Water Quality Indicator Trends Through Time in Kennisis Lake, Haliburton County.

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1. Project review.

This project was undertaken by partnership of U-links Haliburton and Kennisis lake residents along with a Trent student and professor. A collection of data relevant to lake water quality and ecosystem health was amassed and sought to be analysed. Analysis serves to visualize trends overtime so that knowledge might be put to use in management and stewardship.

2. Goals

Here is a short review of the goals of this assignment which serves to explicate the following report. It was requested that visuals were made of certain factors affecting water quality of Kennisis lake over time. Such particular factors requested were phosphorus, the limiting nutrient for phyta or plant species and of those, the most concerning, the algae's which proliferate and 'choke' the lake and other species. Another parameter was secchi depth, an indexing tool to measure clarity or turbidity or light attenuation, the affecting factor of secchi depth is suspended particles, most often algae. The interest for looking at these factors likely came from interest in water quality and ecosystem health in relation, possibly, to the effects of affecting activities in the area or the assessment of successes in mediation actions. Further selection of these factors exclusively came from a lack of other data over time. This is likely due to the fact that eutrophication wrought by algae and often represented in secchi depth when apparent, is of greatest concern and therefore is widely monitored. As these variables were available and others not and after analyzing there relationships, other confounding factors were approached through history, and their likely effects via literature in review of studies done in the past, as well as area facts and observation. The result is a discussion of the possible dynamics of the lake in reference to the few trends at hand. More precisely put, the question guiding my research became: what is affecting the water quality indicator values and trends? This question is inclusive of the trends themselves and the elucidation of effectors.

3. Background information

-History

3.1- No doubt much of the recent relative history is known to the residents of the lake and therefore this quick note is to acknowledge the most relevant actions to the data at hand and as a formality. Kennisis lake's development history is recent in comparison to other lakes in the area and specifically those looked at for figure 4, the comparison on area lake total phosphorus levels. Development of the lake is one of the most relevant factors in terms of impermeable or less permeable surfaces as well as sewage and phosphorus or other nutrient rich additions to the lake such as iron. Another effect on Kennisis lake necessary to recognize is the decreasing quantity of acidic rain, which in Kennisis is likely very slowly beginning to show effects on shield lakes in this area. One of the effects of acidification is an increase in water clarity which is of interest to our secchi depth record, possibly showing a recovery from acid effects with decreasing clarity. Unfortunately this phenomenon is not well understood and any discussion is suggestive in nature.

Characteristics

3.2- Lakes are individual in nature, however in basic characteristics they are often similar to other lakes in their area and sometimes to other lakes within climate like and geologic areas, sometimes spanning vast distances. For our interest, Kennisis will be described in broad terms with some comparison to local lakes or those with a more global nature for contrast. The most significant deviation from this method is the descriptor; shield, which refers to an array of affectual characteristics all relating to the structure of the bedrock which is spread across northcentral well into eastern Ontario. The shield provides deep lakes and nutrient poor lakes due to the lack of erosion of granite both in terrestrial watershed and within the lake. Further, granite lakes in Ontario are much more acidic than calcium rich lakes to the south, due to the calcium rich bedrock and soft nature of the rock. The following is a list of descriptors which suit Kennisis Lakes' characteristics, their descriptions serving to explain the significance of the lakes characteristics to science working with the data parameters here. Also, this section, though lacking some depth in discussion, can and will be referred to in later sections. Kennisis easily resides in the category Oligotrophic, meaning nutrient poor, poor referring to quantity. Not only does Kennisis lie in an area of many Oligotrophic lakes but within lakes it contains fewer nutrients. In this area an Oligotrophic lake has. Whereas a lake of medium nutrients, mesotrophic, has and a Eutrophic lake would have. Kennisis is also a relatively compared to lakes such as the Kawarthas.

