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Temporal Evolution of Net Potential Ratios

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Abstract

As part of acid-base accounting, Net Potential Ratios are the ratios of Neutralization Potential to Acid Potential (NPR = NP / AP) for individual samples. Based on other testwork, a site-specific NPR criterion is developed (such as 2.0). Any sample below the criterion is predicted to become acidic as its NPR value decreases through time, with its decrease accelerating with time, and becomes zero. However, ARD studies often show that samples with non-zero values of NPR are associated with acidic conditions. This highlights one or two errors in such studies:

Error 1) NPR values for samples were determined by using excess NP that was not fully effective and fully reactive. That means NPR values are too high, and thus the potential for ARD is underestimated.

and/or

Error 2) Lag times to the full consumption of reactive NP and the onset of acidic conditions are wrong, because many samples were acidic before NP and NPR decreased to zero. That means ARD will arise faster than predicted, and combined with the Error 1, ARD might arise where not predicted to appear at all.

The resolution to these errors is adjusting the NP used in NPR calculations so that no non-zero NPR value is associated with an acidic pH. In this way, more accurate estimates of ARD potential and lag times can be made.

INTRODUCTION

As part of acid-base accounting (ABA), the Net Potential Ratio (NPR) is calculated as:

NPR = Neutralization Potential (NP) / Acid Potential (AP) (Equation 1)

For this equation, NP and AP are implicitly reactive. Reactive values can sometime deviate substantially from laboratory-measured values (Morin and Hutt, 2008a and 2008b).

An NPR criterion is then identified, such as with kinetic testing, to differentiate net-acid-generating samples from net-acid-neutralizing samples (e.g., Morin and Hutt, 1997, 2001). This is different from "PAG" (Potentially Acid Generating), because both categories can generate acidity but only one has excess NP to offset the acidity.

For example, a criterion of 2.0 means that all samples with an NPR less than 2.0 will display NPR values decreasing more quickly through time towards zero (Figures 1 and 2). They will eventually release net acidity, i.e., become acidic, when NP is exhausted and NPR reaches zero. All samples with an NPR of 2.0 will remain at 2.0 until all AP and NP are. All samples with an NPR above 2.0 will display increasing NPR values through time as AP approaches zero and NPR asymptotically approaches infinity if no default value is set (e.g., Figure 3).

For samples with NPR levels below the site-specific criterion, a "lag time" of many years or decades may pass before NP is fully consumed. This lag time to net acidity is often estimated by dividing a sample's NP by the rate at which NP is consumed, such as that measured by a kinetic test.

A contradiction arises in some ARD predictions at this point. If the lag time is defined as the time to consume all NP, then another way of saying this is that the lag time is defined as the time for a sample's NPR to decrease to zero. If a sample's NPR is not zero, then it still contains reactive NP and should still be near neutral.

Figure 4, extracted from a recent ARD prediction report for a Canadian minesite, illustrates this contradiction. In Figure 4, samples with NPR values up to roughly 1.5 have acidic pH values. This may be interpreted as NPR=1.5 being the applicable NPR criterion for this site, but that would be wrong. In reality, if NPR were calculated correctly, no sample in Figure 1 should be acidic, because all still have NP.

This points to one or two errors in the ARD interpretations and predictions of Figure 4 and similarly interpreted data.

Error 1: NPR values in Figure 4 were calculated using excess NP that was not fully effective and fully reactive. I have reviewed many studies that assume all laboratory-measured NP was effective NP, despite NPR and kinetic tests proving this wrong (Morin and Hutt, 2008a and 2008b). This is a common and major error in ARD predictions. It means NPR values are too high, and thus the potential for ARD is underestimated (Morin, 2010).

and/or

Error 2: Lag times associated with Figure 4 were calculated incorrectly, because many samples were acidic before NP and NPR decreased to zero. This also is a common error. It means ARD will arise faster than predicted, and combined with Error 1, ARD might arise where not predicted to appear at all.

The resolution of these errors is relatively simple. Figure 4 indicates the reactive NP of the samples were not estimated correctly. NP values used for NPR were erroneously high, and thus NPR values were erroneously high, and lag times were erroneously long. NP has to be reduced.

