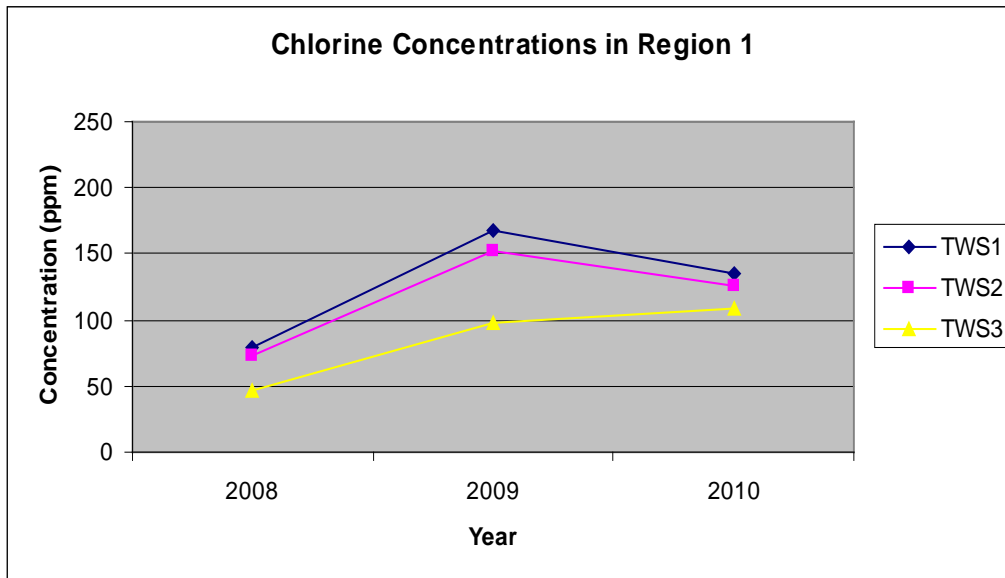


Figure 10. Chlorine Concentrations from 2008-2010 in Region 1.

Region 2: On or Adjacent to the Mill

After dropping by nearly 50% each between 2008 and 2009, calcium concentrations all increased slightly from 2009 and 2010 and were in the range of 2.66 ppm to 4.233 ppm (see Figure 11). It is interesting to note that these values still remained on average lower than the calcium concentrations of region 1. Potassium concentrations increased very slightly at TWS 12 & 13, while decreasing by 2 ppm at TWS 14 (see Figure 12). Sodium levels were significantly lower than previous years, with the exception of TWS 14, a geothermal spring, which still registered as too high for instrumental analysis (see Figure 13).

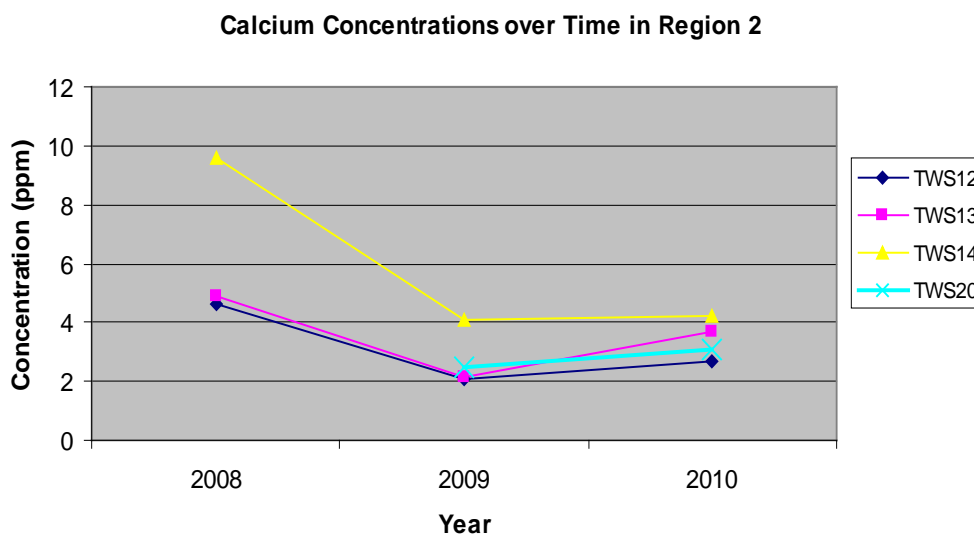


Figure 11. Calcium concentrations from 2008-2010 in Region 2.

