

CEDAR LAKE AQUATIC ECOSYSTEM RESTORATION FEASIBILITY STUDY

CEDAR LAKE, INDIANA

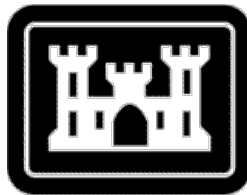
APPENDIX H ALUM TREATMENT ANALYSIS

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- Attachment 1: Work Plan
- Attachment 2: Health and Safety Plan
- Attachment 3: USACE Preliminary Calculations
- Attachment 4: Laboratory Data

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ALUM TREATMENT ANALYSIS

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1. Introduction

Cedar Lake is a 781-acre, glacially formed lake located in the Town of Cedar Lake in Lake County, Indiana. The lake was once a pristine glacial lake left by Wisconsinan Age glaciers with a small watershed of intermingled prairie, savanna, woodlands and wetlands. Today, only fragments of the original landscape remain, replaced by farms initially and residences more recently. Water quality has been degraded and the lake is over-enriched, leading to severe algal blooms. Rooted plant life is minimal and the fishery has become undesirable.

The U.S. Army Corps of Engineers (USACE) is currently conducting an aquatic ecosystem restoration feasibility study of Cedar Lake. The Feasibility Report (FR) will compare different measures for addressing habitat degradation and restoring the natural aquatic ecosystem of Cedar Lake. Elevated internal nutrient loading from bottom sediments is a major contributing factor to habitat degradation. Therefore, reducing the amount of nutrients released into the water column from the sediments within the lake is of high priority. Sediment removal, nutrient inactivation, dilution and flushing, in-lake structures, aquatic vegetation restoration, fish community management, and institutional controls are among the measures being investigated during the feasibility study.

Section 3065 of the Water Resources Development Act of 2007 (PL 110-114) authorizes \$11,050,000 in Federal funds to plan, design, and construct an aquatic ecosystem restoration project at Cedar Lake. Under this authority, USACE and the Town of Cedar Lake as the potential non-federal sponsor have partnered to investigate the feasibility of an aquatic ecosystem restoration project. The USACE aquatic ecosystem restoration mission is to support restoration projects in aquatic ecosystems such as rivers, lakes, and wetlands. These restoration projects must improve the quality of the environment, be in the public interest, and be cost effective. USACE evaluates projects that could potentially benefit the environment by restoring, improving, or protecting aquatic habitat for plants, fish, and other wildlife species. Projects considered for funding must be justified and supported by a detailed investigation indicating that the proposed actions are technically feasible and environmentally acceptable, and that they provide cost-effective ecosystem restoration benefits.

Management of Cedar Lake is expected to involve sediment removal through dredging and phosphorus (P) inactivation to reduce internal nutrient loading, perceived to be a major source of P to the overlying lake water. The USACE is evaluating various options and alternatives, and had performed preliminary calculations of the needed aluminum dose for inactivating sediment P

in parts of Cedar Lake. CTE/ENSR was contracted to review those calculations, having expertise and experience with projects of a similar nature, and having helped advance analytical techniques to aid feasibility evaluation and cost estimation for phosphorus inactivation. ENSR found that while the process applied by the USACE was appropriate, the lack of site-specific data for available sediment P (ASP) introduced uncertainty that affected cost calculations. Additionally, it was believed that simulated laboratory inactivation experiments could further document the necessary dose of aluminum for effective inactivation.

Subsequently, CTE/ENSR was retained to collect additional sediment samples, run the necessary tests, and evaluate the results in terms of planning for internal load reduction. Generalized tasks included:

1. Collection of up to 10 surficial sediment samples and testing for available P and reaction to simulated inactivation
2. Re-calculation of the appropriate aluminum dose to inactivate available sediment P in target areas
3. Estimation of the cost to conduct the proper inactivation
4. Evaluation of the longevity of treatment results under several plausible scenarios
5. Provision of supporting information for other inactivation projects involving aluminum

ENSR was also requested to provide background information on inactivation of phosphorus that would provide background for readers in this approach to ecosystem rehabilitation.

2. Phosphorus Inactivation Background

Phosphorus inactivation has been practiced in water and wastewater treatment for about a century and has been applied in lake management for about 30 years. Much has been learned in that time about “environmental” treatments, and much of this knowledge has been summarized in a manual prepared by ENSR for the Commonwealth of Massachusetts. Based on the Practical Guide to Lake Management in Massachusetts (Wagner 2004), this primer on phosphorus inactivation is offered. While not specific to Cedar Lake, this background material will help readers understand the analysis that follows.

2.1. How Inactivation Works

The release of phosphorus stored in lake sediments can be so extensive in some lakes and reservoirs that algal blooms persist even after incoming phosphorus has been significantly lowered. Phosphorus precipitation by chemical complexing removes phosphorus from the water column and can control algal abundance until the phosphorus supply is replenished. Inactivation of phosphorus in surficial lake sediments can greatly reduce the release of phosphorus from those sediments, minimizing the internal load. It is essentially an “anti-fertilizer” treatment. This technique is most effective after nutrient loading from the watershed is sufficiently reduced, as it acts only on existing phosphorus reserves, not new ones added post-treatment. In-lake treatments are used when studies indicate that the primary source of the phosphorus is internal (recycled from lake sediments). Such nutrient control generally does not reduce macrophyte abundance, but can control algal growths.

The three most common treatments for lakes employ salts of aluminum, iron, or calcium compounds. Nitrate treatments are very rare and are used to enhance phosphorus binding to natural iron oxides in sediments. For the aluminum, iron and calcium treatments, the typical compounds used include aluminum sulfate ($\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$), sodium aluminate ($\text{Na}_2\text{Al}_2\text{O}_4 \cdot x\text{H}_2\text{O}$), iron as ferric chloride (FeCl_3) or ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$), and calcium as lime ($\text{Ca}(\text{OH})_2$) or calcium carbonate (CaCO_3). Additional forms of aluminum are becoming more common.

Inactivators are applied to the surface or subsurface, in either solid or liquid form, normally from a boat or barge. These compounds dissolve and form hydroxides, $\text{Al}(\text{OH})_3$, $\text{Fe}(\text{OH})_3$, or in the case of calcium, carbonates such as calcite (CaCO_3). These minerals form a floc that can remove particulates, including algae, from the water column within minutes to hours and precipitate reactive phosphates. Reactions continue at the surface-water interface, binding phosphorus that could otherwise be released from the sediment. Because aluminum and iron added as sulfates or chlorides dissolve to form acid anions along with the formation of the desired hydroxide precipitates, the pH will tend to decrease in low alkalinity waters unless basic salts such as sodium aluminate or lime are also added. Conversely, calcium is usually added as carbonates or hydroxides that tend to raise pH.

The various floc minerals behave very differently under high or low dissolved oxygen and they also differ in their response to changes in pH. Because of its ability to continue to bind phosphorus under the widest range of pH and oxygen levels, aluminum is usually the preferred phosphorus inactivator. Other binders are applied under specific conditions that favor their use, but not as commonly as aluminum.

Good candidate lakes for this procedure are those that have had external nutrient loads reduced to an acceptable level and have been shown, through a diagnostic feasibility study, to have a high internal phosphorus load (release from sediment). High natural alkalinity is also desirable to provide buffering capacity. Highly flushed impoundments are usually not good candidates because of an inability to limit phosphorus inputs. Treatment of lakes with low doses of alum may effectively remove phosphorus from the water column, but may be inadequate to provide long-term control of phosphorus release from lake sediments. High doses are needed to effectively bind phosphorus in the upper few inches of sediment and retard release.

Low doses of aluminum (1-5 mg/L) can be used to strip phosphorus out of the water column with limited effects on pH or other water quality variables, even in many poorly buffered waters. Mixing with aeration systems can increase treatment efficiency and lower the necessary dose. Aluminum doses in excess of 50 g/m^2 may be needed to thoroughly inactivate sediment phosphorus reserves and maximize treatment longevity. Areal doses (g/m^2) convert to volumetric doses (g/m^3 or mg/L) simply by dividing the areal dose by the water depth in meters. Doses around 10 mg/L are typically applied to storm water discharges, and current efforts in storm water management focus on capturing the floc in detention areas prior to discharge to the lake.

Iron salts are very sensitive to dissolved oxygen levels. Under oxic conditions, the ferric hydroxide floc is stable at normal pH conditions ($\text{pH} > 5$). Under anoxic conditions, however, the

iron in ferric hydroxide is reduced to soluble ferrous iron (Fe^{+2}) and the floc dissolves, releasing the adsorbed phosphorus. Therefore, while iron acts as a natural binder in well-oxygenated systems, loss of oxygen in eutrophic lakes may disrupt this natural phosphorus inactivation process. Inactivation of phosphorus by iron will become very ineffective where anoxia is so strong that sulfate reduction occurs. In such cases, iron is preferentially bound by sulfides released as hydrogen sulfide, leaving little iron to bind with phosphorus. Consequently, iron is only used in well-aerated systems. Iron is generally not toxic at levels applied to lakes.

The stability of calcite is highly sensitive to pH, calcium, and carbonate concentrations. Consequently, treatment with calcium is effective only if pH is maintained at a relatively high level (8 or above). Calcium is more commonly used in alkaline lakes regions, such as Alberta, Canada, and has not been applied commonly in the USA.

Nitrate treatments such as $\text{Ca}(\text{NO}_3)_2$ neither precipitate nor inactivate phosphorus directly. Nitrates are injected directly into the surface sediments as a 'sediment oxidation' treatment, which in this case refers to maintaining a high redox (reduction-oxidation) potential and thus maintaining the stability of natural iron oxides in the sediments. That is, nitrate is broken up to yield oxygen before iron oxides, by preference of the active bacteria. Thus nitrates act indirectly to enhance and stabilize the ability of natural iron oxides to bind phosphorus in the sediments. In this manner, nitrate treatment is analogous to hypolimnetic aeration by providing an alternative source of oxygen. This approach is not commonly practiced in the United States.

2.2. Benefits

- ◆ Rapid removal of available phosphorus from the water column
- ◆ Minimized internal loading of phosphorus
- ◆ Potential removal of a variety of other contaminants and algae

The greatest benefit is the ability to minimize P release from the sediment when such release is a major source of available P, without the need for dredging, which is far more costly.

2.3. Detriments

- ◆ Potential for damage to aquatic life at depressed or elevated pH
- ◆ Limited longevity of effects if external loading is significant

The most serious impact is the possibility for fish or invertebrate kills following treatment in low alkalinity lakes, but such impacts are preventable. Minimal adverse impacts are expected to either surface or groundwater supplies. Aluminum, iron and calcium are commonly added in water and wastewater treatment facilities with no significant adverse impacts (and generally a marked improvement in water quality).

2.4. Information for Proper Application

- ◆ An accurate nutrient budget that includes a detailed analysis of internal sources of phosphorus
- ◆ Sediment testing for available sediment phosphorus (ASP)
- ◆ Recent information on pH and alkalinity at all depths to properly predict potential changes in pH and to minimize impacts
- ◆ Knowledge of lake oxygen regime and biotic components is helpful in planning treatments
- ◆ An accurate depth map of the lake is required to properly evaluate dosing
- ◆ In addition to jar tests to establish doses and ratios of chemicals, toxicity tests with a sensitive fish species may be desirable
- ◆ Monitoring of pH, alkalinity and any biotic reactions is appropriate during treatment, with follow-up monitoring if any deviations from the expected range are detected
- ◆ Estimates of effectiveness should be made for lake recovery in terms of total phosphorus levels and Secchi disk transparency.
- ◆ For deep lakes, hypolimnetic dissolved phosphorus concentration should decrease dramatically and should be checked.

2.5. Factors Favoring the Use of this Technique

- ◆ A substantial portion of the P load is associated with sediment sources within the lake
- ◆ Studies have demonstrated the impact of internal loading on the lake.
- ◆ External P load has been controlled to the maximum practical extent or is documented to be small; historic loading may have been much greater than current loading
- ◆ Inactivation of phosphorus in the water column is expected to provide interim relief from algal blooms and turbidity while a prolonged watershed management program is conducted to reduce external loading
- ◆ The lake is well buffered or buffering can be augmented to prevent major changes in pH during treatment
- ◆ Assays indicate no toxic effects during simulated treatment
- ◆ Where iron is to be used as an inactivator, oxygen is adequate at the bottom to maintain iron-phosphorus bonds
- ◆ Where calcium is to be used as an inactivator, normal background pH is high enough to maintain calcium-phosphorus bonds
- ◆ Where nitrate is to be used to alter redox potential and limit P release, nitrate can be effectively injected into the sediment without major release to the water column

2.6. Performance Guidelines

- ◆ Develop reliable phosphorus budget that demonstrates magnitude of internal loading
- ◆ Determine dose necessary to inactivate targeted phosphorus (water column or sediment)
- ◆ Determine chemicals to be used; consider oxygen regime and minimize shift in pH unless naturally outside range of 6.0 to 8.0 SU
- ◆ Secure appropriate access for equipment and chemicals; adhere to materials handling regulations in the transfer of chemicals to application equipment
- ◆ For larger lakes, treat non-contiguous sections of the lake on sequential days

- ◆ For higher doses of aluminum, split treatment to yield calculated in-lake aluminum level <10 mg/L on any day
- ◆ In pH sensitive lakes with anoxic hypolimnia, consider injecting aluminum at or below the thermocline during stratification
- ◆ Monitor phosphorus, the inactivator compound, pH, alkalinity, water clarity, algae, zooplankton, benthic invertebrates and fish before, during and after treatment as appropriate to determine impacts to sensitive resources.

2.7. Cost Considerations

Aluminum treatment costs typically range from \$500-\$1,500/acre, with the areal cost decreasing for larger treatments, unbuffered treatments, and lesser monitoring requirements. Higher cost may result from extreme controls and monitoring. Costs for iron treatments are similar to those for alum treatment; the chemical is less expensive to purchase but higher doses are recommended. However, iron is best applied in conjunction with aeration systems, so total project cost is likely to be substantially higher. Calcium treatments are slightly less expensive than alum, but are only effective in hard water lakes with high natural pH. Neutral to acidic waters will cause the calcium to remain dissolved and not precipitate and inactivate the targeted phosphorus. Nitrate application to sediments is an expensive treatment, typically on the order of \$5,000-10,000/acre.

3. Methods

This project was governed by an approved Work Plan, provided as *Attachment 1*. Field work was performed in accordance with an approved Health and Safety Plan (HASP), provided as *Attachment 2*. The work conducted by ENSR included sampling of surficial sediments from ten locations within Cedar Lake using an Ekman dredge, followed by laboratory analysis of key sediment features and testing of the response of available sediment phosphorus (ASP) to aluminum additions. Sampling was conducted by boat in April of 2008. Samples were shipped to Spectrum Analytical Laboratories of Agawam, Massachusetts, a lab with which ENSR has worked to advance the testing protocols established by academic researchers. Specific protocols are described in the Work Plan and HASP, and have been applied by ENSR for other, similar projects that have resulted in successful inactivation of sediment phosphorus and achievement of desired in-lake conditions. The remainder of this report describes the resultant data and the associated calculations applied to achieve project goals.

4. Field Assessment of Sediments

Ten sediment samples were collected from Cedar Lake, at the locations shown in *Figure 1*. An additional sample was collected at station MU4-CO2 for quality control purposes, and laboratory duplicates were also tested. It is notable that many sediment samples collected had a thick (up to several inches) coating of algae growing on them as shown in *Figure 2*. There was a distinct gradient moving from the north basin through the central basin to the south basin, with the greatest growths observed in the south basin and the least in the north basin.

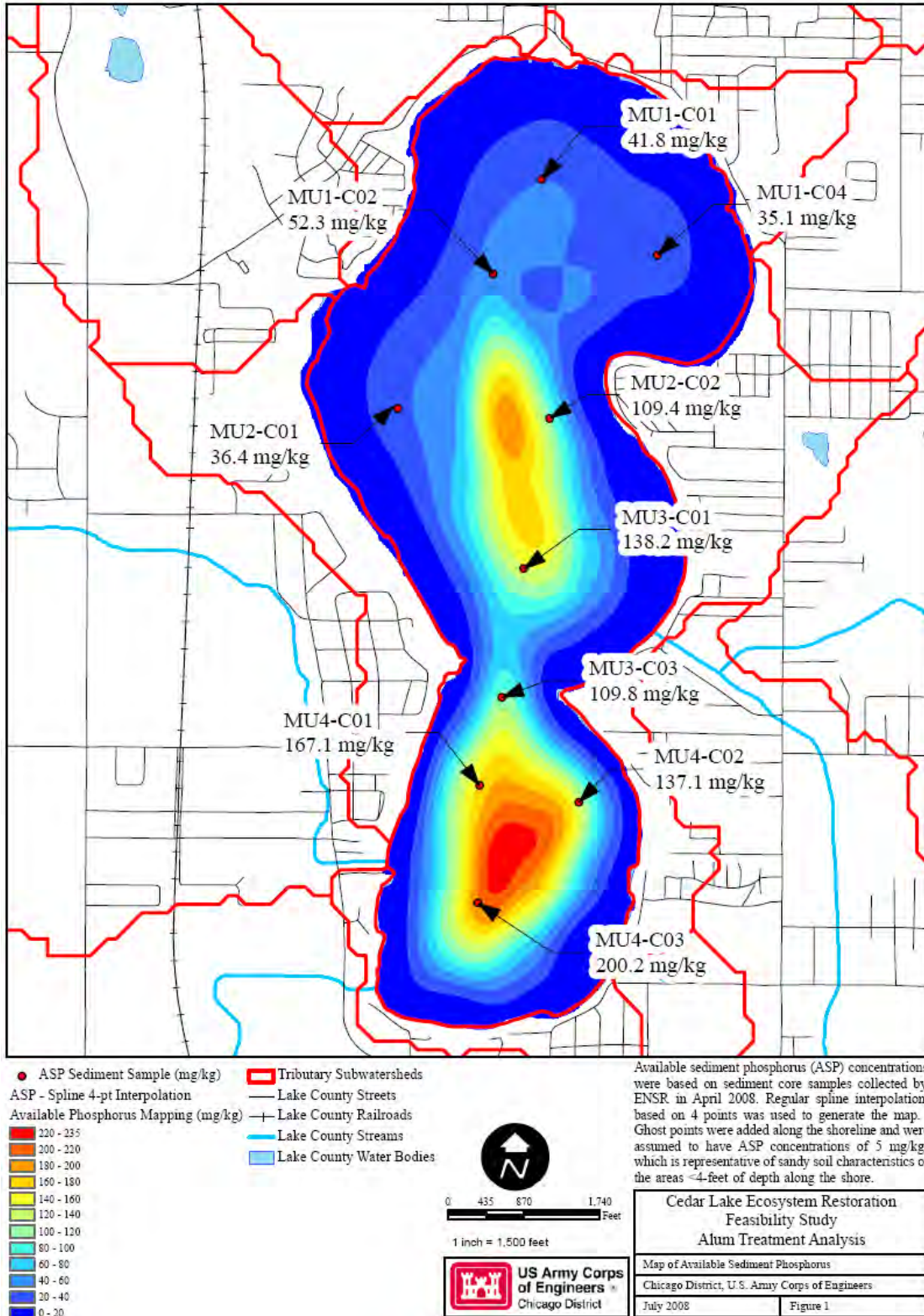


Figure 1. Sampling Locations and Available Phosphorus Mapping Results



Figure 2. Algal Coating from the Surface of Samples Sediments in Cedar Lake

Microscopic analysis revealed the algae present in the overlain sediments to be mainly cyanobacteria, which are associated with water column blooms (specifically *Microcystis* and *Planktolyngbya*), not the expected benthic growths. These algae were coming out of overwintering stages and are very likely to be storing nutrients for upcoming blooms. Pigments were just developing, filaments and cell aggregations were small, but these cyanobacteria were readily identifiable. Previous blooms have included these genera, especially *Microcystis*, which is also a potential toxin-forming alga.

Sediments were more normal in appearance after the algal layer was removed as shown in *Figure 3*, but were very light and lumpy in most cases, having the appearance of cottage cheese. Very fine grain size was evident. High clay content is suggested, and silty sediment clung to the sampling equipment, which was thoroughly washed between sampling locations.



Figure 3. Cedar Lake Sediments after Algal Coating Removed

5. Laboratory Assessment of Sediment

Testing of sediments for total phosphorus (TP), loosely sorbed P, iron-bound P, percent solids and specific gravity was performed as outlined in the Work Plan. Note that loosely sorbed P and iron-bound P are collectively referred to as Available Sediment Phosphorus (ASP). QA/QC data were acceptable, indicating that the data could be relied upon for further use in calculations. Values for a blank were below detection limits. Duplicate and replicate values were very similar. TP values, expressed on a dry weight basis, were similar in magnitude to those obtained from Cedar Lake for two previous studies (Harza 1999 and USACE 2007).

Results shown in *Table 1* indicate that ASP was a smaller fraction of TP (5-15% vs. 70%) than assumed in the original calculations performed by USACE and provided in *Attachment 3*, resulting in less ASP to be inactivated and a smaller necessary aluminum dose. A reasonably reliable relationship between ASP and TP can be constructed for Cedar Lake as shown in *Figure 4*, allowing prediction of ASP values from TP values collected in other parts of the lake. Prediction of ASP from TP by the regression equation established from these data explains 83% of the variability in ASP and is statistically significant at a high level (probability of there not being such a relationship is less than 1 in 1000).

ASP values ranged from 36 to 200 mg/kg, a fairly wide range. Values <20 mg/kg are generally considered low, with limited potential for impact on the overall P budget for the water column. Values between 20 and 100 mg/kg are considered moderate in our experience, having distinct potential to affect overlying water under normally encountered release rates. Values between 100 and 200 mg/kg are considered high, with great potential for impact. Values in excess of 200 mg/kg are very high and typically encountered with ongoing, large inputs of highly available P, such as with sewage or manure discharges.

The values for ASP tended to cluster spatially, with levels increasing from north to south in Cedar Lake. While the clustering was not perfectly oriented by basin, the three basins represent appropriate units for consideration of ASP inactivation as shown in *Figure 5*. Average ASP values were calculated by USACE staff using geographic information systems (GIS). Sediment sampled values were augmented with “ghost” values representing the characteristics of sandy sediments encountered along the shoreline in depths less than four feet. Using mathematical spline interpolation techniques in GIS set to 4 points per region for local approximation, a concentration map over the entire lake area was generated as shown in *Figure 1* and *Figure 5*. The lake was subdivided into three basins (north, central and south) and the areas with >20 mg/kg of ASP were delineated as possible treatment target areas. Averages for these areas were 39.6 mg/kg for the north basin, 88.6 mg/kg for the central basin, and 130.2 mg/kg for the south basin. The area to potentially be treated in the north basin is approximately 100 acres, while the defined central basin area is about 175 acres and the south basin area covers about 125 acres.

Percent solids values as shown in *Table 1* were slightly higher than in previous studies, ranging from 14.5% to 53.4% and generally declining from north to south, although differences were not extreme. Overall, percent solids in the samples averaged 26%, up from the 16% recorded previously, but this value is somewhat dependent on the sampling method, as more or less water

Table 1. Laboratory Results for Sediment Analyses from Cedar Lake, April 2008

Station	Total P mg/kg	Iron P mg/kg	Loose P mg/kg	Available P mg/kg	Available Fraction ASP/TP	Solids %	Specific Gravity
MU1CO1	670	40.3	1.5	41.8	0.062	53.4	1.062
MU1CO2	817	50.2	2.1	52.3	0.064	26.0	1.035
MU1CO4	714	32.7	2.4	35.1	0.049	24.9	1.084
MU1CO4 Lab Replicate		35.1	1.4	36.5			
MU2CO1	726	34.7	1.7	36.4	0.050	28.1	1.119
MU2CO2	948	106.0	3.4	109.4	0.115	24.2	1.041
MU3CO1	1080	131.0	7.2	138.2	0.128	21.2	1.062
MU3CO1 Lab Replicate	1070						
MU3CO3	1240	106.0	3.8	109.8	0.089	24.1	1.046
MU4CO1	1140	162.0	5.1	167.1	0.147	20.1	0.982
MU4CO2	1000	132.0	5.1	137.1	0.137	18.9	1.048
MU4CO2 Lab Replicate		124.0	5.0	129.0			
MU4CO2 Field Duplicate	1210	129.0	6.6	135.6	0.112	14.5	1.119
MU4CO3	1380	196.0	4.2	200.2	0.145	33.1	1.032
Blank	<3	<1.3	<0.3	<1.5			

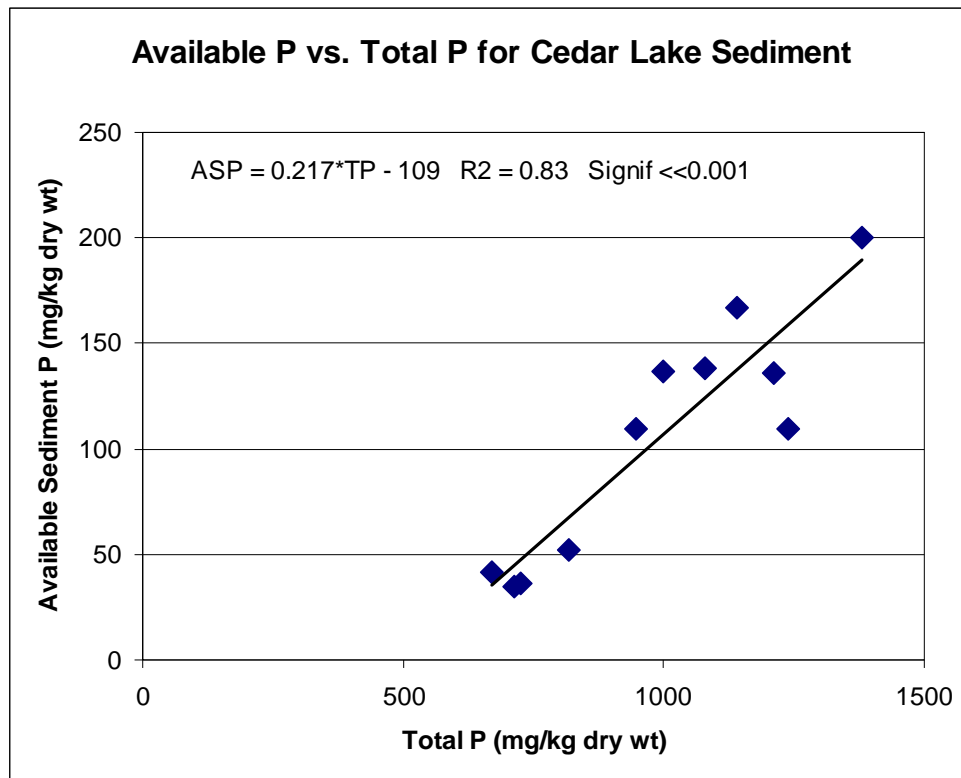


Figure 4. Relationship of ASP to TP for Cedar Lake Sediment Samples

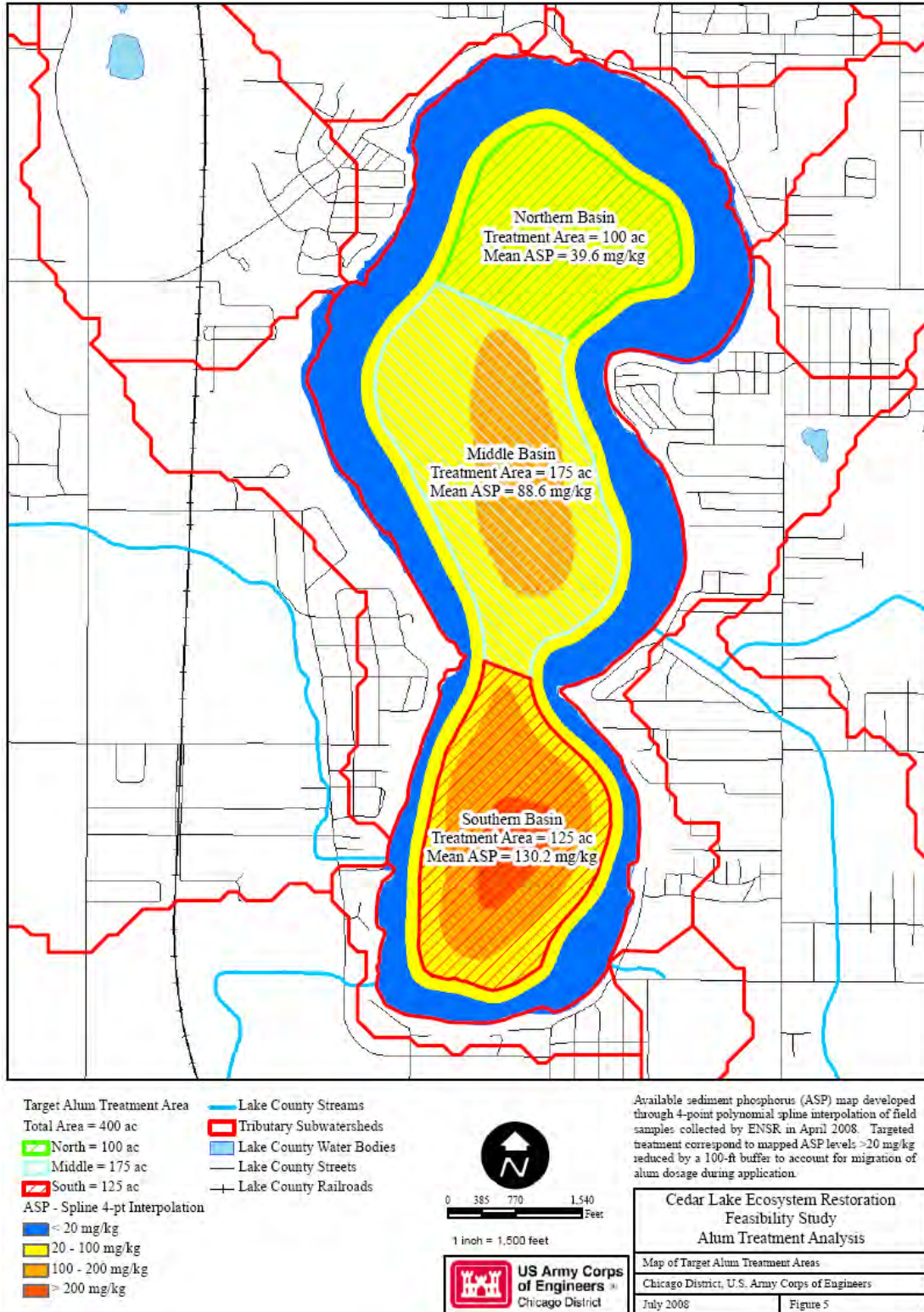


Figure 5. Targeted Alum Treatment Areas from ASP Results

may be captured with the sediment. Specific gravity values were similar to or even slightly lower than in previous studies, with values ranging from 0.98 to 1.12; the sediment weighed little more than water per unit volume. This may explain the ready resuspension observed in this lake.

Percent solids and specific gravity values tended to decline slightly moving from north to south in Cedar Lake, but with more variability than for ASP and not enough to be of major management significance. Still, average values for use in treatment calculations were derived by the same GIS spline interpolation technique applied to the ASP values. A statistical summary of the data by treatment area is provided in *Table 2*.

Table 2. Summary of Sediment Data by Treatment Area

Basin	ASP (mg/kg)				Specific Gravity				% Solids			
	Max	Min	Avg	Sdev	Max	Min	Avg	Sdev	Max	Min	Avg	Sdev
North	80	25	39.6	8.6	1.17	0.96	1.07	0.04	67	18	40.9	12.0
Middle	200	25	88.6	45.9	1.16	0.97	1.08	0.04	67	18	23.2	14.1
South	235	35	130.2	55.4	1.15	0.94	1.04	0.05	72	18	37.1	17.1

6. Simulated Phosphorus Inactivation

Simulated inactivation was conducted in the lab, whereby aluminum at known quantities was applied to aliquots of sediment, mixed and shaken, after which the sediment was consolidated by centrifugation and the ASP testing was repeated. Since loosely sorbed P was such a small portion of the ASP, only iron-bound P was assessed for this analysis as shown in *Table 3*. This is not unusual; loosely sorbed P is often minimal in sediment samples, and assessment of iron-bound P only is justified by the values obtained from samples from Cedar Lake.

Samples from the north and central basins were combined into two corresponding composites, while samples from the three individual south basin stations were tested separately. Using well mixed sediment from which to draw aliquots, the untreated sediment provided a starting ASP (Al dose = 0 g/m²). The starting ASP level for the north basin was 40 mg/kg, nearly identical to the basin average of 39.6 mg/kg (iron-bound P from *Table 2* vs. *Table 3*). The starting ASP for the central basin was 124 mg/kg, substantially higher than the 88.6 mg/kg spline-average for the central basin, but indicative of the variability in the actual sediment samples collected from the central basin. Starting ASP values for MU4 series samples, as shown in *Table 3*, were 165, 114 and 185 mg/kg, corresponding to original sediment measures of 162, 124 to 132, and 196 mg/kg, as shown in *Table 1*, a low level of deviation.

Other sediment aliquots were treated with the equivalent of 10, 30, 50, 80, 100 and 150 g/m² of aluminum, representing a treatment depth of 20 cm into the sediment (based on assumptions regarding specific gravity and percent solids). Results were graphed to demonstrate either the remaining amount of ASP after treatment as shown in *Figure 6* or the percent reduction in ASP

Table 3. Results of Simulated ASP Inactivation

Treatment (g Al/m ²)	Stations				
	North Basin Composite	Central Basin Composite	South Basin		
			MU4-CO1	MU4-CO2	MU4-CO3
Iron Bound P (mg/kg dry)					
0	40.0	124.0	165.0	114.0	185.0
10	22.1	68.1	84.8	50.9	*
30	3.8	27.9	44.7	15.7	61.2
50	3.0	14.1	29.5	7.1	*
80	2.3	9.2	26.0	BRL	21.0
100	0.8	5.1	20.5	BRL	12.5
150	BRL	BRL	12.7	BRL	9.8

* Inadequate sample available

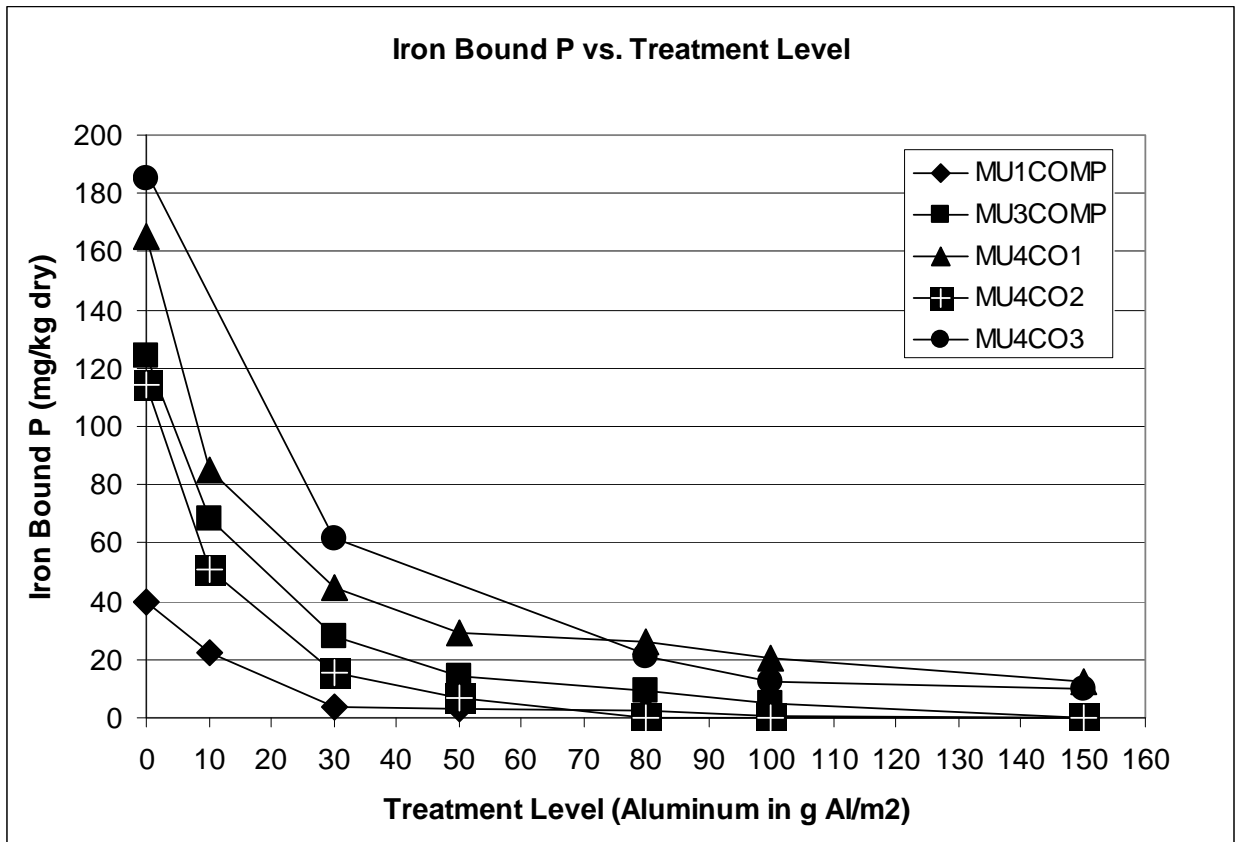


Figure 6. Remaining ASP after Treatment at Specified Aluminum Dose

after treatment as shown in *Figure 7*. Results followed expectations. Increasing aluminum doses reduced the remaining ASP and increased the percent reduction in ASP from the starting value. The pattern was a decelerating power curve; lower doses inactivated less P overall, but proportionally more P than higher doses, creating a “diminishing returns” phenomenon.