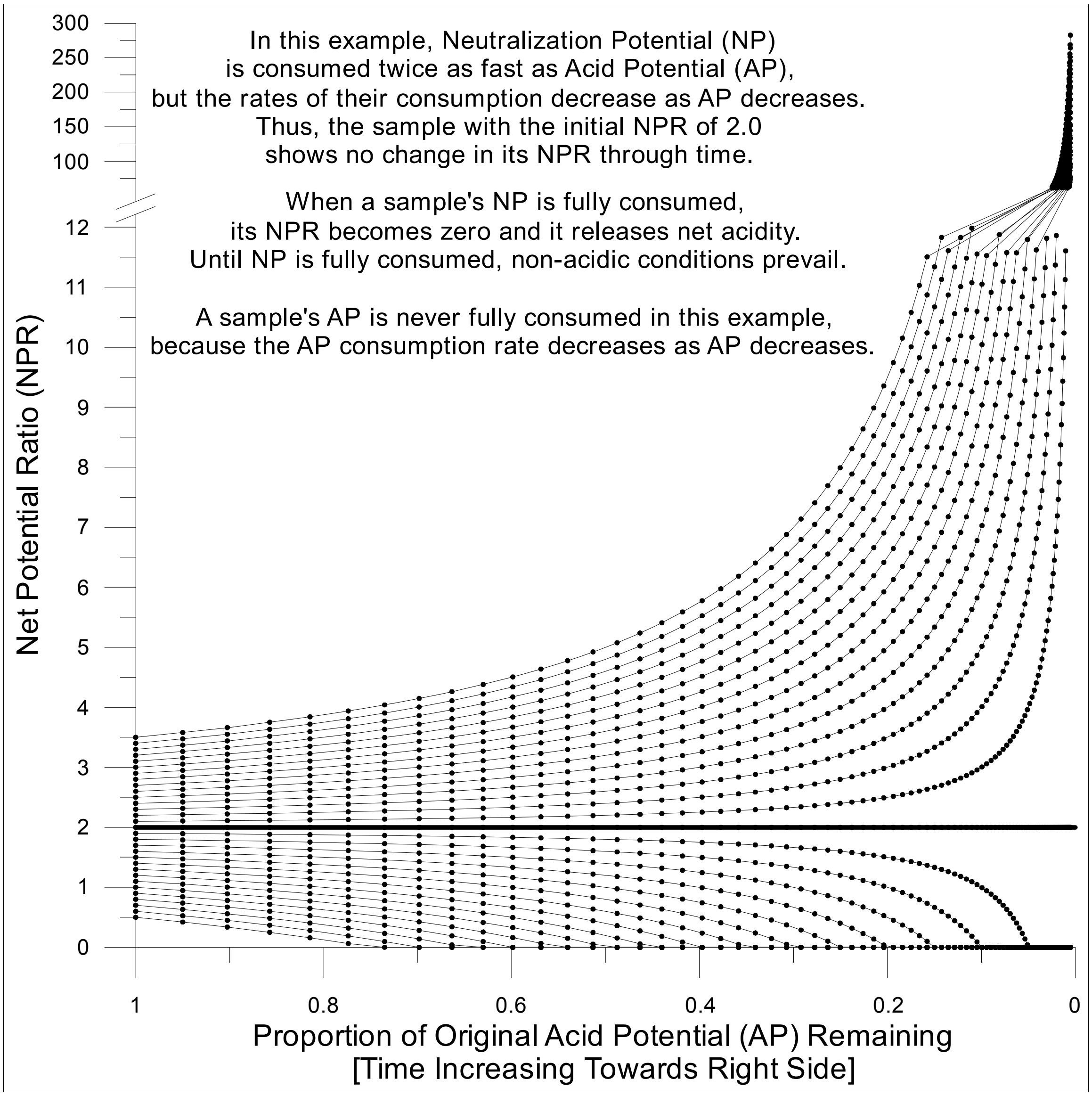