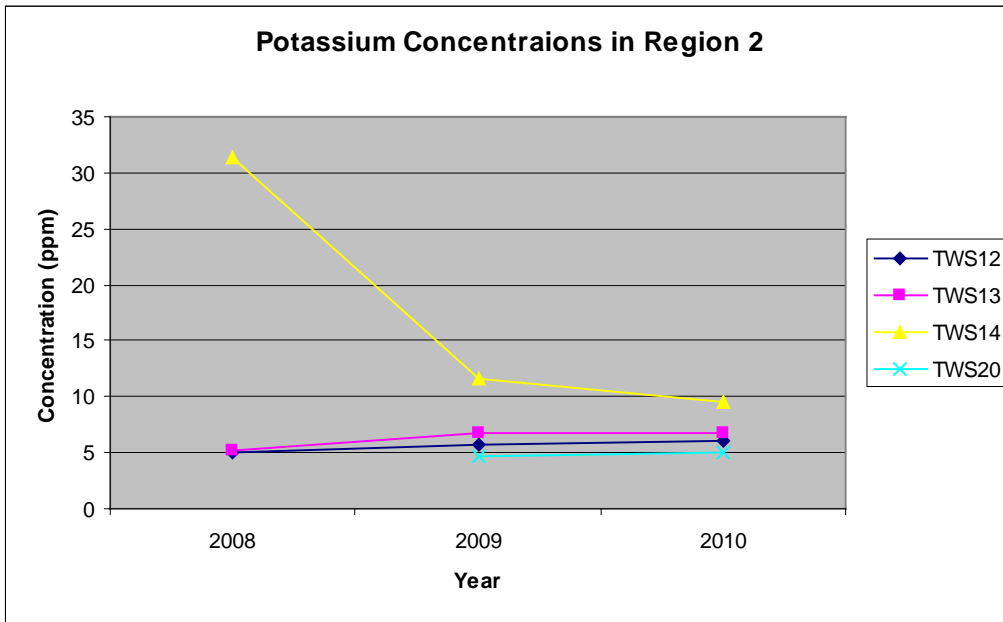


Figure 12. Potassium concentrations from 2008-2010 in Region 2.

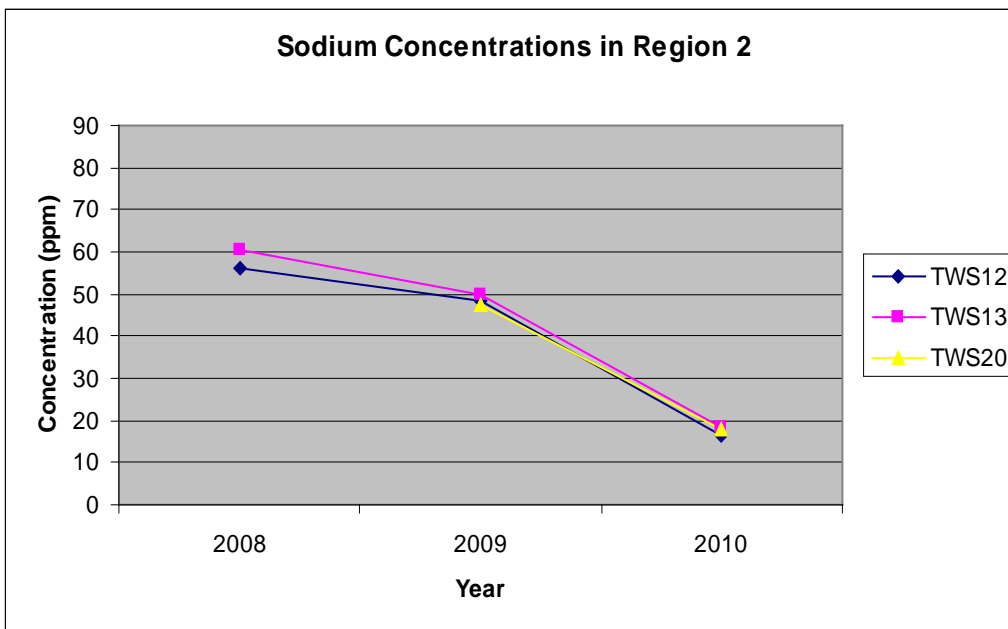


Figure 13. Sodium Concentrations from 2008-2010 in Region 2.

All sulfate measurements decreased slightly from last year's data. TWS 14 experienced the greatest drop, from 124 ppm to 74 ppm (see Figure 14). Chlorine levels at TWS 12 and TWS 13 both decreased by about 20 ppm, while TWS 14 again shows a larger reduction from 209 ppm to 136 ppm (see Figure 15).

