# METALS DEPOSITION IN NORTHERN ARIZONA RESERVOIRS

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## Executive Summary

To understand the sources of mercury (Hg) to Upper Lake Mary, we collected sediment cores from Upper Lake Mary and 11 other reservoirs in northern- and central-Arizona. We performed physical and geochemical analyses on these cores to determine the chronology of sediment deposition, the concentrations of total Hg, lead (Pb), and zinc (Zn), and the stable isotope ratios of Pb. Results indicated that Upper Lake Mary and most of the other study lakes experienced non-point increases in Hg and Pb over their history. We could detect no evidence of point sources of either metals. Although we observed changes in Zn over some of the reservoir histories, we did not detect any significant Zn loading. Stable isotope data point to coal and gasoline combustion as likely sources of Pb in lake sediments. The non-point sources of Hg could be concentration of geologic Hg from within the watershed or atmospheric deposition. The growing consensus among the scientific community is that practically all watershed Hg has atmospheric deposition as the ultimate source. Because of the high affinity Hg has for organic matter, understanding the patterns of storage and release of organically-bound Hg from watersheds may be of far greater importance in managing lakes than detecting the ultimate source. Further study should be directed toward better understanding the delivery of Hg from watersheds and the biological availability of these Hg forms.

## Introduction

Mercury contamination has emerged as a serious public health concern in Arizona. The Arizona Game and Fish Department in cooperation with the Arizona Department of Environmental Quality (ADEQ) and the Arizona Department of Health Services, have currently posted fish consumption advisories for eleven reservoirs statewide. Five are in northern Arizona. The origin of mercury in these reservoirs is unclear; potential sources include atmospheric deposition, geologic formations in the watershed that contain mercury, and historic land use practices.

The objective of this study is to collect and analyze sediment cores from northern Arizona reservoirs to search for temporal and spatial patterns of metals deposition.

## Methods

Field and laboratory methods are outlined in this section. Complete details of standard operating procedures, quality assurance and quality control procedures, and quality assurance data are provided in the Quality Assurance Project Plan in Appendix A.

### Data Management

The three data streams for the procedures below were field notes, laboratory notes, and instrumental records and calculations. All original paper files and source computer files were archived either as paper copies or in computer directories. All processed data was summarized as an Excel database. All data were verified by the principal investigator.

### Field Procedures

Surface sediment cores extending from the surface/water interface to a sediment depth of about 90 cm were collected and sampled from eleven northern Arizona lakes and reservoirs. Coring locations were chosen to retrieve the thickest, undisturbed, sequential sediment package from each site. Sampling locations and summary characteristics of study lakes are provided in Table 1, Figure 1, and field data listings in Appendix B. Tables and figures for are included after the main body of the text of this document.

At each site, the principal investigator trained any new members of the field crew. A floating platform was assembled, rowed to the coring location and stabilized using ropes connected to the shore or anchor bags. A GPS receiver was used to determine and record the latitude and longitude of each sampling location. Water depth (m) was measured from the water surface to the sediment/water interface using a weighted meter tape. Notes were recorded in a field notebook.

A piston-corer (surface corer) attached to a series of steel or titanium rods was used to collect a sediment core extending from several centimeters above the sediment/water interface to about 90 cm below the interface. At Lyman and Alamo we also collected deeper cores in 1-meter intervals using a Livingstone square-rod corer, a piston corer which permits recovery of intact cores from thick sediment deposits. Each surface core was sampled using clean-hands, dirty-hands procedures and preserved in the field within four hours of collection. Each surface core was extruded from the bottom upward in 1.0 cm intervals. At each interval half the sediment

was collected into a Nalgene FLPE container and the remaining half was collected into a Whirl-pak bag. Livingstone cores were double-wrapped in plastic wrap and refrigerated until sampled in the laboratory. Notes regarding sediment descriptions were recorded in the field notebook. Nalgene containers for mercury analysis were preserved in coolers with an ice / dry ice mixture and frozen on arrival at the lab. Whirl-pak bags were preserved in the field in coolers with ice at $4^oC$ and were placed in a refrigerator at $4^o$ C on arrival at the lab.

After each trip, the field crew transported the coolers containing mercury samples directly back to freezers located in NAU Bilby Research Center. The field crew delivered samples for the remaining analyses to a walk-in refrigerator located in the NAU Chemistry Building. All original Field Chain of Custody forms remained with the samples until the samples were processed.