4. Data Quailty and Acquisition

The initial data provided for this project spanned considerable parameters beyond those used such as dissolved oxygen and ph or acidity. These parameters are useful in identifying relationships between factors and are also useful in witnessing their trends through time as they are often pertinent to lake health. Unfortunately, however, the initial data set was not consistent with parameters sampled, sampling time, or date. In light of this and in review of the goals which were to look at phosphorus and secchi depth, new data was sourced from the lake partner program database on the Ministry of Environment website. Here too there was an issue with phosphorus testing methods changing but the data was still more consistent. Unfortunately the lake partner program only covers total phosphorus and secchi depth and so the project becomes more limited in scope, yet these are the most pertinent factors and the ones requested by the host.

5. Review of Phosphorus/Chlorophyll A and Secchi depth

Phosphorus has been established as the limiting nutrient for algae growth in many cases of eutrophication many of these similar to Kennisis. It should be acknowledged that some, maybe few, people still discuss nitrogen as a limiting nutrient. A testament to the importance of phosphorus is it being one of two parameters tested for across Ontario.

Phosphorus acts in algae bodies as an energy carrier in exchanging energy in various systems including photosynthesis systems. Alternatively, nitrogen is used for amino acids and the like, essential biological structures. Nitrogen is nearly always in greater abundance and where it is not there are bacteria algae which fix nitrogen and therefore overcome any shortage of nitrogen, however rare.

High phosphorus causes high algae growth and decrease in water quality along with many other concerning factors. One such factor is fish kills, due to low dissolved oxygen as bacteria use oxygen while decomposing algae matter.

Phosphorus is measured as total phosphorus (TP) and this includes both particulate phosphorus, usually a higher value, and soluble phosphorus or reactive phosphorus, which is often involved or recently incorporated into biological systems. In bio systems phosphorus equates to chlorophyll A, a pigment used in capturing light energy but also corresponding to a majority of photosynthetic and dominant algae. Due to the close relationship between these two factors and that one is often used as an indicator of the other, they are used interchangeably throughout the analysis and any points of discussion.

The purpose for the use of secchi depth and TP together is that they usually have a very strong relationship. Algae growth decreases light penetration and increases scattering while of course absorbing much light through photosynthesis. Secchi depth can be indicative of many things, not just tp levels, and so provides an indication of other factors where tp and secchi depth are not correlated in precautionary testing or monitoring.

6. Statement of Rationale

The purpose of this project is to present data on the lake to interested parties as it appears to science. Visualized trends can be used to assess concerns on lake quality and through placing them within a sensible context.

7. Methods

Data extracted from the lake partner program data set and supplementary data from the Ministry of Environment from the Dorset Lakes Centre was collected and organized into three areas of testing; the east end, mid lake deep spot and 999999). These values for secchi depth were, where applicable, averaged per month and ordered chronologically. The resulting figure lacks yearly values from 1998-2005, the effect of which is an exaggerated decrease visually but the values remain real. This same lack of secchi depth makes difficult the comparison of TP and secchi depth values. For TP, yearly averages were used and outliers, often values from months which were not tested for in other years, were excluded from analysis. Pre-2000 values were amassed into one average per area due to the change in testing practices after 1999 and the variation inherent to pre-2000 testing. Before this date chlorophyll (Tp) was collected without a filter on the vessel and so the collection of zooplankton, which are still difficult to see by eye and are much larger than phytoplankton, were often included in the tests, resulting in impossibly high values of phosphorus. These high values were excluded from average calculations yet other values still may have been affected by particulate and the like, not indicative of phosphorus. Therefore the MOE still instructs that these values be used as one average value and that the resulting 10 or less data points be not used in analyses over time in statistical tests. This is due to the inherent variation from other factors. For this reason the visuals must be considered suggestive and correlations are exempt from here.

For the comparison of other area lakes many inter lake factors are controlled for, or kept constant, by using data from the same month and year.