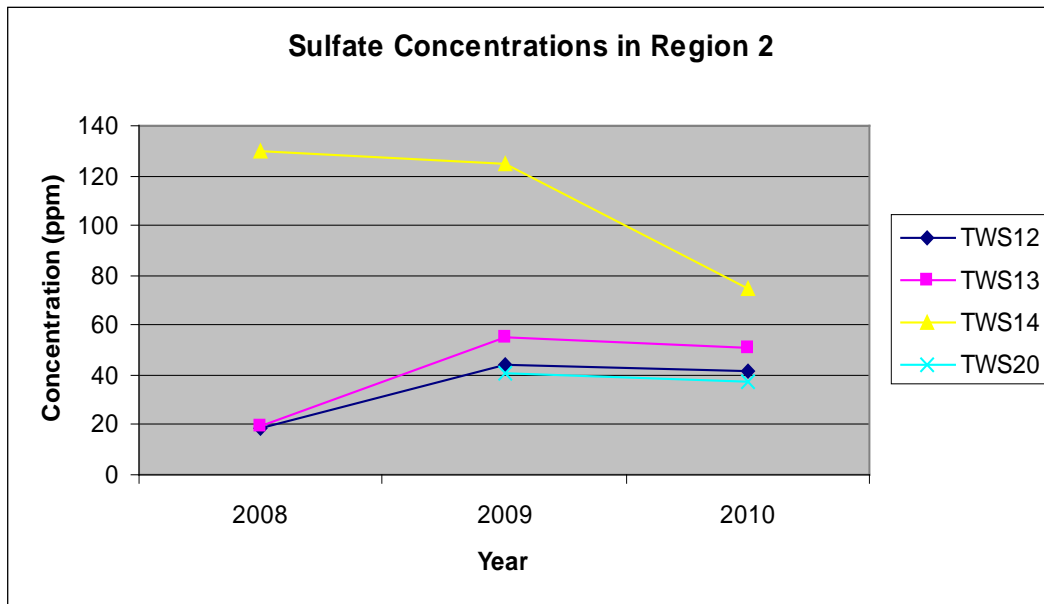


Figure 14. Sulfate Concentrations from 2008-2010 in Region 2.

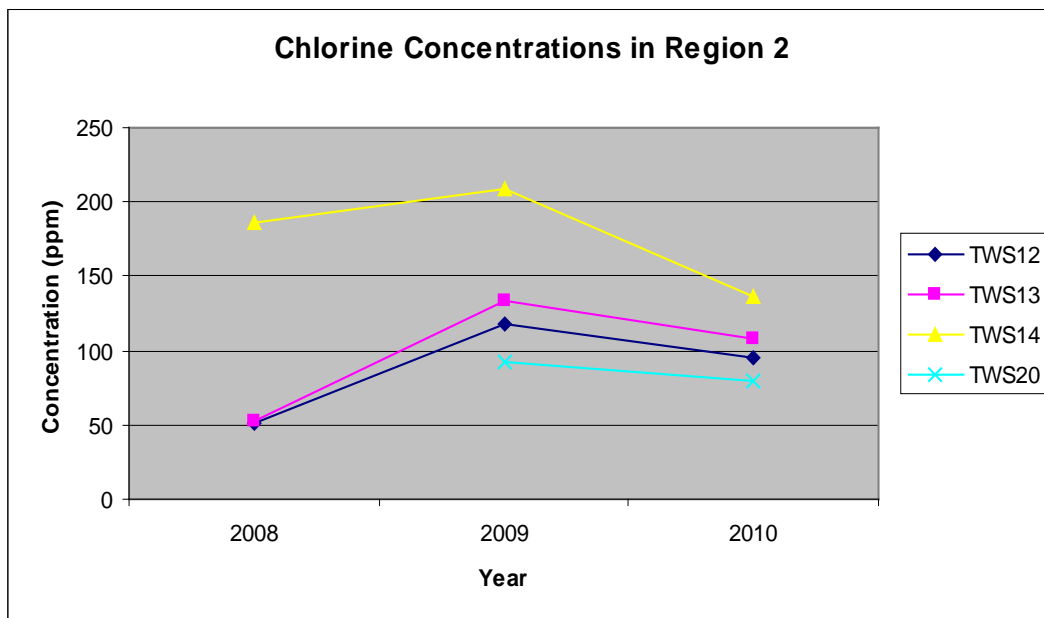


Figure 15. Chlorine Concentrations from 2008-2010 in Region 2.

Region 3: Downstream of the Mill

Calcium levels decreased by over 50% between 2008 and 2009, but experienced a slight increase between 2009 and 2010 (see Figure 16). The only exception to this was TWS 23, Braemar Spring, which barely registered in 2009 or 2010 (no data exists from 2008). Concentrations of potassium in region 3 samples all dropped slightly (see Figure 17). Like regions 1 & 2, the most

significant temporal variation was in sodium concentrations, which decreased from around 50 ppm to between 14-20 ppm in all samples (see Figure 18).