The inflection point, above which greater Al addition yielded noticeably less inactivation per unit of Al added, occurred between 30 and 80 g/m², a very typical range. Samples with higher starting concentrations of ASP required more Al to reach low levels of remaining ASP or high levels of ASP reduction.

Based on the simulated inactivation results, a dose of no more than 30 g/m² would be needed to minimize ASP in the north basin; although a dose of 20 g/m² may be adequate. The central basin would experience almost a 90% reduction in ASP to a very low actual ASP value with a dose of 50 g/m². For the MU4 series samples representing the south basin, a dose of between 50 and 80 g/m² is desirable, but there is a diminishment of return at doses higher than 50 g/m² for the 20 cm assumed treatment depth.

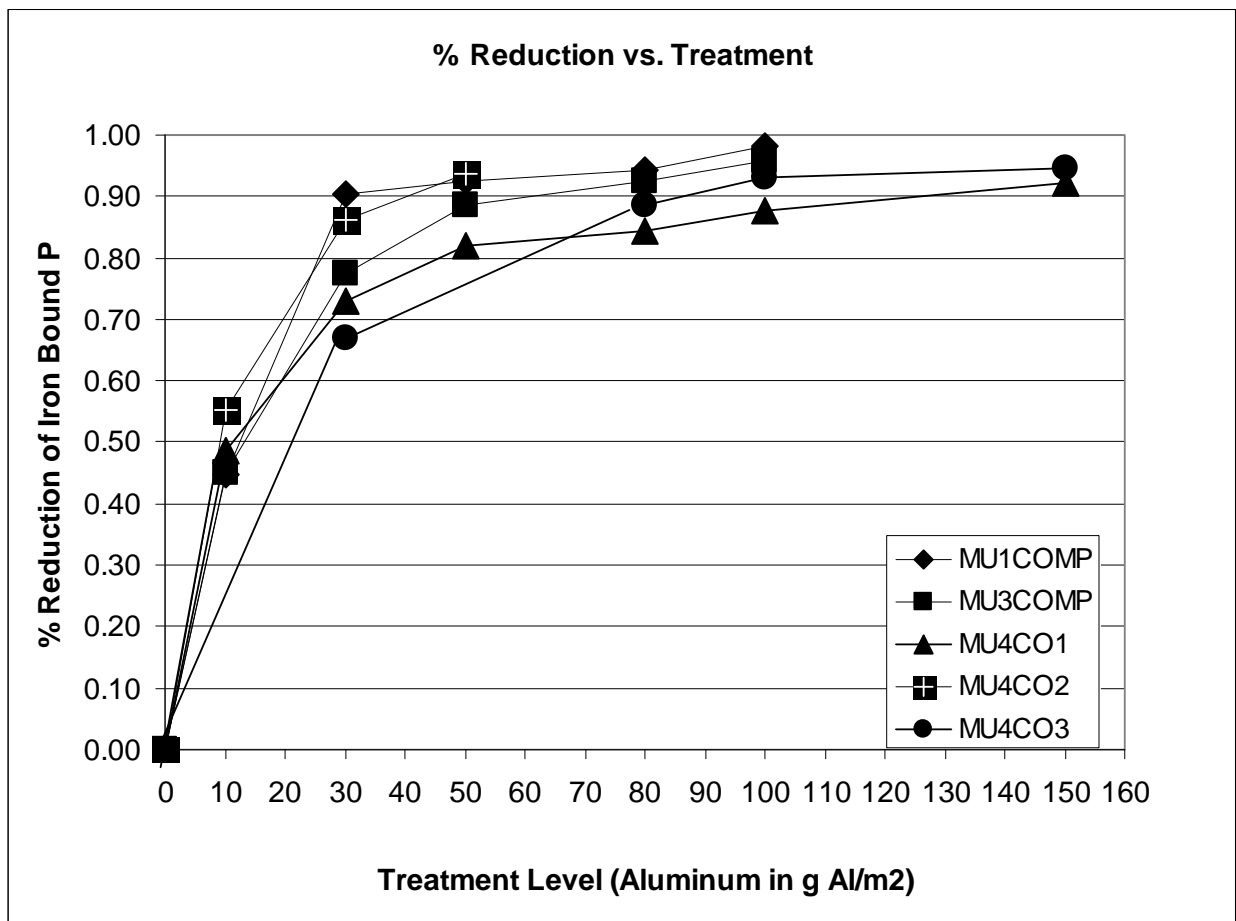


Figure 7. Percent Reduction in ASP after Treatment at Specified Aluminum Dose

7. Alum Treatment Dosage Calculation for Cedar Lake

The data obtained in the ENSR investigation suggest that there is a north-south trend in ASP. The pattern of historic inputs suggests this as well (Echelberger et al. 1984, USACE 2006), with the greatest loading occurring in the south basin. Using the data generated by the ENSR investigation and dividing the lake into potential treatment areas of north (100 acres), central (175 acres), and south (125 acres), as shown in *Figure 5*, a set of calculations for each basin of the lake are developed. The key aspect of this approach is that all perceived areas of potentially significant contribution are covered by this treatment option. The treatment area targeted in this approach is roughly all the area >7 ft deep, or just over half of the lake area. It is also roughly coincident with the area of the lake having a silt and clay bottom, based on a figure from Echelberger et al. (1984).

The equation applied to calculate the amount of aluminum to be applied on an areal basis was defined as:

$$\text{Al Dose} = (\text{ASP}) \times (\text{SG}) \times (\text{SF}) \times (\text{TD}) \times (\text{Al:ASP})$$

Where:

Al Dose = Aluminum concentration in g/m^2

ASP = Available Sediment P in mg/kg dry weight

SG = Specific Gravity in g/cm^3

SF = Solids Fraction, or % solids/100

TD = Treatment Depth in meters

Al:ASP = targeted ratio of Al to ASP for treatment

Unlike the original calculations performed by the USACE as provided in *Attachment 3* that made a number of assumptions to derive the values used in calculations, this investigation used the following site-specific values in the treatment calculations:

1. Site-specific ASP values of 39.6 mg/kg for the north basin, 88.6 mg/kg for the central basin, and 130.2 mg/kg for the south basin (all much lower than the 70% of TP applied previously).
2. Site-specific Sediment bulk density of 1.07 g/cm^3 for the north basin, 1.08 g/cm^3 for the central basin, and 1.04 g/cm^3 for the south basin (all slightly less than the 1.11 g/cm^3 applied previously).
3. Site-specific Solids fractions of 0.409 for the north basin, 0.232 for the central basin, and 0.371 for the south basin (the previous overall value of 0.16 is fairly typical, but sample results varied).
4. Treatment depth of 0.1 to 0.2 m, or 10 to 20 cm (a typical range with greater depth expected to result in greater longevity of inactivation results).
5. The ratio of aluminum to available phosphorus desired to get acceptable binding is set at 10:1 (larger ratios are sometimes used, but greatly increase cost and need to be justified).

Two targeted depth of sediment treatment scenarios were applied, representing the typical range of 10 cm to 20 cm as shown in *Table 4* and *Table 5*, respectively. The dose for the treatment of sediment to a depth of 20 cm is double that for a depth of 10 cm. The mass of ASP to be inactivated is lowest in the north basin, which is also the smallest targeted treatment area. The mass of ASP to be treated in the central basin is slightly higher than for the north basin, but the area is substantially larger, resulting in a slightly larger dose per unit area but a much larger overall dose to the central basin. The mass of ASP to be treated in the south basin is considerably higher than in the other two basins; the targeted area is intermediate, but a much higher dose per unit area is derived for the south basin. Depending on which targeted depth of treatment is selected, the range of aluminum doses to the entire lake is approximately 48,000 to 96,000 kg (105,500 to 211,000 lb). Of this total, 14.6% would be applied to the north basin, 32.6% to the central basin, and 52.8% to the south basin of Cedar Lake.

Either liquid aluminum sulfate (alum) or a combination of alum and sodium aluminate (aluminate) could be used to treat the target areas. The combination of alum and aluminate allows for better pH control and is usually applied when minimization of impacts to aquatic life during treatment is desired. The overall aluminum dose does not change when alum and aluminate is used. The quantity of each chemical needed for alum only or alum plus aluminate treatments is shown in *Table 4* and *Table 5*. Alum and aluminate are typically applied at a 2:1 ratio of alum to aluminate by volume to maintain ambient pH; this ratio can vary slightly (from about 1.8 to 2.2) depending on field conditions, but the assumed 2:1 ratio is quite appropriate for planning purposes.

Given the variability in plausible dose based on treatment depth (as well as other factors such as aluminum:phosphorus stoichiometry not varied in the calculations shown in *Table 4* & *Table 5*), it is helpful to use the simulated inactivation results to support a recommendation. For the north basin, a value between 20 and 30 g/m² appears appropriate from the inactivation data shown in *Figure 6* and *Figure 7* and is consistent with the calculations from ASP data for a ratio of aluminum to phosphorus of 10:1 (17 to 35 g/m² used in *Table 4* and *Table 5*). For the central basin, the range of doses suggested by the simulated inactivations is also consistent with the dose calculated from ASP data and treatment calculations (22 to 44 g/m²). A dose near 50 g/m² appears to provide a high level of reduction in ASP and low absolute ASP values. Higher doses provide little additional reduction, but a dose as low as 40 g/m² might be acceptable. In the south basin, a dose of at least 50 g/m² appears necessary from the simulated inactivations, and a dose of at least 80 g/m² would be preferable to reach a low absolute ASP value, but diminishing returns are evident above a dose of 50 to 60 g/m² in two of the three samples. The calculations in *Table 4* and *Table 5* from ASP data suggest a necessary dose of 50 to 100 g/m².

Table 4. Calculated Doses for Treatment of Areas to a Sediment Depth of 10 cm
 (Shaded cells represent variables that must be determined on a site-specific basis)

Cedar Lake, Indiana				
Lake or Area	N Basin	C Basin	S Basin	Total
Mean Available Sediment P (mg/kg DW)	39.6	88.6	130.2	
Target Depth of Sediment to be Treated (cm)	10	10	10	
Volume of Sediment to be Treated per m2 (m3)	0.100	0.100	0.100	
Specific Gravity of Sediment	1.07	1.08	1.04	
Solids Portion (as a fraction)	0.41	0.23	0.37	
Mass of Sediment to be Treated (kg/m2)	43.8	25.1	38.6	
Mass of P to be Treated (g/m2)	1.73	2.22	5.02	
Target Area (ac)	100	175	125	
Target Area (m2)	403226	705645	504032	
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884	
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1.256	
Stoich. Ratio (ratio of Al to P in treatment)	10	10	10	
Resulting areal dose (g Al/m2)	17	22	50	
Ratio of alum to aluminate during treatment (volumetric)	2	2	2	
Aluminum Load				
Dose (kg/area)	6988	15665	25321	47974
Dose (lb/area)	15374	34463	55706	105542
Dose (gal alum) with Alum only	31477	70563	114057	216098
Application (gal/ac) for alum	315	403	912	
Dose (gal alum) @ specified ratio of Alum to Aluminate	12961	29054	46963	88978
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	7200	16141	26090	49432
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	130	166	376	
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	72	92	209	
Anticipated days of treatment in area	3	6	10	19
Unit Cost				
Alum	\$1.25	\$1.25	\$1.25	
Aluminate	\$2.75	\$2.75	\$2.75	
Labor/Equipment (crew and equipment/day)	\$6,000	\$6,000	\$6,000	
Chemical Cost				
Alum only	\$39,347	\$88,204	\$142,572	\$270,123
Alum + Aluminate	\$36,002	\$80,706	\$130,452	\$247,160
Labor Cost				
Application (assumes 5,000 gal/day)	\$18,553	\$37,865	\$59,355	\$115,773
Mobilization/Contingencies (assumes 1 day/25 ac)	\$24,000	\$42,000	\$30,000	\$96,000
Monitoring (assumes 1 day/trtmt day + 12 days + 20% for lab costs)	\$18,111	\$21,973	\$26,271	\$66,355
Cost Summary (alum only)	\$100,010	\$190,042	\$258,198	\$548,250
Cost Summary (alum + aluminate)	\$96,665	\$182,544	\$246,078	\$525,288

Table 5. Calculated Doses for Treatment of Areas to a Sediment Depth of 20 cm
(Shaded cells represent variables that must be determined on a site-specific basis)

Cedar Lake, Indiana				
Lake or Area	N Basin	C Basin	S Basin	Total
Mean Available Sediment P (mg/kg DW)	39.6	88.6	130.2	
Target Depth of Sediment to be Treated (cm)	20	20	20	
Volume of Sediment to be Treated per m2 (m3)	0.200	0.200	0.200	
Specific Gravity of Sediment	1.07	1.08	1.04	
Solids Portion (as a fraction)	0.41	0.23	0.37	
Mass of Sediment to be Treated (kg/m2)	87.5	50.1	77.2	
Mass of P to be Treated (g/m2)	3.47	4.44	10.05	
Target Area (ac)	100	175	125	
Target Area (m2)	403226	705645	504032	
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884	
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1.256	
Stoich. Ratio (ratio of Al to P in treatment)	10	10	10	
Resulting areal dose (g Al/m2)	35	44	100	
Ratio of alum to aluminate during treatment (volumetric)	2	2	2	
Aluminum Load				
Dose (kg/area)	13976	31330	50642	95948
Dose (lb/area)	30747	68926	111411	211085
Dose (gal alum) with Alum only	62955	141127	228115	432196
Application (gal/ac) for alum	630	806	1825	
Dose (gal alum) @ specified ratio of Alum to Aluminate	25921	58108	93926	177955
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	14401	32282	52181	98864
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	259	332	751	
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	144	184	417	
Anticipated days of treatment in area	6	12	19	37
Unit Cost				
Alum	\$1.25	\$1.25	\$1.25	
Aluminate	\$2.75	\$2.75	\$2.75	
Labor/Equipment (crew and equipment/day)	\$6,000	\$6,000	\$6,000	
Chemical Cost				
Alum only	\$78,693	\$176,408	\$285,144	\$540,245
Alum + Aluminate	\$72,004	\$161,412	\$260,904	\$494,320
Labor Cost				
Application (assumes 5,000 gal/day)	\$34,106	\$72,730	\$115,711	\$222,546
Mobilization/Contingencies (assumes 1 day/25 ac)	\$24,000	\$42,000	\$30,000	\$96,000
Monitoring (assumes 1 day/trtmt day + 12 days + 20% for lab costs)	\$21,221	\$28,946	\$37,542	\$87,709
Cost Summary (alum only)	\$158,020	\$320,084	\$468,396	\$946,501
Cost Summary (alum + aluminate)	\$151,330	\$305,088	\$444,157	\$900,576

From consideration of all data, the following treatment program is recommended as the most advantageous approach under current conditions:

1. Set a target of 20 mg/kg as the maximum ASP value after treatment.
2. Set a target dose for the north basin of 30 g/m², lowering ASP in the largest target area to well below 20 mg/kg for a target treatment depth of 20 cm.
3. Set a target dose for the central basin of 45 g/m², lowering ASP to slightly below 20 mg/kg at a target treatment depth of 20 cm.
4. Set a target dose for the south basin of 80 g/m², lowering average ASP to below 20 mg/kg for a target treatment depth of 20 cm.

The associated calculations for the recommended treatment program are shown in *Table 6*, with a total aluminum input of 84,173 kg (185,181 lb). This program provides a sufficient dose for each area to minimize internal recycling until such time as ASP reserves are replaced, within the bounds of predictability based on available data.

It should be noted that if dredging is conducted in Cedar Lake, ASP values in buried sediments that are exposed may differ from the values used for calculations in this assessment. Extrapolating from total phosphorus data by sediment depth measured almost 30 years ago (Echelberger et al. 1984), ASP could be as little as half the surficial levels currently measured, although direct measurements should be made to allow better predictions following any sediment removal. However, at even half the current ASP levels, there would be adequate P reserves to fuel algal blooms from internal releases, necessitating inactivation unless all nutrient-rich soft sediment within the lake was to be removed.

Note also that the depth of treatment is a useful planning construct, but the two alternative depths should not be viewed as distinct blocks of sediment that would be treated evenly. The aluminum compounds land on the surficial sediment and migrate downward. The uppermost sediments would be most thoroughly inactivated, with declining inactivation over increasing sediment depth. Since each treatment alternative is expected to thoroughly inactivate the most surficial sediments, the initial benefit should be roughly equal between the two alternative treatment depths. However, given the potential for ASP to migrate upward in the sediment or for those surficial sediments to be mixed by wind or boat-induced turbulence, the deeper treatment can be expected to provide a longer duration of benefits. Prediction of the duration of benefits will be addressed separately in this report.

Table 6. Recommended Doses for Treatment Based on Sediment Data and Simulated Inactivation Results

	Cedar Lake, Indiana			
Lake or Area	N Basin	C Basin	S Basin	Total
Mass of P to be Treated (g/m ²)	3.00	4.50	8.00	
Target Area (ac)	100	175	125	
Target Area (m ²)	403226	705645	504032	
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884	
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1.256	
Stoich. Ratio (ratio of Al to P in treatment)	10	10	10	
Resulting areal dose (g Al/m ²)	30	45	80	
Ratio of alum to aluminate during treatment (volumetric)	2	2	2	
Aluminum Load				
Dose (kg/area)	12097	31754	40323	84173
Dose (lb/area)	26613	69859	88710	185181
Dose (gal alum) with Alum only	54490	143036	181633	379159
Application (gal/ac) for alum	545	817	1453	
Dose (gal alum) @ specified ratio of Alum to Aluminate	22436	58895	74787	156118
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	12464	32719	41548	86732
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	224	337	598	
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	125	187	332	
Anticipated days of treatment in area	5	12	15	33
Unit Cost				
Alum	\$1.25	\$1.25	\$1.25	
Aluminate	\$2.75	\$2.75	\$2.75	
Labor/Equipment (crew and equipment/day)	\$6,000	\$6,000	\$6,000	
Chemical Cost				
Alum only	\$68,112	\$178,795	\$227,042	\$473,949
Alum + Aluminate	\$62,322	\$163,596	\$207,741	\$433,660
Labor Cost				
Application (assumes 5,000 gal/day)	\$29,923	\$73,674	\$92,744	\$196,341
Mobilization/Contingencies (assumes 1 day/25 ac)	\$24,000	\$42,000	\$30,000	\$96,000
Monitoring (assumes 1 day/trtmt day + 12 days + 20% for lab costs)	\$20,385	\$29,135	\$32,949	\$82,468
Cost Summary (alum only)	\$142,420	\$323,604	\$382,735	\$848,759
Cost Summary (alum + aluminate)	\$136,630	\$308,405	\$363,434	\$808,469

8. Treatment Cost Calculation for Cedar Lake

Application time and costs have been included relating to dosage calculation as shown in *Tables 4-6*, based on a unit cost of \$1.25/gallon for alum and \$2.75/gallon for aluminate and labor assumptions as noted on the tables. The cost range is \$525,300 to \$946,500, with the suggested approach estimated to cost about \$808,500. Cost is largely a function of dose, although certain fixed costs related to application prevent simple linear scaling of cost when the dose is altered.

Cost is also affected by the form(s) of aluminum chosen for application. The cost of alum and aluminate do not necessarily vary proportionally, so market conditions could alter the spread in the prices of alum vs. alum plus aluminate treatments. More specifically, alum pricing is rather volatile at the present time, mainly due to competition with ethanol production for sulfuric acid, making the use of alum alone more expensive than alum plus aluminate. This was not the case even a year ago. Additionally, both alum and aluminate are affected by increased fuel costs for production and delivery. Some cost increase has been built into these estimates, but uncertainty remains.

Application of alum and aluminate at an approximately 2:1 ratio by volume is the favored approach when attempting to avoid toxicity impacts on fish and other lake fauna. Alum and aluminate can be used to balance each other in terms of pH influence, maintaining a pH in the range where toxic forms of aluminum are minimized. With recent rises in alum cost, this approach is also now preferable in terms of chemical expense.

Another impact avoidance measure involves application of aluminum compounds at no more than 10 mg/L. Where doses in g/m^2 are high and the water is shallow, aluminum application may be spread over two periods separated in time by several days, allowing precipitation and removal from the water column before retreatment. This can add to labor costs and overall project expense.

As noted previously, removal of sediment by dredging could alter ASP levels in daylighted sediment, which would in turn affect costs. Less aluminum may be needed to reach inactivation targets as a consequence of possible lower ASP values. Re-assessment of treatment dosages and associated costs may be necessary when the overall lake management plan is finalized. Application of a contingency cost in the planning stage, to cover costing uncertainties like those associated with the above issues, is advisable.

9. Assessment of Long-Term Effectiveness

Review work by Cooke and Welch (1999) and others (Welch et al. 1988, Payne et al. 1991, Cooke et al. 1993) has been used to estimate the duration of benefits from P inactivation, with a decade suggested for shallow lakes and longer for deeper lakes. Cedar Lake is shallow (i.e., unstratified) by the definition applied by Cooke and Welch, and so one might expect a decade of improved conditions. However, their conclusions are based on experience with treated lakes without consideration of the range of external loads those lakes experienced. The criterion applied by Cooke and Welch was that external loading was not the dominant source of P before treatment, but external loading over time is an important consideration.

Additionally, Cooke and Welch include systems where treatment could have been more effective if we knew then what we know now. Relatively recent advances in determining adequate dosages and new methods for treating at higher doses without adverse impacts to fish and other aquatic biota have greatly enhanced treatment effectiveness, but many of these more recent projects are too new for longevity assessment in review papers. It is entirely possible to obtain longer term benefits from well planned internal P load inactivation if external loads have been properly controlled.

The duration of benefits from inactivation of available sediment P in a lake is a function of the time it takes to replace the load that has been inactivated. A loading analysis for the lake is therefore necessary, with consideration of the portion of the annual load that settles to the bottom and the portion of that settled load that remains available. Availability is a function of the form in which the P is bound, with iron-bound P becoming readily available when exposed to anoxic conditions (i.e., no or very low oxygen) when the P content of the overlying water is also low.

Estimating longevity of benefits from internal P inactivation is a difficult task, but if external loads are kept below the critical limit, improvement should be indefinite. Properly planned and conducted inactivation projects have produced desirable results for more than 30 years and are still producing improved conditions; the oldest projects were performed in the late 1970s and early 1980s, so our longevity database is limited. Where projects have failed it has been a consequence of either inadequate dose or insufficiently controlled external inputs.

The proposed program for Cedar Lake represents an adequate dose to inactivate current ASP reserves that fuel internal loading. In longevity estimates, it is customary to assume some continued release from sediments, typically on the order of 10% of ASP. Yet at a much reduced ASP level, the resultant internal loading would be greatly reduced. The inactivated ASP will remain unavailable permanently, but new ASP will be added from a portion of the settled external loads. Additionally, if the depth of sediment treated is small, some ASP may migrate from below; this is not expected to occur with the targeted 20 cm treatment, however. Consequently, a reliable estimate of the external load is needed to evaluate longevity of any management action in the lake.

Control of external loads is ongoing in the Cedar Lake watershed and great progress has been achieved in the last decade. Watershed management activities have reduced the in-lake P level

by about half, from about 170 ug/L in the 1980s and 1990s to about 85 ug/L in the period of 2005-2007. The actual external load prior to wastewater collection (sewer) system installation was estimated at 3574 kg/yr (Echelberger et al. 1984) and was calculated to range from 610 to 2319 kg/yr with an average value of 1028 kg/yr after wastewater collection was instituted. Reductions in the last decade have been significant but largely unquantified.

Working with typical land use export values of 0.3 to 0.6 kg/ha/yr for mixed use watersheds (ENSR unpublished data) and a watershed of 1815 hectares (4500 acres), the external load would be expected to be on the order of 545 to 1089 kg/yr. Efforts of the last decade may have pushed the external load from the high end of that range, consistent with the 1984 estimate, toward the low end of the range, consistent with more recent in-lake P concentrations that average about half the average from available 1980s and 1990s data.

However, further watershed management without inactivation of internal loads may prove less effective at reducing in-lake P levels, as the increasing gradient between sediment and water column P concentrations will draw P from the sediment. Under high water column P conditions (>80-100 ug/L), actual internal loading will be lower than suggested by ASP reserves (Reddy et al. 2007), but the very high potential internal load in Cedar Lake promotes increased releases as external inputs decline. Consequently, it is essential to reduce ASP in Cedar Lake to facilitate further reduction of in-lake P concentration. If all P-rich sediment cannot be removed, inactivation of ASP will be necessary.

Target concentrations of ASP range from 3.0 g/m² over 100 acres in the north basin to 4.5 g/m² over 175 acres in the central basin to 8.0 g/m² over 125 acres in the south basin. The mass of targeted ASP is therefore estimated at 1210 kg in the north basin, 3175 kg in the central basin, and 4032 kg in the south basin, for a total of 8417 kg of potentially available phosphorus. Actual release is usually much less than 50% of the total as a function of transport processes and chemical equilibrium constraints, but is usually at least 10% of the total, based on experience elsewhere. If we set the release percentage at 10% for minimum estimation purposes, that suggests an annual actual internal load of 842 kg/yr under current conditions.

For an internal load of 842 kg/yr and an estimated volume of 8 million m³ for Cedar Lake,, internal loading could yield a concentration of 105 ug/L on a simple mass balance basis, more than enough to account for the recently recorded lake average (85 ug/L for 2005-2007). This assessment suggests that internal loading could account for virtually all of the water column phosphorus measured in Cedar Lake; external loads may be important in fueling the internal load, but may not be as critical to immediate in-lake water column P levels. A major reduction in the internal load could indeed make a major difference to future in-lake P concentrations, with the duration of benefits tied to the replacement rate for ASP from settled external loads amenable to future releases.

There are multiple empirical models into which one can enter specific information for a lake and use loading to estimate expected concentration or vice versa (using concentration to estimate expected loading). Using a recorded lake average P concentration of 85 ug/L and lake specific characteristics (e.g., volume, depth, flushing rate and related values as provided by the USACE),

an ENSR spreadsheet program (ENSR-LRM, used for TMDL work and in the process of EPA approval) that applies multiple empirical models suggests that Cedar Lake receives an “effective” P load of about 1324 kg/yr. That is, the observed concentration is consistent with 1324 kg of P mixing in the water column each year.

With the minimum estimated internal load of 842 kg/yr being all available and part of the effective load, this suggests an effective external load of 482 kg/yr. The actual total external load could be much higher, depending on how much of it is particulate and settles to the bottom quickly. The fraction of the external load that is available and contributes to the effective load varies widely. Assuming that about half of the external load is immediately available, this suggests a total external load of about 964 kg/yr. If watershed management has depressed particulate transport and 75% of the more reduced load reaching the lake is available P, a total external load of only 643 kg/yr is needed to match the total load expected from in-lake conditions. These values are within the range expected from previous assessment of the lake (Echelberger et al. 1984) and are consistent with expectations based on typical exports from mixed use watersheds.

With a range of estimates for P loading to the lake from external and internal sources, the possible reduction from ASP inactivation and watershed management actions and the longevity of that reduction can be calculated. The new internal load would gradually increase over time as the inactivated ASP is replaced by new external inputs. Predicting the new starting P load and the trajectory of its increase over time can be accomplished with a model developed by ENSR for this purpose, specifically for evaluating the longevity of ASP inactivation projects. The basic principles of the model are as follows:

- The current internal load as calculated is reduced by inactivation by an expected amount; experience dictates that a 90% reduction is typical and reasonable.
- The external load as calculated can also be reduced by any amount specified or estimated from management techniques. Reductions of more than 75% are rare, but reductions of 25 to 50% are achievable in most cases.
- The portion of the total load that remains in the lake, the “sedimentation rate”, is estimated from the flushing rate in accordance with most empirical models, as the inverse of 1 plus the square root of the flushing rate. For Cedar Lake, the average flushing rate is approximately 0.7/yr and sedimentation is therefore 0.67.
- The new starting internal load increases with the addition of sedimented loads that are recyclable. How much of the sedimented load to recycle must be calculated, and is derived in the ENSR model by setting the fraction (between 0 and 1) such that pre-treatment conditions result in a steady state. That is, maintenance of pre-treatment conditions is achieved at some identifiable recycling rate for the sedimented portion external load, and continuation of that rate is assumed at the new loading levels.
- Using an annual time step, the load to the lake can be calculated over as many years as desired. Given the potential for some factors to change over time and few example systems more than 25 years post-treatment, we rarely project more than 25 years into the future. However, as a 50-year program is of interest in this case, the analysis has been extended to 50 years.

The water column concentration will be a mass balance between internal and external loadings and the amount exported from the system. Internal and external loadings are determined by various management actions. Four scenarios were evaluated at the direction of the USACE:

1. Internal loading reduction by inactivation targeting the upper 10 cm (set at 70% based on simulated inactivation results) with no external load reduction.
2. Internal loading reduction by inactivation targeting the upper 20 cm (set at 90% based on simulated inactivation results) with no external load reduction.
3. Internal loading reduction by inactivation (set at 90%) with a 25% reduction in external loading.
4. Internal loading reduction by inactivation (set at 90%) with 50% reduction in the external loading.

These scenarios were run with starting external loads of 643 and 964 kg/yr, with differing availability such that the available or effective external load was 482 kg/yr. Internal reserves were set at 8417 kg/yr, all of which is considered available, but only 10% actually enters the water column in a given year. The resulting change in starting P load to Cedar Lake and the pattern of increase over the subsequent 25 years is provided in *Figure 8* for the 964 kg/yr external load and in *Figure 9* for the 643 kg/yr external load. These graphs are believed to reasonably bracket the range of expected responses.

The permissible and critical limits displayed on *Figures 8* and *9* are calculated from the empirical models in accordance with Vollenweider (1975, 1982). The permissible limit represents the load below which algal blooms should almost never occur, while the critical limit represents the load above which algal blooms might be expected with increasing frequency and sometimes unacceptable severity. The current actual load is clearly well above the critical limit. Loads from all scenarios reset conditions to below the critical limit, from which they gradually rise. At what load conditions become unacceptable on a regular basis is a somewhat subjective issue; the permissible and critical limits have been provided for reference, but do not represent definitive thresholds. Current conditions, provided as the lefthand set of bars in each graph, are considered unacceptable.

Treatment with aluminum compounds alone will result in a reduced P load to the lake for at least 50 years, relative to current conditions, but the critical loading limit will be exceeded after 5 to 10 years at an external load of 964 kg/yr and after 11 to 18 years with an external load of 643 kg/yr, the range of years at each loading level depending on whether the dose is set to address the top 10 cm of ASP reserves or the top 20 cm. It is possible that conditions may be initially better than suggested with the 10 cm dose, as it will take some time for upward migration of deeper ASP to reach the sediment-water interface, at which time conditions may deteriorate more rapidly than projected. Underdosing is to be avoided in projects such as the Cedar Lake restoration. The 5 to 18 year timeframe for major benefits is consistent with experience for other lakes (as with Cooke and Welch 1999) where external loads have not been further reduced in conjunction with in-lake treatment.

Response of Cedar Lake P Load to Management

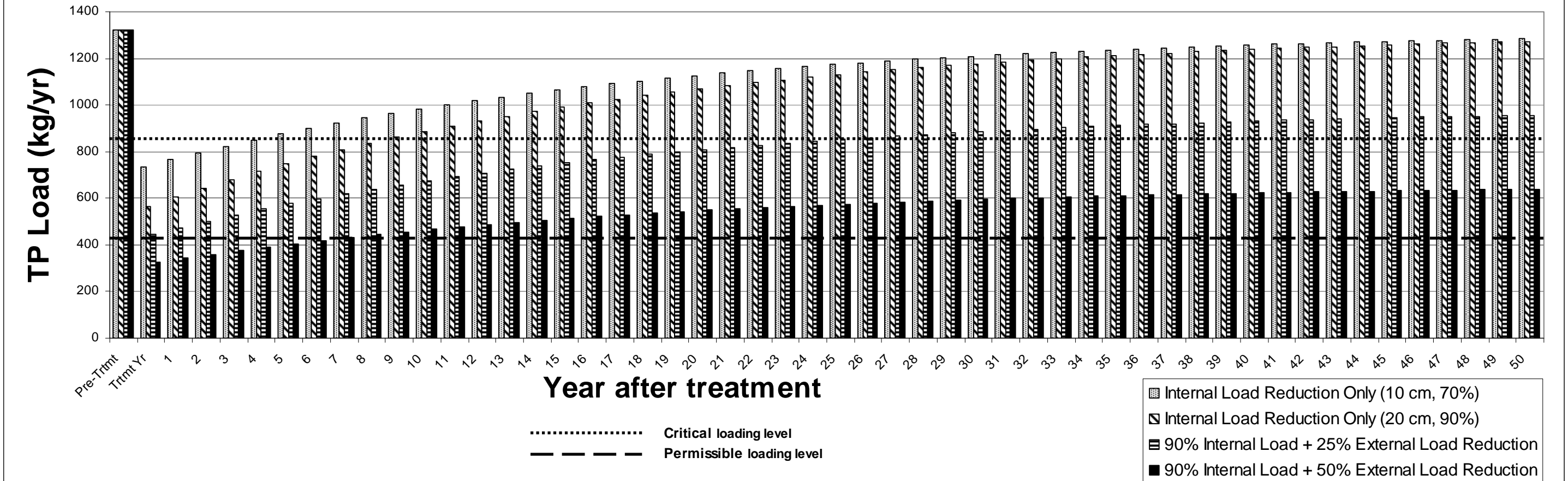


Figure 8. Results of Loading Adjustment Following Management Scenarios at an External Load of 964 kg/yr

Response of Cedar Lake P Load to Management

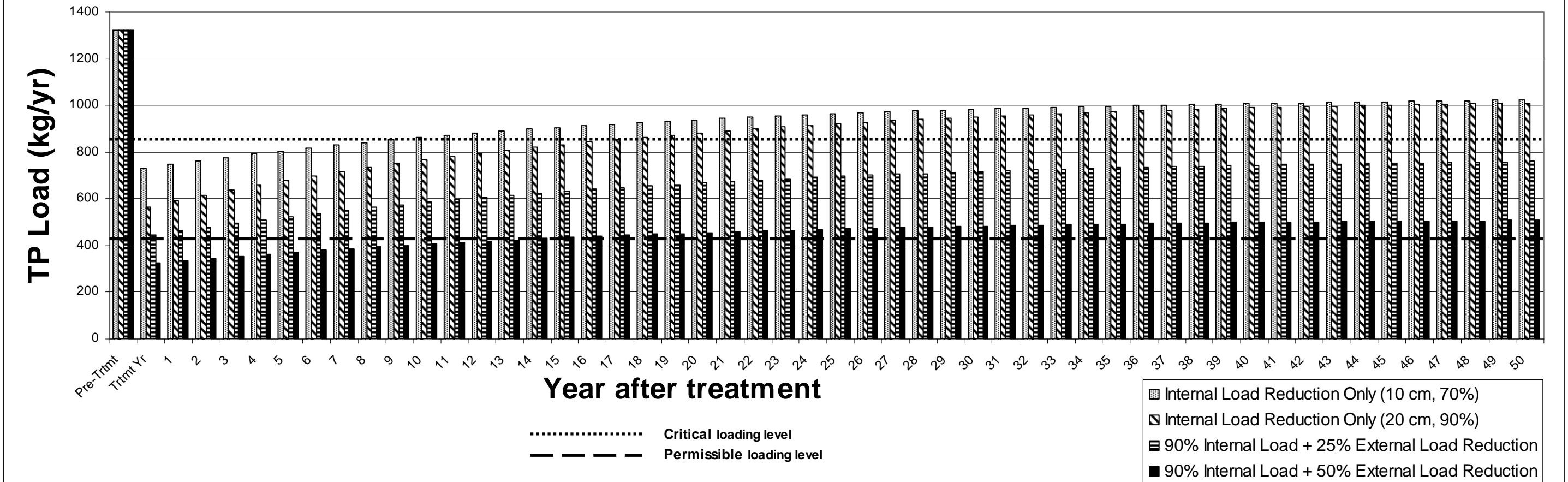


Figure 9. Results of Loading Adjustment Following Management Scenarios at an External Load of 643 kg/yr

For the scenarios involving internal load reduction and additional reductions in external loading of 25% to 50%, Cedar Lake will experience 8 to 15 years of loading below the permissible limit and 30 to 50+ years of loading below the critical limit, the range depending upon the level of reduction. This is attributable to both a reduced total load and a slowing of the rate of accumulation of new ASP that fuels the internal load. Relative to current loading and conditions, the combination of internal load reduction and even a modicum of additional watershed management represents substantial improvement for the projected 50-year horizon.

Based on this analysis using the best available information, inactivation of internal loading, coupled with appropriate and feasible watershed management, could provide desirable conditions for an indefinite period of time. Projection over multiple decades is tenuous, as loading could increase with land use changes or catastrophic events (large storms). On the other hand, major reductions in P by aluminum inactivation of ASP without a commensurate change in N would raise the N:P ratio and potentially shift the algal community away from cyanobacteria. Qualitative as well as quantitative improvement is highly desirable in Cedar Lake and would be fostered by the proposed management plan.

