The University of Montana

University of Montana

CORROSION CONTROL STUDY

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EXECUTIVE SUMMARY

This study is to fulfill the requirement of the Lead and Copper Rule for the "Desktop Corrosion Control Study" by identifying strategies to optimize corrosion control for the University of Montana in Missoula, Montana.

Compliance

Lead levels detected are above the action limit, but well below levels of public health concern.

The University of Montana exceeded the 1992 Lead and Copper Rule (LCR) action level in May of 2003, triggering this study. The LCR established action limits for both lead and copper, which, if exceeded, require some action. The LCR also requires that if the number of samples exceeding the action limit is not below the 90th percentile, a desktop corrosion control study must be completed to examine corrosion problems and any system modifications that may be necessary to improve corrosion control.

The University has gone above and beyond legal requirements in an attempt to understand the big picture and ensure the well being of the students and faculty. They have done more extensive sampling than required to try to understand the overall issue.

Analogous Systems

Similar water, distributed throughout the City of Missoula, has never exceeded the action level for lead or copper. In fact, levels have been consistently low. Mountain Water Company completed initial sampling, required by the LCR, which were well within the regulatory limits. As a result, they are currently on a reduced lead and copper sampling schedule, sampling once every three years.

Findings

The samples that exceed the action level were not found in a localized area of the campus, rather, they were sporadically found in buildings across campus. A few locations that have repeatedly shown lead levels above the action level are addressed in detail in this study.

Recommendations

Since samples collected from the University are near the action level and are well below levels of public health concern for adults, it is recommended that the University complete additional lead and copper sampling prior to implementing any corrosion control treatment. If the system remains out of compliance after a series of samplings, showing a more consistent problem, an orthophosphate inhibitor is recommended.

STUDY OVERVIEW

Introduction

Samples taken at the University of Montana in May 2003 triggered action as established by the Lead and Copper Rule (LCR). Samples taken in May and December of 2003 found that the 90^{th} percentile value for lead was above the lead action level of 0.015 ppm (mg/L). Based on the LCR, when less than 90% of the samples are below the action level, a "Desktop Corrosion Control Study" must be completed to evaluate the optimum corrosion control alternative for the source.

This study will identify options for corrosion control that could assist the University of Montana in bringing the lead levels below the action level. Specifically this study will focus on the locations where drinking water samples have tested above the 0.015 ppm lead action level, and make recommendations to reduce lead levels.

Lead and Copper Rule

Lead levels detected are above the action limit, but well below levels of public health concern.

The purpose of the Lead and Copper Rule was to encourage cities to optimize their corrosion control. In order to enforce this, action levels of 0.015 ppm for lead, and 1.3 ppm for copper were established. There have not yet been maximum contaminant levels (MCLs) established for either lead or copper. It is important to differentiate between an action level and an MCL. An action level implies action, such as this study, where an MCL implies a public health concern.

Lead levels detected at the University of Montana campus have been above the action level, but are well below levels of public health concern, especially for adults.

Background

The University of Montana is classified by EPA and MDEQ, as a non-transient, non-community water provider. The 2003/2004 enrollment for the University was 13,252 students, in addition to 1,300 full time employees. There are on average about 4,000 students that live on campus from September to May.

Facilities

The University of Montana is located in the northwestern section of the City of Missoula. Water is supplied to the University by a private water company that also serves the City of Missoula, Mountain Water Company. The four main meters that provide water to the University distribution system are along Arthur Avenue and can be seen in Figure 1. There are two additional meters that provide small volumes of water to a few select areas on campus.

The average volume of water supplied to the University in the 2003/2004 school year was 2.2 mgd for the months of July through September, and 0.5 mgd over the rest of the year. The amount of metered water fed to the University from the four main meters is shown in Table 1. The two additional meters provide about 8,000 gpd.

Table 1 - Metered Water from Mountain Water Company to University of Montana 2003/2004

Meter	July to Sept 03 MGD	Oct to Dec 03 MGD	Jan to March 04 MGD	April to June 04 MGD
Eddy & Arthur	1.69	0.15	0.08	0.16
Keith & Arthur	0.14	0.12	0.11	0.14
University & Arthur	0.24	0.15	0.11	0.13
Campus-Connell Ave.	0.20	0.10	0.06	0.10
Total	2.28	0.52	0.35	0.52

Source Water Supply and Treatment

Mountain Water Company (Mountain Water) relies solely on groundwater from a sole source aquifer that lies below the City of Missoula and the surrounding area. Mountain Water provides service to about 59,000 residents on an annual basis and produces and estimated 8,630 million gallons per year. There are currently 37 wells owned by Mountain Water that draw from the Missoula aquifer.

The four main meters that supply the University with water are fed from as many as six different wells depending on the time of year. The amount of water produced from each of these wells in 2004 is shown in Table 2. The water from these wells supplies both the University and the surrounding City neighborhoods. During the summer months the system is fed by all six wells. In the winter, the Hilda and Maurice Avenue wells are not used, and the Gerald Avenue well is rarely used.

The water mains that feed the University distribution system are an assortment of pipe types. There is a 14-inch cast iron service line at Eddy and Arthur, a 20-inch steel at Connell and Arthur, a 6-inch steel at 2500 South Higgins, and the meter is tapped off of a 6-inch cast iron main at the law building.

Table 2 - 2004 Mountain Water Well Information

Pump	First Quarter MGD	Second Quarter MGD	Third Quarter MGD	Fourth Quarter * MGD
South Ave. 100 hp	1.83	1.80	1.83	1.68
South Ave. 200 hp	1.15	1.77	1.94	0.75
Hilda Ave.	0.00	0.00	1.13	0.00
E. Central	1.52	1.45	1.53	1.41
Gerald Ave.	0.00	0.34	1.74	0.18
Maurice Ave.	0.00	0.06	0.23	0.00
Total	4.51	5.42	8.39	4.02

* Fourth quarter data only available up to October 15.

Water Quality

Table 3 shows a summary of water quality data from Mountain Water. This source water is well buffered (high alkalinity and high pH), with low chlorine levels, and is moderately mineralized. Corrosive waters generally have low alkalinity and pH levels. This water is not historically corrosive.