8. Results and Visuals

8.1

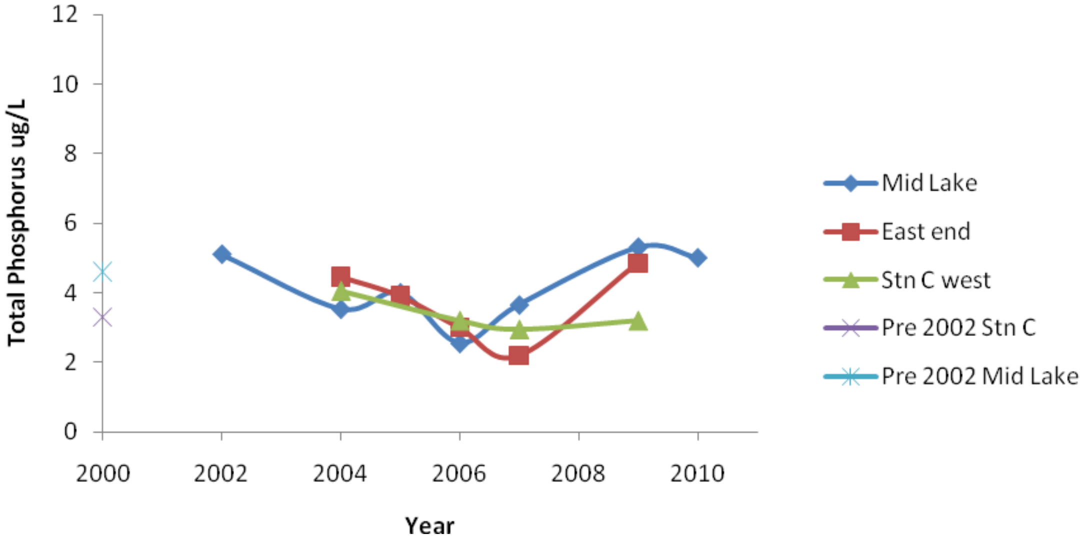

Figure 1. Total phosphorus values as a measure of nutrient state over eight years but along with average data pre 2002.

Figure 1 shows at the left, an average of each the stn C data and mid lake data from all records pre-2002. The lines show variation over the preceding eight years. Pre-2002 averages are between 3.5 and 4.5 ug/l. Post- 2002 data points vary between 1.5 and 7ug/L.