While the focus of the ENSR assessment has been on planning for an effective ASP inactivation program, the same approach to longevity evaluation is applicable to the proposed dredging aspect of the Cedar Lake restoration project. The most optimistic projection is that dredging surficial sediments will reduce the ASP in the daylighted sediments by 50%. Considering that dredging will not likely be conducted in all areas with significant ASP, it is more likely that the lake-wide reduction will be no more than 33%. Assuming this range as representative of the benefits of dredging, the resultant post-dredging load would be 903 to 1046 kg/yr. This is well above the critical level even immediately after dredging, and that load increases much as it does following the inactivation only scenario. If desired conditions are to be achieved, inactivation of ASP appears essential even with the proposed dredging. Only if all sediment with substantial ASP reserves is removed can the need for inactivation be avoided.

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Attachment 1: Work Plan

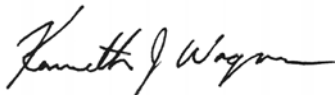
Prepared for:
United States Army Corps of Engineers

WORK PLAN

Cedar Lake Aluminum Treatment Study

Cedar Lake

Cedar Lake, Lake County, Indiana



Prepared By – Ken Wagner – Project Manager



Reviewed By – Wendy Gendron – Field Operations Manager

ENSR Corporation
April 2008

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Attachment A – Proposed Sampling Stations in Cedar Lake

Attachment B – Standard Operating Procedure for Available Phosphorus Determination

Attachment C – Instructions for P Inactivation Lab Simulation

1.0 INTRODUCTION

1.1 Project Intent

This project is intended to provide data essential to a complete analysis of sediment phosphorus inactivation as a lake management technique for Cedar Lake in Indiana. Considerable work has been done by other parties to date, but an assessment of the available phosphorus (P) in the surficial sediments and the potential to inactivate them with aluminum compounds remains to be done. This project will collect surficial sediment samples, arrange for appropriate lab testing, and interpret the results within the context of proposed Cedar Lake management options.

1.2 Organization/Responsibility

The implementation of operations at this project location will be the shared responsibility of the ENSR Project Manager (PM), the ENSR Field Operations Manager (FOM) and other ENSR personnel implementing the proposed scope of work.

1.2.1 ENSR Project Manager

The ENSR PM (Ken Wagner) is the individual who has the primary responsibility for ensuring the overall success of this project. As such, the PM is responsible for ensuring that the requirements of this work plan are implemented. Some of the PM's specific responsibilities include:

- Assuring that all ENSR personnel to are familiar with the Work Plan;
- Assuring that all ENSR personnel to are familiar with the HASP;
- Verifying that all assigned ENSR staff have the qualifications and experience to work on this program;
- Tracking project progress; and
- Supervising report preparation

1.2.2 ENSR Field Operations Manager

The ENSR FOM (Wendy Gendron) is the individual responsible for the actual implementation of the Work Plan. Specific duties of the RHSM include:

- Arranging for needed equipment and coordinating travel arrangements;
- Supervising and participating in actual sampling;
- Coordinating with the laboratory; and
- Assisting with report preparation.

1.2.3 ENSR Field Personnel

- All ENSR field personnel covered by this Work Plan are responsible for following the health and safety procedures specified in the HASP and conducting sampling in a manner consistent with this Work Plan.

1.3 Management of Change/Modification of the Work Plan

1.3.1 Management of Change

The procedures in this Work Plan have been developed based on the current proposed scope of work. Every effort has been made to address situations that may be encountered during the implementation of the proposed sampling program. However, unanticipated site-specific conditions or situations may occur during the implementation of this project, particularly as weather conditions affect sampling. As such, this Work Plan must be considered a working document that is subject to change to meet the needs of this dynamic project.

1.3.2 Work Plan Modification

Should significant information become available regarding impediments to sampling or analysis, it may be necessary to modify this Work Plan. All proposed modifications must be reviewed and approved by the ENSR PM before such modifications are implemented. Any significant modifications must be incorporated into the written document as addenda and the Work Plan must be reissued. It is possible that some changes will be made in the field following appropriate consultation, so written modifications may occur after actual sampling is complete.

2.0 Project Description

Cedar Lake is a 781-acre, glacially formed lake located in the Town of Cedar Lake, in Lake County, Indiana. The lake was once a pristine glacial lake left by Wisconsin Age glaciers with a small watershed of intermingled prairie, savannah, woodlands and wetlands. Today, the ecosystems and habitats of the Cedar Lake subwatershed are almost completely removed, with only highly degraded and fragmented patches left. Cedar Lake has suffered from the effects of cultural eutrophication. Extremely high phosphorus and other nutrient loading over the years have enriched the sediments. Water turbidity is high, submergent macrophytes growth is non-existent, and the fishery in Cedar Lake has become insignificant.

The United States Army Corps of Engineers (USACE) is evaluating alternatives for Cedar Lake that will potentially benefit the environment by restoring, improving or protecting aquatic habitat for plants, fish, and other wildlife species. Nutrient inactivation, to reduce the amount of internal nutrient cycling, is being considered as one of the measures for implementation to improve the aquatic environment in the lake. To properly evaluate this option, it is necessary to sample the surficial sediments and assess them for available P. It is also appropriate to run simulation inactivation in the lab, allowing estimation of the optimal dose of inactivating compounds. The project will collect surficial sediment samples from the lake and deliver them to a laboratory that ENSR personnel have assisted in setting up for this testing and simulation. Once results are provided by the lab, ENSR staff will interpret them in terms of the potential for P inactivation in Cedar Lake and adjust the previously submitted review report (ENSR 2007) accordingly.

3.0 Scope of Work

3.1 Objective of Study

The USACE contracted with CTE/ENSR to perform preliminary alum dosage and long term effectiveness calculations for two treatment measures for Cedar Lake. Further investigation is required to determine if internal phosphorous loads in Cedar Lake can be adequately controlled long-term using nutrient inactivation. Additional treatability studies are necessary to refine the potential treatment process, in terms of treatment level (dosage) and the cost for the inactivation.

3.2 Specific Field Tasks

The specific field tasks being implemented by ENSR to meet the objectives of the study include the following:

- Using a two-person field team, access the lake and collect surficial sediments for analysis
- Sample surficial sediment using an Ekman dredge lowered from a 22' jon boat at 10 sampling locations;
- Remove surficial sediment from Ekman dredge and place in laboratory pre-cleaned sample bottles,
- Rinse dredge with lake water between each sampling location, and
- Process samples for shipment to the chosen laboratory for subsequent analyses.

3.3 Necessary Equipment

The equipment needed to meet the objectives of the study includes the following:

- Two field personnel with appropriate clothing and personal equipment, to include:
 - Clothing layers to provide suitable warmth and protection for cool weather and potentially rainy conditions
 - Waterproof pants
 - Two pair of gloves/mittens (if needed), one waterproof
 - Warm hat (if needed)
 - Waterproof/water resistant, insulated boots
 - Safety glasses or goggles
 - PFD (worn under coat)
 - Spare clothing in a sealed, waterproof container
- Map of lake and sample stations
- Waterproof field book and writing implements
- Tape measure
- Electronic depth finder (hand held by Hondex™ model # 737139)
- GPS with programmed sampling station locations (Garmin GPSMAP76 is sufficient)
- Ekman dredge with at least 50 ft of rope (Wildco 9 X 9 inch steel or equivalent)
- Pan for receiving surficial sediments

- Stainless steel spoon for transferring sediments from the pan to the sample jars
- Bucket for rinsing equipment
- Sample jars – 24 glass or plastic jars, wide mouth 250 ml, screw tops, pre-labeled and wrapped with clear tape (to protect label and stabilize jars under cold wet conditions)
- Padded container to hold sample jars once filled (may be used for shipping as well)
- First aid kit (including eyewash)
- 100 ft of strong rope (for possible rescue need)
- Water for drinking, food as appropriate for duration of on-boat work
- Cell phone
- Weather radio
- Copies of Work Plan and HASP

3.4 Sampling Locations

Attached maps of Cedar Lake (Appendix A) depict the USACE sampling stations from last year and the distribution of silt/clay vs. sand/gravel in the lake from the 1984 Diagnostic/Feasibility study. Since there is no known correlation between total and available P, samples collected anywhere within the silt/clay zone are appropriate for this analysis. Since sampling at locations sampled previously adds value to those past locations and the associated data, it is proposed that we use sampling locations that coincide with USACE sampling sites to the extent possible. Based on discussion with the USACE, nine locations sampled in 2007 were chosen for sampling in 2008, plus one additional station in the northeastern portion of the lake to cover a likely target area not previously sampled; these locations are shown in the final figure in Appendix A. We propose to designate the new site as MU1-CO4, adding to the past sequence for that area. The selected sampling locations are intended to adequately represent the range of targeted sediments over the area of the lake. The longitude and latitude identifiers for those sites are supplied in Appendix A as well.

3.5 Field Procedures

The field team is to do the following:

Follow all provisions of the HASP. Note required equipment specifications and adhere to notification protocols. Specifically:

- Upon arrival to the site, ENSR will contact the local police and other emergency responders to inform them of ENSR's presence on the lake and the extent of our work, including days of sampling and expected times.
- ENSR will inspect the boat provided for safe operation and required safety equipment
- A two-person team will be used at all times while ENSR employees are working on the lake.
- ENSR will have the ability to contact a local third-party by cell phone. This third-party will serve as the check-in for the team. The team will contact this person upon arrival to the site, at lunch and upon leaving the site for the day.
- Employees will not work on the lake before sunrise or after sunset. Preferably, staff will be off the lake at least ½ hour before sunset.
- A briefing with Job Hazard Analysis will be conducted just before commencing any on-water operation

The lake water surface elevation on the day of sampling should be referenced to the outlet weir located near the intersection of Lake Shore Dr. and Binyon Rd on the east side of Cedar Lake.

Actual sampling procedures will involve the following:

- Notify the ENSR off-water contact upon commencement of on-water work
- Locate the station with GPS and verify with the map
- Put on waterproof gloves
- Check and record the water depth, being sure it matches expectations from the map (within 2 feet); relocate as necessary
- Load and lower Ekman dredge until it rests on the bottom; release messenger to trip mechanism and close the jaws
- Retrieve Ekman dredge using proper lifting technique; gently set on sampling pan and move away from the hole
- Decant excess water from dredge as necessary, use stainless steel spoon to transfer sufficient sediment from the top of the Ekman dredge to each of two sample jars, fill sample jars completely and re-cap, cleaning exterior and storing in padded container
- Release unneeded sediment back into the lake, rinse Ekman dredge, pan and spoon with water from the lake until no traces of sediment are visible
- Re-pack equipment on the sled for movement to next station
- Notify the ENSR off-water contact upon completion of on-water work

It is expected that it will take approximately 15 minutes per station to collect samples. It is assumed that it will take 5 minutes to move between stations. Therefore, 10 stations can be sampled in approximately 3.4 hours. Adding time for one duplicate sample at a randomly chosen station, boat inspection, pre-notification to off water contacts, time to get on and off the water, an 8 hour sampling day is projected, from approximately 7:30 AM to 4:30 PM, including an hour break in the middle for food and/or warmth.

It is intended that a test of field conditions and equipment will be run in the afternoon of one day, with full sampling the following day. If conditions are suitable on the first day, it is possible that multiple stations may be sampled, reducing field time on the second day.

Tentative schedule:

- Arrive in Chicago by noon on Monday, April 7, 2008
- Gather shipped equipment and purchase anything else that is needed
- Proceed to Cedar Lake
- Test sampling of up to two stations
- Overnight in area
- Sampling to commence about 7:30 AM on Tuesday, April 8, 2008
- Sampling to be complete by about 4:30 PM on Tuesday, April 8, 2008
- Sampling may extend into Wednesday, April 9, 2008 if necessary
- Ship samples late on Tuesday, April 8 or Wednesday, April 9, 2008
- Field team is expected to depart by evening of April 9, 2008

3.6 Sample Shipping Procedures

Samples are to be shipped according to the following procedures:

- The contractor shall prepare Chain of Custody documentation for all samples; one copy will be placed in a waterproof container and shipped with each sample set.
- Samples will be kept dry but cold, at $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$; samples are to be wrapped in bubble wrap and placed inside ziplock storage bags, then placed in a cooler with separately double-bagged ice sufficient to maintain the temperature during transport. Enough additional packing material will be added to the cooler to prevent significant movement by sample containers during shipping.
- One set of samples (one 250 ml jar per station plus one duplicate) will be packaged in a padded container and properly marked, with a chain of custody form, and shipped for overnight delivery to Spectrum Laboratories, 11 Almgren Drive, Agawam, MA 01001 to the attention of Ms. June O'Connor, 800-789-9018.
- The lab is to be contacted to confirm receipt.
- The second set of samples is to be packaged in a padded container and properly marked, with a chain of custody form, and shipped for overnight delivery to ENSR, 11 Phelps Way, Willington, CT 06279 to the attention of Ken Wagner, 860-429-5323. These are back-up samples and will be stored in a refrigerator in case of any problem with the sample set shipped to the lab.

3.7 Laboratory Analysis Procedures

Samples will be analyzed for percent solids by method SM 2540G and Total P by method ASTM D51588A, backed up by ICP 200.7 when matrix interference causes QA/QC problems. Available P is determined by sequential extraction and inactivation potential is determined by a simulated aluminum treatment in the laboratory; neither method has been issued a standard number as of this time, but both have been employed by academic and some commercial labs for exactly the purpose intended in this project.

The analysis procedure for available P is to follow the standard operating procedures established by the lab and previously approved by ENSR for use in other projects (Appendix B). In essence, these include:

- Determination of the specific gravity of the sediment
- Drying of an aliquot of sample (typically 5 g)
- Extraction of loosely bound and iron bound P fractions through sequential exposure to specified solutions
- Testing for P content in the extractant
- Calculation of available P in the sediment on a mg/kg basis

The simulated inactivation procedure is to follow the directions provided by ENSR for previous simulations (Appendix C). In essence, these include:

- Suspending a known quantity (typically 5 g) of sediment in a container with distilled water
- Adding a known quantity of aluminum to that container and agitating it for several hours
- Centrifuging to recover the sediment
- Testing for available P by the extraction process described above and in Appendix B
- This process will be repeated to evaluate the inactivation induced by doses of between 10 and 150 g Al/m^2 , with at least 6 different doses tested.

3.8 Data Interpretation and Reporting

ENSR staff will use the existing report as a template, adjusting estimates as warranted by the new data on available P and its inactivation potential. Specific tasks to be completed include:

- Generate a graph of dose versus percent available P inactivated in the sediment for each of the sediment sample locations.
- Recalculate the amount of aluminum to be added to Cedar Lake that can reasonably and adequately inactivate the internal P load, including consideration of any buffering needs.
- Derive a dosing program to meet inactivation needs.
- Document the total amount of aluminum to be applied to Cedar Lake along with suggestions of aluminum forms to use to minimize side effects to the aquatic ecosystem.
- Derive a cost estimate for aluminum treatment of Cedar Lake using the refined dosage and possible forms of aluminum needed to inactivate the sediment P loading. The cost estimate could be presented as a range based upon local labor rates and material costs.
- Recalculate the performance of the aluminum treatment over time using tributary loading data derived in the development of the EFDC model. Evaluate the future tributary loading scenarios in the analysis:
 - No reduction in P loading on all seven tributaries to Cedar Lake.
 - Reducing the P loading by 50% on Sleepy Hollow Ditch and Unnamed Inlet/Pickerel Creek tributaries.
 - Reducing the P loading by 25% on all seven tributaries to Cedar Lake.
 - Reducing the P loading by 75% from the Unnamed Inlet/Pickerel Creek tributary.
- Derive a recommended reapplication schedule for inactivating nutrients in Cedar Lake for fifty (50) years based upon the revised performance calculations.
- Provide introductory information that discusses the benefits and negative aspects of treating a lake with aluminum along with typical aluminum dosages applied on similar lakes in the project area. Include description and discussion of similar projects where treatment with aluminum has been implemented along with the outcome and/or effectiveness of the treatment.

3.9 Contingency Plans

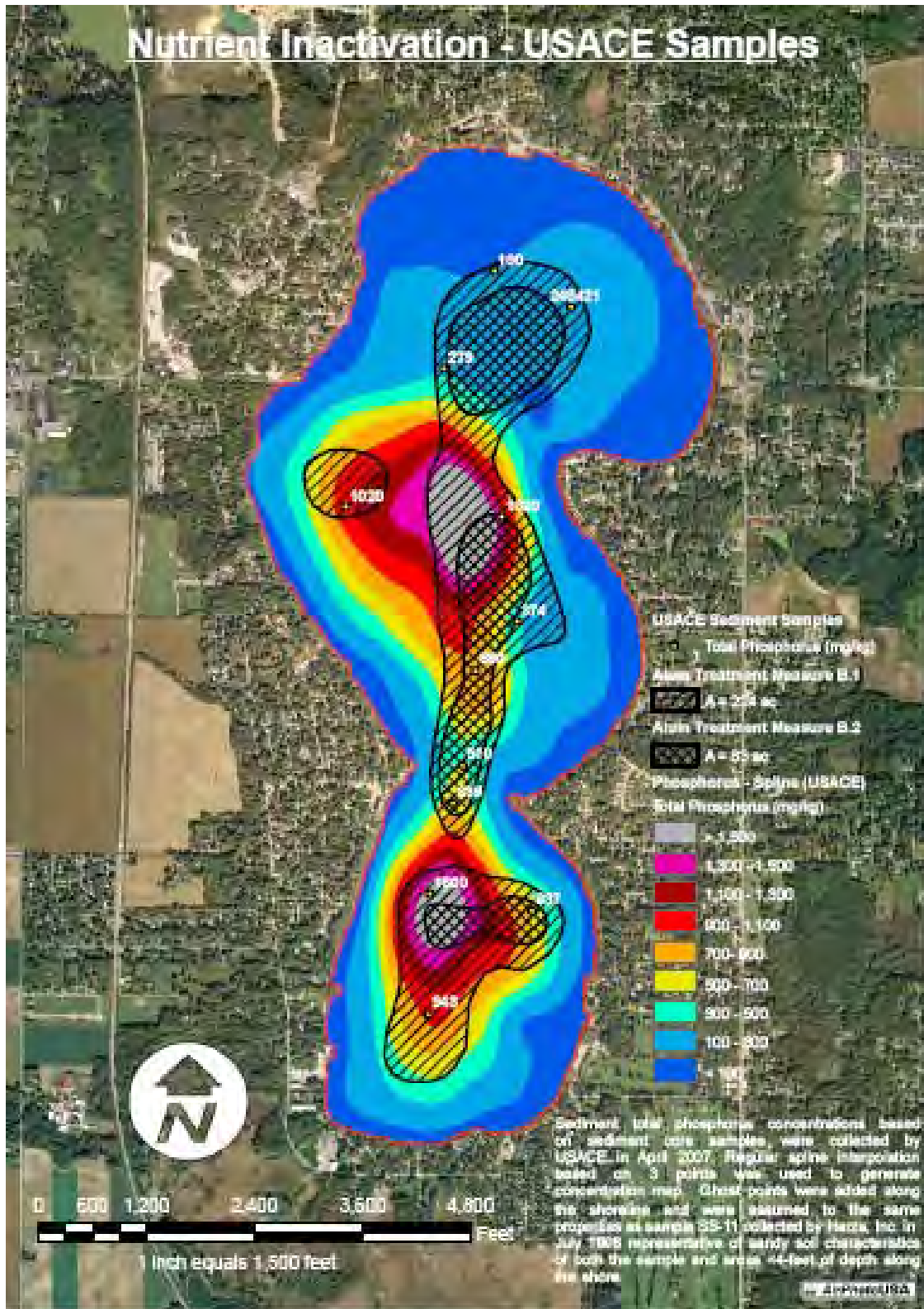
The following contingencies and response plans are offered:

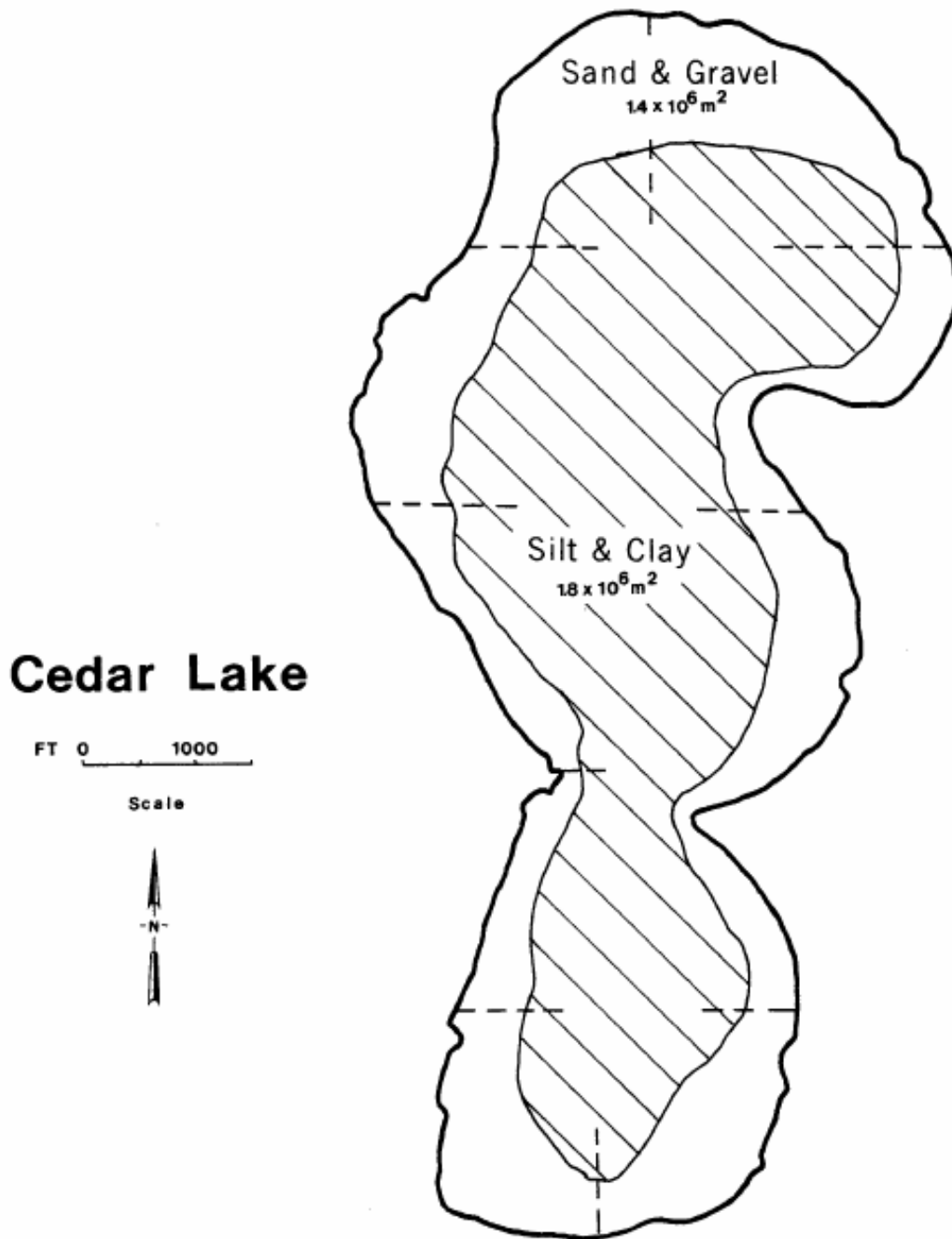
- Unsafe weather conditions: Sampling can be delayed until suitable weather conditions prevail.
- Site exhibits sand and gravel substrate: Move site into the lake in a direction perpendicular to the closest shoreline or in a direction that increases depth until silt/clay substrate is encountered. Note that grain size analysis supplied by the USACE indicates that all but one previously sampled station have a percent solids content between 17 and 25%, suggesting silty sediments of the type sought for sampling. The other sampling location, MU1-CO1 at the north end of the lake, has a percent solids content of 57%, more indicative of coarser sands; this site is at the boundary of the sand/gravel and silt/clay areas shown in Appendix A and may need to be relocated slightly further from shore to reach the targeted sediment. The newly added station in the eastern portion of the northern basin is expected to fall within the silt/clay zone, but will be relocated if sand and gravel are encountered.
- Substrate is too loose to be sampled with Ekman dredge: Freeze coring will be applied; this involves placing dry ice in a hollow metal pipe with a sealed end and inserting it into the sediment. Sediment will adhere to the metal and can be scraped off to provide an adequate sample. Note that grain size analysis supplied by the USACE suggests that all sediments have enough solids content to sample by Ekman dredge.

- Samples damaged in transport: Two sets of samples will be shipped, one directly to the lab and one to an ENSR office near that lab. If any samples from one set are damaged, they can be replaced by samples from the other set.

Appendix A

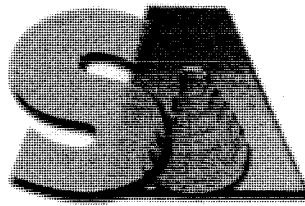
Proposed Sampling Stations in Cedar Lake





Appendix B

Standard Operating Procedure for Available Phosphorus Determination



SPECTRUM ANALYTICAL, INC.

Featuring
HANIBAL TECHNOLOGY

**UNCONTROLLED
COPY**

SPECTRUM ANALYTICAL, INC.

**Featuring
Hanibal Technology
11 Almgren Drive
Agawam, MA 01001**

**Standard Operating Procedures
For
Phosphorus Fractionation of Sediments
for Loosely-Sorbed and Iron-Bound Phosphorus**

Jan A. Conroy
Prepared by

8/26/04
Date

Sergenia Vasilevso
Reviewed by

08/30/04
Date

[Signature]
Lab Director

8/31/04
Date

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ENVIRONMENTAL ANALYSES



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STANDARD OPERATING PROCEDURES
For
Phosphorus Fractionation of Sediments
for Loosely-Sorbed and Iron-Bound Phosphorus

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I. SCOPE AND APPLICATION

An analyst who has been trained in this procedure and documented by authorized personnel can analyze this method at Spectrum Analytical Inc. This method provides detailed instructions for phosphorus fractionation of lake/pond sediments by extraction with a 1.0 M. ammonium chloride solution followed by a buffered dithionite solution. Analysis of the phosphorus is performed via ASTM method D515-88A (colorimetric ascorbic acid reduction).

II. EQUIPMENT, SUPPLIES, REAGENTS, AND INSTRUMENTATION

- A. **Mechanical shaker** or TCLP/SPLP extraction tumbler.
- B. **Spectrophotometer**. A spectrophotometer suitable for measurements at 880 nm for either 1 cm or 2.5 cm cells
- C. **Ammonium Chloride solution (approx. 1.0 molar)**. Partially fill a liter beaker with distilled water. Add 53.49 grams ammonium chloride. Adjust the pH to 7.0 with concentrated ammonium hydroxide. Perform this step dropwise. Do not keep the ammonium hydroxide bottle open during this procedure. Dissolve and bring up to volume with distilled water. Check the pH of the ammonium chloride before each use. (Loosely-sorbed P)
- D. **Buffered Dithionite Solution** Add 9.24 grams NaHCO_3 and 19.15 grams $\text{Na}_2\text{S}_2\text{O}_4$ to approximately 500 ml distilled water. Dissolve and dilute to one liter. Make fresh daily. (Fe-P)
- E. **Aluminum Dosing** Typically this is not needed unless the customer specifically requests an aluminum treated sample. Have the customer specify how much aluminum in mg/L is needed.

Aluminum sulfate octadecahydrate ($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$) F.W. 666.42 gram
 Al^{+3} in $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ = 53.96 gram
 $53.96/666.42 = 8.097\% \text{ Al}^{+3}$

$35.0 \text{ mg/L Al}^{+3} = 35/0.08097 = 0.432 \text{ g Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O per liter} =$
 $1.75 \text{ mg Al}^{+3} \text{ per } 50 \text{ ml dose}$
 $165 \text{ mg/L Al}^{+3} = 165/0.08097 = 2.038 \text{ g Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O per liter} =$
 $8.25 \text{ mg Al}^{+3} \text{ per } 50 \text{ ml dose}$
 $350 \text{ mg/L Al}^{+3} = 350/0.08097 = 4.322 \text{ g Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O per liter} =$
 $17.5 \text{ mg Al}^{+3} \text{ per } 50 \text{ ml dose}$

Buffer the dosing solution to Ph 6.0 with NaHCO_3 before bringing up to final volume.

F. Centrifuge

III. PROCEDURE

A. Loosely-sorbed Extraction Procedure

1. Air-dry the samples overnight to remove most of the residual water. The samples should be semi-solid. After the samples has been air-dried overnight, test for % solids. The % solids analyzed for this procedure is specific to this procedure and will not be reported as the % solids in the original sample.
2. Weigh 5.0 +/-0.2 grams of the semisolid samples into centrifuge tubes. Repeat this step for each sample. Choose one sample to analyze as a duplicate and spike. These sample aliquots will be in the same weight range as the original. If aluminum dosing is needed, go to step 3.
3. Proceed with this step only if aluminum dosing is needed. Add 50 ml. of the required aluminum solutions to the batched sample aliquots. Tumble for two hours. Centrifuge. Carefully pour off the aluminum solution to waste. Go to step 4.
4. Set up a batch in the following manner.
 - a. Blank – 25 ml. buffered ammonium chloride solution
 - b. 5 mg/L Std. – 22.5 ml. buffered ammonium chloride solution and 2.5 mls. 50-mg/L phosphorus stock solution.
 - c. Sample
 - d. Duplicate
 - e. 10 mg/L Spike - 5 ml. 50-mg/L phosphorus stock solution. Bring sample to final volume of 25 ml with ammonium chloride solution. This sample will be used through both extraction procedures.
 - f. Samples 2-20
5. Bring all samples up to 25 ml final volume with ammonium chloride solution.
6. Tumble the centrifuge tubes for two hours.

7. Centrifuge for 15 minutes at approximately speed #7.
8. Analyze supernatant for reactive phosphorus by method ASTM D515-88A. (Refer to Attachment A).
9. Prepare the reactive phosphorus curve by adding 5 ml buffered ammonium chloride to each calibration standard. (final volume- 50 ml)
10. For all samples in the batch, use 5 ml as the sample size. Dilute to 50 ml. This dilution addresses any turbidity interference in the sample aliquot. (DF 10)

B. Iron-bound Extraction Procedure

1. Without disturbing the soil pellet, carefully discard the supernatant ammonium chloride solution from the previous extraction. Remove as much water as possible without discarding any soil sample.
2. Bring up to 25ml final volume with buffered dithionite solution to each sample. This solution must be freshly made.
3. Prepare a sample blank by adding 25 ml of the dithionite solution to a centrifuge tube.
4. Prepare a 5-mg/L standard from the 50 ppm phosphate stock standard by adding 2.5 ml stock standard to 22.5 ml dithionite solution.
5. Tumble the centrifuge tubes for one hour.
6. Centrifuge for 15 minutes at approximately speed #7.
7. Analyze supernatant for reactive phosphorus by method ASTM D515-88A. (See attached SOP).
8. Prepare the reactive phosphorus curve per the directions of the attached ASTM D515-88A SOP. Add 1.0 ml buffered dithionite solution to all calibration standards. (Final volume- 50 ml).
9. For all samples in the batch, use one ml as the sample size. Dilute to 50 ml. With distilled water. This dilution addresses any matrix interference from the dithionite solution in the sample aliquot. (DF 50)

IV. CALCULATION

A. Phosphorus concentration as mg/Kg = (A)(DF)(B/C)

A = Spectrometer Reading (mg/L)
 B = Extract volume in liters (0.025L)
 C = Weight (0.005----Kg)
 DF = Extraction Dilution Factor

B. Phosphorus concentration as mg/Kg (Dry weight) (A)(DF)(B/C)(D)

A = Spectrometer Reading (mg/L)
 B = Extract volume in liters (0.025L)
 C = Weight (0.005----Kg)
 D = Decimal % solids
 DF = Extraction Dilution Factor

C. Value of spike as mg/Kg

50 mg/L Phosphorus Standard Solution / 1000 ml/L = 0.05 mg/ml
 [(5.0 ml) (0.05 mg)] / Weight (Kg) = Approximately 50.0 mg/Kg phosphorous

1. To calculate matrix spike as dry weight, divide the final mg/Kg value by Decimal % Solids.
2. The spike recovery for the loosely sorbed phosphorus extraction is typically low. During the first extraction procedure the phosphorus is taken up by the iron components found in the sample. The final spike recovery is calculated from the combined recovery of the loosely sorbed and the iron bound constituents.

Sample ID	%Solids	Weight (g)	Loosely-sorbed P (mg/Kg)(wet/dry)	Raw L-S P mg/L	Fe-bound P (mg/Kg) (wet/dry)	Raw Fe-B P mg/L
Blank	-	-	-		-	
Standard L-S 5.0 TV (4.0-6.0)	-	-	-		-	
Standard Fe-B 5.0 TV (4.0-6.0)						
Sample						
Duplicate						
50% RPD						
Matrix Spike 30. %R.						

V. SAFETY

A. Use care with all reagents and standards.

- B. Wear laboratory coats and gloves and safety glasses during all segments of analysis from preparation, extraction and colorimetric analysis.

VI. REASON FOR REVISION

New SOP

VII. REFERENCES

Rydin, E. and Welch, E.B.; Dosing Alum to Wisconsin Lake sediments based on In vitro Formation of Aluminum Bound Phosphate; Lake And Reservoir Management, Volume 15, No. 4, December 1999.

VIII. ATTACHMENTS

- A. SOP for ASTM D515-88A
B. Sample Report Sheet

IX. GLOSSARY

- | | | |
|----|---|----------------------------|
| A. | nm | ⇒ Nanometer |
| B. | cm | ⇒ Centimeter |
| C. | P | ⇒ Phosphorus |
| D. | NaHCO ₃ | ⇒ Sodium Hydrogencarbonate |
| E. | Na ₂ S ₂ O ₄ | ⇒ Sodium Hydrosulfite |
| F. | ml | ⇒ Milliliter |
| G. | mg/L | ⇒ Milligram per Liter |
| H. | mg/Kg | ⇒ Milligram per Killigram |

Attachment A

Standard Operating Procedure For ASTM D515-88A Ortho and Total Phosphorous in Water Colorimetric Ascorbic Acid Reduction Method



SPECTRUM ANALYTICAL, INC.
Featuring
Hanibal Technology
11 Almgren Drive
Agawam, MA 01001

Standard Operating Procedure

For

ASTM D515-88(A)
Phosphorous in Water
Colorimetric Ascorbic Acid Reduction Method

UNCONTROLLED COPY

Prepared by

Date

Reviewed by

Date

Lab Director

Date

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STANDARD OPERATING PROCEDURE
ASTM D515-88(A)
Phosphorous in Water
Colorimetric Ascorbic Acid Reduction Method

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1.0 SCOPE

An analyst who has been trained in this procedure and documented by authorized personnel can analyze this method at Spectrum Analytical Inc.. This method covers the determination of specified forms of phosphorus compounds in water and in wastewater. The method is usable in the range from 0.005 to 0.5 mg/L of phosphorus. The range is for photometric measurements made at 880 nm in a 25-mm cell. Higher concentrations can also be determined in diluted sample.

- 1.1 Only orthophosphate is measured when this test is run on an undigested sample. To avoid measurement of any hydrolyzable phosphorous analyze samples as soon as possible after the addition of the acidic reagent.
- 1.2 Hydrolyzable phosphorous, defined as inorganic phosphorous forms other than orthophosphate, can be calculated by boiling the sample in an acid medium. All inorganic forms of phosphorous will be converted to orthophosphate. The hydrolyzable phosphorous form can be calculated by subtracting the previously analyzed orthophosphate.
- 1.3 The method cited for total phosphorous converts both organic and inorganic forms of phosphorous to orthophosphate.

2.0 EQUIPMENT, SUPPLIES, REAGENTS, AND INSTRUMENTATION

- 2.1 Spectrophotometer, for use at 880 nm providing a light path 2.5 cm or longer.
- 2.2 Hot Plate.
- 2.3 300 mL Erlenmeyer flasks washed with hot Hydrochloric Acid (HCL) (1+3) and rinsed with distilled water. Do not use soap to clean the glassware.
- 2.4 **5N Sulfuric Acid (Reagent A)**: Dilute 70 mL of concentrated H₂SO₄ to 500 mL with distilled water.
- 2.5 **Solution Mixture (Reagent B)**: Dissolve 0.13 g of antimony potassium tartrate [K(SbO)-C₄H₄O₆-1/2 H₂O] in a 1 liter volumetric flask containing about 700 mL of water. Add 5.6 g of ammonium molybdate(NH₄)₆Mo₇O₂₄·4H₂O] and Carefully add 70 mL of concentrated sulfuric acid. Cool and dilute solution to the 1 liter mark with distilled water. The solution is stable for at least a year if stored in a polyethylene bottle away from heat.

