Chapter 8

DISCUSSION OF RESULTS

8.1 GIS map - database results:

Figure 12 indicates the view that is afforded to the user by clicking on a particular site once the GIS programme is in use i.e. a short summary of data contained in various databases. The user may also choose to enter the original database to manipulate data and observe immediate changes in the display, should conditions change. In addition, a number of searches may be performed against a user-defined set of conditions.

Figures 13 to 17 demonstrate the illustrative ability of the GIS maps. In these figures, water quality is compared against a number of coal characteristics i.e. fixed carbon, pyrite, ash, total sulphur and mining method, as well as the South African Water Quality Guidelines for specific uses i.e. domestic, recreational, industrial, irrigation, livestock watering, aquaculture and aquatic ecosystems. These comparisons were made possible by tabulating a full chemical analysis of water samples taken in the Witbank and Middelburg Dam catchments and comparing them with those standards stipulated in the South African Water Quality Guidelines (Appendix A). It is important to note that the objective of this exercise was to create a fully interactive user-friendly GIS-based database. In order to develop meaningful water management options for the catchments, it would be necessary to consider the contaminant loading in each stream and identify point sources of pollution.
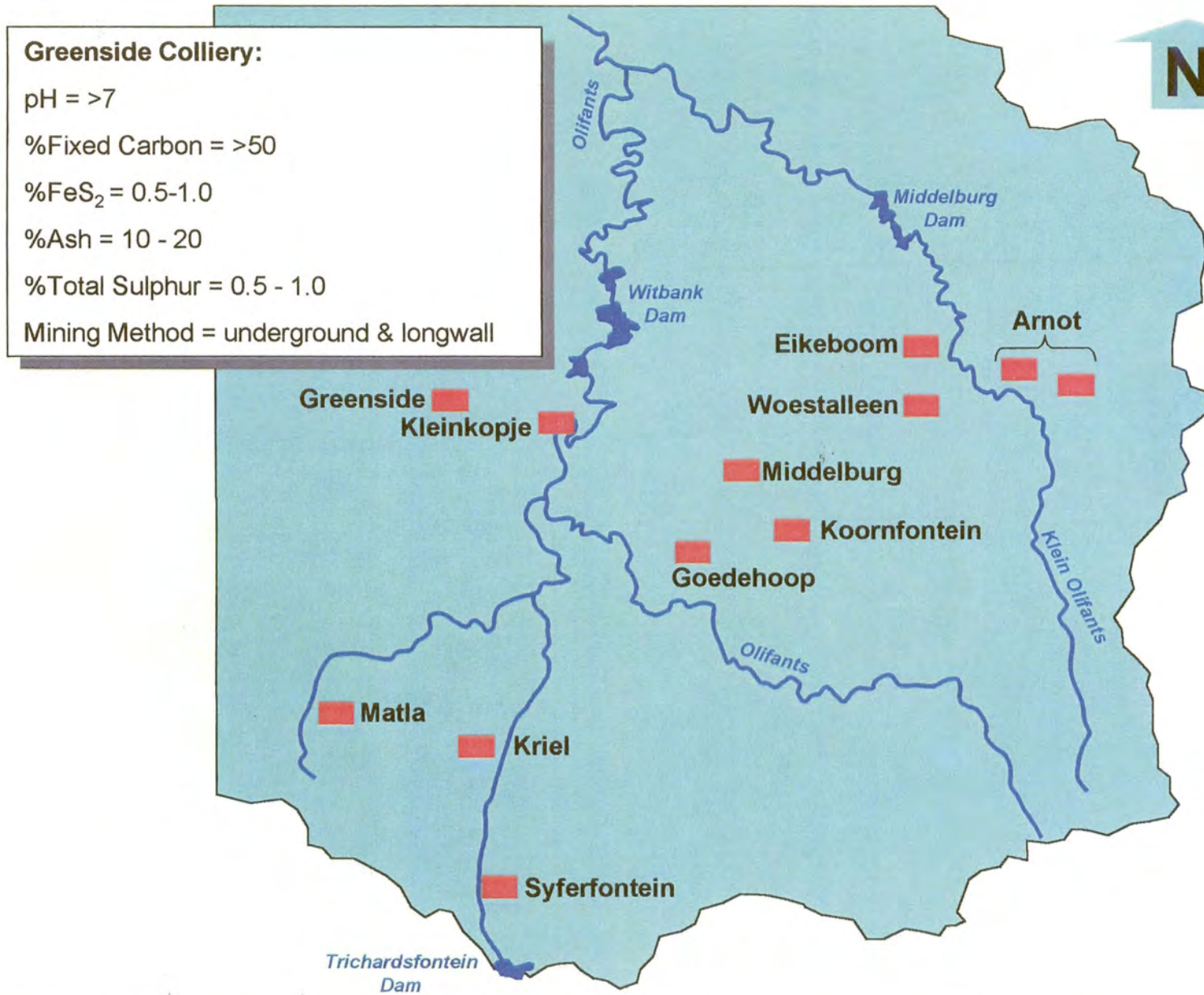
Figure 12: Location of database sample sites in the study area, showing the summary data provided by activating the site icon for Greenside Colliery
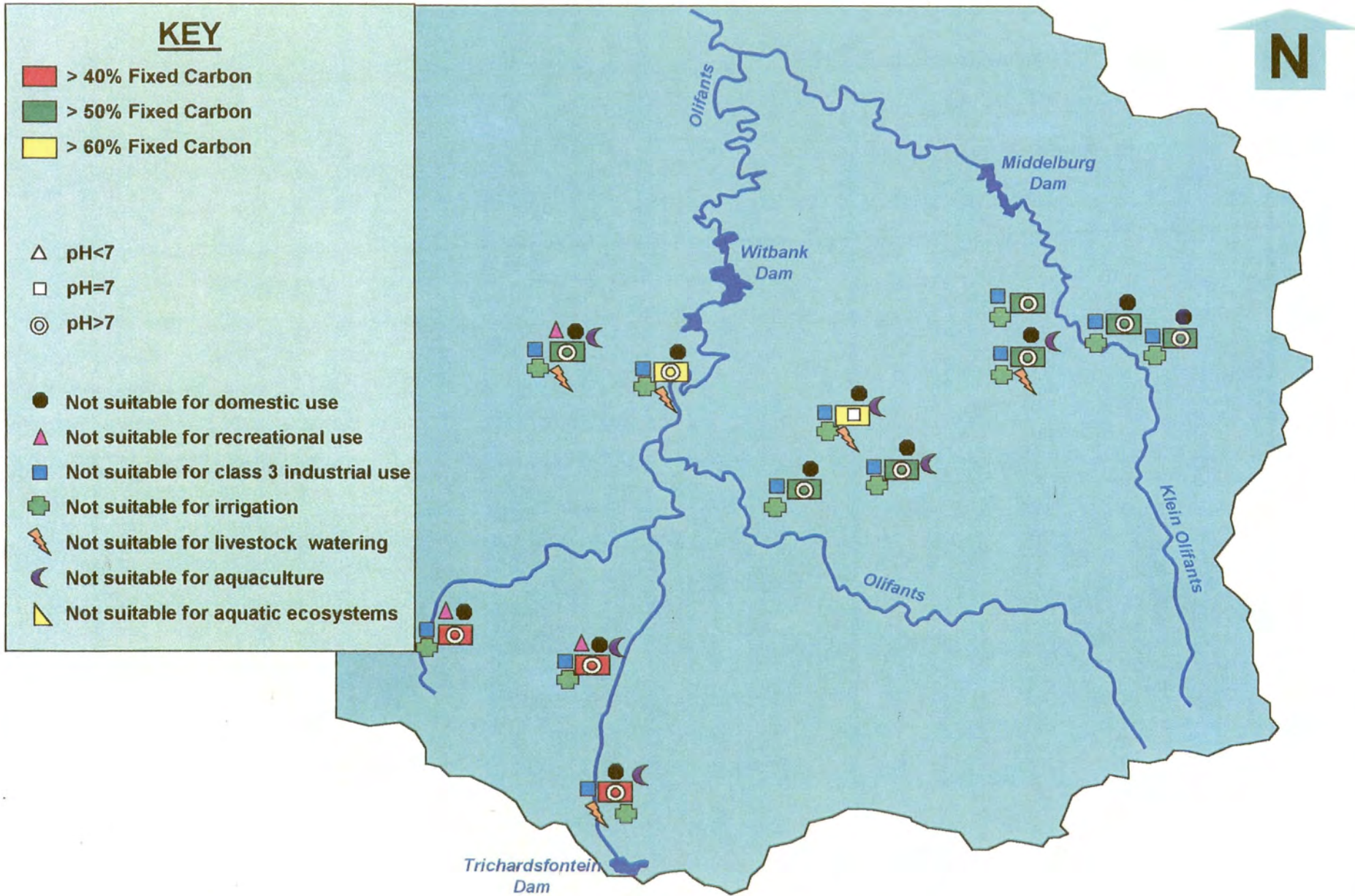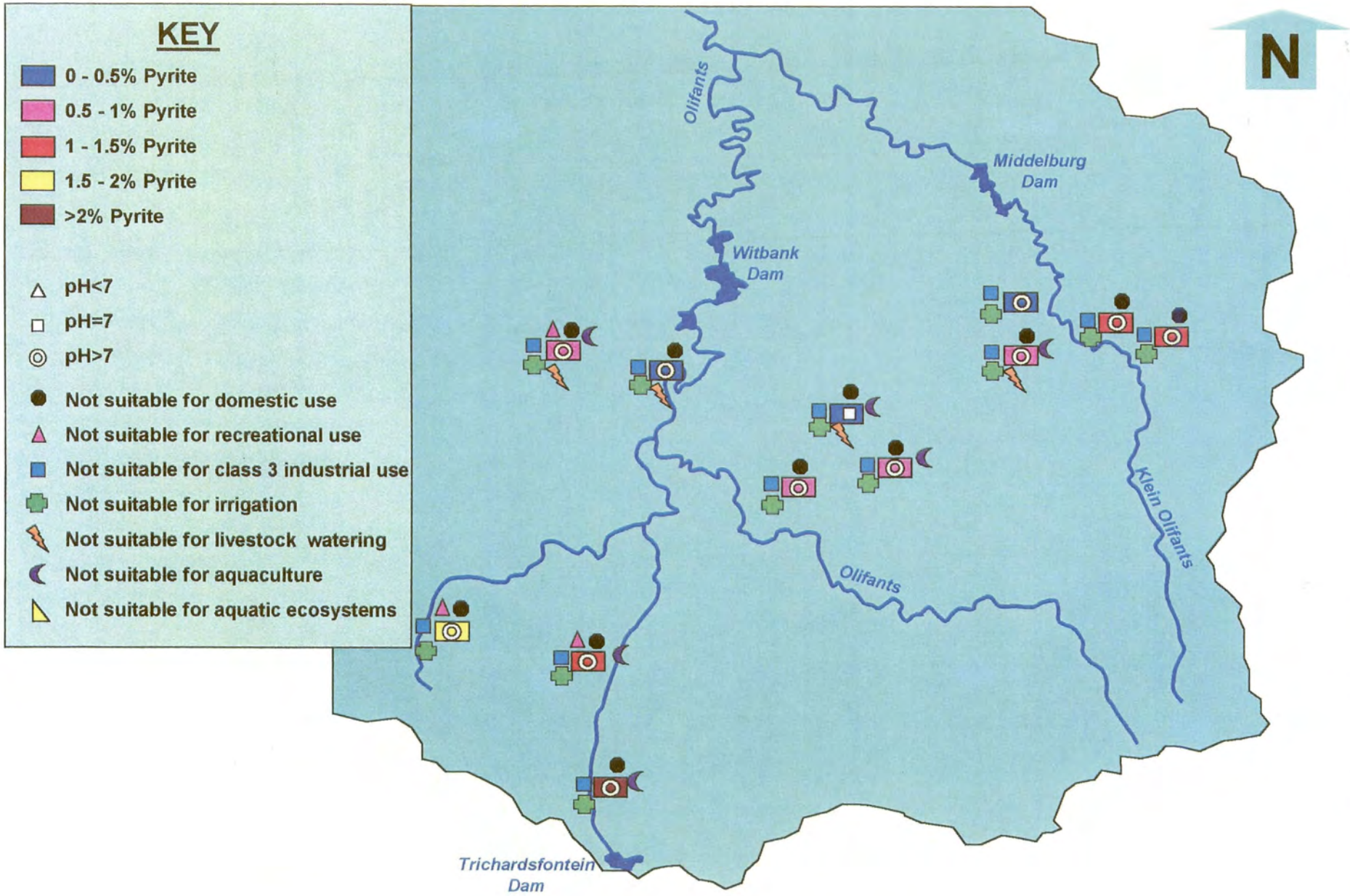
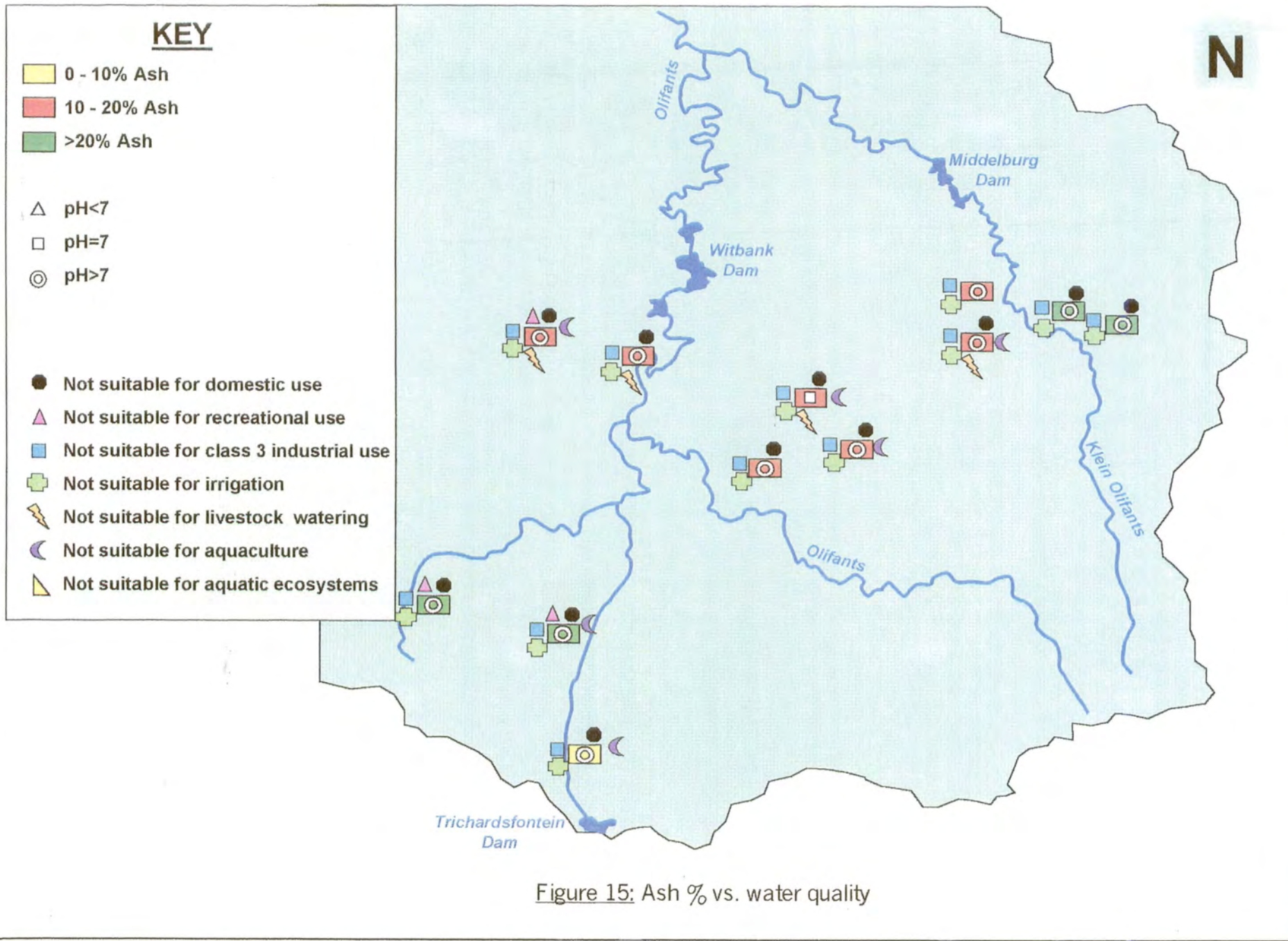**Figure 13:** Fixed Carbon % vs water quality