8.2

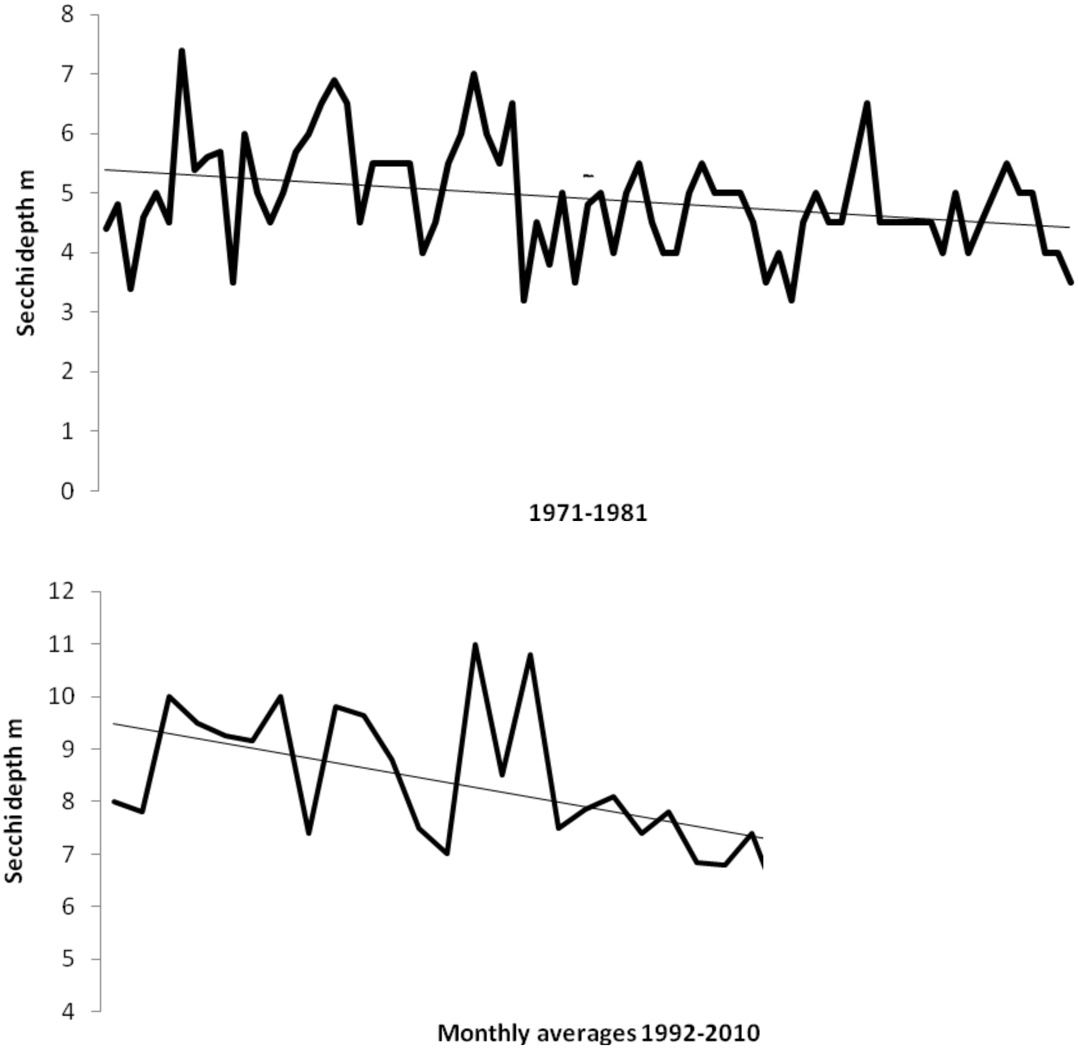

Figure 2. Secchi depth or clarity/turbidity over 10 years above and eighteen years below. Data points correspond to one per month from may through September with some exceptions, many missing data points and some entire years.

8.3

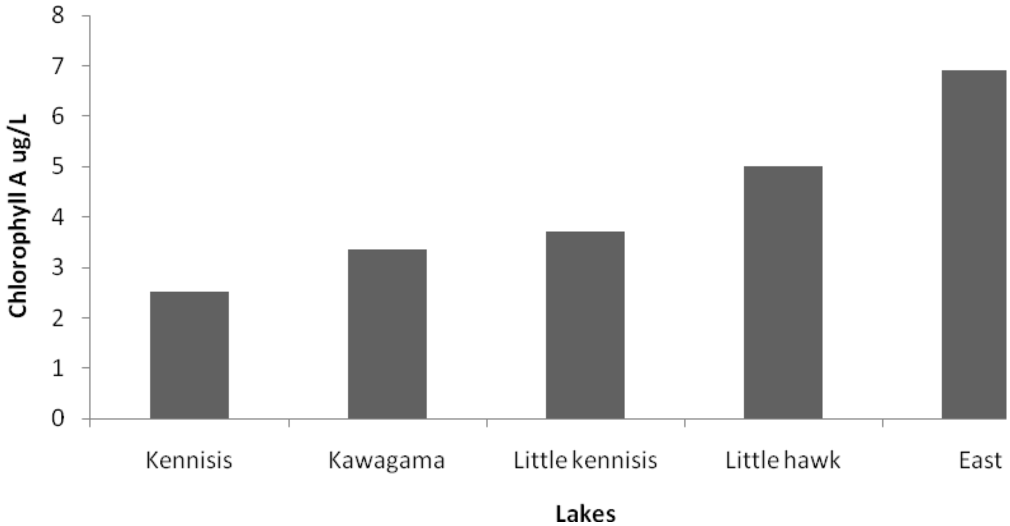

Figure 3. Comparison of Total Phosphorus in area lakes adjacent to Kennisis

In figure 2 the upper graph shows much greater variation and the trend line is nearly flat with an overall decrease of about 1 metre in clarity. The lower graph shows less variation overall with more at the beginning of testing. The trend line shows a decrease in average water clarity of about 3 metres. The difference between the earlier data 1981 at about 4.5 metres and the later data in beginning at 9.5 metres implies that there was an increase of 5 metres in water clarity in the interim 14 years. Figure 3 shows the differences in total phosphorus values between adjacent lakes. Kennisis is the least enriched while little Kennisis is medial and overall difference in value between the highest value and Kennisis is about 4.5ug/l.