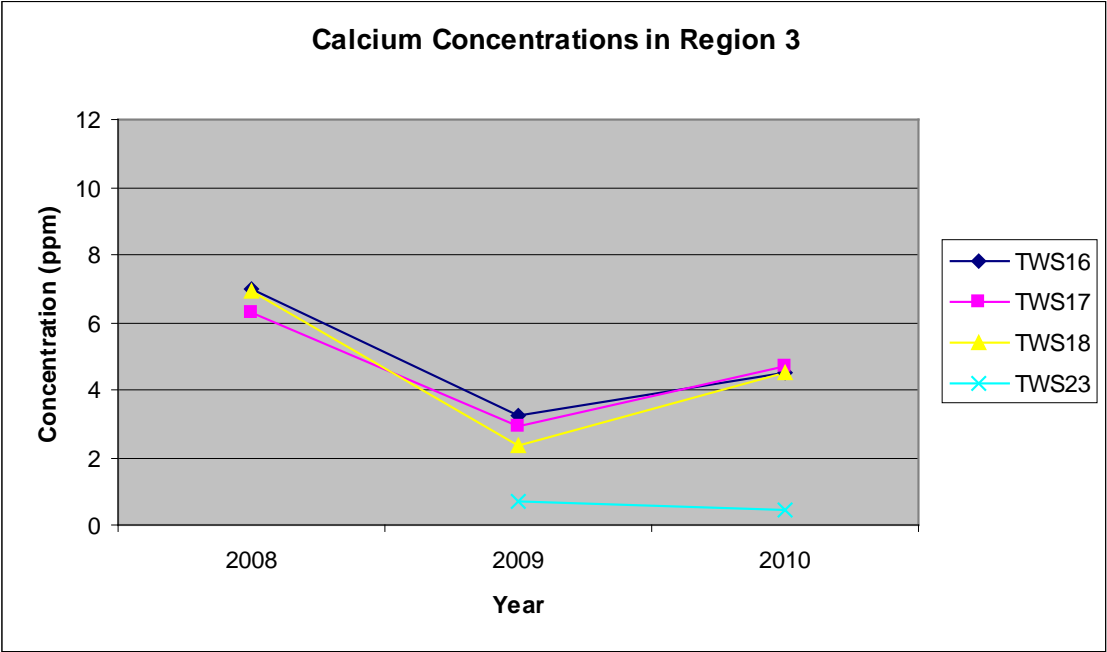


Figure 16. Calcium Concentrations from 2008-2010 in Region 3.

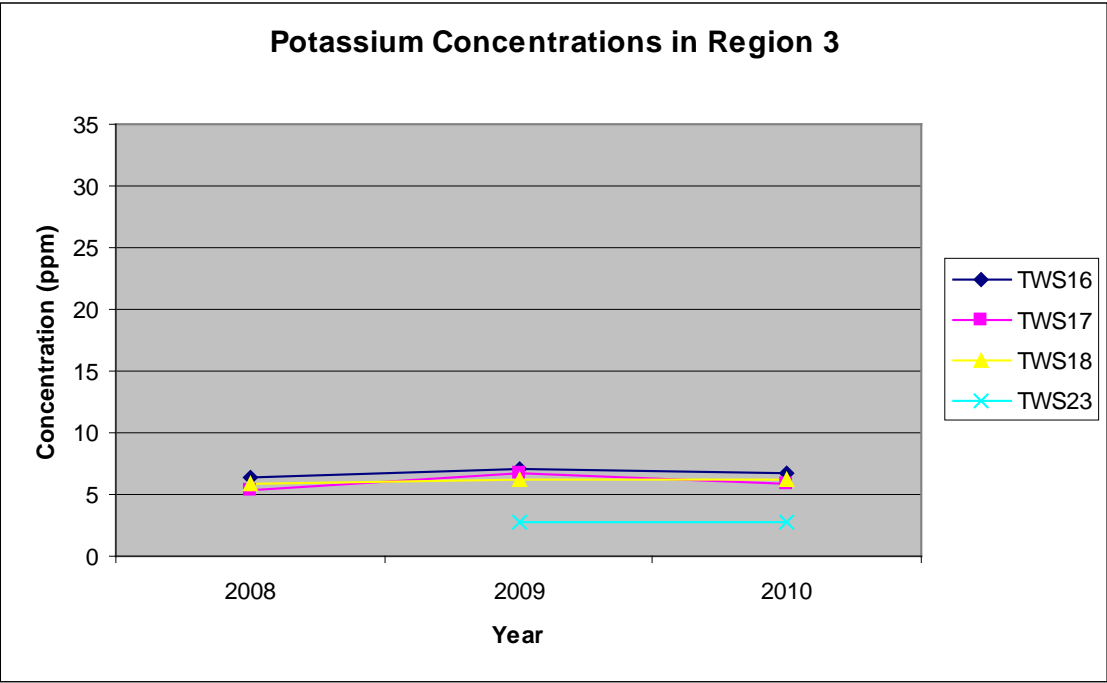


Figure 17. Potassium Concentrations from 2008-2010 in Region 3.