Figure 14: Pyrite % vs water quality

Figure 15: Ash % vs. water quality

KEY

- ☐ 0 - 0.5% Total Sulphur
- ☐ 0.5 - 1.0% Total Sulphur
- ☐ >1.0% Total Sulphur

- △ pH<7
- ☐ pH=7
- ◎ pH>7

- ● Not suitable for domestic use
- △ Not suitable for recreational use
- ☐ Not suitable for class 3 industrial use
- ✚ Not suitable for irrigation
- ⚡ Not suitable for livestock watering
- ☾ Not suitable for aquaculture
- ◣ Not suitable for aquatic ecosystems
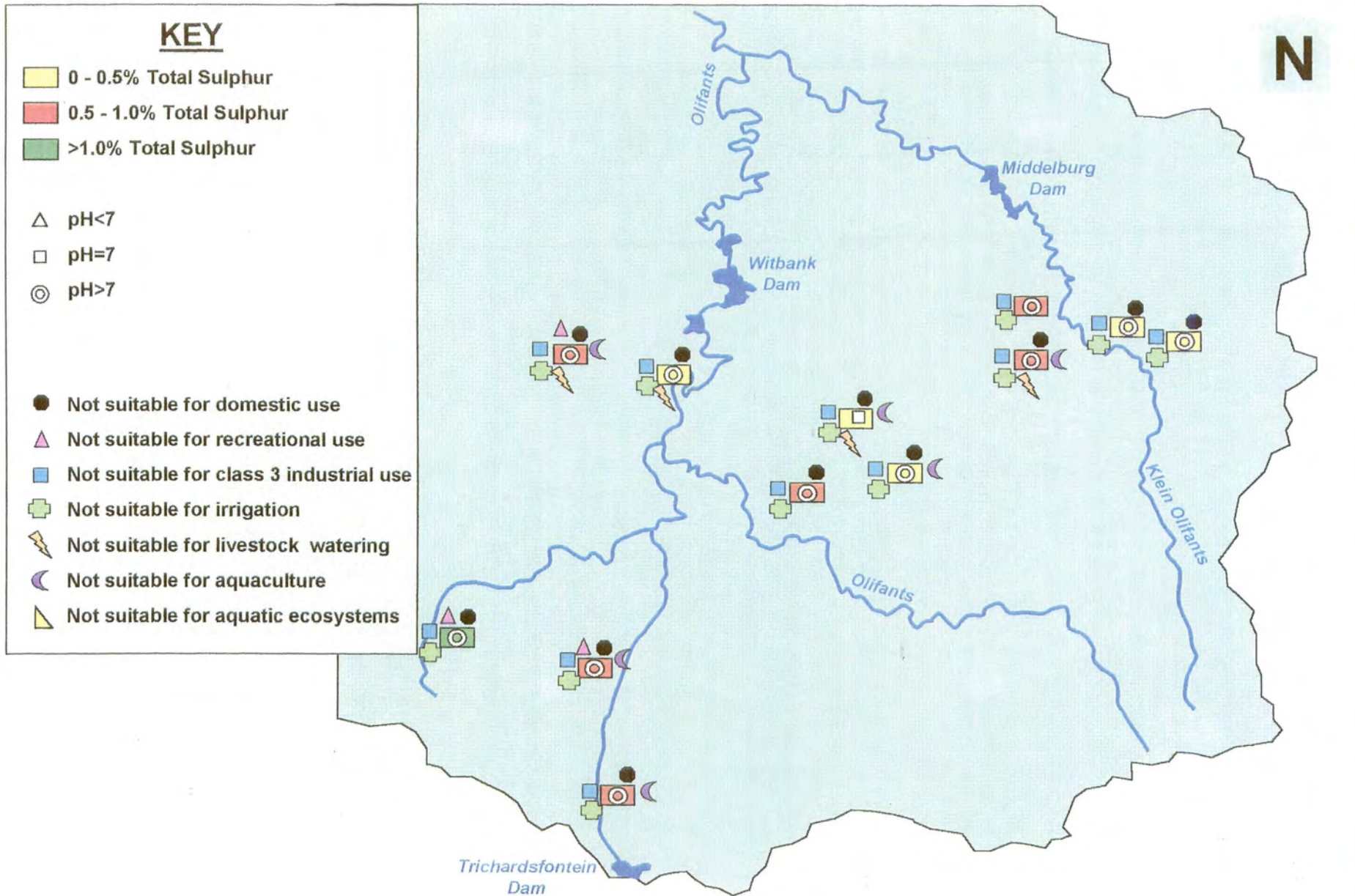
Figure 16: Total Sulphur % vs. water quality

N

KEY

- underground + bord and pillar
- underground + longwall
- opencast
- underground
- mixed

△ pH<7

□ pH=7

◎ pH>7

● Not suitable for domestic use

△ Not suitable for recreational use

■ Not suitable for class 3 industrial use

✚ Not suitable for irrigation

⚡ Not suitable for livestock watering

☾ Not suitable for aquaculture

◣ Not suitable for aquatic ecosystems

Olifants

Middelburg Dam

Witbank Dam

Klein Olifants

Olifants

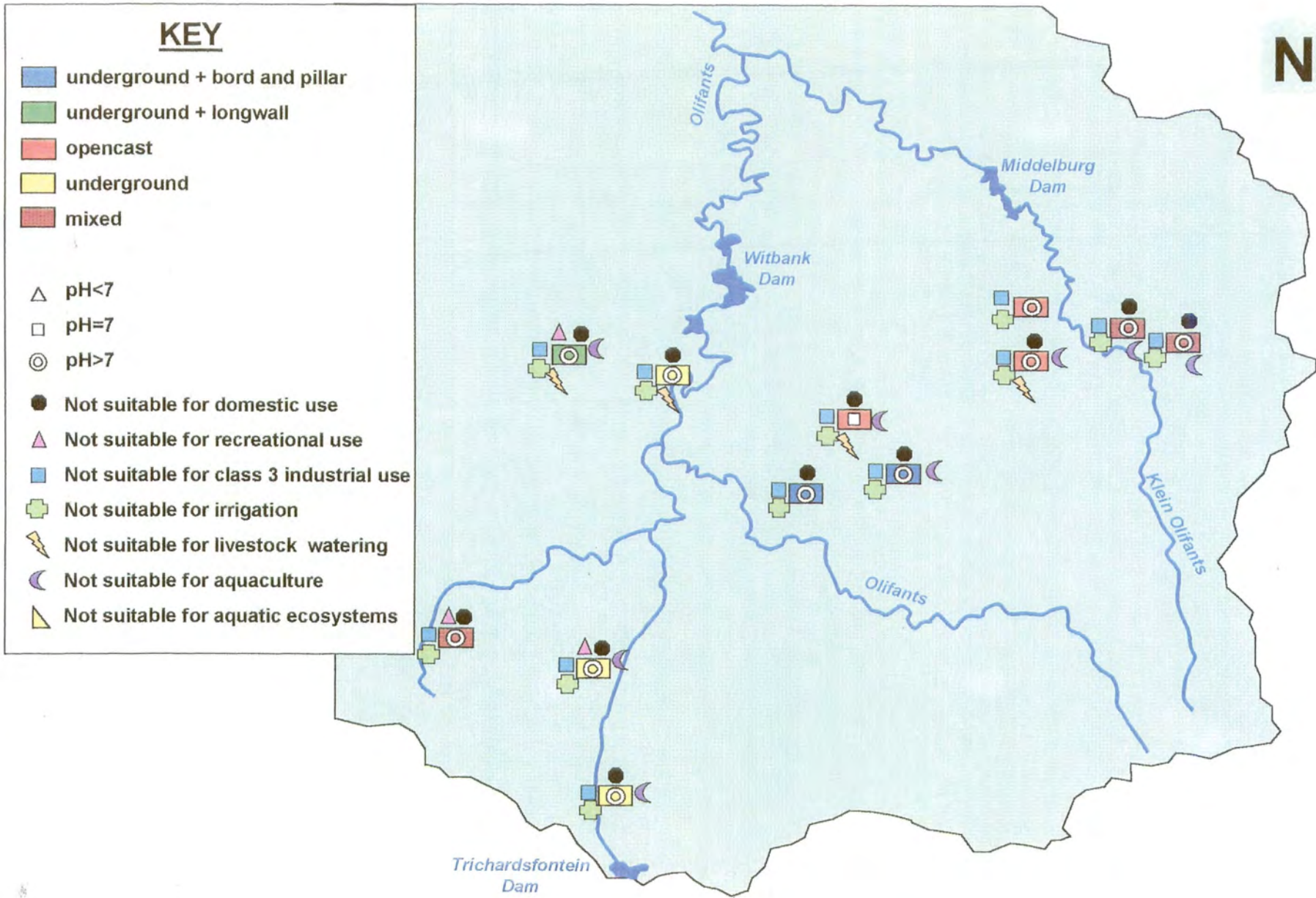Trichardsfontein Dam

Figure 17: Mining method vs water quality

Initially, there are a number of logical results, which can be expected:

- It is not expected that there will be a strong correlation between fixed carbon and water quality.