Table 3 – Summary of Finished Water Data 1999 to 2004

	Five Year Average	*Five Year Minimum*	*Five Year Maximum*
pH	7.7	7.1	8.1
Alkalinity (ppm)	167	125	218
Hardness (as CaCO3) (grains)	168	132	211
Calcium (ppm)	46	33	59
Langlier Index (d) (units)	+0.18	-0.3	+0.60
Sulfate (ppm)	17	9	27
Total Dissolved Solids (ppm)	201	146	290

Sampling

The University of Montana began compliance sampling for lead and copper in May of 2003. There were 40 sites sampled, seven of which came back above the 0.015 ppm action level. In 2003, the seven locations that had come back above the action level were resampled and sent to a different laboratory for comparison. Two of the seven samples had lead detected above the action level. Further testing was done in both October and September of 2004 at the Law building, Knowles Hall, and the Natural Sciences building.

In December 2004, a more comprehensive sampling was completed for the buildings that had shown lead levels above the action limit. The sequential sampling of five locations also took place at this time. This sampling by the University to understand and manage areas with lead levels above the action level has been above and beyond the requirements of the LCR.

A map of the University showing which buildings have produced samples with lead concentrations above the action level are show in Figure 1. A complete list of sampling results is included in Appendix A.

Figure 1 - University of Montana Lead Sample Sites

Comprehensive Sampling

The comprehensive sampling done in December of 2004 included 8 buildings and a total of 44 fixtures (including all drinking fountains in the 8 buildings). This sampling was done to determine how widespread the lead problems were throughout these buildings. The fixtures that were sampled were locations that had not been sampled previously. Only two samples were above the action level. One fixture in North Corbin measured 0.402 ppm, and one fixture in Clinical Psychology measured 0.016 ppm. Table 4 shows the buildings on campus that have had lead concentrations above the action level.

The table includes the total samples that have been taken per building, the number of samples above the action level, the number of locations sampled, and the number of locations with samples above the action level. The table also gives the year the building was constructed and the highest and lowest lead concentrations measured in each building. North Corbin has had the highest number of samples, four, come back above the action level, and the Labor Shack has had three samples above the level.

Table 4 - Total Lead Samples per Building

Building	**Year Constructed**	*Samples per Building*	*Total Samples Above Action Level*	*Number of Locations Sampled*	*Number of Locations Above the Action Level*	*Highest Sample (ppm)*	*Lowest Sample (ppm)*
Brantley	1921	7	1	4	1	0.017	0.004
Clinical Psychology	1983	5	2	5	2	0.050	0.005
N. Corbin		7	4	3	2	0.419	0.004
Fine Arts	1935	7	1	6	1	0.020	ND
Forestry Green House		4	2	1	1	0.038	0.001
Heating Plant	1923	4	1	1	1	0.027	0.004
International Programs/Linguistics	1937	7	2	5	1	0.017	0.002
Journalism	1936	8	1	6	1	0.038	0.002
Knowles	1963	12	2	10	2	0.047	0.006
Labor Shack	1966	4	3	1	1	0.066	0.011
Law	1960	26	1	14	1	0.020	ND
Natural Sciences	1918	11	1	6	1	0.028	ND
Turner	1927	4	2	2	1	0.035	ND
Total		187	22	108	16	-	-

Recommendations

This section covers specific recommendations for buildings where lead levels above the action level have been detected once or twice. Recommendations for the locations where sequential samples were taken, N. Corbin, Forestry Green House, International Programs/Linguistics, Knowles, and the Labor Shack, are addressed in the next section. A recommended sampling plan is included in Appendix C for the next round of LCR sampling.

Brantley

A total of seven samples have been taken in Brantley at four different locations. Only one sample has been above the action level, 0.017 ppm. It is recommended that this building be left in service and remain in the annual sampling schedule.

Clinical Psychology

Two of five samples have shown lead levels above the action level. One sample was just at the action level, 0.016 ppm, and a second was 0.050 ppm. It is recommended that this further testing be completed in this building.

Fine Arts

The Fine Arts building is comprised of an auditorium, along with classrooms. One of seven samples was 0.020 ppm, this was the only sample above the action level. It is recommended that this building remain in service and be included in the annual sampling regimen.

Heating Plant

There have been four samples taken from one location in the heating plant. The initial sample in May 2003 was 0.027 ppm, above the action level. This was the only sample with elevated lead levels and it was believed that this was due to sampling technique. This building should remain in service and continued to be monitored in annual sampling.

Journalism

Six locations have been sampled in the Journalism building. One of eight samples taken was above the action level (0.038 ppm). It is recommended that this building remain in service as is, and continues to be monitored.

Law

The law building has been sampled 26 times in 14 different locations. One sample taken in June 2004 was 0.020 ppm, which is above the action level. The University will replace the one fixture that produced the elevated level. It is recommended that this building remain in service and remain in the annual sampling regime.

Natural Science

One of eleven total samples has been above the action limit in the Natural Science building (0.028 ppm). This building should continue to be monitored in annual sampling and should remain in service as is.

Turner

Turner Hall is a residential building that also includes a few offices, including the main housing office for the University. There have only been four samples taken here, two of which (taken from the same fixture) came back above the action level (0.016 and 0.035 ppm). A number of fixtures were replaced in this building after this sampling took place. It is recommended that further sampling be done in this building.

Sequential Sampling

Sequential samples were taken at five locations in December of 2004. These locations had given two or three samples above the action limit in prior testing. There were six total samples taken at each selected location. Assuming a constant line size of one inch, water was drawn from as far as 46 feet back into the system. Table 5 shows the timing of sample, volume of water flushed between samples, and the estimated distance of the water back in the pipe. This sampling was done by taking a number of samples one after another. This helps determine if the lead is entering the system at the fixture or farther back in the piping.

Samples with elevated lead concentrations were tested for both soluble and insoluble lead. The amount of soluble lead was determined by taking the samples that had shown lead concentrations above 0.007 ppm on the first round of testing, filtering them with a 0.45 micron filter and testing them again. The difference in concentration between the two samples was assumed to be the amount of insoluble, particulate, lead. Results of these samples are shown in Table 6, Table 7, Table 8, Table 9, and Table 10.

Table 5 - Sequential Sampling Procedure

Step	Sample Number	Assumed Pipe Diameter (in)	Volume Displaced (ml)	Location back in pipe (ft)
A	1	1	100	0.5
B	2	1	100	1.5
C	3	1	100	2
D	No sample	1	500	5
E	4	1	100	6
F	No sample	1	1000	12
G	5	1	100	13
H	No sample	1	5000	45
I	6	1	100	46

The following is a discussion of each of the sequential sample locations and results.

