

Proposed Remediation of Acidic Ground Water and Dissolved Metals at Former National Lead Industries Site



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Laura Fotiou, May 2013
MSAG concentration in Hydrogeology

Abstract

The former National Lead Industries, Inc. (NL) site occupies 400 acres bounded by the Raritan River. Previous operations included the processing of ilmenite ore to manufacture titanium dioxide pigments. Ground water remediation is focused on the acidic plume located in the shallow water-bearing unit under the main operational areas of the site. The plume is associated with high concentrations of soluble metals, sulfates, and radionuclides which follow the acidity distribution. Proposed remediation of ground water suggests in-situ neutralization by a network of 325 injections points of calcium hydroxide over a treatment area of approximately 18-acres. Proposed treatment is based on interpretation of acidity distribution and ground water flow using TWODAN and MODFLOW ground water models. Following lime slurry injections, performance monitoring will evaluate the alkalinity distribution and the effectiveness of reducing acidity and concentration of metals over time. The property will be utilized for a mixed-use community including office, retail, and residential space.¹

Background

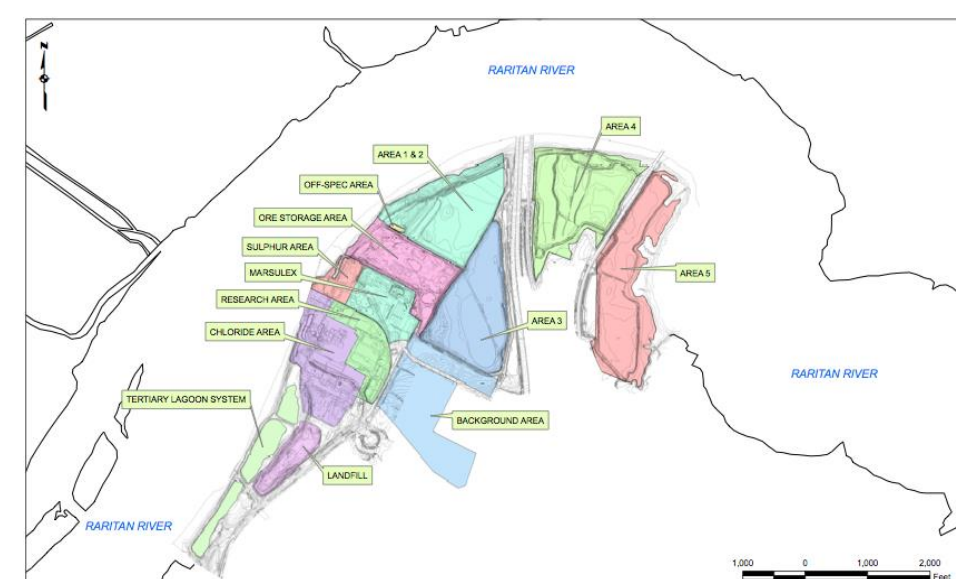


Figure 1: Site layout map with designated areas of concern¹

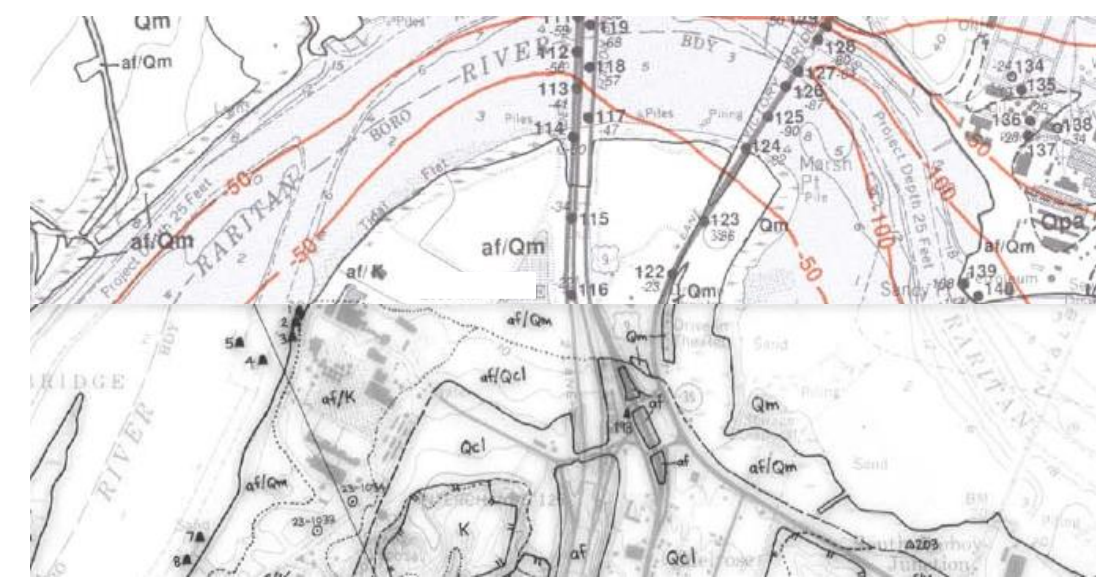


Figure 2: NJGS Map of surficial geology at NL site^{2,3}