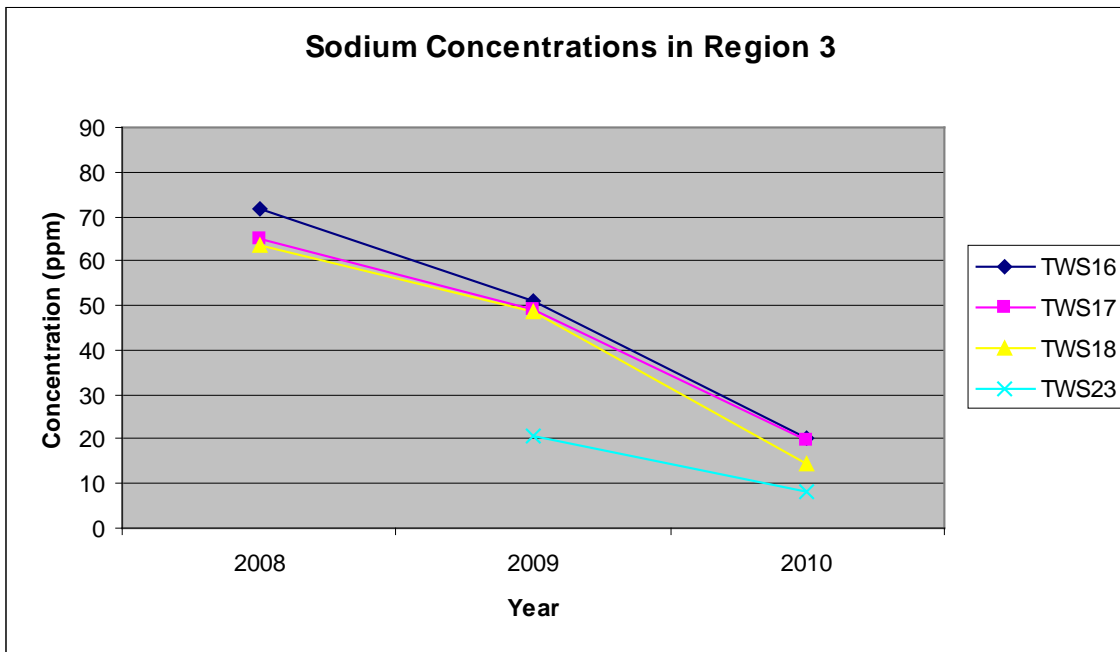


Figure 18. Sodium Concentrations from 2008-2010 in Region 3.

Similar to regions 1 & 2, concentrations of sulfate and chlorine decreased in region 3 samples between 2009 and 2010. Sulfate values were slightly higher than those found in region 2, ranging from 57-70 ppm (see Figure 19). Chlorine levels, on the other hand, were comparable to region 2 and slightly below region 1 values (see Figure 20).