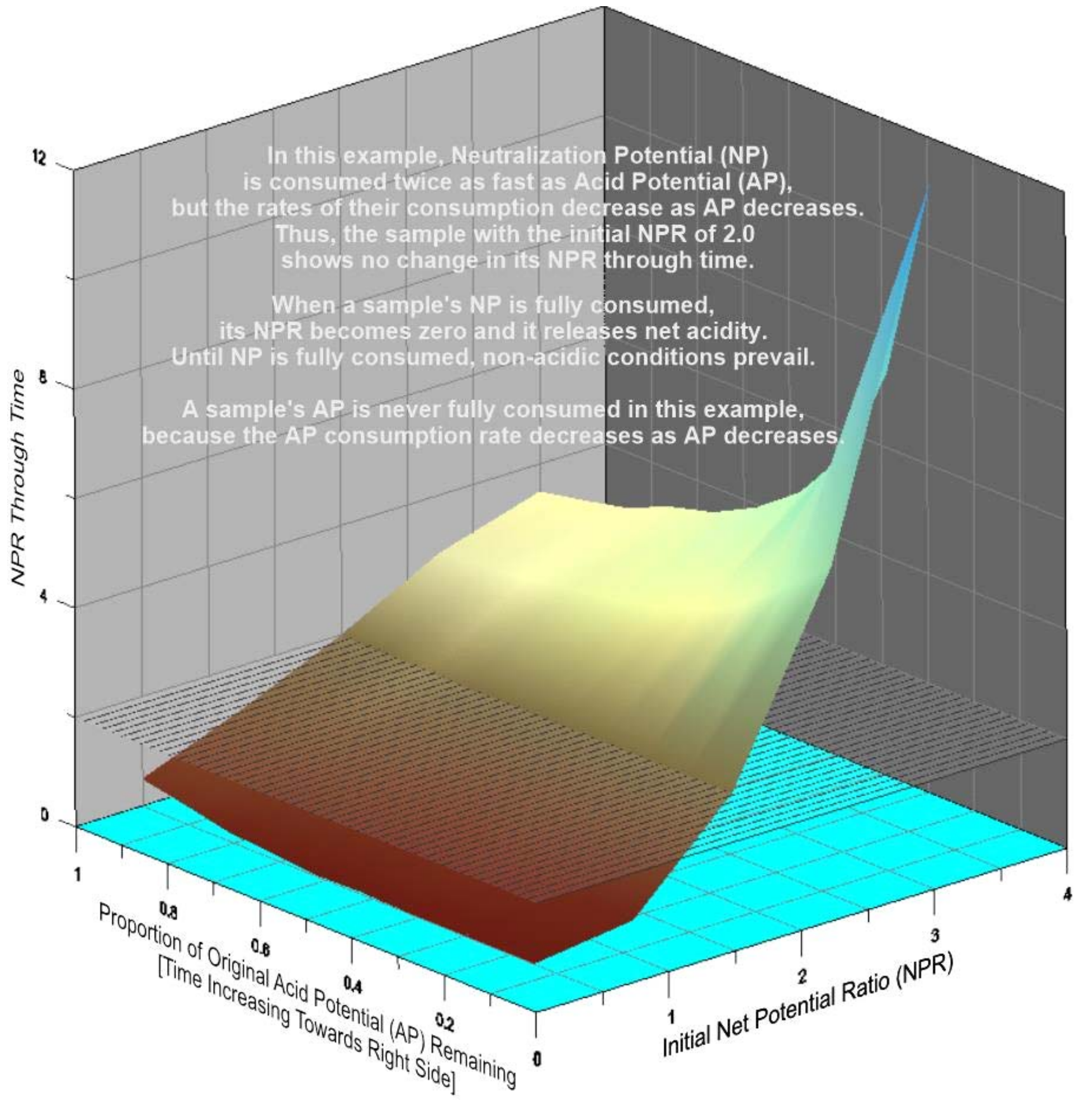