The processing of ilmenite ore as part of titanium dioxide pigment manufacturing has led to serious ground water contamination of the NL site. Measurements of metals, radionuclides, sulfates and pH in the ground water have been made across the site and at various depths in order to define the degree and distribution of contamination and devise a plan for remediation. The principal zone of ground water contamination includes area 3, marsulex, sulfur area, and the southern section of the ore storage (Figure 1). This project is focused on the remediation of the ground water to the standards presented by NJDEP.

NL is located in the Atlantic Coast Physiographic province. Site geology (Figure 2 and Figure 3) consists of three units:

- Overburden material made of artificial fill (af), quaternary-age estuarine deposits from the Raritan River (Qm) and Raritan Terrace deposits (Qrt) on top, and mostly Terrace deposits in the deeper zone
- Woodbridge clay (Krw) of the Raritan formation consisting of regionally extensive, low permeability micaceous clay
- Jurassic diabase (Jd).¹

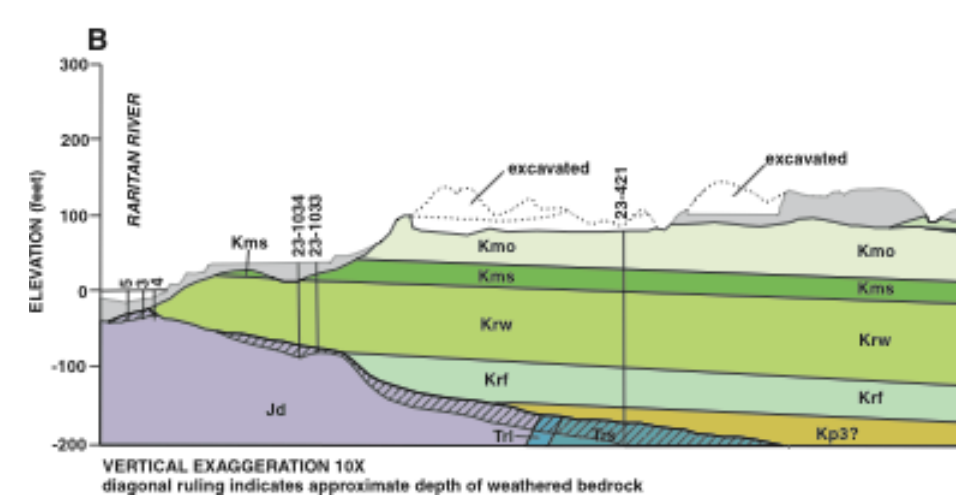


Figure 3: USGS geological map cross-section⁴

Contamination

The contamination is present in the saturated zone of the overburden material. Ground water samples were taken from approximately 90 wells, including well couplets to quantify contamination exceeding the ground water quality criteria in the shallow and deep zones of the saturated zone.¹

Table 1: Measured levels of pH, sulfate, and TDS¹

Measured	GWQC	Shallow Zone	Deep Zone
pH	6.5 – 8.5	1.59 – 6.3	1.4 – 6.19
Sulfate (ppm)	250	300 – 46,400	857 – 119,000
TDS (ppm)	500	586 – 70,900	1,220 – 1,090,000