North Corbin

North Corbin was built in 1927; it is an old residence hall that has been converted to offices. There are sinks in most of the offices. Prior to the comprehensive sampling, only one office sink had been sampled. This fixture had shown lead levels above the action limit three out of four times, and was selected for sequential sampling. All of the sequential samples taken at this location came back well below the action limit. Three other locations were also tested during this round and only one of the locations shown an elevated lead level. This location was well above the action level of 0.015 ppm at 0.402 ppm.

Table 6 - North Corbin Sequential Samples

Office Sink	*Total Lead*	*Dissolved Lead*	*Particulate Lead*	*Upstream Pipe Location (ft)*
Sample 1	0.005	-	-	0.5
Sample 2	0.004	-	-	1.5
Sample 3	0.007	0.004	0.003	2
Sample 4	0.005	-	-	6
Sample 5	0.004	-	-	13
Sample 6	0.005	-	-	46

Recommendation

Based on the sequential samples, there is some evidence that the piping to the fixture may not be problematic. Since only three locations in this building have been sampled, it is recommended that the University sample more office fixtures to gain a better overall perspective before making a final decision.

Knowles Hall

Knowles Hall is a residence hall with a small kitchen on one floor. The kitchen sink in Knowles Hall produced a sample with a lead concentration of 0.036 ppm in December of 2003. Due to the high lead concentration, and the fact that it was a common water source, the fixture was replaced. The new fixture was sampled again in September, 2004, and had a lead concentration of 0.047 ppm. Since the fixture had once been replaced, it was selected for sequential sampling to determine where in the piping the problem may originate.

The initial three sequential samples taken were above the action limit, as can be seen in Table 7. These three samples went back about two feet in the piping, and were tested for total and dissolved lead. The difference between the dissolved and total lead was minimal, about 0.004 ppm, therefore, most of the lead was dissolved. The last three samples had lead levels well below the action limit, which implies that the problem lies in the fixture or the piping upstream of the fixture.

Table 7 - Knowles Hall Sequential Samples

Kitchen Sink	*Total Lead*	*Dissolved Lead*	*Particulate Lead*	*Upstream Pipe Location(ft)*
Sample 1	0.122	0.116	0.006	0.5
Sample 2	0.030	0.026	0.004	1.5
Sample 3	0.022	0.020	0.002	2
Sample 4	0.010	0.009	0.001	6
Sample 5	0.006	-	-	13
Sample 6	0.003	-	-	46

Recommendation

It is recommended that this fixture be removed from service and the service line be capped to prevent the line from being used sometime in the future.

International Programs/Linguistics

The one location in this building that was consistently above the action limit was a sink in a custodial closet. This building does not have many water sources. Two bathrooms and one break room were tested in addition to the custodial closet. The custodial closet fixture had been sampled three times prior to the sequential sampling and had been above the action level (0.017 ppm) twice and below the level (0.012 ppm) once. The first five samples taken during the sequential sampling gave high concentrations of lead for the total lead concentrations, between 0.023 ppm, and 0.053 ppm. When these five samples were filtered and re-tested for dissolved lead, all but one of the samples were below the action limit. The sixth sequential sample was 0.004 ppm, well below the action limit. There were three other locations sampled in this building. Each additional sample showed some lead, but all were below the action limit.

Table 8 - International Programs/Linguistics Sequential Sampling

Custodial Closet Sink	*Total Lead*	*Dissolved Lead*	*Particulate Lead*	*Upstream Pipe Location (ft)*
Sample 1	0.053	0.011	0.042	0.5
Sample 2	0.023	0.008	0.015	1.5
Sample 3	0.027	0.013	0.014	2
Sample 4	0.025	0.018	0.007	6
Sample 5	0.027	0.013	0.014	13
Sample 6	0.004	-	-	46

Recommendation

Due to the nature of the fixture and the fact that it is mostly used for mop water and other, not consumptive uses, it is recommended that it be marked non-potable and remain in service. Other fixtures in the building should be monitored annually.

Forestry Green House

The Forestry Green House has only one water source, which was tested four times prior to the sequential sampling. Two primary samples had lead levels above the action level, one sample was 0.038 ppm, and the other was 0.017 ppm. The sequential samples taken at this fixture were all well below the action level. The highest lead level was in the first sample, and was well below the action level, 0.005 ppm, and the final two samples were 0.001 ppm.

Table 9 - Forestry Green House Sequential Sampling

Sink	*Total Lead*	*Upstream Pipe Location (ft)*
Sample 1	0.005	0.5
Sample 2	0.004	1.5
Sample 3	0.002	2
Sample 4	0.002	6
Sample 5	0.001	13
Sample 6	0.001	46

Recommendation

Even though the sequential sampling did not provide any samples with lead levels above the action level, two prior samples have shown levels twice the action limit. Therefore, it is recommended that this fixture be marked non-potable and remain in service.

Labor Shack

The final location that was sampled sequentially was the sink in the Labor Shack. This is a bathroom sink and the only water source in this building. This fixture had been sampled four times prior to the sequential sampling and had been above the action level three times.

All six sequential samples were well above the action level when tested for total lead, and four of the six were also above the action limit when tested for dissolved lead, the second and third sequential samples were just below the limit. This sampling suggests that the problem is not just the fixture, and fixture replacement would not be an effective option for eliminating high lead levels in this area.

Table 10 - Labor Shack Sequential Samples

Sink	*Total Lead*	*Dissolved Lead*	*Particulate Lead*	*Location in Pipe (ft)*
Sample 1	0.030	0.022	0.008	0.5
Sample 2	0.028	0.014	0.014	1.5
Sample 3	0.025	0.015	0.010	2
Sample 4	0.037	0.032	0.005	6
Sample 5	0.035	0.029	0.006	13
Sample 6	0.037	0.035	0.002	46

Recommendation

Since this seems to be an isolated location, it is recommended that this fixture be marked as non-potable and that drinking water be provided by another source.

Recommendations for Future Sampling

It is recommended that the University continue the semi-annual sampling as required by Montana DEQ. Forty samples are required. Recommendations for number of samples and sample locations are included in Appendix C. It is recommended that the University continue to take multiple samples from locations where lead levels have exceeded action limits in the past. In addition, buildings that have not shown detects of lead will continue to be sampled intermittently up to the required forty samples.

LEAD CORROSION

There are a number of factors that can lead to lead corrosion in a drinking water system. Some factors that can enhance the release of lead from lead-tin solder, or lead pipe, are pH values, chlorine ion levels, and alkalinity.

Types of Lead Corrosion

The two main corrosion types that lead to copper and lead corrosion are uniform and localized corrosion.