9. Discussion of results.

9. Secchi depth visualized over time shows a decrease from 1971 to 1981, followed by an increase over 1981-1992. This spike in value is extreme due to the gap in recorded

values, and the actual increase was likely much more gradual but sample data from 81-92 is not available. It is possible that the increase is due to the different sampling methods and materials, especially as values decrease over time in both data sets. The other obvious possibility is that the increase is due to acid rain and the resultant clarity. The preceding years show a slight decrease but mostly stability whereas the years after the increase show a greater rate of decrease. However it is still merely suggestive and not concerning to many persons or to ambient literature standards. In analysis of lake partner program data from Kennisis lake the MOE states that variability and slight changes over time are due to volunteer perceptions and so this should be kept in mind when assessing other possible factors.

Returning to ph and acidity, acid rain effectors, predominately $SO_{2,}$ were reduced and the effects halted. Therefore it could be that the decrease in clarity is a slow return to normal values as the lake and surrounding terrestrial environment is largely unbuffered or does not contain basic material which neutralizes the effects of acid deposition. Acid rain and their effect reductions are difficult to calculate. In this case, a few ph samples from the lake at 6.83 reveals a very normal value and lake as acidic lakes are below 6 and alkaline are above 8 and so effects may not be present. The effect and recovery on lakes is still not completely understood and so comments are lacking here.

Total phosphorus shows stability over time with some variability but all variability is stable as well over time when considering pre-2002 data. An average value is (00) and this is well below many estimates of concern along with values available for tp levels where other lakes have eutrophied.

Correlation attempts of TP and secchi depth, a correlation which would show the relationship and strength of any relationship, statistically, failed due to the stability and low nature of values. Further, the fact that secchi depth is more prone to error adds to difficulties in performing such statistical tests. From secchi and Chl A data from 71-81 May through September values and

within single year values were used and east basin test site data from the lake partner program inter year from may values only were used. All attempts yielded no relationship. Due to the lack of relationship it needs to be considered that there may be other factors causing the decrease in secchi.

Two factors which remain as possible affectors of clarity are dissolved organic carbon (DOC) additions to the lake and an affector therein but that which maintains other mechanisms as well; climate change and/or variability. DOC comes from degrading or decomposing biological material in the watershed and appears as tea coloured water or brown water on a sliding scale of intensity. Largest contributors are wetlands, their emissions controlled by rainfall. Other sources are not as localized and are generally forested areas. When cleared or disturbed, DOC release increases for a time then decreases as the resources are exhausted. Contributing factors to doc access can be shoreline changes and watershed changes that promote DOC mobility and allow it to be easily carried to lakes by rain events.

Reviewing development history in the area yields little record of intensity of the forestry in the area. It appears that primary removal was early pre-1900 and mills were abandoned pre-1970, then re-established recently in 2009, it is the Haliburton forest. This timeline does not necessarily parallel forestry intensity but suggests other sources.

The record of secchi depth spans 1971-2010 with some sizable gaps in records but in every case a decrease is identifiable. During this same timeline, development of cottages and roadways as well as intensity of activity has increased as an estimate and therefore may explain increased DOC or suspended sediments. A contributing factor to those just discussed is climate change and variability. The most easily relatable mechanism here is variability. Greater frequency of intense rain events can drive up the amount of DOC and sediment. High rainfall saturates upper layers of soil allowing other rainfall to flow overland. This is compounded by less disruption of terrestrial water flow to the streams and water bodies due to clearing and disturbance as consequences of construction and activity. It is easy to imagine a correlation of amount of development to the clarity decrease as they have similar trends. Climate change is a difficult array of effects from which to elucidate a mechanism as it requires much data and consideration but it is an area of future research and possibly interest to Kennisis lake. Indeed, research within Ontario is yielding results.