Table 2: Measured levels of metal contaminants in the shallow ground water across the site in shallow and deep zones¹

Contaminant (ppb)	GWQC	Shallow Zone	Deep Zone
Aluminum	200	3,730 – 354,000	183,000 – 5,650,000
Antimony	6	7.1 – 802	470 – 960
Arsenic	3	3.3 – 2,224	5 – 1,700
Beryllium	1	1.3 – 40	1.2 – 600
Cadmium	4	4.6 – 270	14
Chromium	70	72.7 – 1,260	81 – 34,500
Copper	1,300	1,560 – 27,700	1,430 – 24,200
Iron	300	6,510 – 15,800,000	973 – 38,800,000
Lead	5	5.2 – 1,300	8.8 – 1,100
Manganese	50	199 – 37,700	12,000 – 306,000
Mercury	2	5.9 – 11	0
Nickel	100	156 – 25,5000	451 – 12,700
Selenium	40	151	48.4 – 1,010
Silver	40	---	42 – 430
Thallium	2	21.2 – 345	23.3 – 1,170
Zinc	2,000	2,150 – 830,000	2,160 – 63,000

Fate and Transport Model

Ground water modeling was used to understand the flow of the saturated zone and the acidity plume fate and transport with the proposed remediation

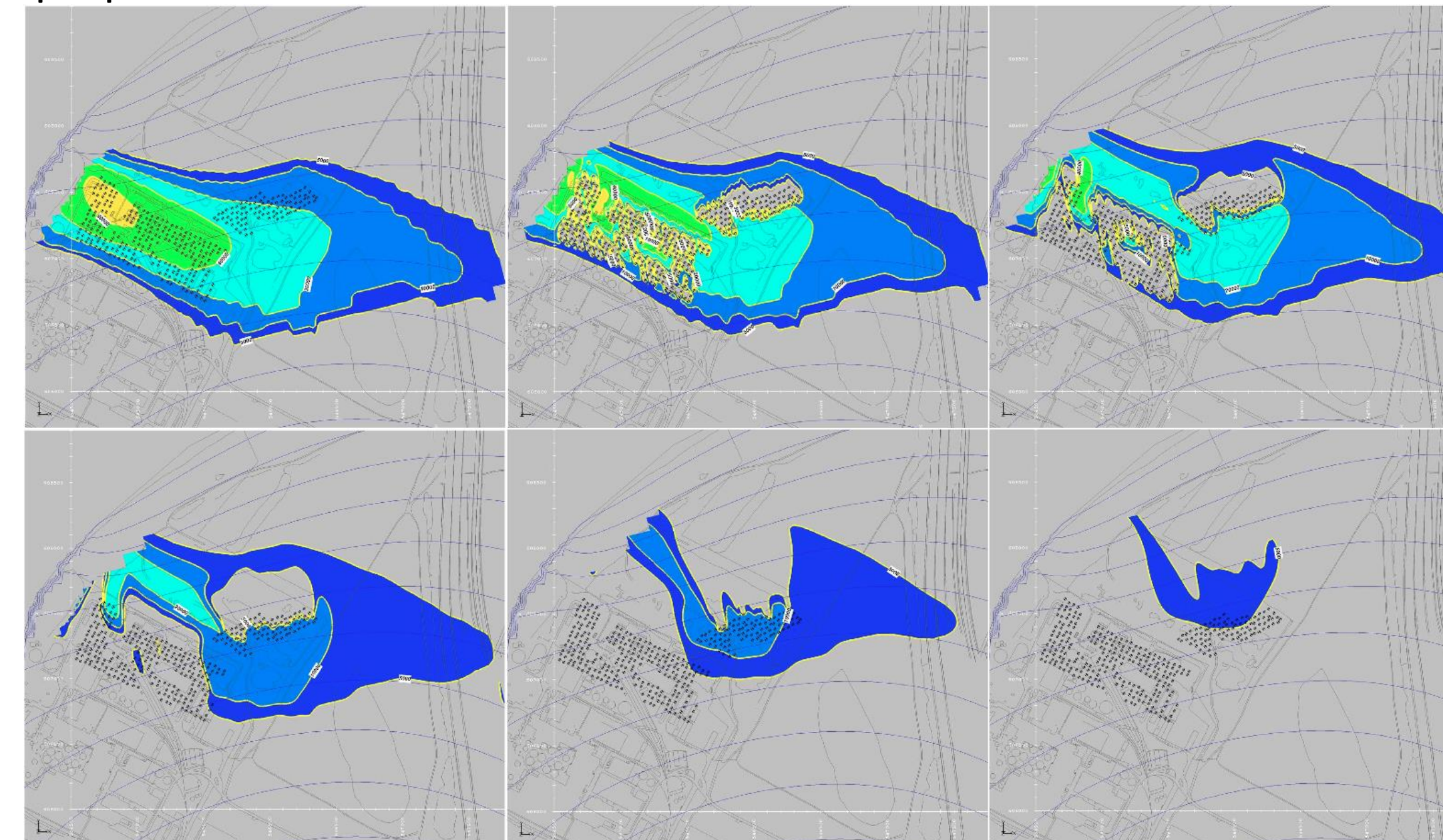
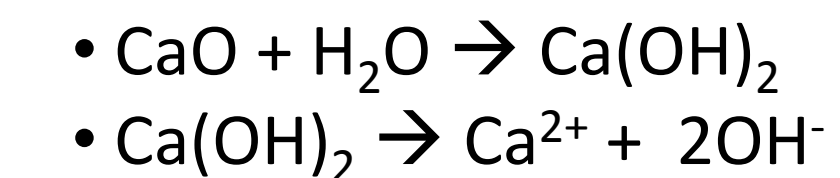