**Laboratory Procedures**

The samples stored in Whirl-pak bags at $4^oC$ in the NAU Chemistry Building were sub-sampled for bulk density, moisture content, loss-on-ignition, total Pb, total Zn, Pu isotopes and Pb isotopes. Each time a sample was handled or a sub-sample created, a Laboratory Chain of Custody form was initiated. One copy of the form accompanied the sub-samples, another copy was kept with the original samples, and a third copy was kept in a laboratory logbook in Room 404 of the Chemistry Building. Analytical laboratory training was conducted by the principal investigator who reviewed standard operating procedures, demonstrated laboratory techniques, and supervised analytical staff as they practiced the procedures.

***Gravimetric Analyses***

Samples for gravimetric analysis were sub-sampled from the Whirl-pak bags preserved at $4^oC$. Samples were analyzed within 28 days of collection in the field according to the standard operating procedures provided in the project QAPP (Appendix A). Analytical procedures are based on ASTM Method D4531-86 for bulk density and APHA Method 2540G for moisture content and loss-on-ignition. Data are reported for moisture content as mass fraction moisture, for bulk density as g dry sediment / $cm^3$, and for loss-on-ignition as mass fraction dry weight.

***Total Pb by ICP-MS***

Samples for total lead were analyzed using total-digestion acid extracts prepared according to the standard operating procedure provided in the QAPP (Appendix A). Samples were analyzed in the Chemistry Department at NAU following procedures based on EPA Method SW-846 6020. Data are reported as ug Total Pb / g dry sediment.

***Total Zn by Flame Atomic Absorption***

Samples for total zinc were analyzed using total-digestion acid extracts prepared according to the standard operating procedure provided in the QAPP (Appendix A). Samples were analyzed in the Chemistry Department at NAU following procedures based on EPA Method SW-846-7951. Data are reported as

***Pu Isotopes by ICP-MS***

Samples were analyzed for the mass 239, 240, and 242 isotopes of plutonium using a potassium pyrosulfate fusion procedure. Plutonium was separated from other constituents and concentrated onto an element-specific resin (TEVA), then released through an ammonium oxalate elution. The QAPP (Appendix A) provides complete documentation of preparation, analysis, and quality assurance procedures. Samples were prepared and analyzed in the Chemistry Department at NAU.

***Pb isotopes by ICP-MS***

Samples were analyzed for the mass 204, 206, 207, and 208 isotopes of lead using a nitric-acid extraction of dry-ashed sediment. Lead was separated from other constituents in the extract and concentrated using lead-specific resin and eluted from the resin using ammonium oxalate. The QAPP (Appendix A) provides complete documentation of preparation, analysis, and quality assurance procedures. Samples were prepared in the Chemistry Department at NAU and analyzed by NAU project personnel at the Harry Reid Center for Environmental Studies at the University of Nevada, Las Vegas.

## Results

### Physical Data

We analyzed samples from each core at 1-cm intervals for three physical parameters: moisture content, bulk density, and loss-on-ignition (LOI). Moisture content and bulk density tended to be inversely related and both are measures of compression in the sediment column. Moisture content is the mass or weight fraction of water in the sediment (mass of water divided by total mass of sample). Bulk density is the dry mass of sediment occupied by a fixed volume of in-situ sediment, expressed as grams dry sediment per cubic centimeter. For example, low bulk density reflects a combination of low soil density (e.g., organic matter is less dense than sand) and high porosity.

LOI is a measure of the organic content of the sediment expressed as the loss in mass on ignition at 550$^{o}$C divided by the original dry mass of the sample. Organic matter in the sediment can be derived from within the lake by primary productivity or can be terrestrial organic matter washed into the lake with runoff. LOI varies based on the absolute input of organic carbon and the dilution of that carbon relative to the total mass of sediment by inorganic sediment washed into the lake. We observed, for example, bands of dark sediment in the Lyman and Alamo cores which we believe reflect summer periods of high biological productivity and little input of inorganic sediment from the watershed. These dark bands were separated by light-colored zones of coarser inorganic sediment from storm runoff.

The Upper Lake Mary and Lyman cores showed the greatest systematic variability in physical parameters. In Upper Lake Mary, two distinct peaks in LOI appear at 27 and 39 cm and are associated with increases in moisture content and decreases in bulk density (Figure 2a).

In Kinnickinick, Long, Carnero, Nelson, and Ashurst, bulk density increased toward the base of the core, presumably due to compression. The weight of overlying sediment collapses pore spaces occupied by water. The increase in bulk density with depth was particularly abrupt in Kinnickinick, Long, Carnero, and Nelson, which may be associated with the onset of permanent flooding after impoundment.