- 2.6 **Combine Reagent (Reagent C):** Dissolve 0.50 g of asorbic acid in 100 mL of solution mixture (Reagent B). The reagent is stable for a week if stored at 4 degrees C; otherwise, prepare the solution fresh daily as needed.
- 2.7 **50 mg/L Stock Phosphorous Solution:** Dissolve in distilled water 0.2197 g of anhydrous H_2PO_4 and dilute to 1000 ml. Dry the potassium dihydrogen phosphate in a 105°C oven for 1 hour prior to use.
- 2.8 **2.5 mg/L Standard Phosphorous Solution:** Dilute 50.0 mL of stock phosphate solution to 1000 mL with distilled water.
- 2.9 **Phenolphthalein Indicator Solution:** Dissolve 0.5 g of phenolphthalein in a mixture of 50 mL ethyl or isopropyl alcohol and 50 mL of distilled water.
- 2.10 **Ammonium Presulfate $(NH_4)_2S_2O_8$:** Crystalline ammonium persulfate $[(NH_4)_2S_2O_8]$.
- 2.11 **1N Sodium Hydroxide:** Dissolve 40 g of NaOH pellets with distilled water and dilute to 1000 mL.
- 2.12 All reagents and standards shall be written in Reagent Book or Standards Log with measurements of components and descriptions of preparation procedure. The reagents and standards have description numbers, for example 147-37-5, where 147 is the number of the Reagent Book, 37 is the page number in the Reagent Book, and 5 is the part of the page.
- 2.13 **Sample Handling:** Store at 4 degrees C for no longer than 48 hours for orthophosphate analysis. If the sample is to be analyzed for **Dissolved Phosphorus**, filter sample (pore size 0.45 micron) immediately and analyze for total phosphorus within 48 hours of sampling. If the dissolved portion cannot be analyzed immediately, preserve the sample with H_2SO_4 after filtration. If the sample is preserved with H_2SO_4 holding time for total phosphorus analysis is 28 days.

3.0 PROCEDURE

3.1 Orthophosphate

- 3.1.1 Standard curve for Orthophosphate. Add the following volumes of the standard phosphorous solution to approximately 20 mls DI H₂O in 50 ml volumetric flasks. Final volume – 50 mls.

<u>mL of standard solution</u>	<u>concentration of standard (mg/L)</u>
0.10	0.005
1.0	0.05
2.0	0.10
10.0.	0.50
20.0.	1.0

- 3.1.2 Set up a blank and the five standards. Follow the directions in the manual for the Hach DR/3000 for the manual program. Repeat the procedure if the correlation factor is below 0.995.
- 3.1.3 Transfer results of R^2 (correlation factor), CF (concentration factor) to the notebook. The CF or concentration factor will be needed whenever this procedure is repeated.
Note: For every sample run a high and low standard. Results should be within 10% of the expected value. If the value of the results are not within 10% remake the curve.
- 3.1.4 Bring samples to room temperature.
- 3.1.5 Add 50 mL of sample to a 150-200 mL Erlenmeyer flask.
- 3.1.6 Add 1 drop of Phenolphthalein Indicator.
- 3.1.7 If a red color develops, add Reagent A, dropwise, to neutralize it.
- 3.1.8 Add 10 mL of Combine Reagent and after 10 minutes read on the spectrophotometer at 880 nm with a 2.5 cm cell. Read within 30 minutes.

3.2 TOTAL-PRESULFATE DIGESTION METHOD*

- 3.2.1 Standard curve for Total phosphorous. Add the following volumes of the standard phosphorous solution to approximately 20 mls DI H₂O in 50 ml volumetric flasks. Final volume – 50 mls.

<u>mL of standard solution</u>	<u>concentration of standard (mg/L)</u>
0.01	0.005
0.20	0.01
1.0	0.05
2.0	0.10
10.0	0.50

- 3.2.2 Set up a blank and the five standards. Follow the directions in the manual for the Hach DR/3000 for the manual program.
- 3.2.3 Repeat the procedure if the correlation factor is below 0.995.
- 3.2.4 Transfer results of R² (correlation factor), CF (concentration factor) to the notebook. The CF or concentration factor will be needed whenever this procedure is repeated.
- Note:** For every sample run a high and low standard. Results should be within 10% of the expected value. If the value of the results are not within 10% remake the curve.
- 3.2.5 Add 50 mL of sample to 300 mL Erlenmeyer flask.
- 3.2.6 Add 1 mL of H₂SO₄ solution (Reagent A).
- 3.2.7 Add a few boiling beads.
- 3.2.8 Add 0.4 gm of ammonium persulfate.
- 3.2.9 Boil gently for approximately 1 hour or until the volume of the solution is reduced to approximately 10 mL.
- 3.2.10 Remove from heat and allow to cool to room temperature.
- 3.2.11 Add 1 drop of Phenolphthalein indicator.
- 3.2.12 Neutralize using 1N NaOH solution until reaching pearl pink color.

- 3.2.13 Add dropwise 5N H₂SO₄ to discharge pink color.
- 3.2.14 Dilute up to 50 mL with distilled water.
- 3.2.15 Add 10 mL of Combine Reagent and after 10 minutes (within 30 minutes) read on spectrophotometer at 880 nm with 2.5 cm cell.
- 3.2.16 *Hydrolyzable Phosphorous can be determined if this digestion Procedure is used. DO NOT add the ammonium persulfate.

4.0 REASON FOR REVISION

- 4.1 Changed the method from the combination of Method 365.3 listed in Methods for Chemical Analysis of Water and Waste and Methods 4500-PB.5 AND 4500 PE in Standard Methods for the Examination of Water and Wastewater to Method D515-88(A) listed in the 1994 Annual Book of ASTM Standards.
- 4.2 Clarified holding times for Total, Dissolved and Orthophosphate. (Rev 1.2)
- 4.3 Company name change

5.0 CALCULATION, DATA REDUCTION

- 5.1 **Phosphorous (P)/0.326 = Phosphate (PO₄)**
- 5.2 Total minus ortho Phosphorous = Meta Phosphorous.
- 5.3 Total phosphorous – Hydrolyzable phosphorous = organic phosphorous
- 5.4 Hydrolyzable phosphorous (3.2.16) – Orthophosphate = Hydrolyzable phosphorous
- 5.5 **All municipalities reported as PO₄.**

6.0 QUALITY CONTROL

- 6.1 Prepare a high and low standard to insure the validity of the curve. The control limit for an acceptable standard is +/- 10%. If either standard is outside the acceptable range repeat the standards. If the standard(s) still exceed the acceptable range remake the curve.
- 6.2 The LCS sample must be within 15 % of the true value. Repeat the analysis if the LCS exceeds 15%.
- 6.3 Any batch containing 20 samples or less must include a blank, a LCS, a duplicate, and a spike.

7.0 SAFETY

- 7.1 Safety glasses must be worn at all times.
- 7.2 Precautionary measures including lab coat and gloves should be adhered to during any laboratory procedure.
- 7.3 The digestion of the sample needs to be performed in a hood.

8.0 REFERENCES

- 8.1 Annual Book of ASTM Standards, Water and Environmental Technology, Volume 11.01, 1995.

9.0 ATTACHMENT

- 9.1 Include a copy of the logbook

10.0 GLOSSARY

- 10.1 LCS – Laboratory Control Standard
- 10.2 H₂SO₄ – Sulfuric Acid



Revision No.0
Date: 8/23/04
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Attachment B

Analytical Determination of Phosphorus Content of Sediment Samples by Serial Extraction

Sample ID	% Total Solids	Sample Weight Used (gm)	Loosely-sorbed P ¹ (mg/Kg) (wet/dry)	Raw Data (mg/L) Loosely-sorbed P	Fe-P ² (2nd extraction) (mg/Kg) (wet/dry)	Raw Data (mg/L) Fe-P
Method Blank						
Standard TV 5.0 mg/L						
SA01724-01	13	5.370	BDL @ 0.47/3.6	BDL @ 0.05	126/970	BDL @ 0.25
Duplicate		6.455	0.39/3.0	5.32 (106%R)	110/850	3.8 (76%R)
Spike 47/362		5.320	0.66/5.1	BDL @ 0.05	158/1220	28.5
SA01724-02	8.0	5.654	1.59/19.9	0.07	102/1280	33.6
SA01724-03	8.0	6.459	2.63/32.9	0.18	272/3400	23.0
SA01724-04	67	5.76	BDL @ 0.43/0.64	0.34	8.9/13.3	70.2
SA01724-05	35	5.431	1.47/4.2	BDL @ 0.05	43.2/123	2.1
SA01724-06	11	5.818	2.06/18.7	0.16	135/1230	9.4
Duplicate		5.392	2.32/21.1	0.24	147/1340	31.4
Spike 48/435		5.229	3.15/28.6	0.25	185/1680	31.7
SA01724-07	8.0	5.358	0.47/5.9	0.33	34.8/435	38.8
SA01724-08	10	5.142	2.53/25.3	0.05	29.2/290	7.5
SA01724-09	11	5.791	4.57/41.6	0.26	23.5/214	6
SA01724-10	11	6.011	BDL @ 0.42/3.8	0.53	38.1/346	5.5
SA01724-11	10	6.182	0.49/4.9	BDL @ 0.05	44.0/440	9.2
Duplicate		5.284	0.47/4.7	0.06	47.3/473	10.9
Spike 48.3/483		5.176	1.45/14.5	0.05	78.7/787	10
SA01724-12	7.0	5.850	BDL @ 0.43/6.1	0.15	18.6/266	16.3
SA01724-13	8.0	6.351	1.57/19.6	BDL @ 0.05	164/2050	4.4
				0.20		41.6

1. 50 ml. aliquots. of a 1 M solution of ammonium chloride (buffered to pH 7) was added to various sample weights and tumbled for a two hour period.

Analysis for **reactive phosphorus** was performed using ASTM method D515-88. Sample spiked during this step display a low % Recovery

2. 25 ml. aliquots of the dithionite solution (0.11 M NaHCO₃/0.11 M Na₂S₂O₄ final pH 6.8) were added to the original samples. The samples were tumbled for 1 hour.

The extract was analyzed via ASTM method D515-88 for **reactive phosphorus**.

3. Spiked samples were analyzed throughout the complete procedure. The spiking solution is absorbed into the sediment and shows no significant recovery during the first extraction. When the recoveries are calculated using both loosely-sorbed and iron bound phosphorus, the following information applies.

SA01724-01 - 70 / 103%R
 SA01724-06 - 106 / 80%R
 SA01724-11 - 74 / 67 %R

Analytical Determination of Phosphorus Content of Sediment Samples by Serial Extraction

4. Both wet and dry results are listed. (wet/dry)
6. The sample is dried at ambient temperature for 24 hours before a aliquot is removed for analysis. The % solids is representative of the fractionation procedure and not the original "as is" sample.

Analytical Determination of Phosphorus Content of Sediment Samples by Serial Extraction

Sample ID	% Total Solids	Sample Weight Used (gm)	Loosely-sorbed P ¹ (mg/Kg) (wet/dry)	Raw Data (mg/L) Loosely-sorbed P	Fe-P ² (2nd extraction) (mg/Kg) (wet/dry)	Raw Data (mg/L) Fe-P
SA11566-01	26.7	5.0174	BDL @0.25/0.94	BDL @ 0.05	6.2/23	1.3
Duplicate	26.7	5.0918	0.25/0.92	0.05	6.9/26	1.4
Sp. 25/94 mg/Kg (wet/Dry)	26.7	5.0092	0.60/2.25	0.12	32/121	6.5
*Al+3 (35 mg/L) 1.75 ml Al/50 ml soln.	26.7	5.033	0.25/0.93	0.05	2.2/8.4	0.45
*Al+3 (100 mg/L) 5.0 ml Al/50 ml soln.	26.7	5.0778	0.25/0.92	0.05	BDL @1.2/4.5	BDL @ 0.25
*Al+3 (165 mg/L) 8.25 ml Al/50 ml soln.	26.7	5.0894	BDL @0.25/0.94	BDL @ 0.05	BDL @1.2/4.6	BDL @ 0.25
*Al+3 (350 mg/L) 17.5 ml Al/50 ml soln.	26.7	5.0187	0.25/0.94	0.05	BDL @1.2/4.7	BDL @ 0.25

1. 25 ml. aliquots. of a 1 M solution of ammonium chloride (buffered to pH 7) was added to various sample weights and tumbled for a two hour period.

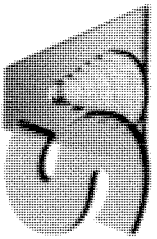
Analysis for **reactive phosphorus** was performed using ASTM method D515-88. A spiked sample was analyzed through the complete procedure. 1.4% recovery.

2. 25 ml. aliquots of the dithionite solution (0.11 M NaHCO₃/0.11 M Na₂S₂O₄ final pH 6.8) were added to the original samples. The samples were tumbled for 1 hour. The extract was analyzed via ASTM method D515-88 for **reactive phosphorus**.

3. A spiked sample was analyzed through the complete procedure. When the recovery is calculated using both loosely-sorbed and iron bound phosphorous, the recovery is 102%.

4. Both wet and dry results are listed. (wet/dry)

5. *Four sample aliquots were treated with aluminum sulfate. Aluminum concentrations are listed in the above table.



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Page _____ of _____

Special Handling:
 Standard TAT - 7 to 10 business days
 Rush TAT - Date Needed: _____
 All TATs subject to laboratory approval.
 Min. 24-hour notification needed for rushes.
 Samples disposed of after 60 days unless otherwise instructed.

Report To: _____ Invoice To: _____ Project No.: _____

Site Name: _____

Location: _____ State: _____

Project Mgr.: _____ P.O. No.: _____ RQN: _____

1=Na₂S₂O₃ 2=HCl 3=H₂SO₄ 4=HNO₃ 5=NaOH 6=Ascorbic Acid
 7=CH₃OH 8=NaHSO₄ 9= 10=

DW=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sludge A=Air
 X1= X2= X3=

G=Grab C=Composite
 Preservative _____ Matrix _____

Lab Id:	Sample Id:	Date:	Time:	Containers:	Analyses:	QA Reporting Notes:
				# of VOA Vials # of Amber Glass # of Clear Glass # of Plastic		State specific reporting standards If applicable, please list below. <input type="checkbox"/> Provide MCP CAM Report Were all field QC requirements met as per MADEP CAM Section 2.0? <input type="checkbox"/> Yes <input type="checkbox"/> No <i>(Response required for CAM report)</i>

Relinquished by: _____ Received by: _____ Date: _____ Time: _____

Fax results when available to () _____
 E-mail to _____
 EDD Format _____
 Condition upon receipt: Iced Ambient °C _____

Appendix C

Instructions for P Inactivation Lab Simulation

Analytical Determination of Phosphorus Inactivation by Aluminum in Sediment Samples

Basic Procedure:

Add 5 g of wet sediment to a reaction vessel and add aluminum at a dose that represents a known quantity per square meter of sediment. Dilute with water to fill the chamber, agitate to facilitate reaction, separate the sediment, then test for available phosphorus.

Wet sediment:

Should represent something close to in-place condition; percent solids should be as it would be in the lake, which is typically 10-20% solids. Specific gravity is typically around 1.25, so a square meter 1 cm deep would weigh 12.5 kg (1 cubic meter of water weighs 1000 kg). 5 g therefore represents a tiny fraction of the mass in a 2-8 cm layer covering 1 sq. m. See accompanying spreadsheet for calculations.

Treatment solution:

If applying just aluminum sulfate, at 4.4% Al, the liquid has an aluminum concentration of 58.27 g/L (or mg/mL). For a dose of 10 g/sq.m, assuming 5 g of sediment representing a 4 cm treatment depth at a specific gravity of 1.25, need 1.0 mg of aluminum added to the 5 g of wet sediment. Assuming a mixing vessel that will hold 50 ml, we want that 1.0 mg to be in <50 mL; distilled water can be added to bring up the volume for mixing purposes. So a stock solution is desired, from which a small portion would be added to the reaction chamber. Lots of variables here, so can do it many ways, depending on mixing vessel volume and amount of stock solution to be mixed. The alum must be diluted to work well, and must be added to very clean water, and this should happen right before use, to minimize undesirable reactions. The accompanying spreadsheet will outline one option for doing this, using 1 L as the stock solution volume to be mixed.

For an aluminum sulfate and sodium aluminate mixture, the standard ratio is 2:1, alum to aluminate, by volume. Ratios in the field are sometimes varied, and the accompanying spreadsheet allows use of other ratios if so desired. Sodium aluminate at 10.38% Al, contains 149.8 g/L of Al (149.8 mg/mL). So aluminate at half the volume of alum still has more Al (2 X 58.27 vs. 1 X 149.8), and more than half of the Al added to the reaction chamber will come from aluminate, even though the added aluminate volume is less than that of alum. The combination must provide the needed mass of Al in the mixing chamber with the sediment. Adding distilled water to fill the chamber will lower the Al concentration, but the amount of aluminum in the chamber will be correct for inactivating P in 5 g of wet sediment under the assumptions outlined.

Reaction and testing:

Set up a control tube with sediment and water only, no Al. Set up other tubes with sediment and Al representing possible doses (a range from 5 to 200 g/sq.m is supplied in the accompanying spreadsheet). Tumble for 2 hours, allow solution to stand at least overnight, then centrifuge the samples and decant to waste. Be sure to allow time for sediment-Al reactions to occur. Under field conditions, this can take days to a few weeks. In the lab, the agitated mixing speeds up reactions, but allow at least 12 hours for reactions to approach completion. Follow with the loosely bound and iron bound extraction procedures to assess changes in P availability through treatment with Al.

Attachment 2: Health and Safety Plan

Prepared for:
United States Army Corps of Engineers Contract No. W912P6-05-D-0002

HEALTH AND SAFETY PLAN

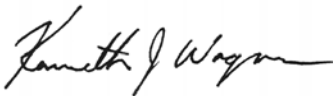
Cedar Lake Aluminum Treatment Study

Cedar Lake

Cedar Lake, Lake County, Indiana



Prepared By – Kathleen Harvey
Regional Health and Safety Manager



Reviewed By – Ken Wagner – Project Manager

Approved By – Kevin Powers, Corporate Director of Health and Safety

ENSR Corporation
March 2008

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Attachment B – Job Hazard Analysis Form

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Appendix A – ENSR Safety Statistics and Program Overview

Appendix B – JHAs for Field Tasks

1.0 INTRODUCTION

1.1 HASP Applicability

This site-specific Health and Safety Plan (HASP) has been developed by ENSR Corporation (ENSR). It establishes the health and safety procedures needed to minimize potential risk to ENSR personnel implementing the proposed sediment sampling and analysis program to determine if internal phosphorous loads in Cedar Lake can be adequately controlled long-term using nutrient inactivation (USACE Contract No. W912P6-05-D-0002). Cedar Lake is located in the Town of Cedar Lake, in Lake County, Indiana.

The provisions of this plan apply to ENSR personnel who may potentially be exposed to safety and/or health hazards related to activities described in Section 3.0 of this document. ENSR is not using any subcontractors for this program.

All activities covered by this HASP must be conducted in complete compliance with this HASP and with all applicable federal, state, and local health and safety regulations and the USACE Safety and Health Requirements Manual (EM 385-1-1 November 2003). This HASP also directly incorporates the USACE requirements for an Accident Prevention Plan (APP) as outlined in Appendix A of the USACE Safety and Health Requirements Manual. As required by the APP, ENSR has appended our injury and illness data and worker's compensation experience modification rates, as well as a copy of our corporate safety and health policy, in Appendix A of this HASP.

This plan will be distributed to each ENSR employee involved with the proposed sampling activities on the lake. Each employee must sign a copy of the attached health and safety plan sign-off sheet (see Attachment A).

1.2 Health and Safety Expectations

1.2.1 ENSR Safety Policy

As a leading global provider of environmental, health, and safety (EHS) engineering and consulting services, ENSR is committed in the conduct of our operations to protecting the environment as well as the health and safety of our employees, clients, subcontractors, suppliers, and the communities which we serve. To demonstrate and support this steadfast commitment, ENSR has adopted nine EHS Guiding Principles. It is the expectation and responsibility of each ENSR employee and subcontractor that ENSR works with to understand and fully support these Principles in the performance of all work activities. A copy of ENSR's EHS Policy is presented in Appendix A of this HASP.

1.2.2 Zero Accident Goal

The safety goal for this project is zero incidents and zero accidents, with work tasks designed to minimize or eliminate hazards to personnel, equipment, the environment and the general public. No individuals shall perform tasks that may endanger their own safety and health or that of others.

1.2.3 Stop Work Authority

Commitment to safety, health, and environmental excellence requires that all work proceed only after it is safe and environmentally sound. The responsibility for ensuring that this takes place rests with every ENSR employee working at this project location. Effectively meeting these responsibilities depends upon open communication between individuals and their supervisors prior to work beginning, and – in certain cases – after safety, health and/or environmental issues are identified.

The safety and health of on-site personnel will take precedence over cost and schedule considerations for all project work. All ENSR personnel have the authority to STOP WORK if they see a potential or actual hazard that may threaten the safety of people or the environment. Upon stopping work, the ENSR Site Safety Officer (SSO) must be immediately notified and provided with information regarding the nature of the safety, health or environmental concern. The SSO should meet with the worker with the intent of resolving the worker's concerns. Once the concerns are resolved to the satisfaction of the worker, work can proceed.

If the concerns are not resolved to the satisfaction of the worker and/or the SSO, work does not proceed. The ENSR Regional Health and Safety Manager (RHSM) will be contacted to obtain assistance in resolving the concerns. Using his/her expertise, safety, health, and environmental rules, regulations, and procedures, the ENSR RHSM will attempt to resolve the matter with all parties involved. Work will not resume until this criterion is met.

1.2.4 Compliance with the HASP/Disciplinary Action

As stated above, personnel covered by this HASP who cannot or will not comply will be excluded from site activities. In consultation with the SSO, the RHSM and PM will determine when this course of action is necessary and if deemed necessary, will ensure that the appropriate resource changes are made to successfully continue and support the field effort.

1.2.5 Accountability

Clearly defined EHS responsibilities and accountabilities for managers, supervisors and employees are stated in ENSR's EHS Policy, each employee's position description, our Best in Class EHS Initiative and Tenets, and are verified in each employee's annual review.

1.3 Organization/Responsibility

The implementation of health and safety at this project location will be the shared responsibility of the ENSR Project Manager (PM), the ENSR Regional Health and Safety Manager (RHSM), the ENSR Project Site Safety Officer (SSO) and other ENSR personnel implementing the proposed scope of work. ENSR is not hiring any subcontractors to work with us on this project.

1.3.1 ENSR Project Manager

The ENSR PM (Ken Wagner) is the individual who has the primary responsibility for ensuring the overall health and safety of this project. As such, the PM is responsible for ensuring that the requirements of this HASP are implemented. Some of the PM's specific responsibilities include:

- Assuring that all ENSR personnel to whom this HASP applies have received a copy of it;
- Verifying that all ENSR staff have the qualifications and experience to work on this program;
- Providing the RHSM with updated information regarding conditions at the site and the scope of site work;
- Providing adequate authority and resources to the on-site SSO to allow for the successful implementation of all necessary safety procedures;
- Supporting the decisions made by the SSO and RHSM; and,
- Maintaining regular communications with the SSO and, if necessary, the RHSM

1.3.2 ENSR Regional Health and Safety Manager

The ENSR RHSM (Kathleen Harvey) is the individual responsible for the preparation, interpretation and modification of this HASP. Modifications to this HASP which may result in less stringent precautions cannot be undertaken by the PM or the SSO without the approval of the RHSM. Specific duties of the RHSM include:

- Writing, approving and amending the HASP for this project;
- Advising the PM and SSO on matters relating to health and safety on this site;
- Recommending appropriate personal protective equipment (PPE) to protect personnel from potential site hazards; and,
- Maintaining regular contact with the PM and SSO to evaluate site conditions and new information which might require modifications to the HASP.

1.3.3 ENSR Site Safety Officer

All ENSR field technicians are responsible for implementing the safety requirements specified in this HASP. However, one field technician will serve as the SSO. The SSO will be appointed by the PM. The SSO will be on-site during all activities covered by this HASP. The SSO is responsible for enforcing the requirements of this HASP once work begins. The SSO has the authority to immediately correct all situations where noncompliance with this HASP is noted and to immediately stop work in cases where an immediate danger is perceived. Some of the SSO's specific responsibilities include:

- Assuring that all personnel to whom this HASP applies have submitted a completed copy of the HASP receipt and acceptance form;
- Assuring that all personnel to whom this HASP applies have attended a pre-entry briefing and any subsequent safety meetings that are conducted during the implementation of the program;
- Maintaining a high level of health and safety consciousness among employees implementing the proposed sampling activities;
- Procuring and distributing the PPE and safety equipment needed for this project for ENSR employees;
- Verifying that all PPE and health and safety equipment used by ENSR is in good working order;
- Notifying the PM of all noncompliance situations and stopping work in the event that an immediate danger situation is perceived;
- Monitoring and controlling the safety performance of ENSR personnel to ensure that required safety and health procedures are being followed;
- Conducting accident/incident investigations and preparing accident/incident investigation reports;
- Conducting the pre-entry briefing prior to beginning work and subsequent safety meetings as necessary; and,
- Initiating emergency response procedures in accordance with Section 11.0 of this HASP.

1.3.4 ENSR Field Personal

All ENSR field personnel covered by this HASP are responsible for following the health and safety procedures specified in this HASP and for performing their work in a safe and responsible manner. Some of the specific responsibilities of the field personnel are as follows:

- Reading the HASP in its entirety prior to the start of on-site work;
- Submitting a completed HASP Acceptance Form to the ENSR SSO prior to the start of work;

- Attending the required pre-entry briefing prior to beginning on-site work and any subsequent safety meetings that are conducted during the implementation of the program;
- Bringing forth any questions or concerns regarding the content of the HASP to the PM or the SSO prior to the start of work;
- Stopping work in the event that an immediate danger situation is perceived;
- Reporting all accidents, injuries and illnesses, regardless of their severity, and all near-miss incidents to the ENSR SSO; and,
- Complying with the requirements of this HASP and the requests of the SSO.

1.3.5 Subcontractors

ENSR is not hiring any subcontractors to work with us on this project.

1.4 Management of Change/Modification of the HASP

1.4.1 Management of Change

The procedures in this HASP have been developed based on the current proposed scope of work. Every effort has been made to address hazards that may be encountered during the implementation of the proposed sampling program. However, unanticipated site-specific conditions or situations may occur during the implementation of this project. Also, ENSR may elect to perform certain tasks in a manner that is different from what was originally intended due to a change in field conditions. As such, this HASP must be considered a working document that is subject to change to meet the needs of this dynamic project.

ENSR will complete a Job Hazard Analysis (JHA) when new tasks or different techniques not addressed in the HASP are proposed. The use of new techniques will be reviewed and if new hazards are associated with the proposed changes, they will be documented on the JHA form. An effective control measure must also be identified for each new hazard. JHA forms will be reviewed by the SSO prior to being implemented. Once approved, the completed forms will be reviewed with all field staff during the daily safety meeting. A blank JHA form is presented as Attachment B.

1.4.2 HASP Modification

Should significant information become available regarding potential on-site hazards, it may be necessary to modify this HASP. All proposed modifications to this HASP must be reviewed and approved by the ENSR RHSM before such modifications are implemented. Any significant modifications must be incorporated into the written document as addenda and the HASP must be reissued. The ENSR PM will ensure that all personnel covered by this HASP receive copies of all issued addenda. Sign-off forms will accompany each addendum and must be signed by all personnel covered by the addendum. Sign-off forms will be submitted to the ENSR PM. The HASP addenda should be distributed during the daily safety meeting so that they can be reviewed and discussed. Attendance forms will be collected during the meeting.

2.0 Project Description

Cedar Lake is a 781-acre, glacially formed lake located in the Town of Cedar Lake, in Lake County, Indiana. The lake was once a pristine glacial lake left by Wisconsin Age glaciers with a small watershed of intermingled prairie, savannah, woodlands and wetlands. Today, the ecosystems and habitats of the Cedar Lake subwatershed are almost completely removed, with only highly degraded and fragmented patches left. Cedar Lake has suffered from the effects of cultural eutrophication. Extremely high phosphorus and other nutrient loading over the years has enriched the sediments. Water turbidity is high, submergent macrophytes growth is non-existent, and the fishery in Cedar Lake has become insignificant.

The United States Army Corps of Engineers (USACE) is evaluating alternatives for Cedar Lake that will potentially benefit the environment by restoring, improving or protecting aquatic habitat for plants, fish, and other wildlife species. Nutrient inactivation, to reduce the amount of internal nutrient cycling, is being considered as one of the measures for implementation to improve the aquatic environment in the lake.

3.0 Scope of Work

3.1 Objective of Study

The USACE contracted with CTE/ENSR to perform preliminary alum dosage and long term effectiveness calculations for two treatment measures for Cedar Lake. Further investigation is required to determine if internal phosphorous loads in Cedar Lake can be adequately controlled long-term using nutrient inactivation. Additional treatability studies are necessary to refine the potential treatment process, in terms of treatment level (dosage) and the cost for the inactivation.

3.2 Specific Field Tasks

The specific field tasks being implemented by ENSR to meet the objectives of the study include the following:

- Using a two-person field team, access the lake, by walking across the ice and using a toboggan to carry sampling equipment, to the 10 pre-determined sediment sampling locations;
- Using a manual or gasoline-powered ice auger, drill a hole through the ice to allow access of Eckman dredge,
- Lower the Ekman dredge through the hole to collect surficial sediment sample from each of the 10 sampling locations;
- Process samples for shipment to laboratory for subsequent analyses; and,
- Rinse dredge with lake water between each sampling location.

If lake conditions change due to thawing or prolonged warm weather, samples will be collected from a 22' jon boat equipped with a gas motor. This boat will be rented from a marina at Cedar Lake and will be operated by ENSR staff who have completed a United States Coast Guard (USCG) approved boating safety course such as America's Boat Operators Course, the United States Power Squadron Boating Course or equivalent State of Massachusetts safe boat operator course which is approved by National Association of Safe Boating Law Administrators (NASBLA) and recognized by the USCG.

4.0 Chemical Hazard Assessment and Controls

4.1 Chemical Hazards

The presence of chemical contamination is not anticipated. Further, no chemical reagents or decontamination solutions are being used as part of the sediment sampling program.

It is possible that ENSR may use a gasoline-powered auger to collect samples through the ice. A 5-gallon Type II steel safety can will be used to store gasoline that is needed to refuel the auger. Extra fuel will be carried by the team to the sampling locations and will be under the team's direct control.

If lake conditions are such that a boat is needed to collect the samples, a jon boat equipped with a gasoline engine will be used. However, due to the short duration of the sampling effort, ENSR does not anticipate having to refuel the boat. If necessary, ENSR will have marina staff perform the refueling.

ENSR has a formal, written hazard communication program, the requirements of which are reviewed during the 40-hr HAZWOPER course and subsequent 8-hr HAZWOPER refresher programs. This training includes a module on the hazards of different fuels, including gasoline, that ENSR staff may encounter as site contaminants or use to fuel certain pieces of field equipment and/or machinery.

A material safety data sheet for gasoline is provided in Attachment C of this HASP. This MSDS will be present with the field team while they perform their sampling.

5.0 Physical Hazards and Controls

The general procedures in this HASP have been developed based on the scope of services and potential for the sampling to be conducted on ice or from a boat. ENSR has prepared a JSA for each task that they plan to execute during the proposed program. These JSAs are attached in Appendix D of this HASP.

While every effort has been made to address the potential hazards that may be encountered during the implementation of the proposed sampling activities, unanticipated site-specific conditions or situations may occur. JSAs will also be used to manage change in the field. ENSR may elect to perform certain tasks in a manner that is different from what was originally intended due to a change in field conditions. As such, ENSR will complete a JSA when new tasks or different techniques not addressed in the HASP are proposed. The use of new techniques will be reviewed and if new hazards are associated with the proposed changes, they will be documented on the JSA form.

5.1 Working on Frozen Lake

Cedar Lake will be accessed via Cedar Lake Park located off of Morse Street between W 137th Avenue and Constitution Avenue on the east side of Cedar Lake. The primary safety hazard associated with this sampling program is the potential for employees to fall into the lake if the ice is not thick enough to support the proposed activities. It is assumed that at the time of sampling that the ice thickness across the lake will be greater than 4 inches deep and that the potential for falling into the lake will be minimal. If that is not the case, sampling will not be conducted on the ice. If the lake is not frozen, sampling will be conducted from a boat. The hazards of boat work are presented in Section 5.5

The following procedures must be followed before going onto the frozen lake and when working on the frozen lake.

5.1.1 Assessing the Safety of the Ice

The following procedures will be implemented by the sampling team before going onto the frozen lake.

- Upon arrival to the site, ENSR will contact the local police and other emergency responders to inform them of ENSR's presence on the lake and the extent of our work, including days of sampling and expected times.
- The ENSR team will obtain air temperature records for the past several days and continue to observe air temperatures for the duration of the program. The focus will be to identify any unusual warming trends.
- When the team arrives to Cedar Lake Park, they will proceed to the lake's edge to visually survey the ice. The team should look for open water areas, and signs of recent changes in water levels. This includes ice sloping down from the bank because the water dropped, or wet areas on the ice because the water rose and flooded areas of the ice that couldn't float because it was frozen to the bottom or the banks. If the ice is snow-covered, look for wet areas in the snow.
- The team will identify an easy point of access to the ice, free of cracks or piled, broken ice.
- Any recent large snowstorm creates a new load on the ice. If the new snow is heavy enough, the ice sheet could sag and its top surface will be submerged below the water level. Then water will flood the top of the ice sheet through cracks, saturating the lower layers of the snow. Until this slush is completely frozen, *stay off* the ice sheet. When the saturated snow becomes frozen, it is an added thickness of white ice.

- A rapid, large air temperature drop can make an ice sheet *brittle*, and the ice *may not be safe* to use for 24 hours or more. Any change of 25 degrees F or greater on a single day will be cause to delay sampling.
- Many state Game and Fish Departments recommend the following minimums for travel on clear- blue lake ice formed under ideal conditions. **It is recommended that the ice be four inches thick for a group of people walking single file. ENSR will verify this thickness using the ice auger.** Before taking the equipment on the ice, the team will go out on foot first to verify ice thickness. **If ice thickness does not meet the 4 inch minimum criteria, work will be postponed.**

5.1.2 Procedures when Working on the Frozen Lake

After it has been determined that the ice is safe to work on (i.e. above criteria is met), the following procedures will be followed.

- No ENSR employee will work on the lake alone. A two-person team will be used at all times while ENSR employees are working on the lake.
- ENSR will have the ability to contact a local third-party by cell phone. This third-party will serve as the check-in for the team. The team will contact this person upon arrival to the site, at lunch and upon leaving the site for the day.
- Employees will not work on the lake before sunrise or after sunset. Preferably, staff will be off the lake at least 1/2hour before sunset.
- The team should keep a good distance apart from each other as they walk out onto the ice. If one team member falls into the water, the other can call for help. All staff working on the ice will be equipped with an ice rescue pick as further described in Section 6.3 of this plan.
- Too many people congregated in one area may be more than the ice can safely support. It is important to disperse the weight of personnel and equipment at each sampling station. Therefore, one ENSR person will be working in the immediate vicinity of the sampling location. The second ENSR person will stand approximately 20 feet away from the work area. Extra equipment will also be located 20 feet away from the hole. Further, the samples will be processed away from the hole as well.

5.2 Frozen Lake Traffic – Snowmobilers and Ice-Fishermen

It is very likely that many people use the frozen lake including ice-fishermen and snowmobilers. Snowmobiles can move very quickly. ENSR staff must keep track of their gear and must not leave any debris on the ice that may interfere with other people enjoying the lake.

Further, don't assume that the snowmobile heading your way can see you. Many lakes and ponds have established trails that lead across the ice in winter. To the extent feasible, the ENSR team should set up their sampling stations out of the main drag. Wearing a bright orange traffic safety vest or a PFD on the outside of your clothing will make you more visible to snowmobilers as well.

If, upon arrival to the lake, the ENSR team observes heavy lake traffic, each work area will be cordoned off with a set of traffic cones. Place the cones at least 25-50 feet in front of and behind the work area so snowmobilers have enough time to react to your presence on the ice and avoid the work area.

5.3 Safe Use of Ice Auger

ENSR will either use a manual or gasoline-powered ice auger to cut through the ice and collect the required samples. The auger blades are razor-sharp and to work effectively, they should be kept that way. However,

this presents a potential hazard for the team. The following safety procedures will be implemented when using an ice auger.

- Employees must be very aware of this hazard when working around the blade-end of the auger. The auger should be handled by the T-bar and not the auger end to avoid being cut.
- When not in use, the team will keep the ice auger covered.
- Employees must be especially careful when removing the blade cover. If the auger slips while you are trying to remove the cover, injury can occur. To help keep a firm grip on the auger, the team will be using waterproof, neoprene gloves with textured palms and fingers.
- When using an ice auger, adjust the handle as needed for operation. It is recommended that you affix a short strap around the ice auger's handle. Attach it to your person, or wrap it carefully around your hand. This will prevent the auger from slipping down through the hole and into the lake.
- When opening a hole, stand the ice auger upright, placing the tip at the center point where you want the hole cut through the ice. Hold it firmly in place while cranking the handle clockwise. The tip should begin carving through the ice.
- Speed up as the tip digs into place. Continue cranking the handle, pushing down on the auger slightly for traction, until you've completed an ice hole.

When using a power auger,

- Powered ice augers are heavy, and difficult to drag around. Therefore, the field team should have a sled with them to transport the auger across the ice.
- The rotating auger can not be shielded so it is extremely important that employees maintain a distance to prevent worker contact with moving machine parts.
- One person should hold the auger upright while the other person starts the machine
- When using a power auger, leave the auger upright in the hole when you need to rest. Prevent the machine from lying on its side, as the spark plug may foul or the gas may leak out through the gas cap.

5.4 Gasoline Storage for Powered Auger

A Type II galvanized steel safety can is recommended for storing gasoline that will be used to refuel the power auger. Storage in anything other than an approved container is strictly prohibited.

5.5 Slips, Trips and Fall Hazards Due to Ice

Walking across the frozen lake presents a potential but significant slip, trip and fall hazard to the sediment sampling team. It is recommended that employees walking across the lake attach ice traction devices, such as YakTrax™ over their insulated boots. Using these devices will provide the team with increased traction when walking over the ice.