Uniform Corrosion

Uniform corrosion is the general dissolution of a metal from a pipe. Uniform corrosion is usually related to the water quality of the water in the pipe, and the solubility of the metal. This type of corrosion generally takes place slowly and is not something that can be easily seen by examining a pipe. Uniform corrosion most often takes place over a significant surface area and produces high levels of soluble lead.

Due to the overall lack of lead detected in the University system, the relatively high concentrations in localized areas, and the stable water quality for Mountain Water, it is likely that uniform corrosion is not the main source of lead corrosion.

Localized Corrosion

When corrosion occurs at specific locations within piping, it is referred to as localized corrosion. Areas of localized corrosion tend to be relatively small in relation to total pipe surface area, but are able to produce high concentrations of lead if the corrosion has a rapid formation rate, or is taking place in a stagnant line. For lead, this type of corrosion is most often due to a galvanic corrosion impact caused by the contact of dissimilar metals, such as lead-tin solder on copper tubing.

There are six main mechanisms that can lead to localized corrosion in potable water systems. These six mechanisms are:

- Pitting
- Galvanic corrosion
- Erosion corrosion (impingement attack)
- Cracking (stress corrosion)
- Microbiologically induced corrosion
- Stray current corrosion

Given the sporadic nature of the lead detection, localized corrosion may be occurring.

Analysis of Corrosion Control Options for Lead

There are three main options for corrosion control:

- pH and alkalinity adjustment
- Calcium hardness adjustment
- Addition of silica or phosphate based corrosion inhibitors

pH and Alkalinity Adjustment

pH

The pH of a water source can have a significant impact on its corrosivity. The pH affects the formation of protective scales inside piping, and the solubility of metal complexes. In general, the corrosion of lead and copper decreases as the pH of the water increases and the rate of corrosion increases significantly below a pH of 7. There are, however, other factors that can influence the impact of pH, such as alkalinity, hardness, free chlorine, dissolved oxygen, chloride, and sulfate. These factors make it difficult to define a specific pH value for optimum corrosion control.

pH and alkalinity adjustment is not recommended.

The average measured pH values of the water feeding the University system have been between 7.1 and 8.1 between 1999 and 2004.

Other forms of corrosion control are also dependent on pH. The use of orthophosphate or polyphosphate is most effective for a pH range of 6 to 7. The addition of zinc and polyphosphate works effectively up to a pH of 7.5. The effectiveness of silicates seems to be effective for preventing corrosion up to a pH of 8. Given the source water pH ranges are 7.1 to 8.1, in the range where other corrosion control additives are effective, pH adjustment in not recommended.

Alkalinity

The measurement of the ability of a water to moderate pH changes is its alkalinity. This measurement includes the carbonate species, bicarbonate ion and carbonate ion, and the hydrogen ion and the hydroxide ion. In general, lower alkalinities reduce corrosion rates of most materials, however, the release of lead, zinc, and copper often increase with increases in alkalinity.

Due to the moderately high alkalinity of the area water, an alkalinity adjustment would not be an appropriate treatment, as it would likely increase the rate of corrosion and precipitation of carbonate species from pipe walls.

Calcium Hardness Adjustment

Calcium hardness is adjusted by varying the amount of calcium carbonate in the system. This provides a similar response to altering the pH or adjusting the alkalinity. The change in equilibrium will allow some scaling to build up on the piping and prevention corrosion reactions from taking place. It can be difficult to control this method of treatment since it is dependent on the balance of calcium carbonate being held in solution so that it is precipitated out at an even rate throughout the system. This process can eventually build up an excess amount of scale and reduce the capacity of the system by decreasing the inside diameter of the pipe.

An adjustment in calcium hardness can be difficult to control and is not recommended.

Due to the difficulty in controlling this process and the potential inconsistency of the wall scale that may be developed, this method of treatment is not recommended.

Corrosion Inhibitor Addition

Another way to affect corrosion is to introduce compounds that are designed specifically to reduce corrosion.

Silica Based Addition

For silica based addition, a silicate-based inhibitor would be added at the source (in this case a well head or the meter), and would both sequester metals and create a "lining" of the distribution system piping that would prevent lead from being released from the plumbing. This type of treatment takes a long time to reach steady state, and has not shown to be particularly effective in similar supplies, and will therefore not be considered for this study.

Phosphate Addition

Phosphates (especially orthophosphates) have proven to be very effective in the reduction of lead corrosion. The phosphates act in a manner similar to the silicates presented earlier; they line the pipes with a protective coating that prevents the lead from being released into the water.

Orthophosphates

The addition of phosphate as an inhibitor has shown to be an effective option for this type of corrosion control in a number of similar cases. Orthophosphate has in fact, proven to be the most effective option, and is best used in high alkalinity waters like the Mountain Water Source. There are several forms of orthophosphate that can be used in drinking water applications. The most common form is that with zinc used as the cationic binding agent, however, sodium-orthophosphates can also be used. Studies have shown that orthophosphates are effective over a pH range of 7.0 to 7.8, and are most effective when used in waters that have a pH level that is consistently above 7.2, which is consistent with the Mountain Water source water.

Corrosion inhibitors create a lining of the distribution system that prevents metals release.

Polyphosphates

Polyphosphates can also be used for prevention of corrosion, however required doses are fairly high, and not often used in this type of application for drinking water. There has also been evidence that polyphosphates may possibly interfere with the protective coatings of calcium carbonate inside pipes. Polyphosphates can also act as a sequestering agent for lead and exacerbate lead release. Due to the potential increase in lead release, polyphosphates should not be used.

Recommendations

Since the levels of lead detected have been relatively low, and the last round of sampling narrowly exceeded (15%) the action level (10%), it is recommended that additional sampling be completed prior to deciding to implement chemical corrosion control. If after implementing the previously recommended course of treatment (removing some fixtures and marking some non-potable), future sampling results consistently show that the system is out of compliance and lead levels above the action level, the addition of a corrosion control inhibitor may be recommended. It would be difficult and expensive for the University to implement system wide treatment however, due to the fact that they do not control the source water.

Based on the water characteristics in the Missoula Valley, an orthophosphate, or zinc-orthophosphate inhibitor would be recommended as the corrosion control inhibitor. This type of corrosion control has shown to be very effective in similar water types.

The addition of orthophosphate would lead to a meaningful decrease in lead levels in area waters. The recommended dose of orthophosphate is 0.25 to 0.5 ppm. A concentration of 0.5 ppm would require about 4.5 pounds of orthophosphate for every million gallons of water, which would cost approximately 10 dollars.