### Chronologies and Sediment Core Integrity

We attempted to establish chronologies to relate positions in each sediment core to known dates. Well-defined chronologies allow us to compare changes across lakes. In this study we

used two age markers: radio-isotopic analysis and date of impoundment. Radiometric dating provides a marker for the peak of above-ground atomic testing in 1963 (Beck and Bennett, 2002). The characteristic change in radioactive fallout over the period of 1954 to about the 1970s also provides an indication of sediment disturbance and remixing. A plot of $^{239+240}$Pu versus depth in the core, for example, which has a single, well-defined peak indicates that sediments have been deposited sequentially over time with a minimum of disturbance. Broad or multiple peaks indicate disturbance and complicate interpretation of data from the core.

We also attempted to relate the date of impoundment of each lake with observations of transitions in physical characteristics of the cores that indicate the onset of permanently-flooded conditions. Reservoirs in this study had several possible origins. Some reservoirs were existing playa-like lakes or wetlands which had dams constructed to create recreational features (e.g., Ashurst Lake), or to improve the reliability of water supply for cattle grazing (e.g., Soldiers and Long Lakes). Others were riverine systems without standing water (e.g., Willow Springs, Nelson, Lyman, and Alamo). Lakes such as Upper Lake Mary and Carnero have more complicated histories, which made the use of the date of impoundment problematic.

The quality of the chronologies for each lake determined which lakes were used for analysis of flux and was the basis in three cases (Willow Springs, Lower Lake Mary, and Stoneman) for excluding lakes from comparative analysis for several analytical parameters.

***Well Defined Chronologies***

Figures 3a through 3e show the data for $^{239+240}$Pu versus core depth for the study lakes. Upper Lake Mary, Ashurst, Lyman and Carnero showed quite well-defined peaks in plutonium activity and we assigned positions for the 1963 marker with confidence. On the basis of this marker, we estimated sedimentation rates for the period 1963 to present (Table 2).

Upper Lake Mary showed a very well defined 1963 peak at 13cm, with little Pu activity below or above the base of the peak. The lake was impounded in 1941 and according to the Arizona Game and Fish Department (Benedict, personal communication, 2005) was a riverine wetland prior to impoundment. We observed a massive peat layer at 39cm (Figure 2a) and assigned the year 1941 to this location.

Ashurst Lake showed a broad single peak with maximum Pu activity at 14cm. Although the lake was impounded in 1954, we did not assign that year to the base of the core, because the lake

was an existing, but likely intermittent, water feature. We extrapolated the 1963-present sedimentation rate below 14 cm.

At Lyman Lake we collected an 80-cm surface core and a series of 1-meter Livingstone cores starting at about 20 cm below the sediment-water interface. Pu dating of both cores provided the basis for an excellent match between the surface and Livingstone cores. Lyman had a well-defined 1963 peak at 98cm, but also showed minor peaks at about 170 and 250 cm, indicating some remixing in that interval. We assigned the base of the core at 475 cm the impoundment date of 1910. The reservoir was clearly riverine prior to impoundment and the base of the core was clearly the transition between aquatic and terrestrial sediment.

Carnero Lake showed a single, well-defined peak at 17.5 cm; however a troubling anomaly with Carnero Lake is that the date of impoundment, according to Arizona Game and Fish Department records (Dreyer, personal communication, 2005), was 1979. According to Dreyer (2005), prior to impoundment the area did not maintain a permanent pool. The USGS topographic quadrangle (Greens Peak, Arizona), which was drawn from photographs taken in 1967, shows the lake in its present configuration, with no indication that it was added in the only other revision to the map in 1969. We are searching for aerial imagery of the site taken in the period from the 1940s to the 1960s to resolve the origin of the sediment. Because the curve is so well defined, however, we included Carnero in further comparative analysis.

As with Lyman, Kinnickinick Lake showed a distinct peak at a high position in the core (7 cm), but minor peaks at lower positions. According to the peak, Kinnickinick also showed the lowest sedimentation rate (0.17 cm/yr, Table 2).

Alamo Lake was impounded in 1968, well after the peak in plutonium activity. The lake was riverine prior to impoundment and the base of our core showed clear signs of terrestrial sediment at 440 cm. We thus based our estimate of the average sedimentation rate of 12.2 cm/year (Table 2) on this single marker.

***Undefined Chronologies***

We were unable to establish reliable chronologies for Nelson, Willow Springs, Lower Lake Mary, and Stoneman for reasons specific to each lake. Data from these cores did, however, yield valuable information.