Employees will keep all unnecessary equipment out of the way when collecting the samples to avoid tripping over it.

The team must also be aware of ice fishing holes that may be present across the lake.

5.6 Working on Open Water

If lake conditions change due to thawing or prolonged warm weather, samples will be collected from a 22' jon boat equipped with a gas motor. This boat will be rented from a marina at Cedar Lake and will be operated by ENSR staff who have completed a United States Coast Guard (USCG) approved boating safety course such

as America's Boat Operators Course, the United States Power Squadron Boating Course or equivalent state safe boat operator course.

Working on boats and in the water has many risks to employees. Potential hazards include collisions with other craft or obstacles, embarking and disembarking accidents, drowning, hypothermia, weather-related incidents and difficult communications. Minimizing the potential for these hazards is addressed in the boat safety information presented below.

5.6.1 Boat Inspection

Before the boat is placed in service, it will be inspected and determined to be in safe operating condition before use. This inspection will be completed by marina personnel and the ENSR boat operator. A pre-use inspection of the watercraft must also be performed by the ENSR operator before each daily use. Watercraft found in an unsafe condition shall be taken out of service and its use prohibited until unsafe conditions have been corrected.

5.6.2 Boat Registration

All watercraft must meet USCG or state watercraft registration and numbering requirements. The US Coast Guard requires that all motorized watercraft be numbered in the state of principal use. A valid certificate showing the numbers issued to the watercraft is required to be on board the watercraft whenever the watercraft is in use. Watercraft registration numbers are required to be painted or permanently attached to each side of the forward half of the watercraft. Watercraft registration must be updated as the governing laws require.

ENSR must verify that any non-ENSR owned/operated boat they are working on is property registered and numbered.

5.6.3 Boat Capacity

Small watercraft shall not be loaded (passengers and gear) beyond the weight capacity printed on the USCG information plate attached to the stern. If there is no capacity label, use the following formula to determine the safe loading capacity:

- # People = (length of boat x width) ÷ 15

Watercraft shall have sufficient room, freeboard, and stability to safely carry the cargo and number of passengers allowed with consideration given to the weather, and water conditions in which it will be operated. Once on board, distribute the load (people and equipment) evenly and secure all equipment to prevent it from shifting.

5.6.4 Personal Flotation Devices

ENSR employees on the boat will be required to wear a USCG-approved Type III personal flotation device (PFD) or a Type V work vest. PFDs will also be worn while transferring from boat to shore. All PFDs must be inspected before use. Any defective PFDs must be placed out of service and replaced.

In situations where the water temperature has fallen below 50°F, a USCG approved Mustang flotation suit shall be worn.

5.6.5 Safe Boating Procedures

The following safe work practices are to be followed:

- Prior to leaving shore, a plan of the day's activities, including time and place of departure, anticipated return time and list of employees working on the project should be left with the PM in case of an emergency.
- All ENSR personnel working on boat(s) that are owned/operated by others are to be informed of the locations of all safety equipment on the boat, including first-aid kit, fire extinguishers and throw-ring, as applicable to the specific boat being used.
- All sampling should be conducted from a seated or otherwise stable position. **Do not stand in the boat.**
- Once on board, distribute the load (people and equipment) evenly and secure all equipment to prevent it from shifting.
- Samples shall be collected from the bow or stern of the boat (not over the sides) to ensure stability.

5.6.6 Marine Safety Meeting

Prior to the start of field operations, the ENSR operator will conduct a mandatory all-hands marine safety briefing. All visitors and/or personnel coming aboard after the fact shall also be briefed immediately upon coming aboard the boat. The marine safety briefing shall cover the following:

- General layout of the boat.
- Planned operational procedures and the potential hazards that may be encountered.
- The location of emergency equipment including work vests, ring buoys, fire extinguishers, first aid kits, and emergency communications equipment. The proper use of marine radios, fire extinguishers, and ring buoys shall be discussed.
- Individual responsibilities and procedures for managing emergency situations such as on-board fire, medical emergencies, and man overboard scenarios.
- All personnel will be advised of the inherent risks of prolonged exposure to the elements; the importance of adequate hydration and the proper use of sunscreen will be mentioned.

5.6.7 Use of Buddy System

No ENSR employee will work on the water alone. A two-person team will be used at all times while ENSR employees are working on the water.

5.6.8 Slips, Trips and Fall Hazards due to Slippery Boat Deck

Due to the nature of the work being performed, it is inevitable that the boat walking surfaces will become wet. This presents a potential slip, trip and fall hazard to the team. To the extent possible, accumulated water should be removed from walking surfaces. Additionally, slip-proof matting can be placed in those areas where the most activity is taking place. All employees working on the boat should be wearing non-slip footwear.

Decks and open spaces must be kept clear and free from clutter and trash to minimize slip, trip, and fall hazards.

Safe means for boarding or leaving the boat shall be provided and guarded to prevent persons from falling or slipping thereon. Personnel exiting the boat will do so in shallow water, over a sandy substrate, placing at least one hand on the gunnel to maximize stability until both feet are on the ground.

5.7 Back Safety

To avoid potential for back injury as well as the potential for slipping or tripping while carrying objects in their hands, the field team will be using a toboggan to transport the sampling equipment from the shore out onto the ice. This is especially important if a powered ice auger is used as they are heavy and difficult to drag around. Therefore, the field team should have a sled with them to transport the auger across the ice

Using the proper techniques to lift and move the sampling equipment at each sampling location is also important to reduce the potential for back injury. The following precautions should be implemented when lifting or moving heavy objects:

- Use the buddy lift whenever necessary.
- Bend at the knees, not the waist. Let your legs do the lifting.
- Do not twist while lifting
- Bring the load as close to you as possible before lifting
- Be sure the path you are taking while carrying a heavy object is free of obstructions and slip, trip and fall hazards

5.8 Cold Stress

Work is being conducted during late March. Therefore, the hazards of cold stress are addressed in this plan.

Types of Cold Stress

Cold injury is classified as either localized, as in frostbite, frostnip or chilblain; or generalized, as in hypothermia. The main factors contributing to cold injury are exposure to humidity and high winds, contact with wetness and inadequate clothing.

The likelihood of developing frostbite occurs when the face or extremities are exposed to a cold wind in addition to cold temperatures. The freezing point of the skin is about 30° F. When fluids around the cells of the body tissue freeze, skin turns white. This freezing is due to exposure to extremely low temperatures. As wind velocity increases, heat loss is greater and frostbite will occur more rapidly.

Symptoms of Cold Stress

The first symptom of frostbite is usually an uncomfortable sensation of coldness, followed by numbness. There may be a tingling, stinging or aching feeling in the effected area. The most vulnerable parts of the body are the nose, cheeks, ears, fingers and toes.

Symptoms of hypothermia, a condition of abnormally low body temperature, include uncontrollable shivering and sensations of cold. The heartbeat slows and may become irregular, the pulse weakens and the blood pressure changes. Pain in the extremities and severe shivering can be the first warning of dangerous exposure to cold.

Maximum severe shivering develops when the body temperature has fallen to 95° F. Productive physical and mental work is limited when severe shivering occurs. Shivering is a serious sign of danger. Immediately remove any person who is shivering from the cold.

Methods to Prevent Cold Stress

When the ambient temperature, or a wind chill equivalent, falls to below 40° F (American Conference of Governmental Industrial Hygienists recommendation), site personnel who must remain outdoors should wear

insulated coveralls, insulated boot liners, hard hat helmet liners and insulated hand protection. Wool mittens are more efficient insulators than gloves. Keeping the head covered is very important, since 40% of body heat can be lost when the head is exposed. If it is not necessary to wear a hard hat, a wool knit cap provides the best head protection. A facemask may also be worn.

Persons should dress in several layers rather than one single heavy outer garment. The outer piece of clothing should ideally be wind and waterproof. Clothing made of thin cotton fabric or synthetic fabrics such as polypropylene is ideal since it helps to evaporate sweat. Polypropylene is best at wicking away moisture while still retaining its insulating properties. Loosely fitting clothing also aids in sweat evaporation. Denim is not a good protective fabric. It is loosely woven which allows moisture to penetrate. Socks with a high wool content are best. If two pairs of socks are worn, the inner sock should be smaller and made of cotton, polypropylene or similar types of synthetic material that wick away moisture. If clothing becomes wet, it should be taken off immediately and a dry set of clothing put on.

If wind conditions become severe, it may become necessary to shield the work area temporarily. The SSO and the PM will determine if this type of action is necessary. Heated break trailers or a designated area that is heated should be available if work is performed continuously in the cold at temperatures, or equivalent wind chill temperatures, of 20° F.

Dehydration occurs in the cold environment and may increase the susceptibility of the worker to cold injury due to significant change in blood flow to the extremities. Drink plenty of fluids, but limit the intake of caffeine.

5.9 Severe Winter Weather

Work will not be conducted if air temperatures are less than 20 degrees F, and wind speeds exceed 20 miles per hour.

6.0 Personal Protective Equipment

6.1 PPE Assessments

ENSR's Regional Health and Safety Manager for this project has reviewed the proposed tasks and has completed personal protective equipment (PPE) assessments for each task. PPE, as described below, will be worn during these activities to prevent on-site personnel from being injured by the safety hazards posed by the site and/or the activities being performed.

By participating in OSHA's 40-hr HAZWOPER safety training, as well as subsequent 8-hr HAZWOPER refresher courses, each employee who is required to wear PPE for this field program has been properly instructed as to how to inspect and maintain their safety gear. Prior to mobilizing to the site, each employee will inspect their safety gear. Any equipment that is defective, such as scratched safety glasses or defective personal flotation devices will be replaced. Sampling gloves will be inspected by each wearer for holes, rips and tears. Defective clothing will be thrown away.

6.2 Cold Weather Gear

The field team should choose clothing that provides protection from low air temperatures, wind, and precipitation while at the same time allowing mobility. Employees walking across the lake will attach ice traction devices, such as YakTrax™ over their insulated boots. Using these devices will provide the team with increased traction when walking over the ice.

In addition, employees should keep in mind the possibility of falling through the ice. Clothing that would severely restrict the ability to swim or to stay afloat is not a good choice. As an example, hip boots or waders should never be worn, as they can fill with water and restrict movement while adding weight.

Each member of the sampling team must bring an extra set of dry clothing in their day packs. Wet clothing, especially gloves, must be changed often to prevent frostbite. Although the team will be using waterproof, neoprene gloves with textured palms and fingers, extra pairs must still be available.

6.3 Personal Flotation Device

When working on the frozen ice or from a boat, a personal flotation device (PFD) will be worn. This can be a US Coast Guard approved Type V work vest or a Type III life jacket. In situations where the water temperature has fallen below 50°F, a USCG approved Mustang flotation suit shall be worn. Training for using this type of PPE is included in ENSR's Marine Safety Training program as well as the USCG safe boating courses.

6.4 Respiratory Protection

Respiratory protection is not required for this program as there are no chemical hazards associated with the program.

6.5 Other Safety Equipment

The following additional safety items should be available:

- Portable, hand-held eyewash bottles
- First aid kit

- Potable Water for drinking and washing
- Portable phones
- NOAA weather radio

6.6 Rescue Equipment for Working on Frozen Lake

In addition to the PFD, a rope or rescue throw bag containing a rope that floats will be brought onto the lake by the sampling team. Another option is for the team to tie a rope to the toboggan.

Each employee will also carry an ice rescue pick, similar to those sold for ice fishermen. Be sure they have wooden handles so if you drop them in the struggle to get out of the water, they won't go straight to the bottom! The picks thread through your jacket sleeves like children's mittens and are immediately available in an emergency for pulling yourself out of the water onto the ice.

7.0 Site Control/Decontamination

7.1 Site Control on Frozen Lake

As discussed previously, it is very likely that many people will be using the frozen lake including ice-fishermen and snowmobilers. ENSR staff should not assume that the snowmobile heading their way can see them. Many lakes and ponds have established trails that lead across the ice in winter. To the extent feasible, the ENSR team should set up their sampling stations out of the main drag. Wearing a bright orange traffic safety vest or a PFD on the outside of your clothing will make you more visible to snowmobilers as well. However, if upon arrival to the lake, the ENSR team observes heavy lake traffic, each work area will be cordoned off with a set of traffic cones. The cones will be placed at least 25-50 feet in front of and behind the work area so snowmobilers have enough time to react to your presence on the ice and avoid the work area.

7.2 Site Control for Open Water Work

Site control is not necessary if the sampling is being conducted from a boat.

7.3 General Site Safety Practices

The following measures are designed to augment the specific health and safety guidelines provided in this plan.

- The "buddy system" will be used at all times by all field personnel. No one is to perform field work alone. Standby team member must be intimately familiar with the procedures for initiating an emergency response.
- Hands and face must be thoroughly washed upon leaving the work area and before eating, drinking or any other activities.
- The use of alcohol or illicit drugs is prohibited during the conduct of field operations.
- All equipment must be decontaminated or properly discarded before leaving the site.

7.4 Hand Washing

As a minimum, a container of potable water and liquid soap should be made available on the toboggan so employees can wash their hands before leaving the site for lunch or for the day. Employees should always wash their face and hands with soap and water before eating.

8.0 Training Requirements

8.1 General Training

All staff assigned to this program must be able to swim, or at least being comfortable staying afloat.

8.2 First Aid Training

At least one member of the ENSR sampling team must be currently certified in CPR and First Aid. The two team members currently proposed for this sampling effort are both current with this training.

8.3 Boat Operator

Only ENSR staff who have completed a United States Coast Guard (USCG) approved boating safety course such as America's Boat Operators Course, the United States Power Squadron Boating Course or equivalent State of Massachusetts safe boat operator course which is approved by National Association of Safe Boating Law Administrators (NASBLA) and recognized by the USCG. Watercraft operators shall also possess basic mechanical knowledge necessary to troubleshoot common mechanical problems that may occur. The watercraft operator shall be responsible for the safety of all personnel on board the watercraft he or she is operating and for the integrity of all watercraft and safety equipment

8.4 Pre-Entry Briefing

Prior to the commencement of on-site activities, a pre-entry briefing will be conducted by the SSO to review the specific requirements of this HASP. Attendance of the pre-entry meeting is mandatory for all personnel covered by this HASP and must be documented on the attendance form provided in Attachment D.. HASP sign-off sheets should also be collected at the time of the pre-entry briefing. All documentation should be maintained in the project file.

The pre-entry briefing must be completed for each new employee before they begin work at the site. Short safety refresher meetings will be conducted, as needed, throughout the duration of the project. Specific topics that will be discussed during the pre-entry briefing include:

- Discussion of work scope
- Discussion of the potential physical hazards associated with implementing scope of work
- Determining safe ice conditions
- Reviewing procedures for using ice auger
- Reviewing safe boating and emergency response procedures
- Completing and implementing float plan
- Review of PPE requirements
- Review of emergency procedures highlighting ice rescue and hospital location/directions

8.5 Daily Safety Meetings for Frozen Lake Work

The sampling is expected to be completed in one day. However, if multiple days of sampling are needed, a daily safety briefing will be conducted prior to accessing the lake.

8.6 Daily Float Plan

Prior to leaving shore, a plan of the day's activities, including time and place of departure, anticipated return time, vessel information, communications information such as number of the cell phones for each on-board employee and list of employees working on the project should be left with the ENSR PM in case of an emergency.

If the PM does not receive a call from the ENSR team indicating that they are off the water within ½ hr of the estimated time of return, the PM will contact the team. If the team does not respond, the PM will contact 9-1-1 to initiate emergency response.

8.7 Project Safety Inspections/Audits

This project is expected to be completed over the course of 1-3 days. As such, formal safety inspections, outside of verifying equipment condition, are not being conducted.

9.0 Emergency Response

The two most likely emergencies that may arise during the implementation of this program are a medical emergency or the need to perform ice rescue as a result of someone falling through the ice. Below are the procedures that will be implemented in the event either of these emergencies occurs.

9.1 Medical Situations

9.1.1 Non-Emergency

If an employee is not seriously injured but requires immediate medical attention, the employee should be transported to the Emergency Room of St. Anthony Medical Center located at 1201 South Main Street in Crown Point, Indiana. Directions to the hospital from Cedar Lake Park are located on the Emergency Response Sheet of this section of the HASP.

For all cases requiring immediate medical attention, someone should accompany the injured employee to the hospital. This individual will normally be the employee providing the transportation. Once at the hospital, he/she should remain with the injured employee to provide information to the clinic, to monitor the employee's status, to phone back to the project manager, and to transport the employee back to the site after being treated and released. If the injury turns out to be serious enough to require hospitalization, he/she should remain with the injured employee until they have been admitted to the hospital.

If the incident is minor and only requires first aid attention, the SSO or other properly trained on-site employees will administer first aid. A portable eye wash station and first aid kit will be brought out onto the ice and will be available at each sampling station.

9.1.2 Medical Emergency

In a life-threatening medical emergency, such as chest pain, stroke-like symptoms, unconsciousness, severe and uncontrolled bleeding or seizure,

- **CALL 911 immediately.** Be clear to explain that you are working on the ice and provide as explicit instructions as possible as to your location on the ice. If possible, enlist the help of another person on the ice and ask them to meet the ambulance at the shore and escort them to your work area
- After calling 911, notify the PM immediately. The PM will then contact the RHSM.
- The PM will also contact the client project representative.

The Emergency Contact List is included on the Emergency Reference Sheet at the end of this section of the HASP. This list must be brought out onto the ice to ensure that immediate contact with local emergency responders can be initiated.

9.2 Ice Rescue

Upon arrival to the site, ENSR will contact the local police and other emergency responders to inform them of ENSR's presence on the lake and the extent of our work. If someone does fall through the ice, regardless of whether self-rescue or assisted rescue can be performed,

CALL 911 first. Be clear to explain that you are working on the ice and provide as explicit instructions as possible as to your location on the ice. If possible, enlist the help of another person on the ice and ask them to meet the ambulance at the shore and escort them to your work area

Employees will be equipped with ice rescue picks. The picks thread through your jacket sleeves like children's mittens and are immediately available in an emergency for pulling yourself out of the water onto the ice.

If you can not spike your way out, the other member of the team will attempt to reach the victim with the rope from the toboggan. If that isn't possible, throw the victim a life jacket, empty water jug or other buoyant object.

The ENSR spotter will go to the victim as the last resort. Should this be necessary, the rescuer will lie on the ice and attempt to pull the victim up and out of the water.

Once the employee spikes their way out or is pulled out of the water, they should not stand. They should roll across the ice.

The employee may need to be treated for hypothermia. Remove wet clothing and replace it with dry clothing as soon as possible and immediately transport the victim to a hospital.

9.3 Boat Emergency

9.3.1 Communications

For this program, each member of the two-person sampling team will have a cellular phone to contact the Project Manager as necessary and/or local emergency responders in the event that an ambulance is needed due to a medical emergency or other on-water emergency. The phone numbers of the police and fire departments, ambulance service, local hospital, and ENSR representatives are provided in the emergency reference sheet. This sheet will be posted in the boat.

9.3.2 Medical Emergency

Both members of the proposed field team are currently trained in first aid and CPR. In the event of a medical emergency, the team will contact local emergency responders and request their assistance at the Cedar Lake marina/boat launch area. The boat operator will transport the injured/ill employee to the launch area.

If the injury or illness requires more than first aid treatment, the SSO will accompany the injured person to the medical facility and will remain with the person until release or admittance is determined. The escort will relay all appropriate medical information to the on-site project manager and the RHSM.

9.3.3 Fire

The jon boat is equipped with a gasoline engine. As such, ENSR team members must determine the location of the fire extinguisher on board and be prepared to use it in the event of an on-board fire.

Most boat fires can be put out rapidly if you act immediately. Do not hesitate. If a fire starts, grab the extinguisher, activate it and direct it at the base of the flames. Use short bursts and sweep it from side to side. Do not wait until a fire starts to read the directions on the label. Take the time to make sure that you and those who boat with you regularly know and understand exactly how to use the fire extinguisher.

When extinguishing the fire, make sure it is completely out. If not, it may smolder for a long while and possibly start again. If possible, soak burning materials over the downwind side of the boat.

Follow these steps if fire breaks out while you are underway in order to prevent the fire from spreading to other parts of the boat:

- Slow or stop the boat. Wind from the boat's motion feeds the flames.
- Keep the fire downwind. If the fire is aft, head the bow into the wind. If forward, put the stern into the wind.
- If the motor catches fire, shut off the fuel supply immediately.

If you realize that the fire cannot be put out with the fire extinguisher, put on your life jacket and exit the boat upwind of the burning craft. Use a radio, cellular phone, or visual distress signals to gain assistance.

9.3.4 Taking on Water/Capsizing

If the boat capsizes or is taking on water, call for emergency assistance and make sure all employees **stay with the boat**. Boats 25 feet or under and built after 1973 must have flotation built in so they should float even if full of water. It's much easier to spot a boat than someone floating alone in the water. Don't try and swim to shore or swim to keep warm. Swimming burns up energy and regardless how warm the water is if you expend all your energy swimming you're likely to succumb to the effects of hypothermia sooner.

9.3.5 Abandoning Ship

You should only abandon ship when the water is a better place to be than the boat such as in the event of a fire that can not be extinguished or the boat is headed in the direction of another hazard.

9.3.6 Man Overboard

The first thing you want to do in a man overboard (MOB) situation is to stop the forward progress of the boat. Next, turn the boat towards the side that the person fell over and post a look out so that at least one person is responsible for keeping in visual contact with the MOB. The next thing to do is take anything that floats and throw it overboard. It gives the person in the water something to float on and it creates a visible floating debris slick which will help you or someone else locate the MOB should you lose visual contact with them. If you have the MOB in site, the best thing to do is make a big oval to get back to where the MOB is and pick them up. Do not back up the boat.

Never have anyone go into the water. They will just be another person that needs to be rescued. If someone needs to go over to help a weak or injured person, make sure they have flotation and a lifeline secured to them.

9.4 Accident Reporting and Investigation

Any incident resulting in injury, illness or property damage requires an accident investigation and report. The investigation should be conducted as soon as emergency conditions are under control. The purpose of the investigation is not to attribute blame but to determine the pertinent facts so that repeat or similar occurrences can be avoided. An ENSR accident investigation form is presented in Attachment E of this HASP. The injured ENSR employee's supervisor and the RHSM should be notified immediately of the injury.

9.5 USACE Reporting Requirements

ENSR will investigate all accidents and near misses. All work-related, OSHA-recordable injuries and illnesses and property damage accidents (excluding on-the-road vehicle accidents), in which property damage exceeds \$2,000 shall be verbally reported to the COR within 48 hours of the incident. USACE ENG Form 3394 shall be completed and submitted to the NAE Safety Manager within six working days of the incident.

9.6 Near Miss and HSE Observation Reporting

9.6.1 Near Miss

A *Near Miss Incident* is defined as any undesired event that, under slightly different circumstances (e.g., timing, distance, chance, etc.) could have resulted in personal harm, property damage, an environmental release or any undesired loss of resources. In other words, a *Near Miss Incident* is a situation in which an accident almost occurred. The purpose of reporting, and following up on, Near Miss Incidents is the same as that for incidents that result in injuries, illnesses, property damage or environmental releases: to prevent their reoccurrence. By reporting and following up on Near Miss Incidents, thereby theoretically reducing their frequency, corporations can reduce the frequency of more serious accidents and incidents. All Near Miss Incidents be reported as soon as possible after their occurrence using the process described below.

9.6.2 HSE Observation

Situations in which a hazard is identified and corrected before an incident occurs do not necessarily meet the definition of a *Near Miss Incident* and are referred to as *HSE Observations*. Reporting and following up on *HSE Observations* can also provide opportunities for learning and improvement in the same manner as reporting and following up on *Near Miss Incidents*. Therefore, all HSE observations will also be reported.

To facilitate reporting during this project, Near Miss and HSE Observation report pads have been created. Pads will be handed out to field staff during the project kick-off meeting. All reports will be submitted to the SSO for review and discussion during the follow day's safety meeting.

EMERGENCY REFERENCES

Ambulance: 911

Fire: 911

Police: 911

Medical Services: 219-738-2100

St. Anthony Medical Center

1201 South Main St

Crown Point, Indiana

Directions	Distance
Total Est. Time: 12 minutes Total Est. Distance: 4.43 miles	
 1: Start out going EAST on W 137TH AVE toward MORSE ST.	<0.1 miles
 2: Turn LEFT onto MORSE ST.	0.5 miles
 3: Turn RIGHT onto W 133RD AVE.	1.5 miles
 4: Turn SLIGHT LEFT onto CEDAR LAKE RD.	1.9 miles
 5: Turn RIGHT onto W 121ST AVE / W FRANCISCAN DR.	0.2 miles
 6: Turn RIGHT onto S MAIN ST.	0.1 miles
 7: End at 1201 S Main St Crown Point, IN 46307-8481, US	

On Site Telephone: Bring portable communications.

ENSR Project Representatives:

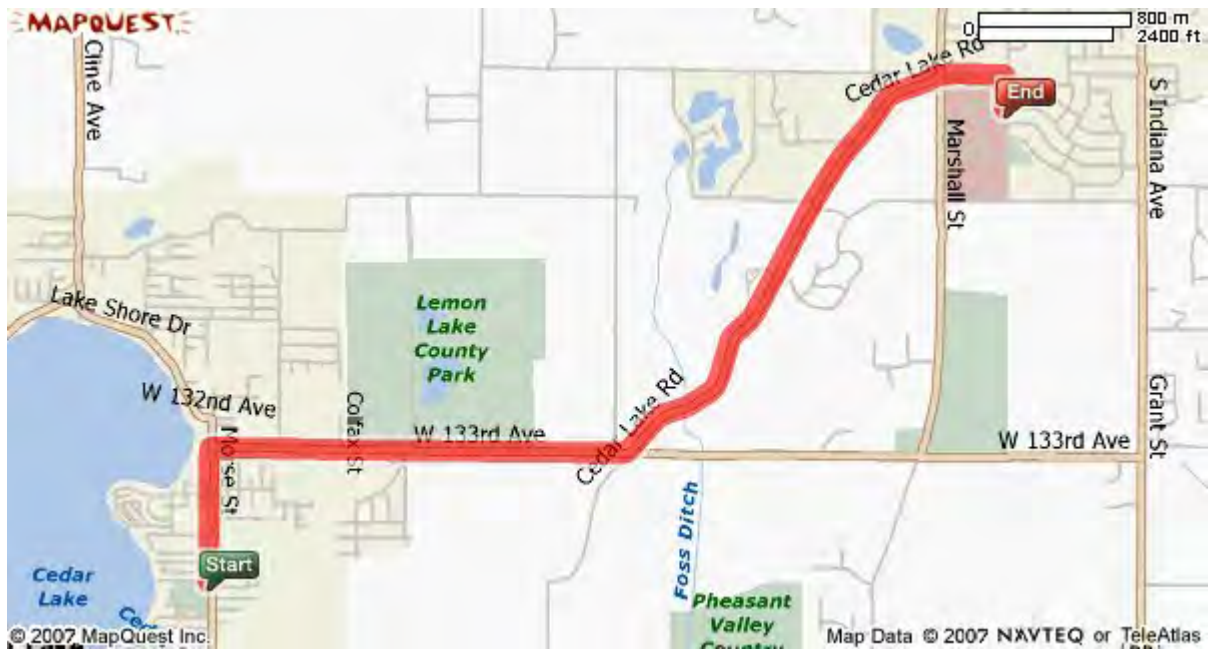
ENSR/Westford, MA (978) 589-3000

-Kathy Harvey (RHSM) x 3325

ENSR/Willington, CT 860-429-5323

-Ken Wagner (PM) x 222 or 508-612-5799

Map from Access Point at Cedar Lake Park
(off Morse St between W 137th Ave and Constitution Ave)
To
St. Anthony Medical Center
1201 South Main St – Crown Point



Attachment A

Health and Safety Plan Receipt and Acceptance Form

Health and Safety Plan Receipt and Acceptance Form

Cedar Lake Aluminum Treatment Study

Cedar Lake

Cedar Lake, Lake County, Indiana

I have received a copy of the Health and Safety Plan prepared for the above-referenced site and activities. I have read and understood its contents and I agree that I will abide by its requirements.

Name: _____

Signature: _____

Date: _____

Representing: _____

Attachment B

Job Hazard Analysis Form

Job Safety Analysis

JSA Type: <input type="checkbox"/> Investigation <input type="checkbox"/> O&M <input type="checkbox"/> Office <input type="checkbox"/> Construction <input type="checkbox"/> Other				<input type="checkbox"/> New <input type="checkbox"/> Revised		Date:		
Work Activity:								
Personal Protective Equipment (PPE): _____								
Development Team		Position/Title		Reviewed By		Position/Title		Date
① Job Steps¹		② Potential Hazards²		③ Critical Actions³		 Stop Work Criteria		
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1 – Target number of job steps: six to ten

2 – Codes for Potential Hazards:

Caught Between (CBT)	Contacted By (CB)	Caught On (CO)	Fall To Below (FB)	Overexertion (O)	Struck Against (SA)
Caught In (CI)	Contact With (CW)	Exposure (E)	Fall - Same Level (FS)	Release To (R)	Struck By (SB)

3 – Types of Critical Actions: Elimination, Engineering Controls, Safe Work Practice / SOP, Administrative Controls, and/or PPE.

4 – Stop Work Trigger: Condition or situation that would require work to be stopped and hazards re-assessed.

Attachment C

Material Safety Data Sheet for Gasoline



CITGO Gasolines, All Grades Unleaded Material Safety Data Sheet

CITGO Petroleum Corporation
P.O. Box 4689
Houston, TX 77210

MSDS No. UNLEAD
Revision Date 05/23/2005

IMPORTANT: Read this MSDS before handling or disposing of this product and pass this information on to employees, customers and users of this product.

Hazard Rankings		
	HMIS	NFPA
Health Hazard	* 2	1
Fire Hazard	3	3
Reactivity	0	0

* = Chronic Health Hazard

Emergency Overview			
Physical State	Liquid.		
Color	Transparent, clear to amber or red.	Odor	Pungent, characteristic gasoline.
DANGER:			
Extremely flammable liquid; vapor may cause flash fire or explosion.			
Vapor may travel considerable distance to source of ignition and flash back.			
Use Only as a Motor Fuel. Do Not Siphon by Mouth.			
Harmful or fatal if swallowed - Can enter lungs and cause damage.			
High concentrations of vapor reduce oxygen available for breathing and may cause suffocation.			
May be harmful if inhaled or absorbed through the skin.			
Mist or vapor may irritate the eyes, mucous membranes, and respiratory tract.			
Liquid contact may cause eye and skin irritation.			
Overexposures may cause central nervous system (CNS) depression and target organ effects (See Section 3).			
Harmful or fatal if swallowed - Can enter lung and cause damage.			
Inhalation overexposure can increase the heart's susceptibility to arrhythmias (irregular beats).			
Contains Benzene - Cancer Hazard.			
Long term exposure to gasoline vapor has caused cancer in laboratory animals.			
Avoid Spills. Spills may present both a physical and an environmental hazard.			

Protective Equipment
Minimum Recommended See Section 8 for Details

SECTION 1. PRODUCT IDENTIFICATION

Trade Name	CITGO Gasolines, All Grades Unleaded	Technical Contact	(800) 248-4684
Product Number	Various	Medical Emergency	(832) 486-4700
CAS Number	Mixture.	CHEMTREC Emergency (United States Only)	(800) 424-9300

MSDS No. UNLEAD Revision Date 05/23/2005 Continued on Next Page Page Number: 1

CITGO Gasolines, All Grades Unleaded

Product Family Motor fuels.
Synonyms Unleaded Gasolines; Motor Gasolines; Petrol; Automobile Motor Fuels; Finished Gasolines; Gasoline, Regular Unleaded; Gasoline, Mid-grade Unleaded; Gasoline, Premium Unleaded; Reformulated Gasolines (RFG); Reformulated Motor Fuels; Oxygenated Motor Spirits; Gasoline, Regular Reformulated; Gasoline, Mid-grade Reformulated; Gasoline, Premium Reformulated.

SECTION 2. COMPOSITION

Gasoline is a complex and variable mixture that originates from finished refinery streams. These streams can contain the hydrocarbons and oxygenated chemicals (oxygenates) listed below that are regulated or are associated with certain potential health effects. The typical concentration of oxygenates in gasoline does not exceed 18% (v/v).

Component Name(s)	CAS Registry No.	Concentration (%)
Methyl tertiary-Butyl Ether (MTBE)	1634-04-4	0 - 15
Tertiary-Amyl Methyl Ether (TAME)	994-05-8	0 - 15
Ethyl tertiary Butyl Ether (ETBE)	637-92-3	0 - 15
Tertiary-Amyl Ethyl Ether (TAEE)	919-94-8	0 - 15
Diisopropyl Ether (DIPE)	108-20-3	0 - 15
Ethanol	64-17-5	0 - 10
Toluene	108-88-3	<20
Xylene, all isomers	1330-20-7	<18
n-Hexane	110-54-3	<8
Trimethylbenzenes, all isomers	25551-13-7	<5
Benzene	71-43-2	<5
Cumene	98-82-8	<4
Ethylbenzene	100-41-4	<4
Cyclohexane	110-82-7	<3
Naphthalene	91-20-3	<2
Styrene	100-42-5	<1

SECTION 3. HAZARDS IDENTIFICATION

Also see **Emergency Overview and Hazard Ratings on the top of Page 1 of this MSDS.**

Major Route(s) of Entry Skin contact. Eye contact. Inhalation. Ingestion.

Signs and Symptoms of Acute Exposure

Inhalation Breathing high concentrations may be harmful. Mist or vapor can irritate the throat and lungs. Breathing this material may cause central nervous system depression with symptoms including nausea, headache, dizziness, fatigue, drowsiness, or unconsciousness. Breathing high concentrations of this material, for example, in an enclosed space or by intentional abuse, can cause irregular heartbeats which can cause death.

Eye Contact This product can cause eye irritation with short-term contact with liquid, mists or vapor. Symptoms include stinging, watering, redness, and swelling. In severe cases, permanent eye damage can result.

Skin Contact This material can cause skin irritation. The severity of irritation will depend on the amount of material that is applied to the skin and the speed and thoroughness that it is removed. It is likely that some components of this material are able to pass into the body through the skin and may cause similar effects as from breathing or swallowing it. If the skin is damaged, absorption increases.

Ingestion

CITGO Gasolines, All Grades Unleaded

If swallowed, this material may irritate the mucous membranes of the mouth, throat, and esophagus. It can be readily absorbed by the stomach and intestinal tract. Symptoms include a burning sensation of the mouth and esophagus, nausea, vomiting, dizziness, staggered gait, drowsiness, loss of consciousness and delirium, as well as additional central nervous system (CNS) effects.

Due to its light viscosity, there is a danger of aspiration into the lungs during swallowing and subsequent vomiting. Aspiration can result in severe lung damage or death. Cardiovascular effects include shallow rapid pulse with pallor (loss of color in the face) followed by flushing (redness of the face). Also, progressive CNS depression, respiratory insufficiency and ventricular fibrillation leads to death.

Chronic Health Effects Summary

Intentional misuse by deliberately concentrating and inhaling gasoline can be harmful or fatal. Altered mental state, drowsiness, peripheral motor neuropathy, irreversible brain damage ("Petrol Sniffers Encephalopathy"), delirium, seizures and sudden death are associated with repeated abuse of gasoline or naphtha.

Chronic effects of ingestion and subsequent aspiration into the lungs may include pneumatocele (lung cavity) formation and chronic lung dysfunction.

Benzene, a component of this product, causes blood disorders and damages the bone marrow (certain types of anemia, leukemia, and lymphoma). It is also capable of causing changes in living cells' genetic material (chromosomes). Benzene is considered to be a mutagen and a cancer-causing agent (leukemogen).

Repeated and prolonged overexposure to n-hexane has been associated with peripheral nerve tissue damage. Adverse effects include numbness, tingling, pain, and loss of muscle control in the extremities, disorientation, impaired vision and reflexes, decline in motor function and paralysis.

Prolonged or repeated overexposure to toluene, a component of this product, has been associated with reproductive effects in experimental animals and in long-term chemical abuse situations. Long-term overexposure to toluene has been associated with impaired color vision. Also, long-term overexposure to toluene in occupational environments have been associated with hearing damage.

Prolonged or repeated overexposure to xylene, a component of this product, has been associated with hearing damage in laboratory animals. Repeated overexposure may cause injury to bone marrow, blood cells, kidney, and liver.

Refer to Section 11 of this MSDS for additional health-related information.

Conditions Aggravated by Exposure

Disorders of the following organs or organ systems that may be aggravated by significant exposure to this material or its components include: Skin, Respiratory System, Liver, Kidneys, Central Nervous System (CNS), Cardiovascular System, Blood-forming system

Target Organs

May cause damage to the following organs: blood, kidneys, lungs, the reproductive system, liver, mucous membranes, heart, peripheral nervous system, cardiovascular system, upper respiratory tract, skin, auditory system, bone marrow, central nervous system (CNS), eye, lens or cornea.

Carcinogenic Potential

This material may contain benzene, ethylbenzene, naphthalene or styrene at concentrations above 0.1%. Benzene is considered to be a known human carcinogen by OSHA, IARC and NTP. IARC has identified ethylbenzene, styrene, naphthalene, gasoline and gasoline engine exhaust as possibly carcinogenic to humans (Group 2B) based on laboratory animal studies.