Figure 1. NPR values above and below the NPR criterion of 2.0 changing with time as AP decreases but never reaches zero due to decreasing reaction rate; values below the criterion eventually decrease to zero and become acidic; values above the criterion approach infinity as AP decreases towards zero.



In this example, Neutralization Potential (NP) is consumed twice as fast as Acid Potential (AP), but the rates of their consumption decrease as AP decreases. Thus, the sample with the initial NPR of 2.0 shows no change in its NPR through time.

When a sample's NP is fully consumed, its NPR becomes zero and it releases net acidity. Until NP is fully consumed, non-acidic conditions prevail.

A sample's AP is never fully consumed in this example, because the AP consumption rate decreases as AP decreases.

Figure 2. A three-dimensional depiction of Figure 1 as a surface.

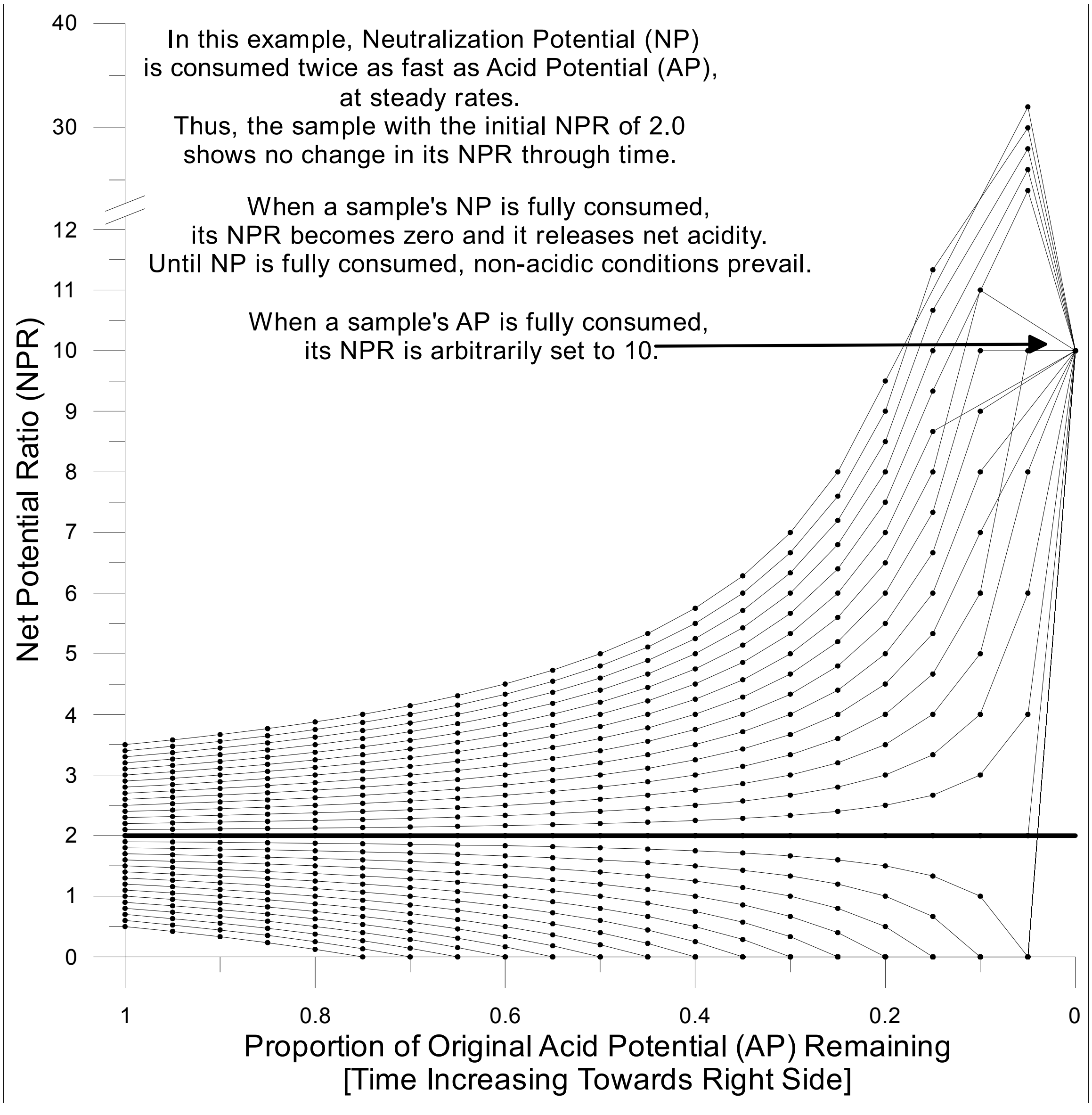


Figure 3. Similar to Figure 1, except AP does eventually reach zero because the reaction rate does not decrease with decreasing AP; to avoid numerical values of infinity, a default NPR value of 10.0 is given to any sample reaching zero AP.