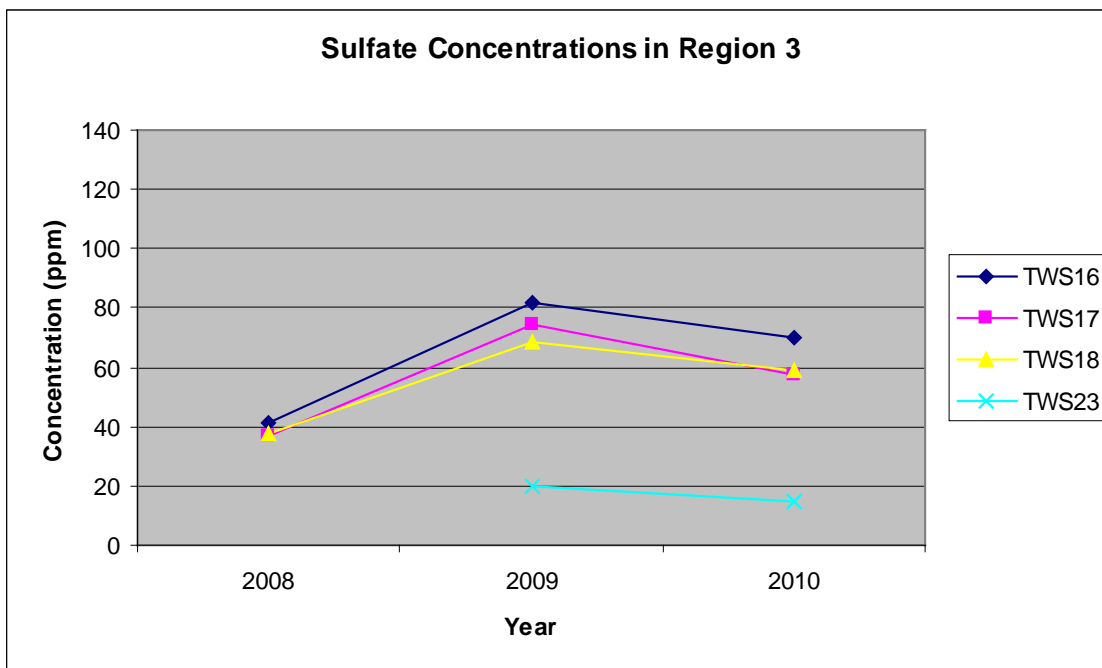


Figure 19. Sulfate Concentrations from 2008-2010 in Region 3.

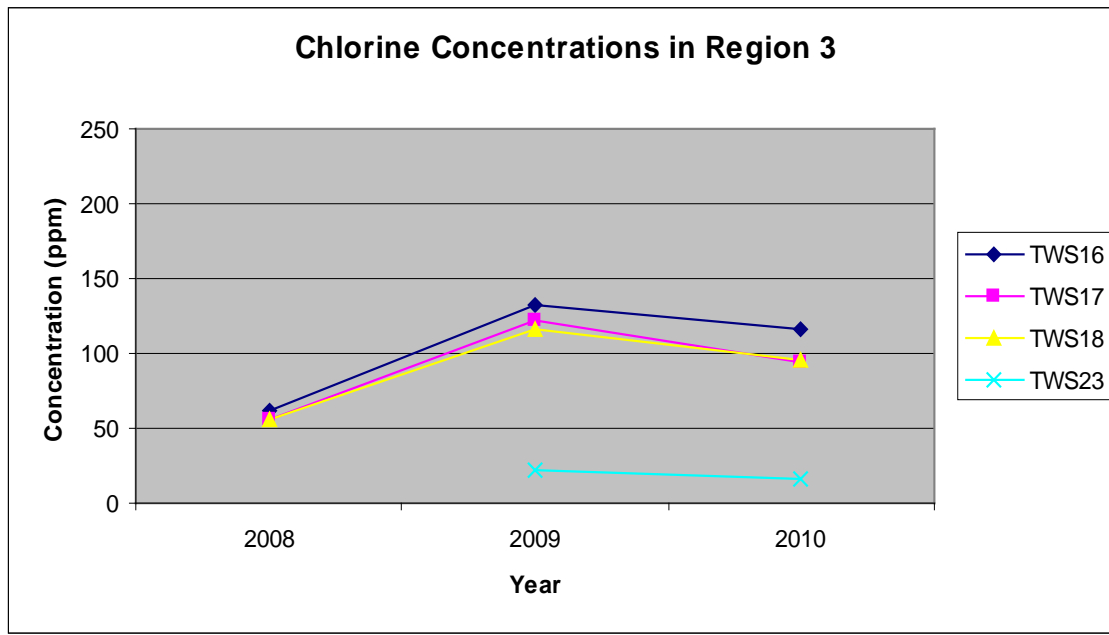


Figure 20. Chlorine Concentrations from 2008-2010 in Region 3.

V. Discussion

Temporal Trends

In general, differences between 2008, 2009 and 2010 measurements were minimal. None of the cations that were tested for approached levels anywhere near ANZECC standards. Values for calcium concentrations varied between less than 1 ppm up to 10 ppm across all sites sampled all three years. These concentrations are so low that it is difficult to determine any patterns or definitively state that the ions are present at all in appreciable amounts. The standard deviation calculations for many of the measurements were large relative to the calculated calcium concentration, indicating that in some cases, experimental error may be responsible for the measurement. In other words, instrumental uncertainty may be registering calcium is present when in reality there is none.

Similarly, potassium concentrations did not fluctuate significantly over the three years studied. Values ranged from 3-8 ppm, with the exception of TWS 14. TWS 14 is the site of a geothermal hot spring, however, which may account for multiple anomalous values, further discussed in the following section addressing spatial trends. These values are still far below ANZECC guidelines, an indication that potassium levels are not of concern, nor are they changing appreciably over time.

The biggest temporal change was seen in sodium concentrations. In 2008, values ranged from 53 ppm to a reading of “high” from the spectrometer. In 2010, while one sample remained “high”, the geothermal hot spring at TWS 14, the remainder of the values fell between 8-20 ppm, lower than both 2008 and 2009 measurements. However, it is important to note here that difficulties with the AAS were experienced when performing the sodium runs. The instrument was becoming clogged easily with the relatively high amounts of sodium. It is not unreasonable to question the validity of this year’s data, which was consistently lower than 2008 and 2009 values. Even if the 2010 data was inaccurately low, data from the previous two years suggest that sodium levels are still of little concern, falling well below the allowable limit of 300 ppm.