Impounded in 1892 (Dreyer, 2005) Nelson Reservoir was the oldest reservoir in this study. Coring revealed the lake has sediment column of about 70 cm. At 57 cm we observed an abrupt transition from dark, un-differentiated, organic sediment (gyttya) above, to lighter, low-organic clay below (appendix, field notes). This position corresponded to an increase in bulk density and a decrease in moisture content with depth (Figure 2e). Ordinarily we would have assigned the date of impoundment to this clear transition; however Pu analysis showed a very narrow, high-magnitude peak at 55 cm (Figure 3e). The 239 and 240 isotopes of plutonium did not exist prior to the atomic era, so the source for this Pu must be in the 1950s or later. The shape of the Pu curve suggests there was zero sediment accumulation until the 1950s, low sedimentation until the mid-1960s, and extremely high sedimentation from the 1960s to present. We are unable to explain sedimentation in this lake and exclude Nelson from chronometric analysis.

Although Willow Springs was a riverine system prior to impoundment in 1967, we were able to collect a 38-cm sediment core. Unlike other reservoir cores in this study, which were typically fine-grained, the core from Willow Springs had a high fraction of sand and low fraction of silt and clay. Pu dating (Figure 3e) revealed low Pu increasing to a maximum at the core top. This shape is highly characteristic of terrestrial soils. A soil profile from Lockett Meadow showing this trend is presented in Figure 4. (Ketterer et al., 2003). We concluded that the core consisted primarily of pre-impoundment terrestrial soil and excluded Willow Springs from comparison with other aquatic sediment cores. We did however, consider concentrations of analytes in the core to reflect terrestrial soil conditions.

Lower Lake Mary and Stoneman Lake both showed Pu curves with relatively high Pu activities and indistinct peaks (Figure 3e). These are characteristic of periodic desiccation and remixing. As a result we did not attempt to construct chronologies of these lakes.

**Flux Calculations**

Bulk density measurements collected with the physical data, and sedimentation rates estimated from the chronometric analysis enabled us to estimate the flux, or annual delivery, of sediment and elements to each lake for which we have reliable chronologies. The form of the flux calculation for an element is

| Flux | = | Metal Concentration | x | Bulk Density | x | Sedimentation |
|---|---|---|---|---|---|---|
| [g/cm$^2$/yr] | = | [g metal / g dry sediment] | x | [g dry sediment / cm$^3$] | x | [cm/yr] |

Flux calculations can enable certain types of pollutant loading to be detected. For example, a constant areal (say $g/m^2$) delivery of an atmospheric pollutant may be observed to fluctuate in a sediment record due to changes in sedimentation patterns. Increased sedimentation rates would dilute the concentration and decreased sedimentation would concentrate the pollutant.

Flux calculations normalize for changes in sediment delivery; however, there is a problem in applying flux calculations associated with estimates of both bulk density and sedimentation. Bulk density tends to increase lower in the core due to compression. This results in a higher effective sedimentation rate toward the bottom of the core (e.g., a sediment layer 1.00-cm thick in 1945 may have been compressed to 0.75 cm by overlying sediment in subsequent decades). High-resolution dating, such as counting annual layers in sediment, can correct for this effect. Our age models, however, are only capable of estimating average sedimentation between known dates in the sediment record. As a result, sedimentation rates are probably overestimated toward the top of the core and underestimated toward the bottom.

Because of errors inherent in the flux calculation, we only calculated flux for lakes which have well-characterized age models. We calculated flux for the time period between 1963 and present for these lakes. This period represents our best estimates for sedimentation rates and corresponds to upper portions of sediment cores, which are likely less affected by compression.

Flux calculations are summarized in Figure 5a for Hg and Figure 5b for Pb and in Table 3. Elemental concentrations are included in Figures 5a and 5b for comparison with fluxes. The influence of relative magnitudes of sedimentation and bulk density can be seen by comparing flux with concentration for Carnero and Lyman. Carnero had high concentrations of both Hg and Pb relative to Lyman. The low bulk density of sediments in Carnero and the high sedimentation rates in Lyman resulted in low flux of both Hg and Pb for Carnero relative to Lyman. Similarly high sedimentation in Soldiers and low sedimentation in Kinnickinick place them at extremes for elemental flux.

**Zinc**

Although present in geologic materials in watershed, changes in sediment Zn are generally associated with atmospheric deposition of high-temperature combustion products (Kim et al., 2000) and from runoff associated with tire wear and other automobile emissions (e.g., Gualtieri et al., 2005; Blok 2005). About half of the lakes in this study showed a clear increase in Zn from

the base of the core Figures 2a through 2e. All lakes except for Willow Springs had an average Zn of 153 ug/g (Table 4). Willow Springs had considerably lower sediment Zn at 70 ug/g, but as was discussed earlier, this may reflect terrestrial soil rather than aquatic sediment. Upper Lake Mary had the highest single concentration of Zn of 1,585 ug/g at 38 cm. This corresponds to a peat layer at the presumed time of impoundment. The highest concentrations of Pb occur in this part of the core, but not the highest concentrations of Hg (Figure 2a).