- Pyrite is expected to have a strong correlation with water quality as pyrite is the primary cause of acid mine drainage. It provides both the sulphur to generate acidic pH and iron which is leached out to contaminate both water and soil.

- Depending on the composition of the ash content of a coal, one can expect some sort of correlation between ash percentage and water quality.

- Similarly, one would only expect a correlation between metallic sulphates and water quality, as these are the sulphur compounds responsible for acid generation. Total sulphur is not as indicative a variable of the capacity of a coal to generate acid water.

- Mining method can be expected to show some correlation with water quality. Generally, it has been found that the more coal that remains in situ the greater the opportunity for coal-water interaction and ultimately the acidification and contamination of the water concerned. Therefore, one would expect poorer quality water where there is bord and pillar mining with some pillars remaining and loose pyrite-rich material lying on the floor.

8.2 Results of beaker tests

The results of beaker tests have been graphically presented in Appendix C. The sites selected for such testing of selected samples are indicated in figure 18.
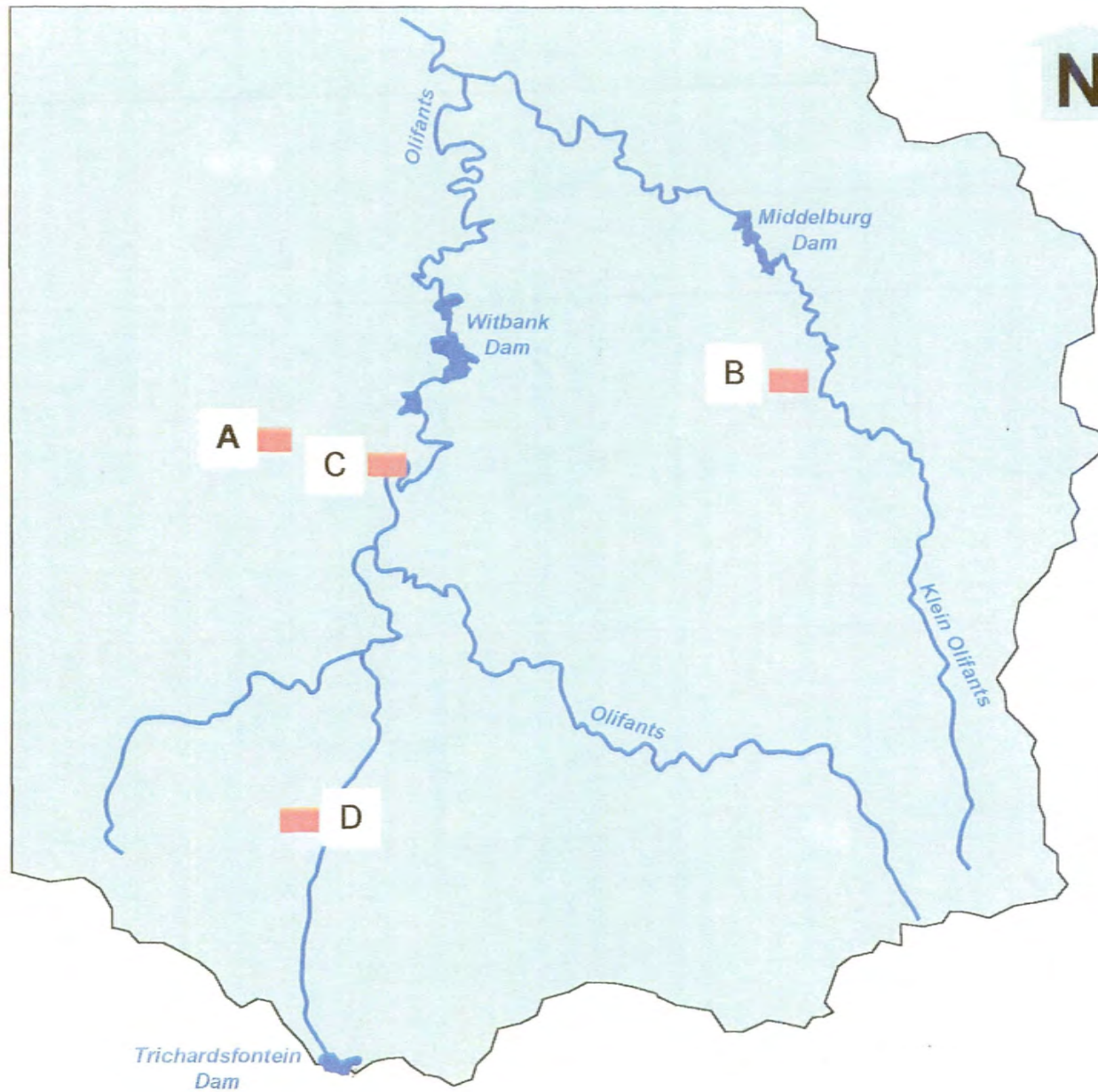
Figure 18: Location of sample sites used for chemical analysis

8.3 Discussion

The following conclusions can be drawn from the results of the GIS map:

- A GIS map is a good way to display the data held within one or more databases. It makes the analysis of that data easier and more accessible to the layperson.

- Those samples with >1% pyrite content are most likely to yield the poorest quality water i.e. not suitable for any use.

- However, in terms of pyrite content alone, there are no sites that are expected to yield water that is unsuitable for aquatic ecosystems.

- Those samples with high pyrite content are generally those with high total sulphur content. In those cases where the resultant water quality is not as poor as might be expected, it is assumed that the sulphur compound is something other than pyrite and/or that there is a neutralising effect caused by a mineral such as calcium carbonate.