CITGO Gasolines, All Grades Unleaded

<p>OSHA Hazard Classification is indicated by an "X" in the box adjacent to the hazard title. If no "X" is present, the product does not exhibit the hazard as defined in the OSHA Hazard Communication Standard (29 CFR 1910.1200).</p>							
OSHA Health Hazard Classification				OSHA Physical Hazard Classification			
Irritant	<input checked="" type="checkbox"/>	Sensitizer	<input type="checkbox"/>	Combustible	<input type="checkbox"/>	Explosive	<input type="checkbox"/>
Toxic	<input type="checkbox"/>	Highly Toxic	<input type="checkbox"/>	Flammable	<input checked="" type="checkbox"/>	Oxidizer	<input type="checkbox"/>
Corrosive	<input type="checkbox"/>	Carcinogenic	<input checked="" type="checkbox"/>	Compressed Gas	<input type="checkbox"/>	Organic Peroxide	<input type="checkbox"/>
						Pyrophoric	<input type="checkbox"/>
						Water-reactive	<input type="checkbox"/>
						Unstable	<input type="checkbox"/>

SECTION 4. FIRST AID MEASURES

Take proper precautions to ensure your own health and safety before attempting rescue or providing first aid. For more specific information, refer to Exposure Controls and Personal Protection in Section 8 of this MSDS.

Inhalation Immediately move victim to fresh air. If victim is not breathing, immediately begin rescue breathing. If heart has stopped, immediately begin cardiopulmonary resuscitation (CPR). If breathing is difficult, 100 percent humidified oxygen should be administered by a qualified individual. Seek medical attention immediately. If exposed to benzene in an emergency situation, a medical evaluation should be completed at the end of the work-shift in accordance with OSHA requirements.

Eye Contact Flush eyes with cool, clean, low-pressure water for at least 15 minutes. Hold eyelids apart to ensure complete irrigation of the eye and eyelid tissue. If easily accomplished, check for and remove contact lenses. If contact lenses cannot be removed, seek immediate medical attention. Do not use eye ointment. Seek medical attention.

Skin Contact Remove contaminated shoes and clothing. Flush affected area with large amounts of water. If skin surface is damaged, apply a clean dressing and seek medical attention. Do not use ointments. If skin surface is not damaged, clean affected area thoroughly with mild soap and water. Seek medical attention if tissue appears damaged or if pain or irritation persists.

Ingestion Do not induce vomiting. If spontaneous vomiting is about to occur, place victim's head below knees. If victim is drowsy or unconscious, place on the left side with head down. Never give anything by mouth to a person who is not fully conscious. Do not leave victim unattended. Seek medical attention immediately.

Notes to Physician INHALATION: Inhalation overexposure can produce toxic effects. Monitor for respiratory distress. If cough or difficulty in breathing develops, evaluate for upper respiratory tract inflammation, bronchitis, and pneumonitis. Administer supplemental oxygen with assisted ventilation, as required.

This material (or a component) sensitizes the heart to the effects of sympathomimetic amines. Epinephrine and other sympathomimetic drugs may initiate cardiac arrhythmias in individuals exposed to this material. Administration of sympathomimetic drugs should be avoided.

INGESTION: If ingested, this material presents a significant aspiration and chemical pneumonitis hazard. Induction of emesis is not recommended. Consider activated charcoal and/or gastric lavage. If patient is obtunded, protect the airway by cuffed endotracheal intubation or by placement of the body in a Trendelenburg and left lateral decubitus position.

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SECTION 5. FIRE FIGHTING MEASURES

NFPA Flammability Classification	NFPA Class-IB flammable liquid.
Flash Point	Closed cup: -43°C (-45°F). (Tagliabue [ASTM D-56])
Lower Flammable Limit	AP 1.4 %
Upper Flammable Limit	AP 7.6 %
Autoignition Temperature	280°C (536°F)
Hazardous Combustion Products	Carbon dioxide, carbon monoxide, smoke, fumes, unburned hydrocarbons, aldehydes and other products of incomplete combustion.
Special Properties	Flammable Liquid! This material releases vapors at or below ambient temperatures. When mixed with air in certain proportions and exposed to an ignition source, its vapor can cause a flash fire. Use only with adequate ventilation. Vapors are heavier than air and may travel long distances along the ground to an ignition source and flash back. A vapor and air mixture can create an explosion hazard in confined spaces such as sewers. If container is not properly cooled, it can rupture in the heat of a fire.
Extinguishing Media	SMALL FIRE: Use dry chemicals, carbon dioxide, foam, or inert gas (nitrogen). Carbon dioxide and inert gas can displace oxygen. Use caution when applying carbon dioxide or inert gas in confined spaces. LARGE FIRE: Use foam, water fog, or water spray. Water May Be Ineffective. Water may not extinguish the fire. Water fog and spray are effective in cooling containers and adjacent structures. However, water can be used to cool the external walls of vessels to prevent excessive pressure, autoignition or explosion. DO NOT use a solid stream of water directly on the fire as the water may spread the fire to a larger area.
Protection of Fire Fighters	Firefighters must use full bunker gear including NIOSH-approved positive pressure self-contained breathing apparatus to protect against potential hazardous combustion or decomposition products and oxygen deficiencies. Evacuate area and fight the fire from a maximum distance or use unmanned hose holders or monitor nozzles. Cover pooling liquid with foam. Containers can build pressure if exposed to radiant heat; cool adjacent containers with flooding quantities of water until well after the fire is out. Withdraw immediately from the area if there is a rising sound from a venting safety device or discoloration of vessels, tanks, or pipelines. Be aware that burning liquid will float on water. Notify appropriate authorities of potential fire and explosion hazard if liquid enter sewers or waterways.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Take proper precautions to ensure your own health and safety before attempting spill control or clean-up. For more specific information, refer to the Emergency Overview on Page 1, Exposure Controls and Personal Protection in Section 8 and Disposal Considerations in Section 13 of this MSDS.

Flammable Liquid! Release causes an immediate fire or explosion hazard. Evacuate all non-essential personnel from immediate area and establish a "regulated zone" with site control and security. A vapor-suppressing foam may be used to reduce vapors. Eliminate all ignition sources. All equipment used when handling this material must be grounded. Stop the leak if it can be done without risk. Do not touch or walk through spilled material. Remove spillage immediately from hard, smooth walking areas. Prevent spilled material from entering waterways, sewers, basements, or confined areas. Absorb or cover with dry earth, sand, or other non-combustible material and transfer to appropriate waste containers. Use clean, non-sparking tools to collect absorbed material.

For large spills, secure the area and control access. Prevent spilled material from entering sewers, storm drains, other drainage systems, and natural waterways. Dike far ahead of a

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liquid spill to ensure complete collection. Water mist or spray may be used to reduce or disperse vapors; but, it may not prevent ignition in closed spaces. This material will float on water and its run-off may create an explosion or fire hazard. Verify that responders are properly HAZWOPER-trained and wearing appropriate respiratory equipment and fire-resistant protective clothing during cleanup operations. In an urban area, cleanup spill as soon as possible; in natural environments, cleanup on advice from specialists. Pick up free liquid for recycle and/or disposal if it can be accomplished safely with explosion-proof equipment. Collect any excess material with absorbant pads, sand, or other inert non-combustible absorbent materials. Place into appropriate waste containers for later disposal. Comply with all applicable local, state and federal laws and regulations.

SECTION 7. HANDLING AND STORAGE

Handling

FLAMMABLE LIQUID AND VAPOR. **USE ONLY as a motor fuel.** DO NOT siphon by mouth. DO NOT use as a lighter fluid, solvent or cleaning fluid. Prior to handling or refueling, stop all engines and auxillary equipment. Turn off all electronic equipment including cellular telephones. DO NOT leave nozzle unattended during filling or refueling a vehicle. DO NOT re-enter vehicle while refueling. Keep nozzle spout in contact with the container during the entire filling operations.

A static electrical charge can accumulate when this material is flowing through pipes, nozzles or filters and when it is agitated. A static spark discharge can ignite accumulated vapors particularly during dry weather conditions. Always bond receiving containers to the fill pipe before and during loading. Always keep nozzle in contact with the container throughout the loading process. Do not fill any portable container in or on a vehicle. Special precautions, such as reduced loading rates and increased monitoring, must be observed during "switch loading" operations (i.e., loading this material in tanks or shipping compartments that previously contained middle distillates or similar products).

A spill or leak can cause an immediate fire hazard. Keep containers closed and do not handle or store near heat, sparks, or any other potential ignition sources. Do not contact with oxidizable materials. Do not breathe vapor. Use only with adequate ventilation and personal protection. Never siphon by mouth. Avoid contact with eyes, skin, and clothing. Prevent contact with food and tobacco products. Do not take internally.

When performing repairs and maintenance on contaminated equipment, keep unnecessary persons away from the area. Eliminate all potential ignition sources. Drain and purge equipment, as necessary, to remove material residues. Follow proper entry procedures, including compliance with 29 CFR 1910.146 prior to entering confined spaces such as tanks or pits. Use gloves constructed of impervious materials and protective clothing if direct contact is anticipated. Provide ventilation to maintain exposure potential below applicable exposure limits. Use appropriate respiratory protection when concentrations exceed any established occupational exposure level (See Section 8). Promptly remove contaminated clothing. Wash exposed skin thoroughly with soap and water after handling.

Protect the environment from releases of this material. Prevent discharges to surface waters and groundwater. Maintain handling, transfer and storage equipment in proper working order.

Misuse of empty containers can be dangerous. Empty containers may contain material residues which can ignite with explosive force. **Cutting or welding of empty containers can cause fire, explosion, or release of toxic fumes from residues.** Do not pressurize or expose empty containers to open flame, sparks, or heat. Keep container closed and drum bungs in place. All label warnings and precautions must be observed. Return empty drums to a qualified reconditioner. Consult appropriate federal, state and local authorities before reusing, reconditioning, reclaiming, recycling, or disposing of empty containers and/or waste residues of this material.

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Storage Store and transport in accordance with all applicable laws. Keep containers tightly closed. Store in a cool, dry, well-ventilated place. Clearly label all containers. Do not allow containers to be kept in enclosed vehicles. Keep away from all ignition sources. Ground all equipment containing this material. Containers must be able to withstand pressures that are created from changes in product temperature. Product samples and other small containers of this flammable liquid should be stored in a separate safety cabinet or room. All electrical equipment in areas where this material is stored or handled should be installed and operated in accordance with applicable regulatory requirements and the National Electrical Code.

SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

Engineering Controls Provide ventilation or other engineering controls to keep the airborne concentrations of vapor or mists below the applicable workplace exposure limits indicated below. All electrical equipment should comply with the National Electric Code. An emergency eye wash station and safety shower should be located near the work-station.

Personal Protective Equipment Personal protective equipment should be selected based upon the conditions under which this material is used. A hazard assessment of the work area for PPE requirements should be conducted by a qualified professional pursuant to OSHA regulations. The following pictograms represent the minimum requirements for personal protective equipment. For certain operations, additional PPE may be required.



Eye Protection Safety glasses equipped with side shields are recommended as minimum protection in industrial settings. Chemical goggles should be worn during transfer operations or when there is a likelihood of misting, splashing, or spraying of this material. A suitable emergency eye wash water and safety shower should be located near the work station.

Hand Protection Avoid skin contact. Use gloves (e.g., disposable PVC, neoprene, nitrile, vinyl, or PVC/NBR). Wash hands with plenty of mild soap and water before eating, drinking, smoking, use of toilet facilities or leaving work. DO NOT use this material as a skin cleaner.

Body Protection Avoid skin contact. Wear long-sleeved fire-retardant garments (e.g., Nomex®) while working with flammable and combustible liquids. Additional chemical-resistant protective gear may be required if splashing or spraying conditions exist. This may include an apron, boots and additional facial protection. If product comes in contact with clothing, immediately remove soaked clothing and shower. Promptly remove and discard contaminated leather goods.

Respiratory Protection For known vapor concentrations above the occupational exposure guidelines (see below), use a NIOSH-approved organic vapor respirator if adequate protection is provided. Protection factors vary depending upon the type of respirator used. Respirators should be used in accordance with OSHA requirements (29 CFR 1910.134). For airborne vapor concentrations that exceed the recommended protection factors for organic vapor respirators, use a full-face, positive-pressure, supplied air respirator. Due to fire and explosion hazards, do not enter atmospheres containing concentrations greater than 10% of the lower flammable limit of this product.

General Comments Warning! Use of this material in spaces without adequate ventilation may result in generation of hazardous levels of combustion products and/or inadequate oxygen levels for breathing. Odor is an inadequate warning for hazardous conditions.

Occupational Exposure Guidelines

Substance **Applicable Workplace Exposure Levels**

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Gasoline	ACGIH (United States). TWA: 300 ppm 8 hour(s). STEL: 500 ppm 15 minute(s).
Toluene	ACGIH (United States). Skin TWA: 50 ppm 8 hour(s). OSHA (United States). TWA: 200 ppm 8 hour(s). CEIL: 300 ppm PEAK: 500 ppm
Xylene, all isomers	ACGIH (United States). TWA: 100 ppm 8 hour(s). STEL: 150 ppm 15 minute(s). OSHA (United States). TWA: 100 ppm 8 hour(s).
Tertiary-Amyl Methyl Ether (TAME)	ACGIH TLV (United States). TWA: 20 ppm 8 hour(s).
Methyl tertiary-Butyl Ether (MTBE)	ACGIH (United States). TWA: 50 ppm 8 hour(s).
Ethyl tertiary Butyl Ether (ETBE)	ACGIH TLV (United States). TWA: 5 ppm 8 hour(s).
n-Hexane	ACGIH (United States). Skin TWA: 50 ppm 8 hour(s). OSHA (United States). TWA: 500 ppm 8 hour(s).
Cumene	ACGIH (United States). TWA: 50 ppm 8 hour(s). OSHA (United States). Skin TWA: 50 ppm 8 hour(s).
Trimethylbenzenes, all isomers	ACGIH (United States). TWA: 25 ppm 8 hour(s).
Benzene	ACGIH (United States). Skin TWA: 0.5 ppm 8 hour(s). STEL: 2.5 ppm 15 minute(s). OSHA (United States). Skin Notes: See Table Z-2 for exclusions in 20 CFR 1910.1028 to the PEL. TWA: 1 ppm 8 hour(s). STEL: 5 ppm 15 minute(s).
Ethylbenzene	ACGIH (United States). TWA: 100 ppm 8 hour(s). STEL: 125 ppm 15 minute(s). OSHA (United States). TWA: 100 ppm 8 hour(s).
Cyclohexane	ACGIH (United States). TWA: 100 ppm 8 hour(s). OSHA (United States). TWA: 300 ppm 8 hour(s).
Naphthalene	ACGIH (United States). Skin TWA: 10 ppm 8 hour(s). STEL: 15 ppm 15 minute(s). OSHA (United States). TWA: 10 ppm 8 hour(s).
Styrene	ACGIH (United States). TWA: 20 ppm 8 hour(s). STEL: 40 ppm 15 minute(s). OSHA (United States). TWA: 100 ppm 8 hour(s). STEL: 200 ppm 15 minute(s). PEAK: 600 ppm

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SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES (TYPICAL)

Physical State	Liquid.	Color	Transparent, clear to amber or red.	Odor	Pungent, characteristic gasoline.
Specific Gravity	0.72 - 0.77 (Water = 1)	pH	Not applicable	Vapor Density	3 to 4 (Air = 1)
Boiling Range	38 to 204°C (100 to 400°F)			Melting/Freezing Point	Not available.
Vapor Pressure	220 to 450 mm Hg at 20°C (68°F) or 6 to 15 Reid-psia at 37.8°C (100°F).			Volatility	720 to 770 g/l VOC (w/v)
Solubility in Water	Hydrocarbon components of gasoline are slightly soluble in water. Oxygenate components, such as MTBE, are more soluble than the hydrocarbon components. Ethanol has greater solubility in water than hydrocarbon components or other oxygenate components.			Viscosity (cSt @ 40°C)	<1
Flash Point	Closed cup: -43°C (-45°F). (Tagliabue [ASTM D-56])				
Additional Properties	Average Density at 60°F = 6.0 to 6.4 lbs./gal. (ASTM D-2161)				

SECTION 10. STABILITY AND REACTIVITY

Chemical Stability	Stable.	Hazardous Polymerization	Not expected to occur.
Conditions to Avoid	Keep away from heat, flame and other potential ignition sources. Keep away from strong oxidizing conditions and agents.		
Materials Incompatibility	Strong acids, alkalis and oxidizers such as liquid chlorine, other halogens, hydrogen peroxide and oxygen.		
Hazardous Decomposition Products	No additional hazardous decomposition products were identified other than the combustion products identified in Section 5 of this MSDS.		

SECTION 11. TOXICOLOGICAL INFORMATION

For other health-related information, refer to the Emergency Overview on Page 1 and the Hazards Identification in Section 3 of this MSDS.

Toxicity Data	<p>Gasoline: VAPOR (TEL_o) Acute: 140 ppm (Human) (8 hours) - Mild eye irritant. VAPOR (TEL_o) Acute: 500 ppm (Human) (1 hour) - Moderate eye irritant. INHALATION (TCL_o) Acute: 900 ppm (Human) (1 hour) - CNS and pulmonary effects. DERMAL (TDL_o) Acute: 53 mg/kg (Human) - Skin allergy effects. INHALATION (LC₅₀) Acute: 101,200 ppm (Rat, Mouse, & Guinea Pig) (5 minutes).</p> <p>Gasoline Containing 15% MTBE: ORAL (LD₅₀) Acute: >5,000 mg/kg (Rat screen level). DERMAL (LD₅₀) Acute: >2,000 mg/kg (Rabbit screen level). INHALATION (LC₅₀) Acute: >5,200 ppm (Rat screen level) (8 hours). DRAIZE EYE Acute: Mild eye irritant. (Rabbit).</p>
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DRAIZE DERMAL Acute: Moderate skin irritant (Rabbit).
 BUEHLER DERMAL Acute: Non-sensitizing. (Guinea Pig).
 28-Day DERMAL Sub-Chronic: Severe skin irritant. (Rabbit).

A major epidemiological study concluded that there was no increased risk of kidney cancer associated with gasoline exposures for petroleum refinery employees or neighboring residents. Another study identified a slight trend in kidney cancers among service station employees following a 30-year latency period. Two-year inhalation toxicity studies with fully vaporized unleaded gasoline (at concentrations of 67, 292 and 2,056 ppm in air) produced kidney damage and kidney tumors in male rats, but not in female rats or mice of either sex. Results from subsequent scientific studies suggest that the kidney damage, and probably the kidney tumor response, is limited to the male rat. The kidney tumors apparently were the result of the formation of alpha-2u-globulin, a protein unique to male rats. This finding is not considered relevant to human exposure. Under conditions of the study, there was no evidence that exposure to unleaded gasoline vapor is associated with developmental toxicity. Experimental studies with laboratory animals did suggest that overexposure to gasoline may adversely effect male reproductive performance. Also, in laboratory studies with rats, the maternal and developmental "no observable adverse effect level" (NOAEL) was determined to be 9,000 ppm (75% of the LEL value). Female mice developed a slightly higher incidence of liver tumor compared to controls at the highest concentration. In a four week inhalation study of Sprague Dawley® rats, gasoline vapor condensate was determined to induce sister chromatid exchanges in peripheral lymphocytes. IARC has listed gasoline as possibly carcinogenic to humans (Group 2B).

Pentanes, all isomers:

Studies of pentane isomers in laboratory animals indicate exposure to extremely high levels (roughly 10 vol.%) may induce cardiac arrhythmias (irregular heartbeats) which may be serious or fatal.

Toluene:

Effects from Acute Exposure:

Deliberate inhalation of toluene at high concentrations (e.g., glue sniffing and solvent abuse) has been associated with adverse effects on the liver, kidney and nervous system and can cause CNS depression, cardiac arrhythmias and death. Case studies of persons abusing toluene suggest isolated incidences of adverse effects on the fetus including birth defects.

Effects from Repeated or Prolonged Exposure:

Studies of workers indicate long-term exposure may be related to impaired color vision and hearing. Some studies of workers suggest long-term exposure may be related to neurobehavioral and cognitive changes. Some of these effects have been observed in laboratory animals following repeated exposure to high levels of toluene. Several studies of workers suggest long-term exposure may be related to small increases in spontaneous abortions and changes in some gonadotropic hormones. However, the weight of evidence does not indicate toluene is a reproductive hazard to humans. Studies in laboratory animals indicate some changes in reproductive organs following high levels of exposure, but no significant effects on mating performance or reproduction were observed. Case studies of persons abusing toluene suggest isolated incidences of adverse effects on the fetus including birth defects. Findings in laboratory animals were largely negative. Positive findings include small increases in minor skeletal and visceral malformations and developmental delays following very high levels of maternal exposure. Studies of workers indicate long-term exposure may be related to effects on the liver, kidney and blood, but these appear to be limited to changes in serum enzymes and decreased leukocyte counts. Studies in laboratory animals indicate some evidence of adverse effects on the liver, kidney, thyroid, and pituitary gland following very high levels of exposure. The relevance of these findings to humans is not clear at this time.

Heptane, all isomers:

n-Heptane was not mutagenic in the Salmonella/microsome (Ames) assay and is not considered to be carcinogenic.

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Xylene, all isomers:

Effects from Acute Exposure:

ORAL (LD₅₀), Acute: 4,300 mg/kg [Rat].

INHALATION (LC₅₀), Acute: 4,550 ppm for four hours [Rat].

DERMAL (LD₅₀), Acute: 14,100 µL/kg [Rabbit].

Overexposure to xylene may cause upper respiratory tract irritation, headache, cyanosis, blood serum changes, CNS damage and narcosis. Effects may be increased by the use of alcoholic beverages. Evidence of liver and kidney impairment were reported in workers recovering from a gross over-exposure.

Effects from Prolonged or Repeated Exposure:

Impaired neurological function was reported in workers exposed to solvents including xylene. Studies in laboratory animals have shown evidence of impaired hearing following high levels of exposure. Studies in laboratory animals suggest some changes in reproductive organs following high levels of exposure but no significant effects on reproduction were observed. Studies in laboratory animals indicate skeletal and visceral malformations, developmental delays, and increased fetal resorptions following extremely high levels of maternal exposure. Adverse effects on the liver, kidney, bone marrow (changes in blood cell parameters) were observed in laboratory animals following high levels of exposure. The relevance of these observations to humans is not clear at this time.

Ethyl tertiary Butyl Ether (ETBE):

ETBE can cause eye, skin and mucous membrane irritation. In a four week inhalation study, moderate ataxia was observed in rats at the highest dose level (4,000 ppm). The test animals appeared normal within 15 minutes of termination of exposure. A no observed adverse effect level (NOAEL) of 500 ppm was indicated by the study authors based on neurotoxic effects. In two unpublished 90 day inhalation studies, rats and mice were exposed six hour/day, five days/week at concentrations of 0, 500, 1750 and 5000 ppm of ETBE vapor. The male rats exhibited time and concentration-dependent nephropathy consistent with alpha-2µ-globulin formation. An ETBE NOAEL for male rats of 500 ppm was suggested based on a finding of testicular lesions. In human studies with eight males, slight, but significant (p<0.05) decreases in objective pulmonary function measures after exposure to ETBE at concentrations of 25 and 50 ppm for two hours.

Tertiary-Amyl Methyl Ether (TAME):

TAME was found to be negative for the induction of structural chromosome aberrations (both metabolically-activated and non-activated) in Chinese hamster ovary (CHO) cells. Inhalation of TAME vapors at concentrations above 250 ppm produced reversible CNS depression in rats and mice. In a four week inhalation study, increases in liver weights with no tissue injury were observed in rats exposed to a TAME concentration of 500 ppm. Birth defects in mice and fetotoxicity in both rats and mice were observed after inhalation exposures to maternally toxic concentrations of TAME.

Methyl tertiary-Butyl Ether (MTBE):

Acute symptoms associated with human exposure to MTBE appear to be mild and transient. In laboratory studies, rats and mice exposed to high doses of MTBE exhibited blood chemistry changes and liver and kidney abnormalities. In laboratory studies, MTBE vapor exposure at the high dose concentration was associated with an increased incidence of liver tumors in female mice. Also, at high dose concentration exposures, MTBE was associated with an increased incidence of kidney and testicular (Leydig cell) tumors in male rats. Additional oncogenicity studies on rats resulted in testicular tumors following administration by ingestion. These data are not generally considered relevant to humans. NTP has not identified MTBE as either a known carcinogen or reasonably anticipated to be carcinogenic to humans. In animal studies, developmental and reproductive toxicity related to MTBE inhalation exposures was observed only at concentrations that were maternally toxic. MTBE was shown to be maternally toxic at 4,000 and 8,000 ppm levels when mice were exposed for six hours per day during their pregnancy. Also, a decrease in the number of successful pregnancies and a reduction in birth weights were observed at these exposure levels. Birth defects (cleft palate) were observed at the high dose level. These data suggest that the risk of developmental and reproductive toxicity in humans is negligible as a result of anticipated

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exposures to MTBE.

Diisopropyl Ether (DIPE):

Increased kidney and liver weights were observed in rats and mice in subchronic and chronic inhalation studies of DIPE. Also, evidence of microscopic changes (hyaline droplets) were reported in liver tissue and kidney tubules of rabbits and male rats exposed to DIPE at concentrations of 7,100 ppm. These findings were similar those found in gasoline studies. Overexposure by inhalation of pregnant rats to DIPE at concentrations of 3,095 and 6,745 ppm increased the frequency of rudimentary 14th ribs in the offspring. This effect was not observed at exposure concentrations of 430 ppm. The significance of these findings to human exposure is unclear.

Ethanol:

Inhalation exposure to ethanol vapor at concentrations above applicable workplace exposure levels is expected to produce eye and mucus membrane irritation. Human exposure at concentrations from 1000 to 5000 ppm produced symptoms of narcosis, stupor and unconsciousness. Subjects exposed to ethanol vapor in concentrations between 500 and 10,000 ppm experienced coughing and smarting of the eyes and nose. At 15,000 ppm there was continuous lacrimation and coughing. While extensive acute and chronic effects can be expected with ethanol consumption, ingestion is not expected to be a significant route of exposure to this product.

Butane, all isomers:

Studies in laboratory animals indicate exposure to extremely high levels of butanes (1-10 or higher vol. % in air) may cause cardiac arrhythmias (irregular heartbeats) which may be serious or fatal.

n-Hexane:

This material contains n-hexane. Long-term or repeated exposure to n-hexane can cause permanent peripheral nerve damage. Initial symptoms are numbness of the fingers and toes. Also, motor weakness can occur in the digits, but may also involve muscles of the arms, thighs and forearms. The onset of these symptoms may be delayed for several months to a year after the beginning of exposure. Co-exposure to methylethyl ketone or methyl isobutyl ketone increases the neurotoxic properties of n-hexane. In laboratory studies, prolonged exposure to elevated concentrations of n-hexane was associated with decreased sperm count and degenerative changes in the testicles of rats.

Cumene:

Effects from Acute Exposure:

Overexposure to cumene may cause upper respiratory tract irritation and severe CNS depression.

Effects from Prolonged or Repeated Exposure:

Studies in laboratory animals indicate evidence of adverse effects on the kidney and adrenal glands following high level exposure. The relevance of these findings to humans is not clear at this time.

Trimethylbenzenes, all isomers:

Studies of Workers:

Levels of total hydrocarbon vapors present in the breathing atmosphere of these workers ranged from 10 to 60 ppm. The TCLo for humans is 10 ppm, with somnolence and respiratory tract irritation noted.

Studies in Laboratory Animals:

In inhalation studies with rats, four of ten animals died after exposures of 2400 ppm for 24 hours. An oral dose of 5 mL/kg resulted in death in one of ten rats. Minimum lethal intraperitoneal doses were 1.5 to 2.0 mL/kg in rats and 1.13 to 12 mL/kg in guinea pigs. Mesitylene (1, 3, 5 Trimethylbenzene) inhalation at concentrations of 1.5, 3.0, and 6.0 mg/L for six hours was associated with dose-related changes in white blood cell counts in rats. No significant effects on the complete blood count were noted with six hours per day exposure

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for five weeks, but elevations of alkaline phosphatase and SGOT were observed. Central nervous system depression and ataxia were noted in rats exposed to 5,100 to 9,180 ppm for two hours.

Benzene:

ORAL (LD50): Acute: 930 mg/kg [Rat]. 4700 mg/kg [Mouse].
 INHALATION (LC50):
 (VAPOR): Acute: 10000 ppm 7 hour(s) [Rat]. 9980 ppm 8 hour(s) [Mouse].

Studies of Workers Over-Exposed to Benzene:

Studies of workers exposed to benzene show clear evidence that over-exposure can cause cancer of the blood forming organs (acute myelogenous leukemia) and aplastic anemia, an often fatal disease. Studies also suggest over-exposure to benzene may be associated with other types of leukemia and other blood disorders. Some studies of workers exposed to benzene have shown an association with increased rates of chromosome aberrations in circulating lymphocytes. One study of women workers exposed to benzene suggested a weak association with irregular menstruation. However, other studies of workers exposed to benzene have not demonstrated clear evidence of an effect on fertility or reproductive outcome in humans. Benzene can cross the placenta and affect the developing fetus. Cases of aplastic anemia have been reported in the offspring of persons severely over-exposed to benzene.

Studies in Laboratory Animals:

Studies in laboratory animals indicate that prolonged, repeated exposure to high levels of benzene vapor can cause bone marrow suppression and cancer in multiple organ systems. Studies in laboratory animals show evidence of adverse effects on male reproductive organs following high levels of exposure but no significant effects on reproduction have been observed. Embryotoxicity has been reported in studies of laboratory animals but effects were limited to reduced fetal weight and skeletal variations.

Ethylbenzene:

Effects from Acute Exposure:

ORAL (LD50), Acute: 3,500 mg/kg [Rat].
 DERMAL (LD50), Acute: 17,800 uL/kg [Rabbit].
 INTRAPERITONEAL (LD50), Acute: 2,624 mg/kg [Rat].

Effects from Prolonged or Repeated Exposure:

Findings from a 2-year inhalation study in rodents conducted by NTP were as follows: Effects were observed only at the highest exposure level (750 ppm). At this level the incidence of renal tumors was elevated in male rats (tubular carcinomas) and female rats (tubular adenomas). Also, the incidence of tumors was elevated in male mice (alveolar and bronchiolar carcinomas) and female mice (hepatocellular carcinomas). IARC has classified ethyl benzene as "possibly carcinogenic to humans" (Group 2B). Studies in laboratory animals indicate some evidence of post-implantation deaths following high levels of maternal exposure. The relevance of these findings to humans is not clear at this time. Studies in laboratory animals indicate limited evidence of renal malformations, resorptions, and developmental delays following high levels of maternal exposure. The relevance of these findings to humans is not clear at this time. Studies in laboratory animals indicate some evidence of adverse effects on the liver, kidney, thyroid, and pituitary gland.

Cyclohexane:

Cyclohexane can cause eye, skin and mucous membrane irritation, CNS depressant and narcosis at elevated concentrations. In experimental animals exposed to lethal concentrations by inhalation or oral route, generalized vascular damage and degenerative changes in the heart, lungs, liver, kidneys and brain were identified.

Cyclohexane has been the focus of substantial testing in laboratory animals. Cyclohexane was not found to be genotoxic in several tests including unscheduled DNA synthesis, bacterial and mammalian cell mutation assays, and in vivo chromosomal aberration. An increase in chromosomal aberrations in bone marrow cells of rats exposed to cyclohexane

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was reported in the 1980's. However, a careful re-evaluation of slides from this study by the laboratory which conducted the study indicates these findings were in error, and that no significant chromosomal effects were observed in animals exposed to cyclohexane. Findings indicate long-term exposure to cyclohexane does not promote dermal tumorigenesis.

Naphthalene:

Studies in Humans Overexposed to Naphthalene:

Severe jaundice, neurotoxicity (kernicterus) and fatalities have been reported in young children and infants as a result of hemolytic anemia from over-exposure to naphthalene. Persons with Glucose 6-phosphate dehydrogenase (G6PD) deficiency are more prone to the hemolytic effects of naphthalene. Adverse effects on the kidney have also been reported from over-exposure to naphthalene but these effects are believed to be a consequence of hemolytic anemia, and not a direct effect.

Studies in Laboratory Animals:

Hemolytic anemia has been observed in laboratory animals exposed to naphthalene. Laboratory rodents exposed to naphthalene vapor for 2 years (lifetime studies) developed non-neoplastic and neoplastic tumors and inflammatory lesions of the nasal and respiratory tract. Cataracts and other adverse effects on the eye have been observed in laboratory animals exposed to high levels of naphthalene. Findings from a large number of bacterial and mammalian cell mutation assays have been negative. A few studies have shown chromosomal effects (elevated levels of Sister Chromatid Exchange or chromosomal aberrations) *in vitro*.

Styrene:

Neurological injury associated with chronic styrene exposure include distal hypesthesia, decreased nerve conduction velocity, and altered psychomotor performance. These effects did not occur with exposures to airborne concentrations that were less than 100 ppm. Increased deaths from degenerative neurological disorders were found in a comprehensive epidemiological study of Danish reinforced plastics workers. These workers were reported to have a 2.5-fold increased risk for myeloid leukemia with clonal chromosome aberrations. Also, there are several studies that suggest potential reproductive effects in humans and experimental animals from overexposure to styrene. Styrene was not mutagenic in the standard (liquid phase) Ames Salmonella/microsome assay, but was weakly positive when tested in the vapor phase. IARC has listed styrene as possibly carcinogenic to humans (Group 2B).

SECTION 12. ECOLOGICAL INFORMATION

Ecotoxicity

Unleaded gasoline is potentially toxic to freshwater and saltwater ecosystems. Various grades of gasoline exhibited range of lethal toxicity (LC₁₀₀) from 40 PPM to 100 PPM in ambient stream water with Rainbow Trout (*Salmo irideus*). A 24-hour TLM (Median Toxic Limit) was calculated to be 90 PPM with juvenile American Shad (*Squalius cephalus*). In Bluegill Sunfish (*Lepomis macrochirus*), Grey Mullet (*Chelon labrosus*) and Gulf Menhaden (*Brevoortia patronus*), gasoline exhibited a 96-hour LC₅₀ of 8 PPM, 2 PPM, and 2 PPM, respectively.

The aquatic toxicity of Methyl tertiary-Butyl Ether (MTBE) is considered to be relatively low. In the crustacean Harpacticoid Copepods (*Nitocra spinipes*), MTBE exhibited an LC₅₀ (96-hour) of 1,000 PPM to 10,000 PPM depending upon various water temperatures. In Bleak Fish (*Alburnus alburnus*), MTBE exhibited an LC₅₀ (24-hour) of 1,700 PPM and an LC₅₀ (96-hour) of 1,000 PPM at 10° C. In Golden Orfe Fish (*Leuciscus idus melanotus*), MTBE exhibited an LC₅₀ (48-hour) of 1,000 PPM and an LC₁₀₀ of 2,000 PPM.

Environmental Fate

CITGO Gasolines, All Grades Unleaded

Avoid spilling gasoline. Spilled gasoline can result in environmental damage. Spilled gasoline can penetrate soil and contaminate ground water. Although gasoline is biodegradable, it may persist for prolonged time periods, particularly where oxygen levels are reduced. The hydrocarbon components of gasoline are slightly soluble in water. Gasoline hydrocarbon components do not readily dissolve in water but can be adsorbed to soils.

Gasoline contains components that are potentially toxic to freshwater and saltwater ecosystems. It will normally float on water. The components of gasoline will evaporate rapidly. Evaporated hydrocarbon components may contribute to atmospheric smog.

MTBE and other oxygenates are more soluble than other gasoline components. In addition, oxygenates such as MTBE do not adsorb to soils, sediments or suspended particulate matter as readily as other gasoline components. MTBE does not degrade as readily as other gasoline components once in ground water or subsoil. MTBE is not expected to bioconcentrate in the aquatic environment.


SECTION 13. DISPOSAL CONSIDERATIONS

Hazard characteristic and regulatory waste stream classification can change with product use. Accordingly, it is the responsibility of the user to determine the proper storage, transportation, treatment and/or disposal methodologies for spent materials and residues at the time of disposition.

Maximize material recovery for reuse or recycling. Recovered non-usable material may be regulated by US EPA as a hazardous waste due to its ignitibility (D001) and/or its toxic (D018) characteristics. Conditions of use may cause this material to become a "hazardous waste", as defined by federal or state regulations. It is the responsibility of the user to determine if the material is a RCRA "hazardous waste" at the time of disposal. Transportation, treatment, storage and disposal of waste material must be conducted in accordance with RCRA regulations (see 40 CFR 260 through 40 CFR 271). State and/or local regulations may be more restrictive. Contact your regional US EPA office for guidance concerning case specific disposal issues.

SECTION 14. TRANSPORT INFORMATION

The shipping description below may not represent requirements for all modes of transportation, shipping methods or locations outside of the United States.

US DOT Status	A U.S. Department of Transportation regulated material.		
Proper Shipping Name	Gasoline, 3, UN 1203, PG II Gasohol, 3, NA 1203, PGII (Use only for gasoline blended with less than 20% ethanol)		
Hazard Class	3 DOT Class: Flammable liquid.	Packing Group(s)	II
		UN/NA Number	UN1203 or NA1203
Reportable Quantity	A Reportable Quantity (RQ) has not been established for this material.		
Placard(s)		Emergency Response Guide No.	128
		MARPOL III Status	Not a DOT "Marine Pollutant" per 49 CFR 171.8.