Figure 4: Modeled Acidity Distribution in deep wells with lime slurry injection after (top left) 0, 2, 5, 10, 20, and 30 years

Proposed Remediation

The method of remediation consists of injections of alkalinity in the form of $\text{Ca}(\text{OH})_2$ into overburden ground water to neutralize the acidity by reaction of the released hydroxide ions (see below reaction schemes) with hydrogen ion and reduce concentrations of dissolved metals and radionuclides by precipitation.



Based on ground water characterization and modeling results the proposed remediation is mapped in Figure 5. Injections are calculated to the stoichiometric equivalence of acidity present at injection point.¹

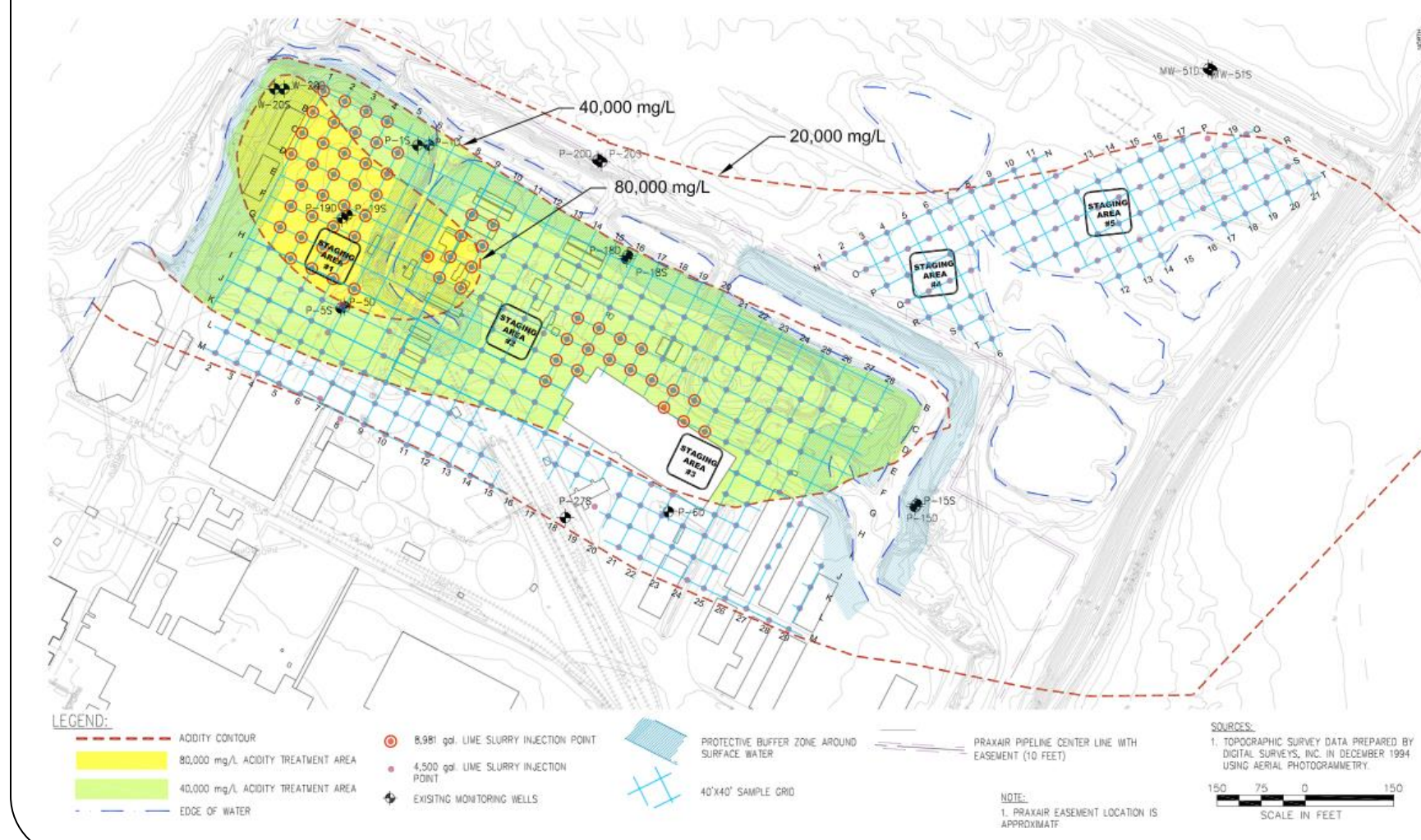


Figure 5: Proposed Lime Slurry injection layout; Injections are focused on highest concentration of total acidic species (40,000-80,000 mg/L) and excess lime slurry in 20,000 mg/L contour to treat upgradient ground water flow.¹

Discussion/Conclusion

The proposed method of remediation of the ground water is a well established method and is in principle capable of reducing the acidity by neutralization and the metal and radionuclide concentration by precipitation and immobilization to the soil. However, the models used for the initial planning have assumed uniform distribution of the injected lime slurry throughout the targeted zone which may not fully apply. Although in general the geology within the application areas is consistent, small-scale heterogeneities exist which can prevent uniform distribution of the injected slurry. Additional