- Water quality is poorest in those areas where samples exhibit an ash content of >20%. However, such water is still suitable for livestock watering, aquaculture and aquatic ecosystems.

- % fixed carbon also has a definite role to play in determining the resultant water quality. Samples with a total carbon % that is >60% yield water of the best quality. This simply means that the mineral content of the coal i.e. ash is low.

- The coal used in this study did not exhibit a significant sulphur content. However, it may be said that the higher the sulphur content of the coal, the poorer the quality of the water into which the leachate enters.

- The method of mining employed does not have as marked an effect on the resulting water quality.

The following conclusions can be drawn from the chemical leaching beaker studies:

- The pH for all sites and all samples (except ash) ranges between 5.6 and 9.0, as can be seen in Figure 19. pH increases most rapidly from 0 minutes to 30minutes and then starts to level off. This is an indication that the most acid water is released within the first 30 minutes of contact with water. In the case of the ash sample, pH ranges from 10.88 to 11.28. However, it is important to note that these values do not increase sequentially. Rather, there is no apparent trend for this type of sample.
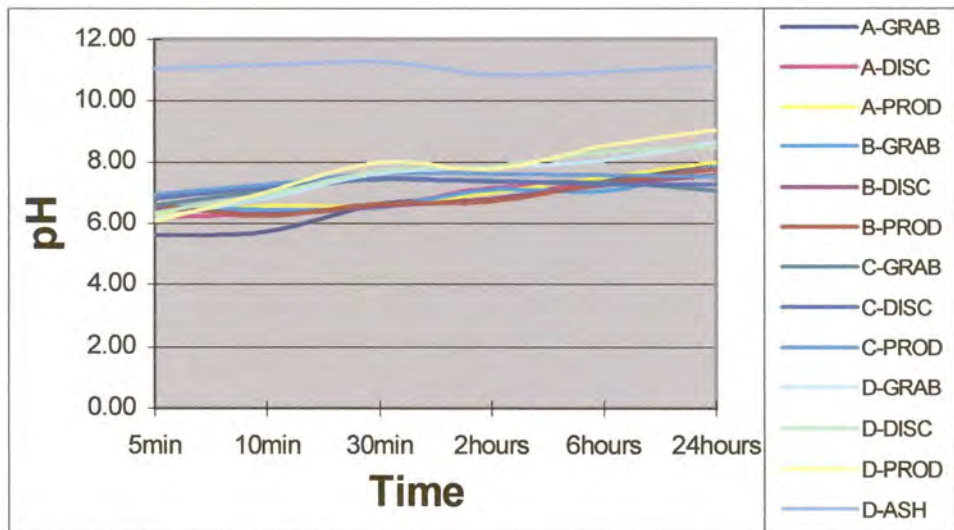

Figure 19:   Summary of all samples: pH over time

- As was to be expected from South African coals, the sulphate value for all sites and all their samples was below 247 mg/l and as such is no cause for concern.
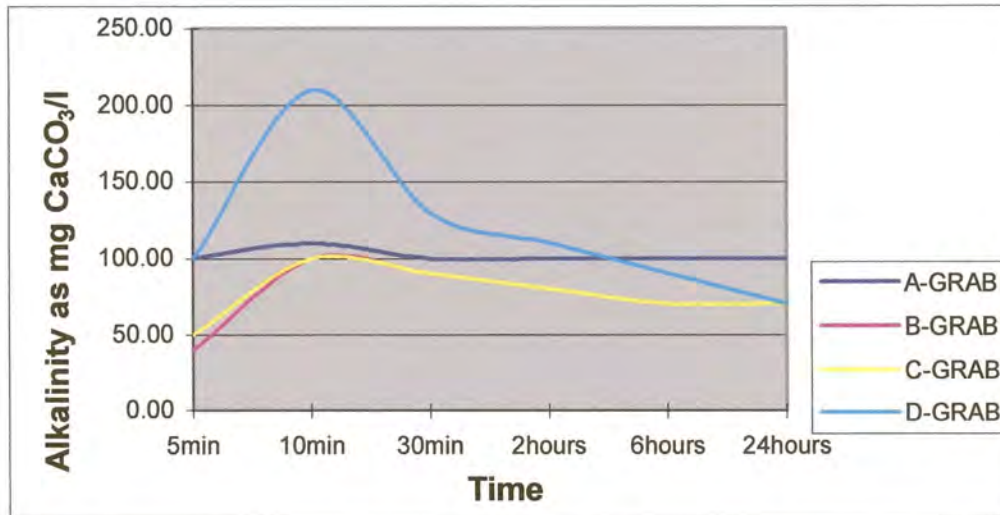
Figure 20:   Summary of 'grab' samples: Alkalinity over time

- The alkalinity that was calculated for Site A shows a similar trend-line to that of its pH i.e. alkalinity increases during the first 15 minutes and then tapers off to a constant value of 100 mg $CaCO_3$/l, as can be seen in Figure 20. This is the trend that could be expected by a sample that is relatively richer in neutralising minerals that counteract the acid-producing effect of the acid-generating minerals successfully over a 24 hour period.

- The 'grab' samples from Sites B and C follow a path more similar to each other i.e. a rapid decrease in alkalinity during the first 15 minutes followed by a gradual decrease during the next 6 hour period. This is the trend that could be expected by a sample that also contains effective buffering minerals, but whose neutralising capacity may be overcome over time owing to the growing acid-generating potential of the sulphide minerals contained in the sample.