To add to the climate change and global change arena of potential factors it seems appropriate to mention wind deposition and disturbance as increased intensity can stir up lake sediment in spring and fall to a greater degree. Notably, this is usually reserved for shallow lakes, which Kennisis is not. More disturbance regionally and globally can result in more mobile sediment in the atmosphere, compounded by dry periods which are increasing in intensity.

Another effect of atmospheric carbon and dust or other matter, including moisture, is a decrease in light intensity of certain wavelengths. Such decrease would directly alter secchi depth readings as less light would result in less reflection.

In consideration of TP as a strong correlate to Chlorophyll, Kennisis appears very healthy and even seasonal variations in TP would likely not result in eutrophied waters. Nutrient richness in shield lakes in commonly framed at between 11 and 20 ug/L as the area of concern, note that Kennisis's highest value is about 7ug/L. To further this point, from some Haliburton and Minden area lakes an average TP value is 9ug/L which is well above Kennisis lake's maximum value. The observed clarity decrease is likely not a reflection of a Chlorophyll A increase, acidification recovery or forestry practices. These exclusions then point to atmospheric contents, local erosion through shoreline land use change, and climate variation as the potential and likely drivers of the clarity decrease on abroad level. These factors do not amount to understanding the mechanisms or the complex nature of a minor decrease. The decrease observed is very slight and is not cause for great concern, indicating that natural variation could have a considerable hand in the effects observed. Additional support for lake health comes from assessing figure 4: A comparison of area lakes chlorophyll A levels as it is seen that Kennisis has some of he lowest algae production in the area.

Other factors, Macrophytes

10- This section is meant to discuss some further measures of attention which can aid in lake health and combat some effects of nutrient loading. Much of the measures of interest have been discussed and so only macrophytes remain. Macrophytes as phytoplankton or algae absorb phosphorus and other nutrients in the same manner thereby mineralizing and removing them from the water column. They are also decomposed by bacteria and can thereby reducing dissolved oxygen. Plants though provide more diversity of life by nature of their own speciation and by providing habitat for zooplankton and engaging in other ecosystem functions which support species diversity. Some of the physical influences of macrophytes are their reduction of turbulence in wave action and wind by absorbing and transferring or moderating energy, potentially reducing sediment disruption and driving down turbidity in near shore areas. Often viewed as nuisances, macrophytes can be integral parts of local lake ecosystems and are in some areas beginning to return.

Summary

11- It now seems appropriate to summarize the previous reasoning and also provide a few thoughts on future research along with recommendations wrought from the data and its affectors. The question set about to address was: what is affecting water quality indicator trends? In light of the strong correlations between Chlorophyll A or TP and secchi depth it was expected that the trends for each would be framed and a correlation obvious. The study elucidated the stability of values of Chl A and the slow descent of clarity and so other factors effecting clarity were sought. It seems that ph and watershed scale development in logging is not a large factor and so the remaining obvious factors are climate and local erosion through intensity and land use. The values observed in both phosphorus and clarity are moderate and are not cause for great concern especially when made relative to area lakes as well, levels of Chlorophyll A and TP are often cause for eutrophicaion at great values not at the value seen here. It is necessary to recognize that secchi and all the intricities of europhication and lake health are far from known and vary greatly between lakes and areas. Further, lake systems and ecosystems in general have lag times or do not always show the effects of affecters immediately but rather, such effects can occur after a time or along with critical points of some affecter(s). With this knowledge it seems appropriate to always act with the precautionary principle or with doubt of what we know. In order to adequately protect our and others lake water we might assume or prepare for negative effects.

Further research might include assessment of erosive causes in local areas and watersheds. By making these values relative to different lake values in the area, the strongest effects of change in secchi depth may become apparent and this could be valuable in focusing efforts on stemming or moderating those effects. As the cause of many of these effects are already widely established, development of tools both social and scientific can be developed to avoid possible future consequences. Fortunately, as was seen at the recent u-links fair, some tools are already being developed.