The City of Missoula recently upgraded their wastewater treatment plant (WWTP) to include both nitrogen and phosphorus removal. The design flow of the WWTP is 12 MGD, and the capacity for phosphorus removal is 720 lbs/day (approximately 8 mg/L). The NPDES permit for the WWTP effluent is 1 mg/L of total phosphorus. The addition of orthophosphate (at a concentration of 0.5 ppm) at the four main meters that provide water to the University of Montana would add an average of about 2.5 pounds of orthophosphate to the system per day, or less than half of a percent of the maximum influent total phosphorus the plan is designed to handle.

ANALOGOUS SYSTEMS

The lead levels detected in the University of Montana distribution system are unexpected, based on the source water chemistry (stable alkalinity and pH). The City of Missoula is supplied with water by the same utility, Mountain Water, which has not had compliance problems in twelve years of lead and copper sampling. Mountain Water is within the allowable limits, implying that the water is not corrosive. Mountain Water Lead and Copper sampling results can be found in Appendix B.

CORROSION CONTROL PROCESS ANALYSIS

It is required by the LCR that corrosion control is optimized in order to provide consumers minimal exposure to lead and copper in the water they drink. For the University of Montana, this means reducing lead release without increasing the release of copper into the system or negatively impacting other public health parameters.

The recommended approach for corrosion control is to deal with problem areas on a case by case basis, by removing some fixtures from use and marking some non-potable as recommended previously. If the system does not then return to compliance, the addition of orthophosphate or zinc-orthophosphate to the source water may be recommended.

If chemical addition were required, below ground vaults would be constructed at the four meters feeding the University, downstream of the backflow preventers.

If the chemical addition were to take place at the meters, chemical cost would be based on the flow measured at those meters. Metered data from 2004 shows a total of 218 million gallons were supplied to the University from the four main meters at Eddy and Arthur, Keith and Arthur, University and Arthur, and Campus and Connell Avenue.

Assuming 0.25 ppm, orthophosphate, approximately 460 lbs of orthophosphate would be used each year. If a dose of 0.5 ppm were required, about 910 lbs would be needed. Based on the relatively low lead concentrations found in University water samples, it is suggested that the lower dose of 0.25 ppm would be sufficient.

The effect of orthophosphate as a corrosion inhibitor would likely be detectable after just a few weeks of addition to the system. It would be necessary to monitor the orthophosphate residual in the system on an annual basis.

COSTS

Capital Costs

Estimates of the capital and operational costs were calculated for the addition of orthophosphate to the system at the four meters that provide water to the University system. In the case that the addition of chemical corrosion control inhibitor is required, a more thorough system design and site evaluation would be completed and submitted to MDEQ for approval. A basic schematic of the system can be seen in Figure 2.

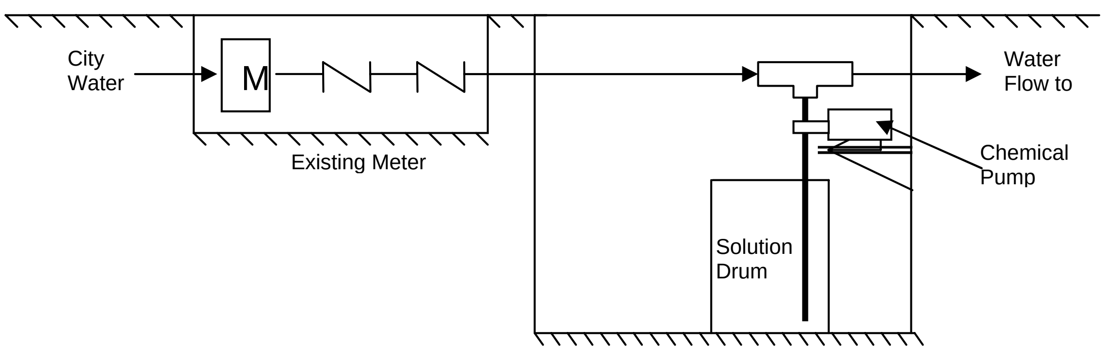

Figure 2 - Schematic of Chemical Corrosion Control Addition

The estimated capital costs are shown in

Table 11. The following assumptions were made:

- Chemicals and chemical feed equipment would reside in vaults at the four main meters supplying the University
- Orthophosphate addition

If the decision is made to go forward with the addition of a corrosion control inhibitor, a review of zinc orthophosphate versus orthophosphate would need to take place.

Table 11 - Estimated Capital Costs for Orthophosphate Addition

	Estimated Cost
Chemical Feed Pumps and Piping	$ 30,000
Chemical Storage and Appurtenances	$ 6,000
Four Vaults for Housing Equipment	$ 15,000
Excavation/Surface Restoration	$ 5,500
Traffic Control	$ 2,000
Installation of Equipment	$ 30,000
Electrical/Instrumentation	$ 20,000
Piping and Valves	$ 15,000
Demolition	$ 3,000
Engineering and Contingencies	$ 56,000
Total	**$183, 000**

Operational Costs

The operational costs are based largely on chemical costs. The orthophosphate addition would be between 2 and 4 pounds per million gallons, and assuming a price of $4.50 per pound for orthophosphate, the price would be between $10 and $20 per million gallons treated depending on the necessary dosage. Table 12 shows the high and low estimates of annual chemical costs for treatment of the six wells feeding the University system. The annual chemical cost would range between $2,100 and $4,100.

Additional costs would include power and labor costs. The power supply for the chemical feed pumps would be the only additional power costs, and would be minimal. System monitoring would be labor intensive due to the location and potential difficult access to the vaults. A summary of estimated chemical and operations and maintenance costs can be seen in Table 12.