- The alkalinity trend for sample D shows the most marked variation, but follows a similar trend to that of sites B and C. Approximately 10 minutes after contact with water, all of the buffering minerals have had their effect on the solution. Thereafter, alkalinity rapidly decreases to another critical point at 30 minutes, where most of the acid-generating minerals have had their effect. However, due to relatively more or stronger acid-generating minerals in solution, alkalinity continues to decrease over the 24 hour period. This type

of sample could be expected to generate more strongly acid leachate in the longer term and therefore, long-term management strategies would have to be developed for such a site.
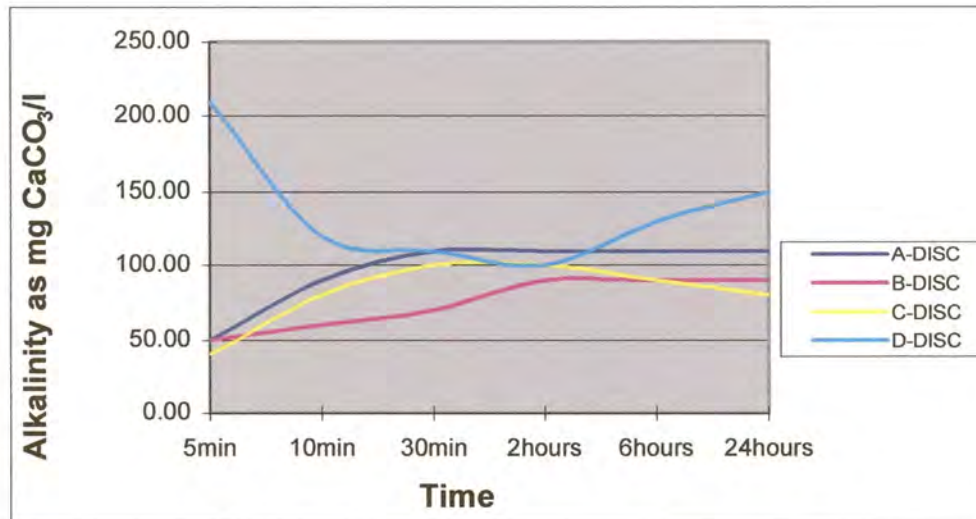

Figure 21:   Summary of discard samples: Alkalinity over time

- When discussing the alkalinity trends of any discard sample relative to a grab sample from the same site, it must be remembered that all grab samples were taken in situ from a particular coal seam in each mine and the discard samples were taken randomly from a depth of 1m in the discard dump of that same mine. All discard samples have therefore been subjected to a greater intensity and variety of weathering, prior to these tests, than the grab samples.

- The alkalinity trend for the discard sample from Site A shows an increase during the first 30 minutes and then remains relatively constant for the remainder of the 24 hour period.

- The discard sample from Site B shows a slower increase in alkalinity than that of Sites A and C, only reaching maximum alkalinity after 2 hours and then remaining constant.

- The alkalinity of the discard sample from Site C increases during the first 30 minutes and then very gradually decreases over the remainder of the 24-hour period. This decrease in alkalinity was also evident in the grab sample from

Site C and is thus cause for concern when considering management options for the discard dumps at this mine.

• The discard sample from Site D is very distinct. It is interesting to note that the decrease in alkalinity of the grab sample is not followed by the discard sample, rather there is a marked increase in alkalinity over the final 19 hours of the beaker test. This indicates the increased effectiveness of the buffering minerals in this sample over an extended period of time once the sample has been allowed to weather naturally. There could thus be less cause for concern than that expressed in response to the alkalinity trend of the grab sample from this mine.
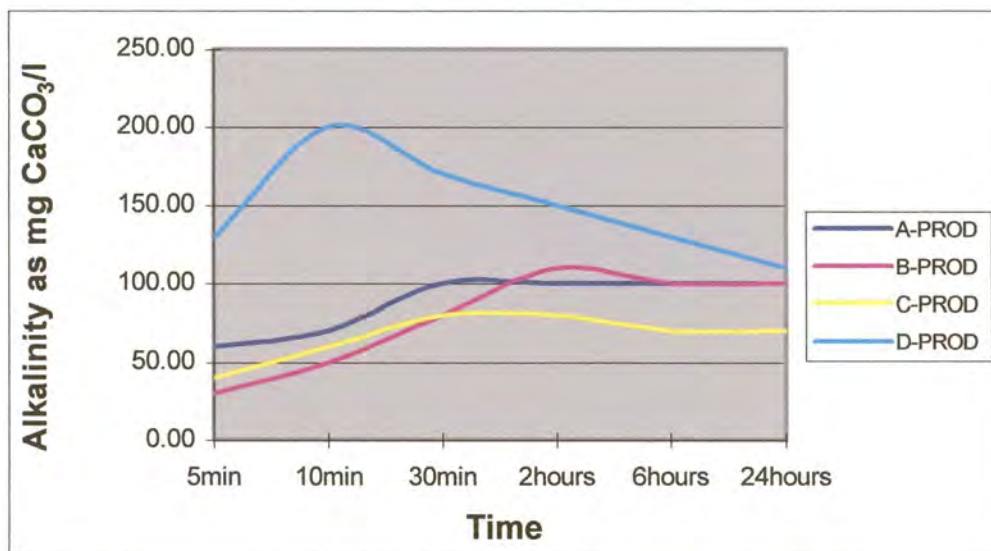

Figure 22:   Summary of product samples: Alkalinity over time

• The alkalinity trend for the product sample from Site A exhibits an increase in alkalinity during the first 30 minutes and then remains constant at 100 mg $CaCO_3$/l. This trend is much the same as that for the discard sample from the same site.

• The product sample from Site B also shows an increased alkalinity, but this occurs over the first 2 hours of the test. There is then a slight decrease over the next 4 hours and then the alkalinity also remains constant at 100 mg

CaCO₃/l. This trend is much the same as that for the grab and discard samples from the same site.

- The alkalinity trend for the product sample from Site C shows a marked increase during the first 30 minutes, a gradual decrease over the next 5 ½ hours and is then constant for the remainder of the 24 hour period.

- The product sample from Site D shows a much higher alkalinity than that of the other sites. The trend exhibited is much the same as that of the grab sample for the same site.
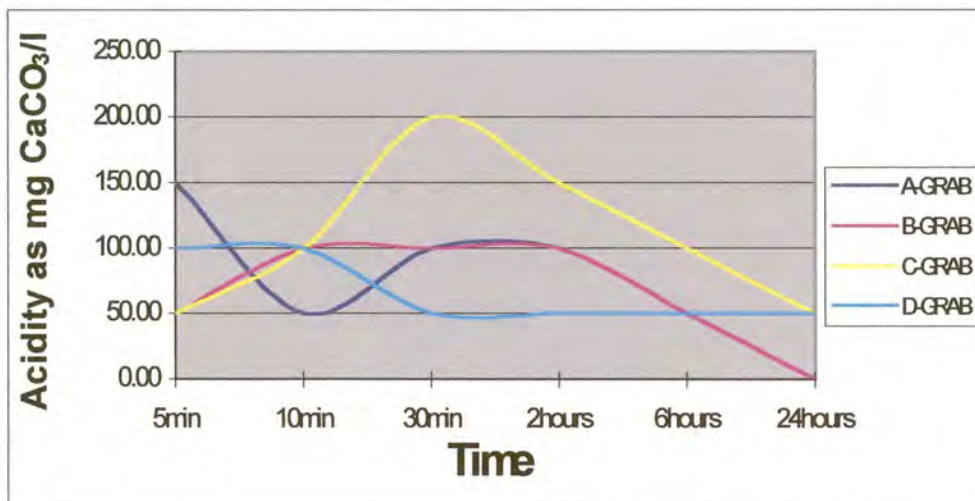