CITGO Gasolines, All Grades Unleaded

SECTION 15. REGULATORY INFORMATION

TSCA Inventory	This product and/or its components are listed on the Toxic Substances Control Act (TSCA) inventory.
SARA 302/304 Emergency Planning and Notification	The Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III requires facilities subject to Subparts 302 and 304 to submit emergency planning and notification information based on Threshold Planning Quantities (TPQs) and Reportable Quantities (RQs) for "Extremely Hazardous Substances" listed in 40 CFR 302.4 and 40 CFR 355. No components were identified.
SARA 311/312 Hazard Identification	The Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III requires facilities subject to this subpart to submit aggregate information on chemicals by "Hazard Category" as defined in 40 CFR 370.2. This material would be classified under the following hazard categories: fire, Acute (Immediate) Health Hazard, Chronic (Delayed) Health Hazard
SARA 313 Toxic Chemical Notification and Release Reporting	This product contains the following components in concentrations above de minimis levels that are listed as toxic chemicals in 40 CFR Part 372 pursuant to the requirements of Section 313 of SARA: Toluene [CAS No.: 108-88-3] Concentration: <20% Xylene, all isomers [CAS No.: 1330-20-7] Concentration: <18% Methyl tertiary-Butyl Ether (MTBE) [CAS No.: 1634-04-4] Concentration: <15% n-Hexane [CAS No.: 110-54-3] Concentration: <8% Cumene [CAS No.: 98-82-8] Concentration: <4% Benzene [CAS No.: 71-43-2] Concentration: <5% Ethylbenzene [CAS No.: 100-41-4] Concentration: <4% 1, 2, 4 Trimethylbenzene [CAS No.: 95-63-6] Concentration: <4% Cyclohexane [CAS No.: 110-82-7] Concentration: <3% Naphthalene [CAS No.: 91-20-3] Concentration: <2% Styrene [CAS No.: 100-42-5] Concentration: <1%
CERCLA	The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requires notification of the National Response Center concerning release of quantities of "hazardous substances" equal to or greater than the reportable quantities (RQ's) listed in 40 CFR 302.4. As defined by CERCLA, the term "hazardous substance" does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically designated in 40 CFR 302.4. Chemical substances present in this product or refinery stream that may be subject to this statute are: Toluene [CAS No.: 108-88-3] RQ = 1000 lbs. (453.6 kg) Concentration: <20% Xylene, all isomers [CAS No.: 1330-20-7] RQ = 100 lbs. (45.36 kg) Concentration: <18% Methyl tertiary-Butyl Ether (MTBE) [CAS No.: 1634-04-4] RQ = 1000 lbs. (453.6 kg) Concentration: <15% n-Hexane [CAS No.: 110-54-3] RQ = 5000 lbs. (2268 kg) Concentration: <8% 2,2,4-Trimethylpentane [CAS No.: 540-84-1] RQ = 1000 lbs. (453.6 kg) Concentration: <5% Benzene [CAS No.: 71-43-2] RQ = 10 lbs. (4.536 kg) Concentration: <5% Cumene [CAS No.: 98-82-8] RQ = 5000 lbs. (2268 kg) Concentration: <4% Ethylbenzene [CAS No.: 100-41-4] RQ = 1000 lbs. (453.6 kg) Concentration: <4% Cyclohexane [CAS No.: 110-82-7] RQ = 1000 lbs. (453.6 kg) Concentration: <3% Naphthalene [CAS No.: 91-20-3] RQ = 100 lbs. (45.36 kg) Concentration: <2% Styrene [CAS No.: 100-42-5] RQ = 1000 lbs. (453.6 kg) Concentration: <1%
Clean Water Act (CWA)	This material is classified as an oil under Section 311 of the Clean Water Act (CWA) and the Oil Pollution Act of 1990 (OPA). Discharges or spills which produce a visible sheen on waters of the United States, their adjoining shorelines, or into conduits leading to surface waters must be reported to the EPA's National Response Center at (800) 424-8802.
California Proposition 65	

CITGO Gasolines, All Grades Unleaded

This material may contain the following components which are known to the State of California to cause cancer, birth defects or other reproductive harm, and may be subject to the requirements of California Proposition 65 (CA Health & Safety Code Section 25249.5): Gasoline (Wholly Vaporized and Engine Exhaust), Benzene [CAS No. 71-43-3], Toluene [CAS No. 108-88-3], Ethylbenzene [CAS No. 100-41-4] and Naphthalene [CAS No. 91-20-3]

**New Jersey
Right-to-Know Label**

Gasoline [NJDEP CAS No. 8006-61-9]

**Additional Regulatory
Remarks**

As minimum requirements, CITGO recommends that the following advisory information be displayed on equipment used to dispense gasoline in motor vehicles. Additional warnings specified by various regulatory authorities may be required: "DANGER: Extremely Flammable. Use as a Motor Fuel Only. No Smoking. Stop Engine. Turn Off All Electronic Equipment including Cellular Telephones. Do Not Overfill Tank. Keep Away from Heat and Flames. Do Not leave nozzle unattended during refueling. **Static Sparks Can Cause a Fire, especially when filling portable containers.** Containers must be metal or other material approved for storing gasoline. PLACE CONTAINER ON GROUND. DO NOT FILL ANY PORTABLE CONTAINER IN OR ON A VEHICLE. Keep nozzle spout in contact with the container during the entire filling operation. **Harmful or Fatal if Swallowed. Long-Exposure Has Caused Cancer in Laboratory Animals.** Avoid prolonged breathing of vapors. Keep face away from nozzle and gas tank. Never siphon by mouth."

WHMIS Class B-2: Flammable liquid with a flash point lower than 37.8°C (100°F).
WHMIS Class D-2B: Material causing other toxic effects (TOXIC).

SECTION 16. OTHER INFORMATION

Refer to the top of Page 1 for the HMIS and NFPA Hazard Ratings for this product.

REVISION INFORMATION

Version Number 7.0
Revision Date 05/23/2005
Print Date Printed on 05/23/2005.

ABBREVIATIONS

AP: Approximately	EQ: Equal	>: Greater Than	<: Less Than	NA: Not Applicable	ND: No Data	NE: Not Established
ACGIH: American Conference of Governmental Industrial Hygienists				AIHA: American Industrial Hygiene Association		
IARC: International Agency for Research on Cancer				NTP: National Toxicology Program		
NIOSH: National Institute of Occupational Safety and Health				OSHA: Occupational Safety and Health Administration		
NPCA: National Paint and Coating Manufacturers Association				HMIS: Hazardous Materials Information System		
NFPA: National Fire Protection Association				EPA: US Environmental Protection Agency		

DISCLAIMER OF LIABILITY

THE INFORMATION IN THIS MSDS WAS OBTAINED FROM SOURCES WHICH WE BELIEVE ARE RELIABLE. HOWEVER, THE INFORMATION IS PROVIDED WITHOUT ANY WARRANTY, EXPRESSED OR IMPLIED REGARDING ITS CORRECTNESS. SOME INFORMATION PRESENTED AND CONCLUSIONS DRAWN HEREIN ARE FROM SOURCES OTHER THAN DIRECT TEST DATA ON THE SUBSTANCE ITSELF. THIS MSDS WAS PREPARED AND IS TO BE USED ONLY FOR THIS PRODUCT. IF THE PRODUCT IS USED AS A COMPONENT IN ANOTHER PRODUCT, THIS MSDS INFORMATION MAY NOT BE APPLICABLE. USERS SHOULD MAKE THEIR OWN INVESTIGATIONS TO DETERMINE THE SUITABILITY OF THE INFORMATION OR PRODUCTS FOR THEIR PARTICULAR PURPOSE.

THE CONDITIONS OR METHODS OF HANDLING, STORAGE, USE, AND DISPOSAL OF THE PRODUCT ARE BEYOND OUR CONTROL AND MAY BE BEYOND OUR KNOWLEDGE. FOR THIS AND OTHER REASONS, WE DO NOT ASSUME RESPONSIBILITY AND EXPRESSLY DISCLAIM LIABILITY FOR LOSS, DAMAGE OR EXPENSE ARISING OUT OF OR IN ANY WAY CONNECTED WITH HANDLING, STORAGE, USE OR DISPOSAL OF THE PRODUCT.

MSDS No. UNLEAD Revision Date 05/23/2005 Continued on Next Page Page Number: 17

CITGO Gasolines, All Grades Unleaded

***** END OF MSDS *****

Attachment D

Health and Safety Plan Pre-Entry Briefing Attendance Form

Health and Safety Plan Pre-Entry Briefing Attendance Form

Cedar Lake Aluminum Treatment Study

Cedar Lake

Cedar Lake, Lake County, Indiana

Conducted by:		Date Performed:	
Topics Discussed:	1. Review of the content of the HASP (Required)		
	2.		
	3.		
	4.		

Printed Name	Signature	Representing

Attachment E

Supervisor's Accident Investigation Report Form

H&S SOP NO: 4.2

SUPERVISOR'S ACCIDENT INVESTIGATION REPORT

Injured Employee _____ Job Title _____

Home Office _____ Division/Department _____

Date/Time of Accident _____

Location of Accident _____

Witnesses to the Accident _____

Injury Incurred? _____ Nature of Injury _____

Engaged in What Task When Injured? _____

Will Lost Time Occur? _____ How Long? _____ Date Lost Time Began _____

Were Other Persons Involved/Injured? _____

How Did the Accident Occur? _____

What Could Be Done to Prevent Recurrence of the Accident? _____

What Actions Have You Taken Thus Far to Prevent Recurrence? _____

Supervisor's Signature _____ Title _____ Date _____

Reviewer's Signature _____ Title _____ Date _____

Note: If the space provided on this form is insufficient, provide additional information on a separate page and attach. The completed accident investigation report must be submitted to the Regional Health and Safety Manager within two days of the occurrence of the accident.

Appendix A

ENSR's Injury and Illness Statistics and Safety Program Overview

OSHA Recordable Cases and Rates

Year	Hours Worked	Fatalities	OSHA Recordable Cases		Cases with Restricted Work ⁽³⁾		Cases with Days Away from Work	
			Cases	Rate ⁽²⁾	Cases	Rate ⁽²⁾	Cases	Rate ⁽²⁾
2007	3,945,248	0	16	0.8	4	0.15	3	0.2
2006	2,179,430	0	11	1.0	2	0.2	1	0.1
2005	2,027,708	0	13	1.3	0	0.0	3	0.3
2004	1,892,353	0	13	1.4	5	0.5	0	0.0
2003	1,670,458	0	16	1.9	3	0.4	2	0.2
2002	1,955,224	0	18	1.8	3	0.3	6	0.6
2001	2,066,790	0	25	2.4	5	0.5	6	0.6
2000	2,116,919	0	30	2.8	5	0.5	6	0.6
1999	2,105,372	0	32	3.0	5	0.5	4	0.4

⁽¹⁾ 2007 statistics are provided through December 31 and reflect ENSR's Global Operations.

⁽²⁾ All injury and illness rates are provided per 200,000 employee hours worked.

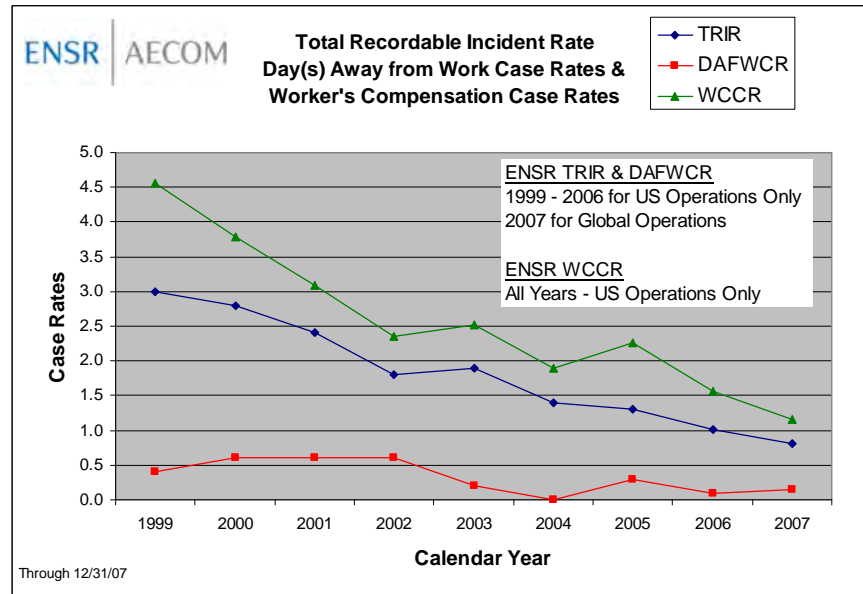
⁽³⁾ Restricted Work Cases are those cases that result in restricted work only. Restricted Work Cases that also result in Days Away from Work are classified as Days Away from Work Cases.

ENSR Corp. Experience Modification Rates (EMR)

EMR Type	2007	2006	2005	2004	2003	2002	2001	2000
Interstate ⁽¹⁾	0.75	0.82	0.84	0.80	0.84	0.79	0.75	0.75

⁽¹⁾ The Interstate EMR covers the majority of the states in which ENSR offices are located.

Positive Trends in Key H&S Performance Indicators



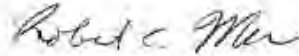
As evidence of the overall success of our H&S program, ENSR's:

- Total Recordable Incident Rate has each declined in 7 of the last 8 years
- Our 2007 TRIR is the lowest in our history

Environmental Health and Safety Policy

Issue Date: July 2007

Approval:

Robert C. Weber
President & CEO

As a leading global provider of environmental, health, and safety (EHS) engineering and consulting services, ENSR is committed in the conduct of our operations to protecting the environment as well as the health and safety of our employees, clients, subcontractors, suppliers, and the communities which we serve. To demonstrate and support this steadfast commitment, ENSR has adopted the following EHS Guiding Principles:


- We will conduct our day-to-day business in a manner consistent with our philosophy that protecting people and the environment is our highest priority and that no aspect of the Company's activities, including expediency and cost, shall ever take precedence;
- We will take every reasonable measure to assure a workplace that is free from occupational injuries and illnesses;
- We will comply with all relevant EHS legal and other voluntary requirements to which we subscribe;
- We will promote environmental sustainability through the efficient use of energy, conservation of natural resources, and prevention of pollution through reuse, recycling, and reduction wherever practical at every stage of our business;
- We will rigorously pursue the development and use of environmentally sound and intrinsically safe processes, technology, and management methods in the planning and execution of our services;
- We will identify and effectively manage the environmental impacts and health and safety risks caused by our operations;
- We will educate our employees and inform our subcontractors, as appropriate, on this Policy and the importance of fulfilling their EHS responsibilities, and will encourage our clients, suppliers, and service partners to commit to similar EHS standards;
- We will strive to continually improve our EHS performance by setting and reviewing periodic goals and by regularly conducting assessments to ensure that our EHS programs, procedures, and practices are effectively and consistently implemented; and
- We will provide the necessary human, financial, and material resources to adequately implement this Policy.

It is the expectation and responsibility of each ENSR employee and subcontractor to understand and fully support this Policy in the performance of all work activities.

Appendix B

Job Safety Analysis for Field Tasks

Job Safety Analysis


JSA Type: <input checked="" type="checkbox"/> Investigation <input type="checkbox"/> O&M <input type="checkbox"/> Office <input type="checkbox"/> Construction <input type="checkbox"/> Other		<input checked="" type="checkbox"/> New <input type="checkbox"/> Revised	Date: 03/03/08	
Work Activity: Collect sediment samples with an Eckman dredge by drilling a hole through the ice using a manual or power auger Assumes Safe Ice Conditions				
Personal Protective Equipment (PPE): Insulated steel-toed boots with yak-trax, leather gloves for augering, waterproof sampling gloves, cold weather gear, Type III PFD or Type V work vest				
Development Team	Position/Title	Reviewed By	Position/Title	Date
Kathleen Harvey	Regional H/S Manager			
❶ Job Steps ¹	❷ Potential Hazards ²	❸ Critical Actions ³	 Stop Work Criteria	
Transport Auger from Mobilization Area onto Lake and across lake to each sampling location	Slip, trip and fall (FS)	<ul style="list-style-type: none"> Attach ice traction devices, such as YakTrax™ over insulated boots. Be aware of ice fishing holes that may be present across the lake Use of buddy system 	<ul style="list-style-type: none"> Excessive snow on ice prevents safe transport Buddy is unavailable – no one works alone on ice 	
	Back strain (O)	<ul style="list-style-type: none"> Do not attempt to hand carry auger, especially a power auger. Use a sled or toboggan to carry auger across ice. 	<ul style="list-style-type: none"> No equipment is available to transport auger safely to reduce potential for back injury 	
	Exposure to cold (E)	<ul style="list-style-type: none"> Wear insulated clothing and dress in layers Have extra set of dry clothes available 	<ul style="list-style-type: none"> Work will not be conducted if air temperatures are less than 20 degrees F, and wind speeds exceed 20 miles per hour 	
	Struck by snowmobilers on ice	<ul style="list-style-type: none"> Set up sampling stations out of the main drag. Wear bright orange traffic safety vest or a PFD. If heavy lake traffic, cordon off each work area with a set of traffic cones. 	<ul style="list-style-type: none"> If traffic barriers are insufficient to protect team from snowmobilers 	

JSA Type: Investigation O&M Office Construction Other New Revised **Date:** 03/03/08


Work Activity: Collect sediment samples with an Eckman dredge by drilling a hole through the ice using a manual or power auger
Assumes Safe Ice Conditions

Personal Protective Equipment (PPE): Insulated steel-toed boots with yak-trax, leather gloves for augering, waterproof sampling gloves, cold weather gear, Type III PFD or Type V work vest

Development Team	Position/Title	Reviewed By	Position/Title	Date
Kathleen Harvey	Regional H/S Manager			

❶ Job Steps ¹	❷ Potential Hazards ²	❸ Critical Actions ³	 Stop Work Criteria
Drill Hole through Ice	Cuts and Lacerations	<ul style="list-style-type: none"> When opening a hole, stand the ice auger upright, placing the tip at the center point where you want the hole cut through the ice. Hold it firmly in place while cranking the handle clockwise. The tip should begin carving through the ice 	<ul style="list-style-type: none">
	Entanglement	<ul style="list-style-type: none"> Maintain a distance to prevent worker contact with moving machine parts. 	<ul style="list-style-type: none">
	Back Strain and Fatigue	<ul style="list-style-type: none"> Rotate augering tasks between team members especially if using a manual auger 	<ul style="list-style-type: none"> Fatigue is leading to impaired judgement or inability to perform work efficiently or effectively
	Slip, Trip and Fall	<ul style="list-style-type: none"> Keep all unnecessary equipment out of the way when augering – place on sled or toboggan 	<ul style="list-style-type: none">
Collecting Sediment Samples with Eckman Dredge	Contact with Water and Sediment	<ul style="list-style-type: none"> Although not chemically-impacted, appropriate water-proof sampling gloves will be worn. Extra clothes are needed to avoid hypothermia/frostbite 	<ul style="list-style-type: none">

Job Safety Analysis


JSA Type: <input checked="" type="checkbox"/> Investigation <input type="checkbox"/> O&M <input type="checkbox"/> Office <input type="checkbox"/> Construction <input type="checkbox"/> Other		<input checked="" type="checkbox"/> New <input type="checkbox"/> Revised		Date: 03/03/08	
Work Activity: Collect sediment samples with an Eckman dredge from a 22' jon boat					
Personal Protective Equipment (PPE): Cold weather gear, waterproof boots, waterproof sampling gloves, Type III PFD or Type V work vest, safety glasses when sampling					
Development Team		Position/Title		Reviewed By	
Kathleen Harvey		Regional H/S Manager			
❶ Job Steps ¹	❷ Potential Hazards ²	❸ Critical Actions ³	 Stop Work Criteria		
Operate boat to access sediment sampling locations	Boat malfunction	<ul style="list-style-type: none"> Inspect boat with marina personnel Verify boat registration Operator must have successfully completed USCG-approved safe boating course Determine boat capacity so as not to overload 	<ul style="list-style-type: none"> Defects noted Invalid/outdated registration Operator is not trained Too much equipment for boat capacity 		
	Boat emergency	<ul style="list-style-type: none"> Identify location of emergency equipment Complete float plan and submit to PM Use of buddy system 	<ul style="list-style-type: none"> Do not operate if emergency equipment is not available Float plan is not completed No one can work alone on the water 		
Collecting Sediment Samples with Eckman Dredge	Drowning	<ul style="list-style-type: none"> Use of PFDs Maintain boat capacity- do not overload Perform sampling from stable position from bow or stern of boat 	<ul style="list-style-type: none"> PFDs are unavailable or defects noted Too much equipment 		
	Slip, Trip or Fall	<ul style="list-style-type: none"> Secure all equipment to prevent shifting Wear water-proof, skid-proof boots Place anti-slip mats on deck Remove accumulated water/sediment from boat deck 	<ul style="list-style-type: none"> Equipment and PPE unavailable or ineffective to control hazards 		

JSA Type: Investigation O&M Office Construction Other New Revised **Date:** 03/03/08

Work Activity: Collect sediment samples with an Eckman dredge from a 22' jon boat

Personal Protective Equipment (PPE): Cold weather gear, waterproof boots, waterproof sampling gloves, Type III PFD or Type V work vest, safety glasses when sampling

Development Team	Position/Title	Reviewed By	Position/Title	Date
Kathleen Harvey	Regional H/S Manager			

① Job Steps ¹	② Potential Hazards ²	③ Critical Actions ³	 Stop Work Criteria
	Contact with Water and Sediment	<ul style="list-style-type: none"> Although not chemically-impacted, appropriate water-proof sampling gloves will be worn. Extra clothes are needed to avoid hypothermia/frostbite 	<ul style="list-style-type: none"> PPE unavailable
	Exposure to cold (E)	<ul style="list-style-type: none"> Wear insulated clothing and dress in layers Have extra set of dry clothes available 	<ul style="list-style-type: none"> Work will not be conducted if air temperatures are less than 20 degrees F, and wind speeds exceed 20 miles per hour

Attachment 3: USACE Preliminary Calculations



**US Army Corps
of Engineers®**
Chicago District

PROJECT TITLE:

Cedar Lake Section 206

COMPUTED BY:

DFB

DATE:

14Jun07

SHEET:

1 of 4

COMPUTATION TITLE:

Alum Treatment Dosage Calculations

CHECKED BY:

DATE:

The application of aluminum sulfate ($Al_2(SO_4)_3$), also referred to as alum, to inactivate sediment phosphorus, thereby reducing internal phosphorus loading and availability to blue-green bacteria has been successful in several lakes. Achieving the proper aluminum dose is extremely important, not so much for potential toxicity from aluminum and pH—because this will be minimized or eliminated with adequate buffering—but to ensure inactivation of all mobile phosphorus in the effective sediment layer. As with any chemical treatment of water and wastewater, treatment effectiveness is dependent on the dose of the chemical used. For phosphorus inactivation of lake sediments, dose can be estimated three ways: alkalinity method, internal loading method, and the sediment phosphorus method. The sediment phosphorus method developed by (Rydin and Welch, 1999) was used to estimate the dosage requirements as shown below.

Sediment Mobile Phosphorus:

Sediment total phosphorus concentrations based on sediment core samples were collected by Harza, Inc. in July 1998. Regular spline interpolation based on 3 points was used to generate a concentration map of Cedar Lake. Ghost points were added along the shoreline and were assumed to have the same properties as SS-11 due to sandy soil characteristics of both the sample and areas <4-feet of depth along the shore. There are two nutrient inactivation measures being considered for Cedar Lake based on the phosphorus concentration mapping. Measure B.1 involves alum treatment to areas that contain elevated levels of phosphorus >500mg/kg, which equals an area of 224-ac. Measure B.2 involves alum treatment to areas that contain elevated levels of phosphorus >700mg/kg, which equals an area of 83-ac. Since the area of Measure B.2 is included in Measure B.1, the areas will be split up for Measure B.1.

Total phosphorus concentrations were area averaged by measure in order to calculate dosage requirements. Based on the phosphorus concentration map, the average total concentration for Measure B.2 was determined to be 850 mg/kg and the additional portion added to B.1 was determined to be 600 mg/kg. The mobile fraction of the total phosphorus concentration were not determined for Cedar Lake, but based on research done on other lakes (Cercio and Cole, 1993) the percentage of mobile phosphorus equals the dissolved and labile portions while the refractory portion is not mobile. An assumed ratio of mobile to non-mobile phosphorus is 70% and 30% respectively. Based on these assumed ratios, the average mobile phosphorus for each measure is shown in the table below:

Measure	Area (ac)	Average Total Phosphorus Concentration (mg/kg)	Mobile Phosphorus Fraction (%)	Average Mobile Phosphorus Concentration (mg/kg)
B.1	83	850	70	595
	141	600	70	420
B.2	83	850	70	595

Sediment Properties:

Bulk density and percent solids information were based on sediment core samples collected and analyzed by Sandia National Laboratory in July 2005. Data from each sediment core were first averaged over depth and then averaged over the footprint area for each measure. A list of sediment core data used is shown in the table below:

Sediment Core ID	Average Bulk Density (g/cm ³)	Average Water Content (%)	Average Solids Content (%)
3	1.12	0.82	0.18
4	1.10	0.85	0.15
5	1.14	0.81	0.19
7	1.09	0.86	0.14
8	1.12	0.82	0.18
10	1.11	0.84	0.16
13	1.12	0.83	0.17
15	1.10	0.86	0.14
Average	1.11	0.84	0.16



**US Army Corps
of Engineers®**
Chicago District

PROJECT TITLE:

Cedar Lake Section 206

COMPUTED BY:

DFB

DATE:

14Jun07

SHEET:

2 of 4

COMPUTATION TITLE:

Alum Treatment Dosage Calculations

CHECKED BY:

DATE:

Aluminum Dosage:

For Cedar Lake, a ratio of 10:1 for aluminum added: aluminum-bound phosphorus formed in treated lake sediments was chosen based on similar alum treatments done on other lakes (Rydin and Welch 1998). A 20 cm sediment depth for treatment was selected based on phosphorus concentrations measured over depth in Cedar Lake sediments. I was shown that concentrations remained relatively constant with depth over the first 20 cm (Echelberger 1984). To estimate alum dosage, average mobile phosphorus concentrations are multiplied by average bulk sediment density and then multiplied by sediment treatment depth and the percentage of solids and then multiplied by the ratio of aluminum added to phosphorus bound. The equation is shown below:

$$(\text{mobile P conc.}) \times (\text{sed. bulk density}) \times (\text{sed. depth}) \times (\% \text{ solids}) \times (\text{ratio of Al added to mobile P}) = \text{Al added}$$

the application of this equation for Measure B.2 is shown below:

$$595 \frac{\text{mg}}{\text{kg}} P_{\text{mobile}} \times 1.11 \frac{\text{g}}{\text{cm}^3} \times 20\text{cm} \times 0.16 \times 10 \frac{\text{Al}_{\text{added}}}{P_{\text{mobile}}} \times \frac{1\text{kg}}{1000\text{g}} \times \frac{10000\text{cm}^2}{1\text{m}^2} \times \frac{1\text{g}}{1000\text{mg}} = 211 \frac{\text{g}}{\text{m}^2} \text{Al}_{\text{added}}$$

the application of this equation to the additional area for Measure B.1 is shown below:

$$420 \frac{\text{mg}}{\text{kg}} P_{\text{mobile}} \times 1.11 \frac{\text{g}}{\text{cm}^3} \times 20\text{cm} \times 0.16 \times 10 \frac{\text{Al}_{\text{added}}}{P_{\text{mobile}}} \times \frac{1\text{kg}}{1000\text{g}} \times \frac{10000\text{cm}^2}{1\text{m}^2} \times \frac{1\text{g}}{1000\text{mg}} = 149 \frac{\text{g}}{\text{m}^2} \text{Al}_{\text{added}}$$

These area doses were then corrected for mean depth to arrive at volumetric Al doses. Using GIS, the average depth of water was calculated for Measure B.2 and the additional area of B.1 as 11.37 ft and 11.51ft respectively. Volumetric Al doses were determined based on the volume of water above the areas to be treated. Using average depth of water, the volumetric Al dose required for Measure B.2 equals:

$$211 \frac{\text{g}}{\text{m}^2} \text{Al}_{\text{added}} \times \frac{1}{11.37\text{ft}} \times \frac{3.28\text{ft}}{1\text{m}} \times \frac{1\text{m}^3}{1000\text{l}} \times \frac{1000\text{mg}}{1\text{g}} = 60.9 \frac{\text{mg}}{\text{l}} \text{Al}_{\text{added}}$$

the volumetric Al dose required for the additional area of Measure B.1 is shown below:

$$149 \frac{\text{g}}{\text{m}^2} \text{Al}_{\text{added}} \times \frac{1}{11.51\text{ft}} \times \frac{3.28\text{ft}}{1\text{m}} \times \frac{1\text{m}^3}{1000\text{l}} \times \frac{1000\text{mg}}{1\text{g}} = 42.5 \frac{\text{mg}}{\text{l}} \text{Al}_{\text{added}}$$

The above doses are required to treat mobile P in the sediments and does not account for water column total phosphorus. Therefore, an additional amount of alum is required to treat phosphorus in the water column. The average total phosphorus concentration as observed during the summer of 2005 was 0.11 mg/l. In order to account for phosphorus in the water column, the average total phosphorus concentration was multiplied by the Al added: mobile P ratio resulting in an additional 1.1 mg/l. The resulting volumetric Al dose required for each measure is shown in the table below:

Measure	Area (ac)	Volumetric Al _{added} for Sediments (mg/l)	Volumetric Al _{added} for Water Column (mg/l)	Total Volumetric Al _{added} (mg/l)
B.1	83	60.9	1.1	62.0
	141	42.5	1.1	43.6
B.2	83	60.9	1.1	62.0

Mass of Aluminum Dosage:

The volumetric dose of aluminum needed to inactivate phosphorus is assumed to require a buffer to prevent the pH of the water from dropping below 6.0 during treatment, which will make water quality toxic to aquatic life. The most cost effective method for buffering is to apply sodium aluminate and alum in the lake simultaneously. Sodium aluminate (Na₂Al₂O₄) is a buffering agent which also contributes aluminum thereby reducing the amount of alum that is necessary for phosphorus inactivation. The ratio of alum to sodium aluminate to maintain neutral pH is 2 parts alum to 1 part sodium aluminate by volume.



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Cedar Lake Section 206

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DATE:

14Jun07

SHEET:

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COMPUTATION TITLE:

Alum Treatment Dosage Calculations

CHECKED BY:

DATE:

The total weight of aluminum required is calculated based on the dosage required over the volume of water in the application area. Volumes of water for Measure B.2 and the additional area of B.1 were computed to 944 ac-ft and 1,623 ac-ft respectively. The total weight of aluminum required for Measure B.2 equals:

$$62.0 \frac{mg}{l} Al_{added} \times 944 ac \cdot ft \times \frac{1233482l}{1ac \cdot ft} \times \frac{1lb}{453592mg} = 159159lbAl_{added}$$

the total weight of aluminum required for the additional area of Measure B.1 is shown below:

$$43.6 \frac{mg}{l} Al_{added} \times 1623 ac \cdot ft \times \frac{1233482l}{1ac \cdot ft} \times \frac{1lb}{453592mg} = 192430lbAl_{added}$$

Quantity of Alum and Sodium Aluminate Needed:

In order to determine the total amount of alum and sodium aluminate required for application, standard concentrations of water-soluble aluminum on the market were found. It should be noted that percentages of water-soluble aluminum in alum and sodium aluminate varies, though requiring different amounts of bulk product. In determining costs, these differences must be taken into account. The following parameters are used in calculating the amount of alum and sodium aluminate required:

- Liquid alum weighs 11.1 lb/gal and contains 4.4% Al+++
- Liquid sodium aluminate weights 12.1 lb/gal and contains 10.4% Al+++
- One gallon sodium aluminate will buffer two gallons alum
- 2.3 conversion factor percentage of available aluminum in sodium aluminate versus alum

Based on these parameters, the total amount of alum and sodium aluminate for each measure can be determined. The total pounds of alum containing 4.4% water-soluble aluminum for Measure B.2 equals:

$$159159lbAl_{added} \times \frac{1lb_{alum}}{0.044lbAl_{added}} \times \frac{1}{2.3} \times \frac{1ton_{alum}}{2000lb_{alum}} = 786ton_{alum}$$

the amount of alum if purchased in liquid form based on 11.1 lb/gal for Measure B.2 equals:

$$786ton_{alum} \times \frac{1}{11.1 \frac{lb_{alum}}{gal_{alum}}} \times \frac{2000lb_{alum}}{1ton_{alum}} = 141622gal_{alum}$$

since the buffer application ratio of alum to sodium aluminate is 2:1, the amount of sodium aluminate containing 10.4% water-soluble aluminum if purchased in liquid form for Measure B.2 equals:

$$141622gal_{alum} \times \frac{1gal_{sodiumAl}}{2gal_{alum}} = 70811gal_{sodiumAl}$$

therefore, the total pounds of sodium aluminate based on 12.1 lb/gal for Measure B.2 equals:

$$70811gal_{sodiumAl} \times 12.1 \frac{lb_{sodiumAl}}{gal_{sodiumAl}} \times \frac{1ton_{sodiumAl}}{2000lb_{sodiumAl}} = 428ton_{sodiumAl}$$



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COMPUTATION TITLE:

Alum Treatment Dosage Calculations

CHECKED BY:

DATE:

Based on the calculations performed above, the amount of alum and sodium aluminate required for each measure is shown in the table below:

Measure	Area (ac)	Mass of Water-Soluble Aluminum ion Required (lb)	Quantity of Alum ¹ Required (tons)	Quantity of Alum ¹ Required (gal)	Quantity of Sodium Aluminate ² Required (tons)	Quantity of Sodium Aluminate ² Required (gal)
B.1	83	159,159	786	141,622	428	70,811
	141	192,430	950	171,305	518	85,652
	224	351,589	1,736	312,927	946	156,463
B.2	83	159,159	786	141,622	428	70,811

¹ assume liquid alum weighs 11.1 lb/gal and contains 4.4% Al+++ water-soluble aluminum ions

² assume liquid sodium aluminate weighs 12.1 lb/gal and contains 10.4% Al+++ water-soluble aluminum ions

Cost Estimate for Alum Treatment:

A cost estimate can be developed based the quantities of alum and sodium aluminate calculated above. Based on the deep depth of sediment treatment selected (20-cm) and the relatively high ratio of aluminum added to mobile phosphorus bound (10:1), the longevity of treating Cedar Lake with the prescribed dosages above is predicted to be approximately 10 years.

References:

¹Rydin, E. and E.B. Welch. 1999. Dosing Alum to Wisconsin Lake Sediments Based on in Vitro Formation of Aluminum-Bound Phosphate. Lake and Reservoir Management. 15:324-331.

²Cerco, C. F., and Cole, T. 1993. Three-dimensional eutrophication model of Chesapeake Bay. J. Envir. Engrg., 119(6), 1006-1025.

³Rydin, E. and E.B. Welch. 1998. Aluminum Dose Required to Inactivate Phosphorus in Lake Sediments. Water Research. 32:2969-2976.

⁴Echelberger, W.F., 1984. Cedar Lake Restoration Feasibility Study: Final report, Environmental Systems Application Center, School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana, ESAC-84-01.

Attachment 4: Laboratory Data

Report Date:
09-May-08 10:55



- Final Report
- Re-Issued Report
- Revised Report

SPECTRUM ANALYTICAL, INC.

Featuring

HANIBAL TECHNOLOGY

Laboratory Report

ENSR Corporation
11 Phelps Way, P.O. Box 506
Willington, CT 06279
Attn: Ken Wagner

Project: Cedar Lake - IN
Project 12005-021-100

<u>Laboratory ID</u>	<u>Client Sample ID</u>	<u>Matrix</u>	<u>Date Sampled</u>	<u>Date Received</u>
SA76837-01	MU3CO3	Sediment	07-Apr-08 11:50	08-Apr-08 10:39
SA76837-02	MU3CO1	Sediment	07-Apr-08 12:18	08-Apr-08 10:39
SA76837-03	MU1CO1	Sediment	07-Apr-08 12:28	08-Apr-08 10:39
SA76837-04	MU1CO4	Sediment	07-Apr-08 12:37	08-Apr-08 10:39
SA76837-05	MU1CO2	Sediment	07-Apr-08 12:55	08-Apr-08 10:39
SA76837-06	MU2CO1	Sediment	07-Apr-08 13:07	08-Apr-08 10:39
SA76837-07	MU2CO2	Sediment	07-Apr-08 13:18	08-Apr-08 10:39
SA76837-08	MU4CO1	Sediment	07-Apr-08 13:41	08-Apr-08 10:39
SA76837-09	MU4CO2	Sediment	07-Apr-08 13:50	08-Apr-08 10:39
SA76837-10	MU4CO2D	Sediment	07-Apr-08 13:57	08-Apr-08 10:39
SA76837-11	MU4CO3	Sediment	07-Apr-08 14:08	08-Apr-08 10:39

I attest that the information contained within the report has been reviewed for accuracy and checked against the quality control requirements for each method. These results relate only to the sample(s) as received.

All applicable NELAC requirements have been met.

Please note that this report contains 17 pages of analytical data plus Chain of Custody document(s).

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New Jersey # MA011/MA012
New York # 11393/11840
Rhode Island # 98
USDA # S-51435
Vermont # VT-11393



Authorized by:

Hanibal C. Tayeh, Ph.D.
President/Laboratory Director

Technical Reviewer's Initial:

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CASE NARRATIVE:

The data has been revised to take the %solids into consideration for phosphorus via method 200.7 only. All other results remain the same.

