G ALUM DOSE RATES AND COST ESTIMATES

G.1 ALUMINUM DOSE REQUIREMENTS

The amount of aluminum needed for a lake-wide sediment treatment was calculated based upon the sediment results described above in Section C. The following equation with adjustments for appropriate units was used to determine the appropriate aluminum dose to inactivate phosphorus in the deep sediments of the lake:

$$Al = P_{avail} * BD * D_{sed} * Al{:}P * z$$

Where:

Al = Aluminum dose (kg/L)
P_{avail} = Available phosphorus in sediment (mg/g)
BD = Bulk density of solids in sediment (g/cm^3)
D_{sed} = Depth of active sediment zone (cm)
AL:P = The ratio of Al added to available phosphorus
z = average depth of the lake (m)

The aluminum dose rate was first calculated for deep areas of the lake or the area greater than 15 feet depth (4.57 m). The target zone for the sediment treatment in Lake Ketchum is the first 10 cm of sediment, as this is the most active zone of biochemical mineralization. In addition, the total phosphorus in the deep sediment profile is significantly lower after the first 10 cm (Figure C-2). The available-P (loosely sorbed-P + Fe-P + biogenic-P) at the deep site averaged 0.805 mg/g in the top 10 cm (Figure C-2). The sediment bulk density (BD) was found to be 1.052 g/cm³, the solids portion of this bulk density is 0.052 g/cm^3 and was used in the formula above. A ratio of 20:1 for Al added to available-P was determined to be needed to inactivate sediment phosphorus. The 20:1 ratio for 10 cm was derived from the 100:1 ratio for 4 cm proposed by Rydin and Welch (1999). However, non-reactive (nr)-P, or biogenic-P, was not included in those calculations, but was about equal to mobile (Fe-P + loosely sorbed P) in those Wisconsin lake sediments. Therefore, had biogenic-P been included, the ratio would have been lowered to 50:1, and extending the depth to 10 cm from 4 cm would further lower it to 20:1. These factors were multiplied together as shown in the above equation to find the areal aluminum dose rate of 83.72 grams of Al/m^2. The areal aluminum dose (in g/m^2) was multiplied by the mean lake depth of 3.5 meters to obtain a volumetric dose of 24 mg Al/L.

The same procedures were followed to calculate a dose rate in areas less than 15 feet deep. With a lower available P of 0.571 mg/g in these areas, the dose for shallower areas was determined to be 60 g/m² Al/L. However, given that the deeper sediments yielded a higher dose requirement than the shallower sediments, it is recommended that the higher dose rate of 24 mg Al/L be used to determine the volumetric dose in Al concentration and to provide a measure of safety.

The water column contained about 200 µg/L TP prior to stratification. This concentration multiplied by the 20:1 ratio gives an additional water column stripping dose of 4 mg Al/L. Therefore, the total volumetric dose (sediment inactivation + water column stripping) is 28 mg Al/L.

G.2 ALUM AND BUFFER REQUIREMENTS

With the high dose of aluminum needed for Lake Ketchum, both aluminum sulfate and the buffer sodium aluminate will be needed. The following assumptions were used to determine the specific amounts of each compound for the initial sediment treatment as well as for the annual water column treatments.

Dosage Assumptions:

- Initial Aluminum Treatment Dose (sediment & water column): 28 mg/L
- Water Column Treatment Dose: 4 mg/L
- Lake volume, 363,670 m^3
- Ratio of Al from Alum:Sodium Aluminate by weight is = 44:56
- Volume application rate 2:1 Alum:Sodium Aluminate
- Al per gallon Alum = 0.22 kg
- Al per gallon Sodium Aluminate = 0.56 kg

FIGURE G-1: AMOUNT OF ALUM & SODIUM ALUMINATE REQUIRED FOR INITIAL TREATMENT & ANNUAL WATER COLUMN TREATMENTS

Sediment Treatment			
	Alum	Sodium Aluminate	**Total**
Amount of Aluminum (kg)	4,484	5,708	**10,192**
Volume (gal)	20,384	10,192	

Water Column Treatment			
	Alum	Sodium Aluminate	**Total**
Amount of Aluminum (kg)	641	815	**1,456**
Volume (gal)	2,912	1,456	

G.3 ALUM TREATMENT COST ESTIMATES

THE PROJECTED COSTS OF THE WHOLE-LAKE SEDIMENT INACTIVATION ALUM TREATMENT AND THE ANNUAL WATER COLUMN TREATMENTS WERE DERIVED FROM EXPERIENCES WITH RECENT ALUM TREATMENTS IN WASHINGTON STATE AND OHIO. FIGURE G-2 PROVIDES THE ASSUMPTIONS AND COST CALCULATIONS FOR THE SEDIMENT TREATMENT.

Figure G-3 provides the assumptions and calculations for the annual water column alum treatments. All costs are in 2011 dollars.

FIGURE G-2: COST ESTIMATE FOR SEDIMENT PHOSPHORUS INACTIVATION ALUM TREATMENT

Assumptions			
Applied cost of alum per gallon -- $2.50			
Applied cost of sodium aluminate per gallon -- $3.80			
Mobilization -- 20% of total applied costs			
Tax -- 9% of total applied costs and mobilization			
Planning/Design/Permiting (P/D/P) -- 35% of applied costs plus mobilization and taxes			
Contigency -- 30% of applied costs plus mobilization and taxes			
Item	Unit Cost	# of Units	Item cost
Alum	$2.50 per gallon	20400 gallons	$ 51,000
Sodium Aluminate	$3.80 per gallon	10200 gallons	$ 38,760
		Subtotal	$ 89,760
Mobilization	20% of subtotal		$ 17,952
		New Subtotal	$ 107,712
Tax	9% of new subtotal		$ 9,694
		Final Subtotal	$ 117,406
P/D/P	35% of final subtotal		$ 41,092
Contingency	30% of final subtotal		$ 35,222
		Total Cost	**$ 193,720**

FIGURE G-3: COST ESTIMATE FOR WATER COLUMN ALUM TREATMENTS

Assumptions			
Applied cost of alum per gallon -- $3.50			
Applied cost of sodium aluminate per gallon -- $4.80			
Mobilization -- 20% of total applied costs			
Note: costs of alum and sodium aluminate materials and application and			
costs for mobilization are higher than for sediment treatment because of			
much smaller quantities			
Tax -- 9% of total applied costs and mobilization			
Planning/Design/Permiting (P/D/P) -- 18% of applied costs plus mobilization and taxes			
Contigency -- 30% of applied costs plus mobilization and taxes			
Item	Unit Cost	# of Units	Item cost
Alum	$3.50 per gallon	2912 gallons	$ 10,192
Sodium Aluminate	$4.80 per gallon	1456 gallons	$ 6,989
		Subtotal	$ 17,181
Mobilization	30% of subtotal		$ 5,154
		New Subtotal	$ 22,335
Tax	9% of new subtotal		$ 2,010
		Final Subtotal	$ 24,345
P/D/P	18% of final subtotal		$ 4,382
Contingency	30% of final subtotal		$ 7,304
		Total Cost	**$ 36,031**