Figure 23:   Summary of 'grab' samples: Acidity over time

- The acidity values calculated for the 'grab' samples for each Sample Site have only one characteristic in common i.e. they all ultimately decrease over a 24-hour period to a negligible value (Figure 23), except for the sample from Site D which shows constant acidity from 30 minutes onwards. It is important here to compare trend in acidity to trends in alkalinity in order to determine whether there is a direct correlation between the effects of acid-generating and neutralising minerals in the samples.

- It is assumed that sample A generates acidity during the first 5 minutes (due to a lack of neutralising minerals), whereas sample B only begins to generate acidity after the first 5 minutes (possibly due to the counter effects of

neutralising minerals) and sample C in turn issues a steady generation of acidity that decreases after the first 30 minutes.

- It is also assumed that sample D generates acid during the first 5 minutes. In the case of this sample, the counter effects of buffering minerals is experienced during the second 5 minutes and this buffering effect increases to a maximum at 30 minutes. After this, acidity remains constant at a value of 50 mg $CaCO_3$/l.
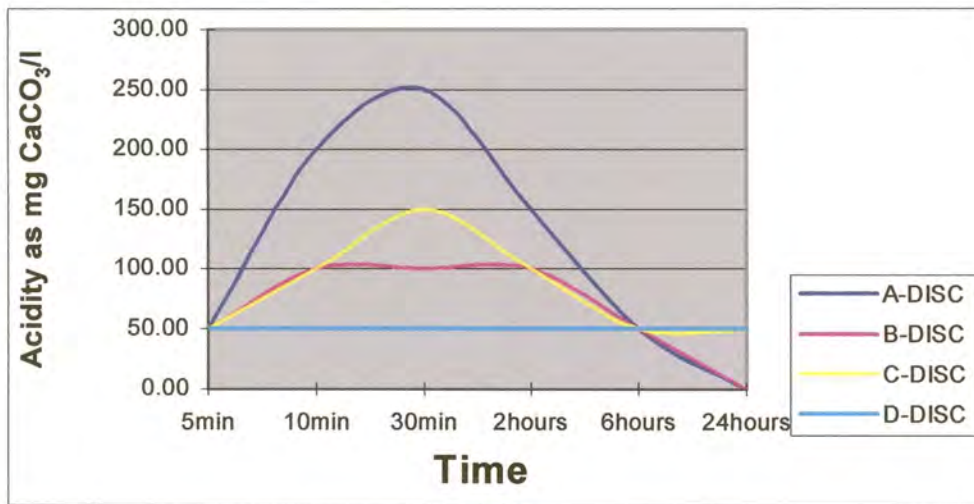

Figure 24:   Summary of discard samples: Acidity over time

- The acidity values calculated for the discard samples for each Sample Site have only one characteristic in common i.e. they all ultimately decrease over a 24 hour period to a negligible value; except for the sample from Site D which maintains a constant acidity of 50 mg $CaCO_3$/l throughout the 24 hour period. The other inconsistencies in their trend must once again be explained by the relative neutralising capacity of their mineralogical make-up (Figure 24).
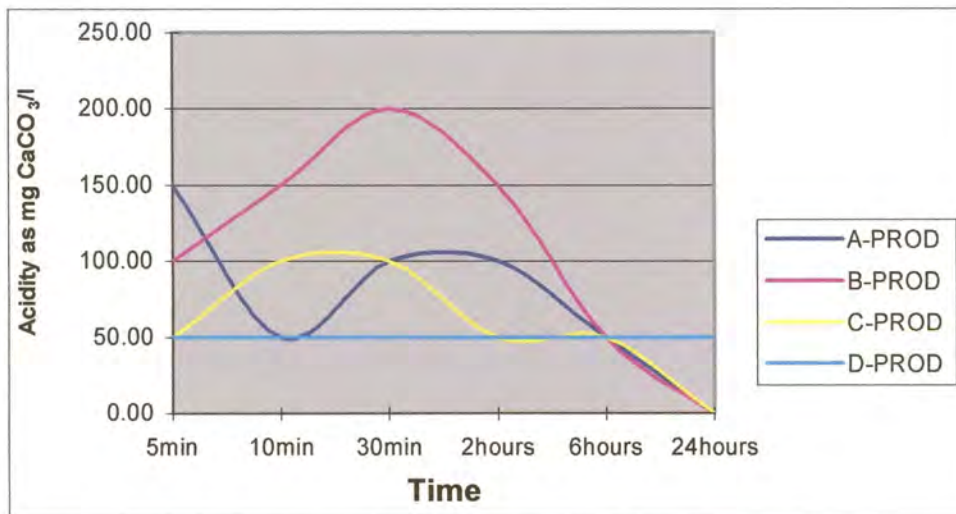
Figure 25:   Summary of product samples: Acidity over time

- The acidity values calculated for the product samples for each Sample Site have only one characteristic in common i.e. they all ultimately decrease over a 24-hour period to a negligible value (Figure 25).

- Samples A and B have a high initial release of acidity i.e. during the first 5 minutes, after which they decrease only to increase again after about 2 hours. This second burst could be due to a simultaneous decrease in available neutralising agents within the product itself.

- Sample D is different in that it releases a relatively constant amount of acidity over the course of the experiment.   It is assumed that this is due to the treatment process involved with producing this particular coal product.

- In general it may be stated that:
  - ➤ 'Grab' samples are likely to generate the most acid leachate;
  - ➤ Product samples are most likely to exhibit the highest alkalinity due to their processing and treatment; and
  - ➤ Ash samples, or samples with a high ash content, are most likely to produce highly alkaline leachate.