Concentrations of sulfate increased between 2008 and 2009 at all sites with the exception of TWS 14. These increases, however, were partially counterbalanced by decreases from 2009 to 2010. Values from 2010 data range from 14-90 ppm, all well below ANZECC guidelines of 1000 ppm. The highest measured sulfate concentration was 130 ppm in 2008, which is still not a worrisome value.

Chlorine concentrations followed a similar pattern, increasing from 2008 to 2009 but decreasing slightly from 2009 to 2010. The maximum concentration reached in 2008 was 186 ppm, at TWS 14, which rose to 209 ppm in 2009 and then dropped to 136 ppm in 2010. These values are all below 1000 ppm, ANZECC safe limits for chlorine concentration.

Overall, the temporal changes were minimal. None of the measured species ever approached levels anywhere close to ANZECC guidelines. With little previous study of surface water, it is difficult to say whether this confirms or contradicts the hypothesis. This is a positive result, suggesting that the river has been maintaining low levels of inorganic contaminants over the past three years. It is encouraging that between 2008 and 2010 the concentrations have not increased appreciably.

Spatial Trends

The hypothesis of this study was that concentrations of contaminants would be greatest on or adjacent to the waste site (region 2), followed by slightly elevated concentrations downstream (region 3), with the lowest levels found in samples upstream of the dump site (region 1). The data, however, do not support this hypothesis. In many cases, samples taken from region 2 (TWS 12, 13 & 20), measured lower levels of contaminants than their upstream counterparts (TWS 1, 2 & 3).

This is true in the cases of calcium, sodium, sulfate and chlorine. The only exception is potassium, where levels in the two regions are comparable. Region 3 samples resembled values closest to those found in region 2, suggesting that there is no significant variation between the mill site samples and the river further downstream. The lack of variation between the three sites suggests that the mill is not a substantial contributor to inorganic species in the river. This is not what the study expected to find. It is possible that waste water emptied into the Tarawera River is not as loaded with inorganic contaminants as some have feared.

Alternatively, it is possible that organic wastes originating from the mill are complexing with some of the metal species, explaining why concentrations of many of the metals are lower downstream. AAS analysis does not take into account ions that may be locked up in complexes. For a more comprehensive analysis, other techniques are necessary. Because of this, it is important to look at the bigger picture of pollution. The metals tested here may not be of concern, but the possibility that they are complexing suggests that there are other species, possibly harmful, that are present in the mill waste that could be of concern. Although all the species measured here were well below what are deemed safe limits, there are other chemicals, most notably a variety of halogenated organic compounds, which can have devastating impacts. These chemicals were not tested for in this analysis but provide ample room for further studies to expand upon the work done here. This is an important avenue to explore; the inorganic species tested here, while important, are only part of the picture.

Mauri Model Assessment

Furthermore, while scientific data is a necessary component to understanding the impact of the mill, this is not the only relevant measure. The environmental impact is important, but should not be singled out as the sole indicator of the mill's success or failure. A useful tool for assessing the impact the mill has had on its surroundings is the Mauri Model, which incorporates measures of environmental, social, cultural and economic impacts. Using this approach, a more holistic assessment can be conducted. This model seeks to measure the mauri, an indigenous Maori concept of life force or capacity of something to sustain life (Morgan, 2006). There are four dimensions to the Mauri Model: environmental, social, cultural and economic. Weightings of the dimensions can be changed based on the world view of any individual completing the assessment. In this case, they are all equally weighted to avoid any bias.

Each of the four dimensions is measured with three ratings (see Figure 21). Each rating is given an integer score between -2 (mauri destroyed) and +2 (mauri enhanced - see Figure 22). A Mauri Model assessment of the mauri of the Tarawera River was undertaken as part of this project, the results of which are presented below. Prior to development, the mauri of the Tarawera River was +1.58, classified as between “maintaining” and “enhanced” mauri. This is representative of a healthy system. After construction of the mill, before a waste treatment system was implemented, the mauri of the system decreased drastically to -0.73, or “diminished” mauri. Scores decreased in every dimension except for economic where the boost in the local economy, employment and property value were all rated positively. The mauri improved slightly with the addition of a waste treatment plant, although the overall mauri score is still below zero, indicating degradation of the well-being over time.