Table 12 - Estimated Annual O&M Costs

	0.25 ppm Orthophosphate (low estimate)	*0.5 ppm Orthophosphate (high estimate)*
Orthophosphate Addition (lb/MG)	2.1	4.2
Chemical Cost ($/MG)	$10	$20
Water Treated Annually (MG)	219	219
Estimated Annual Chemical Cost	**$2,100**	**$4,100**
Estimated Annual Labor Cost	**$15,000**	**$15,000**
Total Estimated Annual O&M	**$17,100**	**$19,100**

Appendix B
Mountain Water Lead and Copper Testing

Data Sampled	Location	Cu	Pb
	1992		
7/9/1992	1803 Missoula Ave	0.42	<0.005
7/13/1992	110 N. Easy St	0.62	<0.005
7/13/1992	215 N. Easy St,	0.44	0.006
7/13/1992	107 South Easy St.	0.83	0.006
7/14/1992	516 Whitney Lane	0.35	<0.005
7/14/1992	1900 Alivino	0.67	0.006
7/14/1992	197 S. Easy St.	0.57	<0.005
7/14/1992	140 N. Easy St	0.2	<0.005
7/14/1992	165 N. Easy St.	0.52	<0.005
7/14/1992	155 N. Easy St.	0.79	0.007
7/15/1992	227 S. Easy St.	0.39	<0.005
7/15/1992	200 N. Easy St.	0.41	<0.005
7/16/1992	218 Evans	0.27	<0.005
7/16/1992	1914 Charlotte	1.24	0.005
7/16/1992	155 Fairway Dr.	0.27	0.006
7/16/1992	123 Fairway Dr.	0.39	<0.005
7/16/1992	137 S. Easy St.	0.39	<0.005
7/16/1992	2326 Mount Ave.	0.12	<0.005
7/17/1992	106 Shelby Dr.	0.81	<0.005
7/17/1992	2340 Cottage Court	0.51	<0.005
7/20/1992	2380 Cottage Court	0.41	0.006
7/21/1992	2801 Highwood Dr.	0.3	0.011
7/21/1992	2340 Mount	0.23	<0.005
7/21/1992	262 Jamie Court	0.4	0.006
7/21/1992	180 North Easy St.	0.77	<0.005
7/21/1992	260 North Easy St.	1	<0.005
7/24/1992	270 North Easy St.	0.47	<0.005
7/24/1992	272 Jamie Court	0.52	<0.005
7/24/1992	2639 Valley View Drive	0.14	<0.005
7/28/1992	185 North Easy St.	0.76	0.007
7/28/1992	519 Whitney	1.22	<0.005
8/20/1992	2120 Gilbert	0.75	<0.005
8/21/1992	327 S. Easy Street	0.77	<0.005
8/21/1992	167 S. Easy Street	0.93	<0.005
8/21/1992	#12 September Drive	0.69	<0.005
8/24/1992	1820 Missoula Ave.	0.75	<0.005
8/24/1992	1503 St. Ann Drive	0.43	<0.005
8/25/1992	2604 South 7th West	0.38	<0.005
8/25/1992	712 Kemp	0.23	<0.005
8/26/1992	645 West Crestline	0.6	<0.005
8/26/1992	107 Westview	0.35	<0.005
8/28/1992	504 Artemos	0.25	<0.005
8/28/1992	2110 Gilbert	0.74	0.016
8/28/1992	104 Bannack Place	0.89	<0.005
8/31/1992	616 Whitney	1.25	<0.005

Data Sampled	Location	Cu	Pb
9/1/1992	2360 Cottage Court	<0.01	<0.005
9/1/1992	2385 Cottage Court	0.2	<0.005
9/1/1992	509 Simons Drive	0.73	<0.005
9/1/1992	2808 Highwood	0.21	<0.005
9/2/1992	132 Fairway Drive	1.05	<0.005
9/2/1992	104 Shelby Court	0.42	<0.005
9/2/1992	502 Westview	0.34	0.006
9/3/1992	2224 North Ave. West	0.7	<0.005
9/3/1992	312 David Court	0.37	<0.005
9/10/1992	2316 Spurgin Rd.	0.36	0.006
9/23/1992	1700 Cyrus Crt.	1.17	<0.005
9/24/1992	123 West Hillcrest Drive	0.41	0.008
9/24/1992	601 Whitney	0.72	0.014
9/27/1992	168 Fairway Drive	0.36	0.008
10/1/1992	107 North Ave West #1	1.35	<0.005
10/1/1992	107 North Ave West #2	0.52	<0.005
10/1/1992	108 North Ave West #3	0.67	<0.005
10/1/1992	109 North Ave West #4	0.88	<0.005
	1993		
1/27/1993	2110 Gilbert	1.1	0.01
1/27/1993	2120 Gilbert	0.78	<0.005
1/27/1993	601 Whitney	0.45	<0.005
1/27/1993	1503 Saint Ann Drive	0.64	<0.005
1/27/1993	#12 September Drive	0.66	<0.005
1/28/1993	1900 Alvina	0.54	<0.005
1/28/1993	616 Whitney	1.16	<0.005
2/2/1993	200 North Easy St.	0.41	<0.005
2/2/1993	180 North Easy St.	0.09	<0.005
2/2/1993	260 North Easy St.	0.84	<0.005
2/2/1993	110 North Easy St.	0.79	<0.005
2/2/1993	1803 Missoula Ave.	0.54	0.005
2/3/1993	165 North Easy St.	0.78	<0.005
2/3/1993	270 North Easy St.	0.72	<0.005
2/5/1993	197 South Easy St.	0.96	<0.005
2/5/1993	167 South Easy St.	0.23	0.006
2/5/1993	227 South Easy St.	0.71	<0.005
2/5/1993	327 South Easy St.	0.78	<0.005
2/9/1993	155 North Easy St.	0.69	0.006
2/9/1993	502 Westview	0.49	<0.005
2/9/1993	107 Westview	25	<0.005
2/9/1993	272 Jamie Court	0.38	<0.005
2/9/1993	155 Fairway Drive	0.28	<0.005
2/9/1993	645 Crestline Drive	0.63	<0.005
2/10/1993	218 Evans	0.31	<0.005
2/10/1993	509 Simmons Drive	1.12	<0.005
2/10/1993	712 Kemp	0.24	<0.005
2/17/1993	2808 Highwood Dr.	0.31	<0.005
2/17/1993	2340 Cottage Drive	0.3	<0.005
2/17/1993	1914 Charlott	0.95	<0.005