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Appendix.

Table1. Lake partner program phosphorus means Kennisis (ug/L)

Mid lake		Stn C west		East end	
2002	4.6	2002	3.3	2004	4.45
2002	5.1	2004	4.05	2005	3.9
2004	3.53	2006	3.2	2006	3
2005	4	2007	2.95	2007	2.2
2006	2.55	2009	3.2	2009	4.85
2007	3.65				
2009	5.3				
2010	5				3.3

Table 2. Phosphorus ug/L

Total Phosphorus averages May 2007			
East	6.9	Kennisis	2.53
Kennegawa	3.36	Kawagama	3.36
Kennisis	2.53	Little kennisis	3.7
Little hawk	5	Little hawk	5
Little kennisis	3.7	East	6.9

Table 3. Secchi depth (metres)

Secchi depth 92-10		Secchi depth 71-81
########	9.0	4.4
5-Jul-92	7.0	4.8
19-Jul-92	9.0	3.4
3-Aug-92	8.0	4.6
16-Aug-92	8.0	5
23-Aug-92	7.0	4.5
13-Jun-93	10.0	7.4
3-Jul-93	8.0	5.4
11-Jul-93	9.0	5.6
18-Jul-93	11.0	5.7
2-Aug-93	11.0	3.5
8-Aug-93	10.0	6
22-Aug-93	8.0	5
29-Aug-93	8.0	4.5
6-Jun-95	8.5	5

25-Jun-95	9.8	5.7
30-Jul-95	10.0	6
9-Aug-95	7.5	6.5
13-Aug-95	7.3	6.9
2-Sep-95	9.8	6.5
1-Jul-96	9.5	4.5
14-Jul-96	9.8	5.5
13-Aug-96	8.8	5.5
2-Sep-96	7.5	5.5
1-Jul-97	4.0	5.5
20-Jul-97	9.8	4
4-Aug-97	11.0	4.5
28-Jun-98	8.5	5.5
3-Aug-98	10.8	6
########	7.5	7
11-Jun-05	8.0	6
3-Jul-05	7.0	5.5
1-Aug-05	8.3	6.5
14-Aug-05	7.6	3.2
4-Sep-05	8.4	4.5
17-Sep-05	7.8	3.8
2-Oct-05	7.4	5
########	8.4	3.5
########	8.8	4.8
17-Jun-07	8.1	5
17-Jun-07	8.1	4
8-Jul-07	7.4	5
8-Jul-07	7.4	5.5
22-Jul-07	7.5	4.5
22-Jul-07	7.5	4
11-Aug-07	6.8	4
11-Aug-07	6.8	5
26-Aug-07	6.9	5.5
26-Aug-07	6.9	5
25-Sep-07	6.8	5
25-Sep-07	6.8	5
1-Jul-08	8.2	4.5
5-Jul-08	8.3	3.5
20-Jul-08	6.5	4
3-Aug-08	5.5	3.2
4-Aug-08	5.8	4.5
17-Aug-	6.9	5

08		
31-Aug-08	5.9	4.5
28-Sep-08	6.6	4.5
5-Oct-08	7.1	5.5
18-Oct-08	6.9	6.5
########	7.5	4.5
5-Jul-09	6.8	4.5
19-Jul-09	6.9	4.5
25-Jul-09	6.5	4.5
3-Aug-09	6.0	4.5
25-Aug-09	6.0	4
30-Aug-09	5.7	5
7-Sep-09	6.3	4
19-Sep-09	7.3	4.5
4-Oct-09	6.1	5
########	9.0	5.5
6-Jun-10	7.4	5
5-Jul-10	8.0	5
10-Jul-10	7.4	4
24-Jul-10	6.0	4
5-Aug-10	6.0	3.5
22-Aug-10	6.0	
29-Aug-10	6.0	
6-Sep-10	6.1	
12-Sep-10	6.1	
2-Oct-10	6.9	
23-Oct-10	7.3	