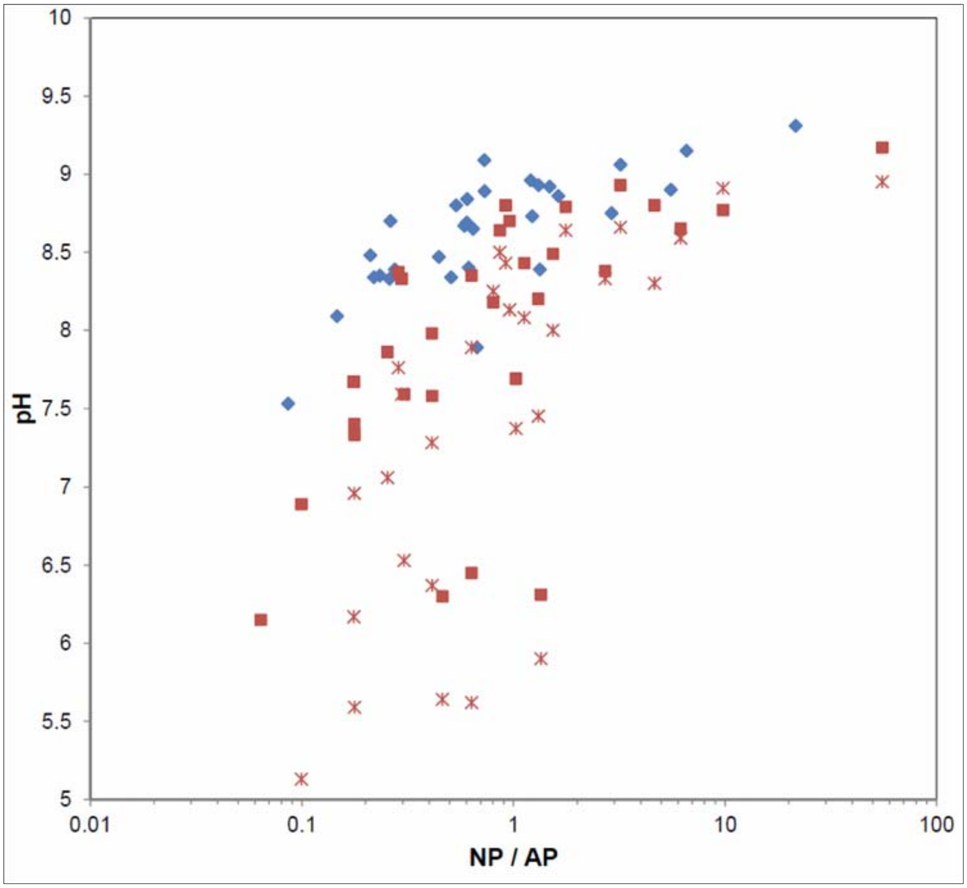


Figure 4. An example of Net Potential Ratio (NPR = ENP / EAP) showing acidic values of pH associated with non-zero values of NPR.

As another example, Figure 5 shows NPR values are wrong because non-zero values are associated with acidic conditions. When NP is lowered by subtracting one adjustment (20 kg/t) from all NP values in Figure 5, no non-zero NPR has an acidic paste pH (Figure 6) and more reasonable predictions are obtained. Lag times can also be estimated more accurately.

However, with this adjustment, several samples in Figure 6 with NPR=0 have near-neutral pH. This could mean that these samples were relatively fresh and did not yet generate acidity, or that a single-value NP adjustment is not appropriate for all samples. Additional kinetic testwork would be needed to resolve this.