In addition to phosphorus via EPA method 200.7, phosphorus was analyzed via ASTM D515 88A. The data was not originally reported due to low recovery for the Standard Reference Material (SRM). The results have to be evaluated as biased low based on the low recovery of 9% for the SRM.

Sample Identification

MU3CO3
SA76837-01

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 11:50

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,240		mg/kg dry	23.0	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	35.6		mg/kg dry	1.93	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	24.1		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	106		mg/kg dry dry	5.19	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	3.80		mg/kg dry dry	1.04	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.046		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU3CO1
SA76837-02

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 12:18

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,080		mg/kg dry	24.7	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	101		mg/kg dry	2.26	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	21.2		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	131		mg/kg dry dry	5.90	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	7.15		mg/kg dry dry	1.18	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.062		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU1CO1
SA76837-03

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 12:28

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	670		mg/kg dry	10.6	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	10.4		mg/kg dry	0.896	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	53.4		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	40.3		mg/kg dry dry	2.34	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	1.48		mg/kg dry dry	0.47	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.062		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification
MU1CO4
 SA76837-04

Client Project #
 12005-021-100

Matrix
 Sediment

Collection Date/Time
 07-Apr-08 12:37

Received
 08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	714		mg/kg dry	22.8	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	71.9		mg/kg dry	2.02	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	24.9		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	32.7		mg/kg dry dry	5.02	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	2.36		mg/kg dry dry	1.00	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.084		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU1CO2
SA76837-05

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 12:55

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	817		mg/kg dry	21.9	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	41.5		mg/kg dry	1.73	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	26.0		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	50.2		mg/kg dry dry	4.81	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	2.08		mg/kg dry dry	0.96	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.035		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU2CO1
SA76837-06

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 13:07

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	726		mg/kg dry	19.5	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	30.9		mg/kg dry	1.78	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	28.1		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	34.7		mg/kg dry dry	4.45	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	1.69		mg/kg dry dry	0.89	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.119		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU2CO2
SA76837-07

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 13:18

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	948		mg/kg dry	23.6	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	85.7		mg/kg dry	2.06	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	24.2		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	106		mg/kg dry dry	5.17	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	3.38		mg/kg dry dry	1.03	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.041		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU4CO1
SA76837-08

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 13:41

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,140		mg/kg dry	28.4	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	31.7		mg/kg dry	2.48	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	20.1		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	162		mg/kg dry dry	6.22	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	5.09		mg/kg dry dry	1.24	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	0.982		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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Sample Identification

MU4CO2
SA76837-09

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 13:50

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,000		mg/kg dry	28.8	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	81.1		mg/kg dry	2.54	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	18.9		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	132		mg/kg dry dry	6.61	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	5.05		mg/kg dry dry	1.32	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.048		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

This laboratory report is not valid without an authorized signature on the cover page.

* Reportable Detection Limit

BRL = Below Reporting Limit

Page 11 of 17

Sample Identification**MU4CO2D**

SA76837-10

Client Project #

12005-021-100

Matrix

Sediment

Collection Date/Time

07-Apr-08 13:57

Received

08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,210		mg/kg dry	38.2	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	196		mg/kg dry	3.36	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	14.5		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	129		mg/kg dry dry	8.62	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	6.61		mg/kg dry dry	1.72	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.119		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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* Reportable Detection Limit

BRL = Below Reporting Limit

Page 12 of 17

Sample Identification

MU4CO3
SA76837-11

Client Project #
12005-021-100

Matrix
Sediment

Collection Date/Time
07-Apr-08 14:08

Received
08-Apr-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
Total Metals by EPA 200 Series Methods											
7723-14-0	Phosphorus as P	1,380		mg/kg dry	18.1	1	EPA 200.7	23-Apr-08	23-Apr-08	8042015	SA
General Chemistry Parameters											
7723-14-0	Phosphorus as P	38.8		mg/kg dry	1.46	1	ASTM D515-88(A)	18-Apr-08	18-Apr-08	8050672	ELE
	% Solids	33.1		%		1	SM2540 G Mod.	18-Apr-08	20-Apr-08	8041765	JOC
	Iron bound Phosphorus as P	196		mg/kg dry dry	3.78	1	ASTM D515-88(A)	18-Apr-08	20-Apr-08	8041716	"
	Loosely-sorbed Phosphorus as P	4.23		mg/kg dry dry	0.76	1	"	18-Apr-08	20-Apr-08	8041713	"
Subcontracted Analyses											
	Specific Gravity @ 60F	1.032		N/A		1	ASTM D792		19-Apr-08	'[none]'	MT.TO

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* Reportable Detection Limit

BRL = Below Reporting Limit

Page 13 of 17

Total Metals by EPA 200 Series Methods - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 8042015 - EPA 200 Series										
<u>Blank (8042015-BLK1)</u>										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	BRL		mg/kg wet	5.90						
<u>Duplicate (8042015-DUP1)</u> Source: SA76837-02										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	1070		mg/kg dry	24.4		1080			0.8	20
<u>Matrix Spike (8042015-MS1)</u> Source: SA76837-05										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	1230		mg/kg dry	20.1	420	817	98	80-120		
<u>Matrix Spike (8042015-MS2)</u> Source: SA76837-06										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	1160		mg/kg dry	21.3	444	726	97	80-120		
<u>Post Spike (8042015-PS1)</u> Source: SA76837-05										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	1270		mg/kg dry	22.6	472	817	95	85-115		
<u>Post Spike (8042015-PS2)</u> Source: SA76837-06										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	1120		mg/kg dry	19.1	397	726	100	85-115		
<u>Reference (8042015-SRM1)</u>										
Prepared & Analyzed: 23-Apr-08										
Phosphorus as P	349		mg/kg wet	6.00	294		118	54.8-145.2		

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* Reportable Detection Limit

BRL = Below Reporting Limit

General Chemistry Parameters - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC Limits	RPD	RPD Limit
Batch 8041713 - Phosphorus Fractionation									
<u>Blank (8041713-BLK1)</u>									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	BRL		mg/kg dry we	0.25					
<u>LCS (8041713-BS1)</u>									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	130		mg/kg dry we	0.25	125		104 90-110		
<u>Duplicate (8041713-DUP1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	BRL	QR6	mg/kg dry dry	1.00		2.36		54	35
<u>Duplicate (8041713-DUP2)</u> Source: SA76837-09									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	5.01		mg/kg dry dry	1.32		5.05		0.8	35
<u>Matrix Spike (8041713-MS1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	10.4	Z-2c	mg/kg dry dry	1.00	99.8	2.36	8 80-120		
<u>Matrix Spike (8041713-MS2)</u> Source: SA76837-09									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	31.9	Z-2c	mg/kg dry dry	1.32	134	5.05	20 80-120		
<u>Matrix Spike Dup (8041713-MSD1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	10.7	Z-2c	mg/kg dry dry	1.00	101	2.36	8 80-120	3	35
<u>Matrix Spike Dup (8041713-MSD2)</u> Source: SA76837-09									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Loosely-sorbed Phosphorus as P	32.6	Z-2c	mg/kg dry dry	1.32	132	5.05	21 80-120	2	35
Batch 8041716 - Phosphorus Fractionation									
<u>Blank (8041716-BLK1)</u>									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	BRL		mg/kg dry we	1.25					
<u>LCS (8041716-BS1)</u>									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	134		mg/kg dry we	1.25	125		107 90-110		
<u>Duplicate (8041716-DUP1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	35.1		mg/kg dry dry	5.02		32.7		7	35
<u>Duplicate (8041716-DUP2)</u> Source: SA76837-09									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	124		mg/kg dry dry	6.61		132		6	35
<u>Matrix Spike (8041716-MS1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	111	Z-2a	mg/kg dry dry	5.02	99.8	32.7	78 80-120		
<u>Matrix Spike (8041716-MS2)</u> Source: SA76837-09									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	216	Z-2	mg/kg dry dry	6.61	134	132	63 80-120		
<u>Matrix Spike Dup (8041716-MSD1)</u> Source: SA76837-04									
Prepared: 18-Apr-08 Analyzed: 20-Apr-08									
Iron bound Phosphorus as P	109	Z-2	mg/kg dry dry	5.02	101	32.7	75 80-120	1	35

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General Chemistry Parameters - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 8041716 - Phosphorus Fractionation										
<u>Matrix Spike Dup (8041716-MSD1)</u> Source: SA76837-04										
Prepared: 18-Apr-08 Analyzed: 20-Apr-08										
<u>Matrix Spike Dup (8041716-MSD2)</u> Source: SA76837-09										
Prepared: 18-Apr-08 Analyzed: 20-Apr-08										
Iron bound Phosphorus as P	219	Z-2b	mg/kg dry dry	6.61	132	132	67	80-120	2	35
Batch 8041765 - General Preparation										
<u>Duplicate (8041765-DUP1)</u> Source: SA76837-05										
Prepared: 18-Apr-08 Analyzed: 20-Apr-08										
% Solids	26.1		%			26.0			0.4	200
Batch 8050672 - General Preparation										
<u>Blank (8050672-BLK1)</u>										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	BRL		mg/kg wet	0.00500						
<u>LCS (8050672-BS1)</u>										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	BRL		mg/kg wet	0.00500	0.200		101	90-110		
<u>Duplicate (8050672-DUP1)</u> Source: SA76837-04										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	65.2		mg/kg dry	1.96		71.9			10	35
<u>Matrix Spike (8050672-MS1)</u> Source: SA76837-04										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	138		mg/kg dry	1.92	76.7	71.9	86	80-120		
<u>Matrix Spike Dup (8050672-MSD1)</u> Source: SA76837-04										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	140		mg/kg dry	1.80	72.1	71.9	95	80-120	2	200
<u>Reference (8050672-SRM1)</u>										
Prepared & Analyzed: 18-Apr-08										
Phosphorus as P	54.0	QC1	mg/kg wet	1.22	569		9	54.8-145.2		

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* Reportable Detection Limit

BRL = Below Reporting Limit

Notes and Definitions

QC1	Analyte out of acceptance range.
QR6	The RPD exceeded the QC control limits; however precision is demonstrated with acceptable RPD values for MS/MSD.
Z-2	Combined recovery for the phosphorus fractionation is 83%.
Z-2a	Combined recovery for the phosphorus fractionation is 86%.
Z-2b	Combined recovery for the phosphorus fractionation is 88%.
Z-2c	Spiked samples are analyzed throughout the extraction procedure. Typically results for the loosely bound fraction show little to no recovery.
BRL	Below Reporting Limit - Analyte NOT DETECTED at or above the reporting limit
dry	Sample results reported on a dry weight basis
NR	Not Reported
RPD	Relative Percent Difference

A plus sign (+) in the Method Reference column indicates the method is not accredited by NELAC.

Laboratory Control Sample (LCS): A known matrix spiked with compound(s) representative of the target analytes, which is used to document laboratory performance.

Matrix Duplicate: An intra-laboratory split sample which is used to document the precision of a method in a given sample matrix.

Matrix Spike: An aliquot of a sample spiked with a known concentration of target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix.

Method Blank: An analyte-free matrix to which all reagents are added in the same volumes or proportions as used in sample processing. The method blank should be carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.

Method Detection Limit (MDL): The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.

Reportable Detection Limit (RDL): The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. For many analytes the RDL analyte concentration is selected as the lowest non-zero standard in the calibration curve. While the RDL is approximately 5 to 10 times the MDL, the RDL for each sample takes into account the sample volume/weight, extract/digestate volume, cleanup procedures and, if applicable, dry weight correction. Sample RDLs are highly matrix-dependent.

Surrogate: An organic compound which is similar to the target analyte(s) in chemical composition and behavior in the analytical process, but which is not normally found in environmental samples. These compounds are spiked into all blanks, standards, and samples prior to analysis. Percent recoveries are calculated for each surrogate.

Validated by:
Hanibal C. Tayeh, Ph.D.
June O'Connor



CHAIN OF CUSTODY RECORD

Page 1 of 2

SA: 76837 EM

Special Handling:

Standard TAT - 7 to 10 business days
 Rush TAT - Date Needed: _____
 All TATs subject to laboratory approval.
 Min. 24-hour notification needed for rushes.
 Samples disposed of after 60 days unless otherwise instructed.

Report To: K. Wagner
11 Phelps Way
Willington, CT 06279

Invoice To: Same
 P.O. No.: 2059039 RQN: _____

Project No.: 12005-021-100
 Site Name: Cedar Lake
 Location: Cedar Lake State: IN
 Sampler(s): J. Berg / W. Gendron

Project Mgr.: K. Wagner
 1=Na₂S₂O₅ 2=HCl 3=H₂SO₄ 4=HNO₃ 5=NaOH 6=Ascorbic Acid
 7=CH₃OH 8=NaHSO₄ 9=Ice 10=up
 DW=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sludge A=Air
 XI=Sediment X2= X3=

G=Grab C=Composite
 Containers:
 # of VOA Vials
 # of Amber Glass
 # of Clear Glass
 # of Plastic

Applies:
 % Solids (SM 2540A)
 Total Phosp. (ASPM DS1588A)
 Specific Gravity
 Loosely Bound-P
 Iron bound-P

QA Reporting Notes:
 (check if needed)
 Provide MA DEP MCP CAM Report
 Provide CT DEP RCP Report
 QA/QC Reporting Level
 Standard No QC
 Other _____
 * State specific reporting standards:

Lab Id:	Sample Id:	Date:	Time:	Type	Matrix	Preservative	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic	Applies:	QA Reporting Notes:
76837-01	MU3C03	4/7/08	11:50	G	XI	9	1				X X X X	* See SOP for Phosp. Fractionation of Sediments for methods
02	MU3C01		12:18				1					
03	MU1C01		12:28				1					
04	MU1C04		12:37				1					
05	MU1C02		12:55				1					
06	MU2C01		13:07				1					Hold samples for further analysis
07	MU2C02		13:18				1					
08	MU1C01		13:41				1					
09	MU4C02		13:50				1					
10	MU4C02D		13:57				1					

Condition upon receipt: Iced Ambient °C 3

Reinquished by: [Signature] Received by: [Signature]

EDD Format: 4/8/08 1039

Condition upon receipt: Iced Ambient °C 3



HANBRAL TECHNOLOGY
Company

CHAIN OF CUSTODY RECORD

Page 2 of 2

Special Handling:

- Standard TAT - 7 to 10 business days
- Rush TAT - Date Needed: _____
- All TATs subject to laboratory approval.
- Min. 24-hour notification needed for rushes.
- Samples disposed of after 60 days unless otherwise instructed.

SA 76837 EM

Report To: K. Wagner

Invoice To: Same

Project No.: 18005-021-100

11 Preles Way

Willington CT 06279

Site Name: Cedar Lake

Project Mgr.: K. Wagner

P.O. No. 2059037 RQN: _____

Location: Cedar Lake State: IN

1=Na2S2O8 2=HCl 3=H2SO4 4=HNO3 5=NaOH 6=Ascorbic Acid

7=CH3OH 8=NaHSO4 9=H2O2 10=_____

Sampler(s): J. Berg / w. Gendron

DW=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sludge A=Air
 XI=Sediment X2=_____ X3=_____

G=Grab C=Composite

Containers:

Analyses:

QA Reporting Notes:
(check if needed)

- Provide MIA DEP MCP CAM Report
- Provide CT DPH RCP Report
- QA/QC Reporting Level
 - Standard
 - No QC
 - Other _____
- * State specific reporting standards:

Lab Id:	Sample Id:	Date:	Time:	Type	Matrix	Preservative	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic	% Solids	Total Phos.	Specific Gravity	Iron Bound P	QA/QC Reporting Level	Notes
	76837-11	MU4E03	4/17/08	14:08	G	XI	9	1			X	X	X	X	<input type="checkbox"/>	* See SOP for Phos fractionation to sediment for methods
															<input type="checkbox"/>	Hold for further analysis

Fax results when available to () _____
 E-mail to KWagner@spectra.com
 EDD Format _____
 Condition upon receipt: Iced Ambient °C 3

Relinquished by: John Stall

Received by: T. Gendron

Date: 4/18/08 Time: 1039

Report Date:
15-May-08 16:32



- Final Report
- Re-Issued Report
- Revised Report

SPECTRUM ANALYTICAL, INC.

Featuring

HANIBAL TECHNOLOGY

Laboratory Report

ENSR Corporation
11 Phelps Way, P.O. Box 506
Willington, CT 06279
Attn: Ken Wagner

Project: Cedar Lake - IN
Project 12005-021-100

<u>Laboratory ID</u>	<u>Client Sample ID</u>	<u>Matrix</u>	<u>Date Sampled</u>	<u>Date Received</u>
SA78376-01	MU1CO1-Comp	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-02	MU1CO1-10g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-03	MU1CO1-30g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-04	MU1CO1-50g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-05	MU1CO1-80g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-06	MU1CO1-100g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-07	MU1CO1-150g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-08	MU3CO1-Comp	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-09	MU3CO1-10g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-10	MU3CO1-30g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-11	MU3CO1-50g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-12	MU3CO1-80g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-13	MU3CO1-100g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-14	MU3CO1-150g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-15	MU4CO1-Comp	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-16	MU4CO1-10g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-17	MU4CO1-30g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-18	MU4CO1-50g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-19	MU4CO1-80g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-20	MU4CO1-100g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-21	MU4CO1-150g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-22	MU4CO2-Comp	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-23	MU4CO2-10g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-24	MU4CO2-30g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-25	MU4CO2-50g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-26	MU4CO2-80g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-27	MU4CO2-100g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-28	MU4CO2-150g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-29	MU4CO3-Comp	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-31	MU4CO3-30g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-33	MU4CO3-80g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-34	MU4CO3-100g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40
SA78376-35	MU4CO3-150g/m2	Soill	07-Apr-08 00:00	09-May-08 12:40

I attest that the information contained within the report has been reviewed for accuracy and checked against the quality control requirements for each method. These results relate only to the sample(s) as received.

All applicable NELAC requirements have been met.

Please note that this report contains 11 pages of analytical data plus Chain of Custody document(s).

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Connecticut # PH-0777
Florida # E87600/E87936
Maine # MA138
New Hampshire # 2538
New Jersey # MA011/MA012
New York # 11393/11840
Rhode Island # 98
USDA # S-51435
Vermont # VT-11393



Authorized by:

A handwritten signature in black ink, appearing to read "H. Tayeh", is written over a light yellow rectangular background.

Hanibal C. Tayeh, Ph.D.
President/Laboratory Director

Technical Reviewer's Initial:

Handwritten initials "CW" in black ink, enclosed within a hand-drawn circle.

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CASE NARRATIVE:

Due to limited sample, aliquots for 30g/m2 and 50g/m2 were not treated with aluminum sulfate for Sample MU4CO3.

Sample Identification
MU1CO1-Comp
SA78376-01

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
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General Chemistry Parameters

% Solids	32.5			%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
Iron bound Phosphorus as P	40.0			mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU1CO1-10g/m2
SA78376-02

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
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General Chemistry Parameters

% Solids	32.5			%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
Iron bound Phosphorus as P	22.1			mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU1CO1-30g/m2
SA78376-03

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
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General Chemistry Parameters

% Solids	32.5			%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
Iron bound Phosphorus as P	3.82	J		mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU1CO1-50g/m2
SA78376-04

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
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General Chemistry Parameters

% Solids	32.5			%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
Iron bound Phosphorus as P	2.98	J		mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU1CO1-80g/m2
SA78376-05

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
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General Chemistry Parameters

% Solids	32.5			%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
Iron bound Phosphorus as P	2.34	J		mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

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* Reportable Detection Limit

BRL = Below Reporting Limit

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Sample Identification
MU1CO1-100g/m2
SA78376-06

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	32.5		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	0.75	J	mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU1CO1-150g/m2
SA78376-07

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	32.5		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	BRL	U	mg/kg dry dry	3.85		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-Comp
SA78376-08

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	124		mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-10g/m2
SA78376-09

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	68.1		mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-30g/m2
SA78376-10

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	27.9		mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

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BRL = Below Reporting Limit

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Sample Identification
MU3CO1-50g/m2
SA78376-11

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	14.1		mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-80g/m2
SA78376-12

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	9.23		mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-100g/m2
SA78376-13

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	5.12	J	mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU3CO1-150g/m2
SA78376-14

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	24.1		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	BRL	U	mg/kg dry dry	5.19		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO1-Comp
SA78376-15

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	165		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

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BRL = Below Reporting Limit

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Sample Identification
MU4CO1-10g/m2
SA78376-16

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	84.8		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO1-30g/m2
SA78376-17

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	44.7		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO1-50g/m2
SA78376-18

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	29.5		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO1-80g/m2
SA78376-19

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	26.0		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO1-100g/m2
SA78376-20

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	20.5		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

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Sample Identification
MU4CO1-150g/m2
SA78376-21

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Batch	Analyst
General Chemistry Parameters												
	% Solids	21.7		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	12.7		mg/kg dry dry	5.77		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-Comp
SA78376-22

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Batch	Analyst
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	114		mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-10g/m2
SA78376-23

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Batch	Analyst
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	50.9		mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-30g/m2
SA78376-24

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Batch	Analyst
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	15.7		mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-50g/m2
SA78376-25

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Batch	Analyst
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	7.07	J	mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

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BRL = Below Reporting Limit

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Sample Identification
MU4CO2-80g/m2
SA78376-26

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	BRL	U	mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-100g/m2
SA78376-27

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	BRL	U	mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO2-150g/m2
SA78376-28

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	17.3		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	BRL	U	mg/kg dry dry	7.23		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO3-Comp
SA78376-29

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	35.6		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	185		mg/kg dry dry	3.51		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO3-30g/m2
SA78376-31

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	35.6		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	61.2		mg/kg dry dry	3.51		1	\ASTM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

This laboratory report is not valid without an authorized signature on the cover page.

* Reportable Detection Limit

BRL = Below Reporting Limit

Sample Identification
MU4CO3-80g/m2
SA78376-33

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	35.6		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	21.0		mg/kg dry dry	3.51		1	\STM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO3-100g/m2
SA78376-34

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	35.6		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	12.5		mg/kg dry dry	3.51		1	\STM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

Sample Identification
MU4CO3-150g/m2
SA78376-35

Client Project #
12005-021-100

Matrix
Soill

Collection Date/Time
07-Apr-08 00:00

Received
09-May-08

<i>CAS No.</i>	<i>Analyte(s)</i>	<i>Result</i>	<i>Flag</i>	<i>Units</i>	<i>*RDL</i>	<i>MDL</i>	<i>Dilution</i>	<i>Method Ref.</i>	<i>Prepared</i>	<i>Analyzed</i>	<i>Batch</i>	<i>Analyst</i>
General Chemistry Parameters												
	% Solids	35.6		%			1	SM2540 G Mod.	13-May-08	13-May-08	8050981	JB
	Iron bound Phosphorus as P	9.82		mg/kg dry dry	3.51		1	\STM D515-88(A13-May-08	13-May-08	15-May-08	8050939	RD

This laboratory report is not valid without an authorized signature on the cover page.

* Reportable Detection Limit

BRL = Below Reporting Limit

Page 9 of 11

General Chemistry Parameters - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 8050939 - Phosphorus Fractionation										
<u>Blank (8050939-BLK1)</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	BRL	U	mg/kg dry we	1.25						
<u>Blank (8050939-BLK2)</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	BRL	U	mg/kg dry we	1.25						
<u>LCS (8050939-BS1)</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	119		mg/kg dry we	1.25	125		95	90-110		
<u>LCS (8050939-BS2)</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	139	QC1	mg/kg dry we	1.25	125		111	90-110		
<u>Matrix Spike (8050939-MS1) Source: SA78376-01</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	89.0	Z-2	mg/kg dry dry	3.85	77.5	40.0	63	80-120		
<u>Matrix Spike (8050939-MS2) Source: SA78376-22</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	235		mg/kg dry dry	7.23	147	114	82	80-120		
<u>Matrix Spike Dup (8050939-MSD1) Source: SA78376-01</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	94.8	Z-2	mg/kg dry dry	3.85	77.2	40.0	71	80-120	6	35
<u>Matrix Spike Dup (8050939-MSD2) Source: SA78376-22</u>										
Prepared: 13-May-08 Analyzed: 15-May-08										
Iron bound Phosphorus as P	215	Z-2	mg/kg dry dry	7.23	142	114	71	80-120	9	35

This laboratory report is not valid without an authorized signature on the cover page.

* Reportable Detection Limit BRL = Below Reporting Limit

Notes and Definitions

J	Detected above the Method Detection Limit but below the Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
QC1	Analyte out of acceptance range.
U	Analyte included in the analysis, but not detected
Z-2	The matrix spike was not analyzed on the loosely bound fraction. Recovery of phosphorus in the iron bound fraction consistent with historical data.
BRL	Below Reporting Limit - Analyte NOT DETECTED at or above the reporting limit
dry	Sample results reported on a dry weight basis
NR	Not Reported
RPD	Relative Percent Difference

A plus sign (+) in the Method Reference column indicates the method is not accredited by NELAC.

Laboratory Control Sample (LCS): A known matrix spiked with compound(s) representative of the target analytes, which is used to document laboratory performance.

Matrix Duplicate: An intra-laboratory split sample which is used to document the precision of a method in a given sample matrix.

Matrix Spike: An aliquot of a sample spiked with a known concentration of target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix.

Method Blank: An analyte-free matrix to which all reagents are added in the same volumes or proportions as used in sample processing. The method blank should be carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.

Method Detection Limit (MDL): The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.

Reportable Detection Limit (RDL): The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. For many analytes the RDL analyte concentration is selected as the lowest non-zero standard in the calibration curve. While the RDL is approximately 5 to 10 times the MDL, the RDL for each sample takes into account the sample volume/weight, extract/digestate volume, cleanup procedures and, if applicable, dry weight correction. Sample RDLs are highly matrix-dependent.

Surrogate: An organic compound which is similar to the target analyte(s) in chemical composition and behavior in the analytical process, but which is not normally found in environmental samples. These compounds are spiked into all blanks, standards, and samples prior to analysis. Percent recoveries are calculated for each surrogate.

Validated by:
Hanibal C. Tayeh, Ph.D.
June O'Connor

CHAIN OF CUSTODY RECORD

Page 1 of 5

Special Handling:
 Standard TAT - 7 to 10 business days
 Rush TAT - Date Specified: _____
 All TATs subject to laboratory approval
 Min. 24-hour notification needed for rushes
 Samples disposed of after 60 days unless otherwise instructed.

SA 78376


Report To: K. W. Papper
11 Phelps Way
Wallington MA 02119

Invoice To: Same
 P.O. No.: _____
 R.O.N.: _____

Project No.: 12005-021-100 Site: _____
 Name: Cedar Lake
 Location: Cedar Lake State: _____
 Sample(s): J. Bergler Cedar Camp by Jackson

Project Mgr.: _____
 1=Na₂SO₄ 2=HCl 3=H₂SO₄ 4=HNO₃ 5=NaOH 6=Acetic Acid
 7=CH₃OH 8=NaHSO₄ 9= _____ 10= _____
 DW=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sludge A=Air
 X1= _____ X2= _____ X3= _____

Containers:
 # of VOA Vials _____
 # of Amber Glass _____
 # of Clear Glass _____
 # of Plastic _____

Analyses:
 QA Reporting Notes: (check and for as needed)
 Probe MA DEP M.P.C.M. Report
 Probe CT DEP RC P Report
 QA/QC Reporting Level
 Standard Single
 Same specific reporting standards

Lab Id	Sample Id	Date	Time	Type	Matrix	Preservative	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic	Analyses
78376-01	MU1201	4/7/08		C	S						
	-02	10	g/m ²								
	-03	30									
	-04	50									
	-05	80									
	-06	100									
	-07	150									

Requisitioned by: [Signature]
 Received by: [Signature]
 Date: 4-06 Time: 17:82
 76837-03 9.36 gu
 -04 20.09
 -05 19.25
 Composite of All MU1 samples and MU2C01
 See Attached

Fax results when available to ()
 E-mail to _____
 EDD Format _____
 Condition upon receipt: Iced Ambient °C _____

Received by: [Signature]
 Date: 4-06 Time: 17:82

SA 168 1240

CHAIN OF CUSTODY RECORD

SPECTRUM ANALYTICAL, INC.
11 ALINGREEN DRIVE
AGUWAM, MA 01901

Page 2 of 5

79374

- Special Handling:**
- Standard TAT - 7 to 10 business days
 - Rush TAT - Date Needed: _____
 - All TATs subject to laboratory approval.
 - Min. 24-hour notification needed for rushes.
 - Samples disposed of after 60 days unless otherwise instructed.

Report To: K. Pappas
11 Phelps Way
Willington CT
06229

Invoice To: Same

P.O. No.: _____ RQN: _____

Project No.: 18005-021-100 Site: _____

Name: Cedar Lake

Location: Cedar Lake State: _____

Sample(s): 1 Bags for Cedar Comby JOCONS

Project Mgr.: _____

1= $\text{Na}_2\text{S}_2\text{O}_8$, 2= HCl , 3= H_2SO_4 , 4= HNO_3 , 5= NaOH , 6= Ascorbic Acid
7= CH_3OH , 8= NaHSO_4 , 9=_____ 10=_____

DW=Drinking Water CW=Coolingwater WW=Wastewater
O=Oil SW=Surface Water SO=Soil SL=Sediment A=Air
X1=_____ X2=_____ X3=_____

Containers:

of VOA Vials _____

of Amber Glass _____

of Clear Glass _____

of Plastic _____

Analysis:

QA Reporting Notes (check and list as needed)

Positive MA DEP MCP CAM Report

Positive CT DEP RCP Report

QA/QC Reporting Level

Standard No QC

State specific reporting standards

Lab Id:	Sample Id:	Date:	Title:	Type:	Matrix:	Preservative:	# of VOA Vials:	# of Amber Glass:	# of Clear Glass:	# of Plastic:	Analysis:	QA Reporting Notes:
<u>79374-08</u>	<u>MU3C01</u>	<u>4/7/08</u>		<u>CS</u>	<u>S</u>						<u>FILED. P. FRACTIONATION</u>	
<u>-05</u>	<u>10 g/m²</u>										<u>% Solids</u>	
<u>-10</u>	<u>30</u>											
<u>-11</u>	<u>50</u>											
<u>-12</u>	<u>80</u>											
<u>-13</u>	<u>100</u>											
<u>-14</u>	<u>150</u>											
	<u>0</u>											

Relinquished by: [Signature]

Received by: _____

Date: _____ Time: _____

Condition upon receipt: Good Ambient Ice

79374-07 20.65 gm.

-01 20.78

-02 23.62

Composite of
MU3C02 and
MU3C01 samples

CHAIN OF CUSTODY RECORD

78576

NOV 01 11 44 AM '09
 HANOVER LABORATORY, INC.
 HANOVER, MA 01030

Page 3 of 5

Special Handling:

- Standard TAT - 7 to 10 business days
- Rush TAT - Date Needed: _____
- All TATs subject to laboratory approval
- Min. 24-hour notification needed for rush
- Samples disposed of after 60 days unless otherwise instructed

Report To: R Warner
11 Pelops Way
Willington VT
05229

Invoice To: Same
 P.O. No.: RON

Project No.: 12005-021-100 Site: _____
 Name: Cedar Lake
 Location: Cedar Lake State: _____
 Sampler(s): J Briggs, Cedar Campby, JOCover

Project Mgr: _____
 1=Na₂SO₄, 2=HCl, 3=H₂SO₄, 4=HNO₃, 5=NaOH, 6=Ascorbic Acid
 7=CH₃OH, 8=NaHSO₄, 9= _____, 10= _____

Containers:

Analyses:

QA Reporting Notes:
 (check and list as needed)

DW=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sediment A=Air
 X1= _____ X2= _____ X3= _____

of VOA Vials
 # of Amber Glass
 # of Clear Glass
 # of Plastic

Pseudo MHA DR-MCP-CAM Report
 Pseudo CT 1004 RCP Report
 QA/QC Reporting Level
 Standard No QC
 State specific reporting standards

Lab Id	Sample Id	Date	Time	Type	Matrix	Preservative	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic	Analyses	Date	Time
78576-75	MU4001	4/1/08		GS	GS						FB & BOND. P FRACTIONATION X % Solids	7/6/08	AS 15
	10						X	X	X	X			
	30						X	X	X	X			
	50						X	X	X	X			
	80						X	X	X	X			
	100						X	X	X	X			
	150						X	X	X	X			
	21						X	X	X	X			

Fax results when available to: _____
 E-mail to: _____
 EDD Form # _____
 Condition upon receipt: Good Ambient C

Relinquished by: [Signature]
 Received by: _____
 Date: _____ Time: _____

CHAIN OF CUSTODY RECORD

ANALYTICAL CHEMISTRY
LABORATORY

Page 4 of 5

Special Handling:

- Standard TAT - 7 to 10 business days
- Rush TAT - Date Needed
- All TATs subject to laboratory approval
- Min. 24-hour notification needed for rushes
- Samples disposed of after 60 days unless otherwise instructed

78376

Report To: R. Wagner
11 Pellets Way
Willington VT
05224

Invoice To: Same
P.O. No.: RON

Project No.: 12005-021-100 Site: _____
Name: Cedar Lake
Location: Cedar Lake State: _____
Sampler(s): J Bergstedt/Cedron Campbell/JOCome

1-Na₂SO₄ 2-HCl 3-H₂SO₄ 4-HNO₃ 5-NaOH 6-Ascorbic Acid
7-CH₃OH 8-NaHSO₄ 9-_____
10-_____
11-_____
12-_____
13-_____
14-_____
15-_____
16-_____
17-_____
18-_____
19-_____
20-_____
21-_____
22-_____
23-_____
24-_____
25-_____
26-_____
27-_____
28-_____
29-_____
30-_____
31-_____
32-_____
33-_____
34-_____
35-_____
36-_____
37-_____
38-_____
39-_____
40-_____

Containers:
of VOA Vials _____
of Amber Glass _____
of Clear Glass _____
of Plastic _____

Analytes: _____

QA Reporting Notes:
(check and list as needed)
 Provide MA DEP MCP CMA Report
 Provide CT DEP RCP Report
 QA/QC Reporting Level
 Standard No QC
State specific reporting standards

Lab Id	Sample Id	Date	Time	Type	Matrix	Preservative	Containers:				Analytes:		QA Reporting Notes:	
							# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic				
<u>7837-23</u>	<u>MU4C02</u>	<u>4/3/08</u>		<u>GS</u>							<u>FR BOUND</u>	<u>P FRACTIONATION</u>	<u>% Solids</u>	
<u>-23</u>	<u>10</u>	<u>g/m²</u>									<u>X</u>	<u>X</u>	<u>X</u>	
<u>-24</u>	<u>30</u>										<u>X</u>	<u>X</u>	<u>X</u>	
<u>-25</u>	<u>50</u>										<u>X</u>	<u>X</u>	<u>X</u>	
<u>-26</u>	<u>80</u>										<u>X</u>	<u>X</u>	<u>X</u>	
<u>-27</u>	<u>100</u>										<u>X</u>	<u>X</u>	<u>X</u>	
<u>-28</u>	<u>150</u>										<u>X</u>	<u>X</u>	<u>X</u>	
<u>0</u>														

Fax results when available to (_____)
 E-mail to _____
EDD Format _____

Retrieved by: R. Wagner

Received by: _____ Date: _____ Time: _____

7837-09 05:29
↓
10 34:58

78376

CHAIN OF CUSTODY RECORD

WATER ANALYSIS
HYDROLYZABLE
AMMONIA

Page 5 of 5

Special Handling

- Standard TAT - 7 to 10 business days
- Rush TAT - Date Needed _____
- All TATs subject to laboratory approval
- Min. 24-hour notification needed for rush.
- Samples disposed of after 60 days unless otherwise instructed

Report To: K. W. Barber
11 Phelps Way
Willington VT
05279

Invoice To: Same

Project No.: 12005-021-100 Site: _____

Project Mgr.: _____

P.O. No.: _____ RQN: _____

Name: Gadon Lake
 Location: Cedar Lake State: _____
 Sampler(s): J. Berglund/Gordon Conchy J. Adams

1=NH4NO3, 2=HCl, 3=H2SO4, 4=HNO3, 5=NaOH, 6=Ascorbic Acid
 7=ClO4, 8=NaHSO4, 9= _____ 10= _____

Containers:

Analyses:

QA Reporting Notes:
 (check and init as needed)

DP=Drinking Water GW=Groundwater WW=Wastewater
 O=Oil SW=Surface Water SO=Soil SL=Sludge A=Air
 X1= _____ X2= _____ X3= _____

G=Grab C=Composite

Preservative
 # of VOA Vials
 # of Amber Glass
 # of Clear Glass
 # of Plastic

FR. BOUND.
 PER FRACTIONATION
 % Solids

Possible MAH DEP 3079 CAM Report
 Possible CI 1014 DEP Report
 QAVQC Reporting Level
 Standard 3079
 T1= _____
 State specific reporting standards

Lab ID	Sample ID	Date	Time	Type	Matrix	Preservative	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic	Analyses	QA Reporting Notes
78376-29	MD4C03	4/2/08		G	S							
	30											
	31											
	32											
	33											
	34											
	35											

70837-11 AS IS

Relinquished by: [Signature]

Received by: _____

Date: _____ Time: _____

Fax results when available to _____
 E-mail to _____
 EDD Format: _____

Condition upon receipt: cool Ambient °C _____