Data Sampled	Location	Cu	Pb
2/17/1993	2316 Spurgis Road	0.51	<0.005
2/18/1993	132 Fairway Drive	0.74	<0.005
2/23/1993	107 North Ave. West	1.01	<0.005
2/24/1993	504 Artemos Drive	0.27	<0.005
2/24/1993	2340 Mount	0.31	<0.005
2/24/1993	2360 Cottage Court	0.45	<0.005
2/25/1993	2326 Mount	0.29	0.007
2/26/1993	1700 Cyprus Court	1.49	<0.005
2/26/1993	168 Fairway Drive	0.26	<0.005
2/26/1993	185 North Easy St.	0.41	<0.005
2/26/1993	2604 South 7th West	0.53	<0.005
2/26/1993	215 North Easy St.	0.62	<0.005
2/26/1993	262 Jamie Court	0.66	<0.005
2/26/1993	2939 Valley View	0.13	<0.005
2/26/1993	106 Shelby Drive	0.86	<0.005
2/26/1993	104 Shelby Court	0.43	<0.005
2/26/1993	104 Bannack Pl.	1.29	<0.005
2/26/1993	2385 Cottage Court	0.32	<0.005
2/27/1993	312 David Court	0.98	<0.005
3/1/1993	2801 Highwood Drive		0.013
3/2/1993	123 West Hillcrest Drive		0.005
3/3/1993	140 North Easy St.		0.005
3/3/1993	107 South Easy St.		<0.005
3/4/1993	137 South Easy St.		0.007
3/10/1993	2224 North Ave. W		<0.005
3/12/1993	123 Fairway Drive		<0.005
3/15/1993	1820 Missoula Ave.		<0.005
3/25/1993	516 Whitney Lane		<0.005
3/26/1993	2380 Cottage Court		0.006
3/26/1993	519 Whitney Lane		<0.005
	1994		
6/2/1994	#12 September Dr.	0.68	<0.005
6/3/1994	1803 Missoula Ave.	0.5	<0.005
6/3/1994	519 Whitney	0.92	0.009
6/3/1994	327 South Easy St.	0.42	<0.005
6/3/1994	616 Whitney	1.05	<0.005
6/3/1994	1503 Saint Ann St.	0.54	<0.005
6/3/1994	2604 South 7th West	0.48	<0.005
6/3/1994	107 North Avenue W.	1.06	<0.005
6/3/1994	227 South Easy St.	0.59	<0.005
6/4/1994	106 Shelby Drive	0.95	<0.005
6/4/1994	2385 Cottage Ct.	0.2	<0.005
6/4/1994	132 Fairway	0.6	<0.005
6/6/1994	712 Kemp	0.28	<0.005
6/7/1994	155 Fairway	0.19	<0.005
6/7/1994	2801 Highwood	0.21	<0.005
6/8/1994	104 Shelby Ct.	0.07	<0.005
6/8/1994	2224 North Ave, W.	0.74	<0.005
6/8/1994	123 West Hillcrest	0.15	<0.005

Data Sampled	Location	Cu	Pb
6/8/1994	2639 Valley View Dr.	0.17	<0.005
6/8/1994	645 Crestline Dr.	0.81	<0.005
6/8/1994	107 Westview Dr.	0.26	<0.005
6/8/1994	165 North East St.	0.57	<0.005
6/8/1994	509 Simons	0.89	<0.005
6/8/1994	218 Evans	0.32	0.005
6/9/1994	601 Whitney Dr.	0.66	0.005
6/9/1994	502 Westview Dr.	0.3	<0.005
6/9/1994	123 Fairway Dr.	0.1	<0.005
6/10/1994	1900 Alvina	0.88	<0.005
6/10/1994	104 Bannack Pl.	0.58	<0.005
6/12/1994	504 Artemos Dr.	0.18	<0.005
6/15/1994	2326 Mount	0.28	<0.005
	1995		
7/10/1995	111 Gold Nugget	0.3	<0.005
7/11/1995	218 Evans St.	0.14	0.008
7/11/1995	601 Whitney Lane	0.52	<0.005
7/12/1995	502 Westview Dr.	0.32	0.007
7/12/1995	132 Fairway Dr.	0.49	<0.005
7/12/1995	2604 South 7th West	0.65	<0.005
7/12/1995	1503 Saint Ann Dr.	0.6	<0.005
7/12/1995	519 Whitney Lane	0.33	<0.005
7/12/1995	6200 Raelene Court	0.19	<0.005
7/12/1995	227 South Easy St.	0.36	<0.005
7/12/1995	107 Westview Dr.	0.29	<0.005
7/12/1995	104 Shelby Cr.	0.23	<0.005
7/12/1995	106 Shelby Dr.	0.73	<0.005
7/12/1995	104 Bannack Place	0.89	<0.005
7/12/1995	155 Fairway Dr.	0.15	<0.005
7/12/1995	2385 Cottage Court	0.15	<0.005
7/13/1995	2639 Valley View	0.08	<0.005
7/13/1995	327 South Easy St.	0.57	<0.005
7/13/1995	1900 Alvina Dr.	0.84	<0.005
7/13/1995	1803 Missoula Ave.	0.36	<0.005
7/13/1995	07 North Ave. W	1.28	<0.005
7/14/1995	2326 Mount Ave.	0.17	<0.005
7/14/1995	509 Simons	1.1	<0.005
7/14/1995	123 West Hillcrest Dr.	0.12	<0.005
7/19/1995	165 North Easy St.	0.82	<0.005
7/20/1995	102 Gold Nugget	0.48	<0.005
7/21/1995	112 Gold Nugget	0.34	<0.005
7/27/1995	504 Artemos	0.15	<0.005
8/2/1995	645 West Crestline	0.27	<0.005
8/3/1995	115 Alliance Way	0.18	<0.005
8/3/1995	2224 North Ave. W.	0.11	<0.005
8/9/1995	5101 Mainview	0.4	<0.005
8/15/1995	1145 Lolo St.	N/A	0.006
8/24/1995	5500 Momont	0.28	<0.005
8/24/1995	5500 Industrial Park	0.38	<0.005

Data Sampled	Location	Cu	Pb
8/24/1995	5225 Highway 10 West (Airport)	0.21	<0.005
8/24/1995	5225 Highway 10 W. (Aerotronics)	0.78	<0.005
8/24/1995	#12 September Dr.	0.59	<0.005
8/25/1995	5755 Highway 10 W. (NWS)	0.33	<0.005
8/25/1995	5775 Highway 10 West (Fire Lab)	0.3	<0.005
8/26/1995	5450 Momont	0.27	<0.005
8/28/1995	6900 Butler Creek	0.17	0.009
8/29/1995	5765 Highway 10 West (Warehouse)	0.17	0.008
8/30/1995	5405 Momont	0.22	0.008
9/1/1995	104 Gold Nugget	0.62	<0.005
9/1/1995	712 Kemp	0.24	<0.005
	1998		
8/3/1998	1803 Missoula Ave	0.135	4.1
8/3/1998	327 S. Easy St.	165	nd
8/3/1998	227 S. Easy St.	185	2.1
8/3/1998	111 Gold Nugget	150	1.4
8/3/1998	155 Fariway Dr.	125	2.2
8/3/1998	502 Westview	145	4.2
8/3/1998	107 N. Ave West	720	2.6
8/3/1998	132 Fairway Dr.	290	1.8
8/3/1998	4200 Placer Lane	185	1.9
8/3/1998	2385 Cottage Ct.	190	2.1
8/3/1998	509 Simons Dr.	320	1.3
8/3/1998	1503 St. Ann	380	1.3
8/3/1998	12 September Dr.	490	4.1
8/3/1998	2639 Valley View	97	2.3
8/3/1998	2604 So. 7th West	440	2.2
8/3/1998	519 Whitney	930	1.5
8/25/1998	712 Kemp	205	nd
8/25/1998	294 Evans	160	nd
8/25/1998	2326 Mount	84	nd
8/25/1998	165 North Easy St.	450	nd
8/25/1998	104 Shelby Ct.	170	nd
8/25/1998	115 Allince Wy.	110	nd
8/25/1998	1900 Alvina	650	5.6
8/29/1998	106 Shelby Dr	640	nd
8/29/1998	104 Bannack Pl.	150	nd
8/29/1998	504 W. Artemos	205	nd
8/29/1998	2224 No. Ave. W.	280	nd
8/29/1998	645 W. Crestline	157	nd
	2001		
6/12/2001	504 W. Artemos	0.19	<0.005
6/12/2001	#12 September Dr.	0.26	<0.005
6/13/2001	155 Fairway	0.11	<0..005
6/13/2001	2385 Cottage Ct.	0.17	<0.005
6/13/2001	2224 North Ave. W.	0.3	<0.005
6/13/2001	132 Fairway	0.22	<0.005
6/13/2001	165 N. Easy St.	0.5	<0.005