		<i>1800s</i>	<i>pre-waste treatment</i>	<i>post-waste treatment (present)</i>
Environmental	-water quality: N&P	+2	-1	-1
	-water quality: mill waste	+2	-2	-1
	-biodiversity	+2	-1	-1
Cultural	-tikanga (food basket)	+2	-2	-1
	-identity (river as ancestor)	+2	-1	-1
	-spiritual relevance (wahi tapu)	+2	-1	-1
Social	-public amenity	+1	-2	-1
	-aesthetic value (river colour)	+2	-2	-1
	-recreational fishing	0	-2	-1
Economic	-local economy	+2	+2	+2
	-local employment	+2	+2	+1
	-property value (Kawerau)	0	+1	+1
	Mauri	+1.58	-0.73	-0.42

Figure 21. Mauri Model Assessment. Scores for the assessment of the four dimensions of mauri are tallied here. Prior to the construction of the mill, the mauri was well above zero. Since the introduction of the mill, the mauri has been diminishing, although the rate of diminishment has decreased since the introduction of waste treatment.

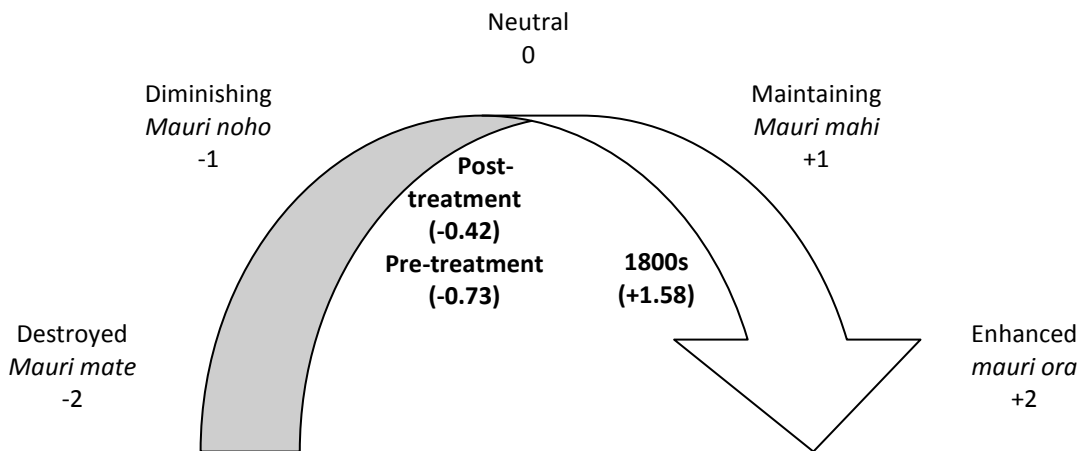


Figure 22. *Sustainability Barometer for Mauri* (adapted from Morgan, 2006). This diagram shows where the three ratings of the Tarawera River mauri fall on the mauri scale.

Based on this Mauri Model assessment, the Tarawera River is still not a healthy system. The economic dimension is the only one that rated positively in the present state. In order to improve the mauri, all three of the other dimensions (environmental, social and cultural) must be addressed. Luckily, none of the present ratings received a score of -2, an indication of destroyed mauri. While -1 is not a desired score, it suggests that with the right adjustments the mauri of the system can recover. It will take time and effort, but many of the ratings have the potential to be improved in the future. Many of these ratings relate directly to the quality of the water (i.e. the status of the river as “food basket”, biodiversity and aesthetic value), which helps highlight the importance of this study. The water quality of the Tarawera River is not just important as a scientific parameter, but also as a strong indicator of the mauri of the entire system.

VI. Conclusions

This study has added valuable water quality data to a growing body of research concerning the Tasman Pulp and Paper Mill and its impact on the nearby Tarawera River. Previous years of research have shown that certain contaminants have been at elevated levels in the groundwater beneath the landfill site (GRLM, 2004; SKM, 2007; Wolfe, unpublished). However, very little data previously existed concerning surface water analysis. This study determined that changes in water quality with regards to a variety of inorganic species have not changed appreciably between 2008 and 2010. In addition to temporal changes, spatial variation was examined by collecting samples

from three regions: upstream of the mill waste site, adjacent to the waste site, and further downstream of the waste site. The study concluded that variation between the three areas was minimal with no significant inorganic input from the mill waste at the Tasman plant. In some cases, metal concentrations were actually higher upstream than they were downstream, which could be explained by organic mill waste complexing with free metal ions.

While this study provides some very useful data, it is important to bear in mind that this does not tell the whole story. Just because the chemicals analyzed here are low does not mean that the mill waste discharging into the river is clean or safe. Toxic organic compounds are possibly present and anyone looking at the river directly downstream of the mill can see the aesthetic degradation of the Tarawera River due to mill waste. The Mauri Model was used in this case to show how although the scientific data may support the idea of a healthy ecosystem, this is far from saying the mill is not having a negative impact. Environmental factors are clearly important, but so are the social, cultural and economic impacts. The importance of maintaining positive mauri, or well-being, in all four of these dimensions should be kept in mind, especially as the return of the land to the local Maori trust in 2013 approaches.

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