limitations in the alkalinity coming into contact with the acidic water could be the presence of insoluble forms of iron around the lime and the formation of solid calcium sulfate from the reaction of calcium ions with sulfates. Another assumption is that the high pH ground water initially surrounding the injection area will mix effectively with the low pH zones via water movement, however this process may be slow. In addition, considering that the solubility of the lime slurry in water is low (1.9 gram per liter) the time period required to achieve the ground water quality criteria cannot be accurately predicted. Another complication could be retardation in the rate of transport of the metals due to the complex geochemistry of the subsurface. Therefore, performance monitoring will be needed to follow the progress of the remediation with time and adjust the amount and position of lime injections.

¹ERM, March 2008. Remedial Action Work Plan, NL Industries, Inc., Sayreville Site. Environmental Resource Management, ERM Project #0011241-09. ²Stanford, S.D., 1995. Surficial Geology of the Perth Amboy and Arthur Kill Quadrangles, Middlesex and Union Counties, New Jersey: N.J. Geological Survey Open-File Map OFM 28

³Stanford, S.D., 1995. Surficial Geology of the South Amboy Quadrangle, Middlesex and Monmouth Counties, New Jersey: N.J. Geological Survey Open-File Map OFM 18. ⁴Sugarman, P.J., Stanford, S.D., Owens, J.P., and Gilbert, J.B., 2005. Bedrock geology of South Amboy Quadrangle, Middlesex and Monmouth Counties, New Jersey: N.J. Geological Survey Open-File Map OFM 65