Data Sampled	Location	Cu	Pb
6/13/2001	106 Shelby Dr.	0.32	<0.005
6/14/2001	2709 Old Quarry	0.07	<0.005
6/14/2001	2701 Old Quarry	0.06	<0.005
6/14/2001	2604 S. 7th St. W	0.39	<0.005
6/15/2001	1503 St. Ann Dr.	0.31	<0.005
6/19/2001	115 Alliance	0.1	<0.005
6/19/2001	502 Westview	0.11	<0.005
6/19/2001	4200 Placer Ln.	0.19	<0.005
6/20/2001	218 Evans	0.19	<0.005
6/20/2001	519 Whitney Ln	0.56	<0.005
6/21/2001	227 S. Easy St.	0.25	<0.005
6/21/2001	712 Kemp	0.26	<0.005
6/22/2001	111 Gold Nugget	0.2	<0.005
6/22/2001	327 S. Easy	0.74	<0.005
6/24/2001	2326 Mount	0.11	<0.005
6/26/2001	104 Shelby	0.25	<0.005
6/26/2001	601 Whitney	0.28	<0.005
6/26/2001	1900 Alvina Dr.	0.45	<0.005
6/26/2001	2639 Valley View	0.07	<0.005
6/27/2001	1803 Missoula	0.14	<0.005
6/27/2001	5416 Prospect Dr.	0.06	<0.005
6/27/2001	2617 Old Quarry Rd.	0.06	<0.005
6/28/2001	123 W. Hillcrest Dr.	0.12	<0.005

Data Sampled	Location	Cu	Pb
	2004		
7/11/2004	1503 St. Ann Dr.	0.26	ND
7/12/2004	#12 September Dr.	0.1	ND
7/14/2004	1803 Missoula Ave.	0.11	ND
7/15/2004	165 N. Easy St.	0.27	ND
7/15/2004	111 Gold Nugget	0.12	ND
7/16/2004	227 S. Easy St.	0.61	ND
7/16/2004	519 Whitney Ln	0.36	ND
7/19/2004	1900 Alvina	0.6	ND
7/20/2004	2326 Mount	0.22	ND
7/20/2004	2701 Old Quarry Rd.	0.12	ND
7/20/2004	2709 Old Quarry Rd.	0.09	ND
7/20/2004	2385 Cottage Ct.	0.16	ND
7/20/2004	504 Artemos	0.11	ND
7/20/2004	327 S. Easy St.	0.68	ND
7/20/2004	115 Alliance Way	0.13	ND
7/20/2004	4200 Placer Ln	0.19	ND
7/20/2004	2639 Valley View	0.1	ND
7/21/2004	601 Whitney	0.28	ND
7/21/2004	155 Fairway Dr.	0.13	ND
7/21/2004	2617 Old Quarry Rd.	0.07	ND
7/21/2004	106 Shelby Dr.	0.22	ND
7/21/2004	502 West View	0.13	ND
7/22/2004	5416 Prospect	0.07	ND
7/22/2004	2604 S. 7th W.	0.41	ND
7/23/2004	132 Fairway Dr.	0.22	0.008
7/23/2004	2224 North Avenue	0.27	0.012
7/30/2004	218 Evans	0.16	0.011
8/3/2004	123 W. Hillcrest	0.27	ND
8/3/2004	712 Kemp	0.16	ND

Appendix C
Recommended Sampling Plan

Sampling locations were selected in order to gain a broad look at fixtures campus wide. A few buildings that have locations that have consistently shown lead levels above the action level have been selected for multiple samples. Samples should be taken in locations that have not been sampled previously where possible.

Building	Number of Samples	Previously Sampled Location	New Sample Location
Aber			
Adams Center	1		1
Art Annex			
1000 E Beckwith			
Brantley	1		1
Chem - Pharm			
Chemistry Stores			
Clinical Psychology	2	1	1
Corbin	1		1
N. Corbin	3	1	2
Craig			
Curry Health	1		1
Duniway	1		1
724 Eddy			
730 Eddy			
Education	2	1	1
Elrod	1		1
Fine Arts	1		1
Forestry	1		1
Forestry Green House			
Gallagher	1		1
Garage	1		1
Health Sciences			
Heating Plant	1		1
Honors College			
International Programs/Linguistics	1		1
Jesse	1		1
Journalism	2	1	1
Knowles	2	1	1
Labor Shack			
Law	1		1
Liberal Arts			
Library	1		1
Lommasson/Lodge			
Main Hall	1		1
Math			
McGill*	1		1
Miller	1		1
Music			
Native American Studies			
Natural Sciences	1		1
Natural Sci Green House			
Pantzer			
PARTV			

Building	Number of Samples	Previously Sampled Location	New Sample Location
Physical Plant	2	1	1
Pool			
Rankin	1		1
Rec Annex			
Schreiber/ROTC			
Science Complex	1		1
Skaggs			
Social Science	1		1
Todd/Print Shop	1		1
Todd/Continuing Ed			
Turner	3	1	2
UC			
North Underground Lecture Hall			
Urey Lecture Hall	1		1
Total	40		

* Must be sampled annually due to Preschool Classroom.