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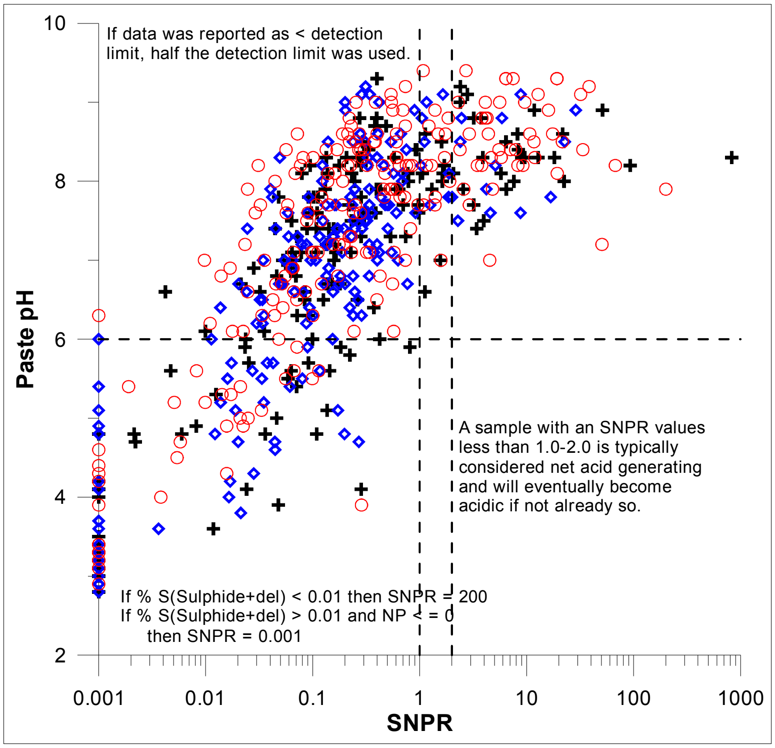

Figure 5. Paste pH vs. unadjusted sulphide-based net potential ratio (SNPR) in hundreds of core samples from a proposed minesite.

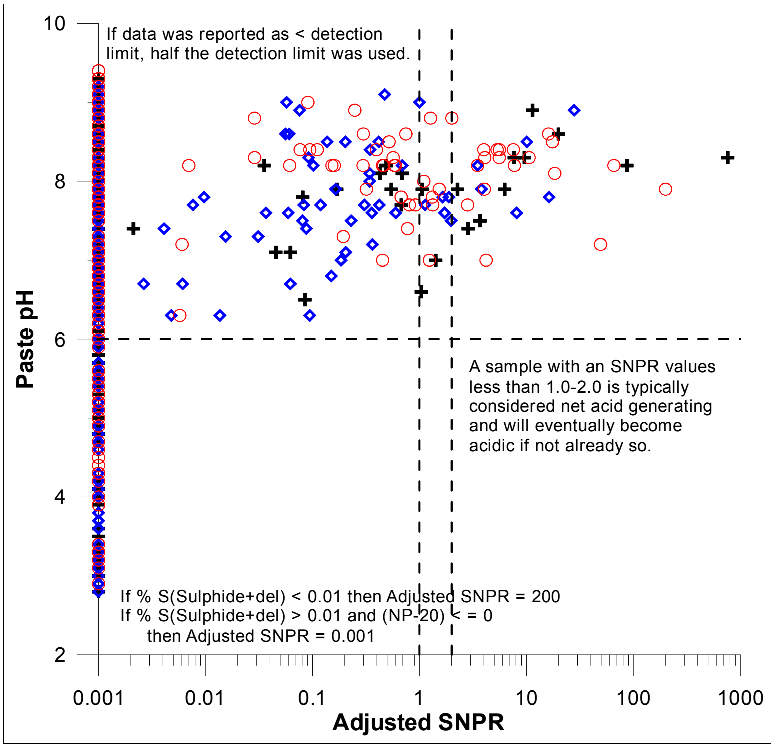

Figure 6. Paste pH vs. adjusted sulphide-based net potential ratio (Adj SNPR) in hundreds of core samples from the same proposed minesite.