Regardless of changes in concentration lower in the cores, Upper Lake Mary, Ashurst, and Kinnickinck show a clear trend of increasing Zn concentration in the top 4 or 5 cm of the cores (Figure 2). These lakes are all located in the same general region, on or at the margin of the Anderson Mesa. The other two nearby lakes, Long and Soldiers, do not show this trend. Of all the lakes, only Upper Lake Mary and Lower Lake Mary are subject to direct highway runoff, although no clear effect of this runoff is evident.

**Total Lead**

Total lead showed clear increases from the base of the core in Upper Lake Mary, Ashurst, Kinnickinick, and Carnero. The remaining lakes all showed at least some excursions of higher values than at the base. Pb concentrations at the base of cores averaged 23 ug/g, while averages across entire cores ranged from 20 ug/g in Long to 54 ug/g in Lower Lake Mary.

Analysis of Pb flux (Figure 5 and Table 3) indicates that Soldiers, Lyman, and Alamo received the greatest quantity of Pb. These high delivery rates are associated with high sedimentation rates, and in the case of Soldiers high bulk density, rather than unusually high Pb concentrations.

**Lead Stable Isotopes**

Of the four stable isotopes of lead (mass 204, 206, 207, and 208), all but the mass-204 isotope are radiogenic. These isotopes are the decay products of other radioactive isotopes. As a result, the ratios of these isotopes relative to the mass-204 isotope vary depending on the age of the parent geologic formation and the quantities of parent radioisotopes (Faure, 2005). This phenomenon has been useful in fingerprinting sources of Pb in environmental contamination studies (e.g., Graney and Erikson 2004; Hurst 2002; Renberg et al., 2002).

Potential sources of Pb which have distinctive isotope ratios are termed *end members*, as they form the extreme bounds of plots of the isotope data. We considered two principal sources for Pb: gasoline from the leaded-gasoline era and coal. The isotopic signature for lead from gasoline is now well understood and is known to vary over the production life of leaded gasoline from 1924 to mid-1960s. We use the ALAS (recite acronym) model to define the end-member 206/207 Pb ratio for gasoline over time (Hurst 2002).

The other likely end member for Pb isotopes is coal. We analyzed coal from four northern-Arizona / northwest-New Mexico mines which provide coal to nearby power plants. The data are summarized in Table 5 and plotted as combinations of isotope ratios in Figure 6. Figure 6a plots the likely end members, along with 1-standard-deviation error bars for the samples analyzed. The gasoline data were taken from literature values for California gasoline from the mid-1960s (Chow and Johnstone, 1965). We also included data from Willow Springs, which likely represents terrestrial soil conditions. These data indicate that Pb isotope values are constrained by gasoline, at the highest end of values for isotope ratios, to coal from the Black Mesa mine, at the lowest end of values.

Figure 6b re-plots these data in addition to observations from the lake sediment samples. All but the Alamo and Stoneman samples fall generally between the end-member values. Lyman sediments also deviate somewhat from end-member combinations on plots of 208/206 versus 204/206 and 208/206 versus 207/206.

Figure 7 shows the average 206/207 ratio of coal plotted as a constant value versus date, along with the gasoline signature for 206/207 from the ALAS model (Hurst 2002) and lake sediment data. These data show that 206/207 varies in Upper Lake Mary and Ashurst between the end members for gasoline and coal until the mid-1970s, then stabilizes from the 1970s to present. Observations from other lakes plot close to the average value for coal, except for Alamo, which has much higher values for 206/207. It is possible that other lakes demonstrate distinct trends in 206/207 over time, but we only have a limited number of observations for lakes other than Upper Lake Mary and Ashurst (Figure 2).

**Total Mercury**

All lakes except Alamo showed clear increases in Hg from the base of the core (Figure 2 and Table 4), although the patterns of change over the length of the cores varied from lake to lake.

Hg at the base of cores averaged 36 ng/g and at the tops of cores the average Hg was 80 ng/g. Only Nelson had a core-wide average Hg (33 ng/g) less than the average Hg of core base values. Hg in Alamo showed systematic changes (changes that occurred over several data points), but did not vary more than 15 ng/g from the mean of 65 ng/g over the length of the core.

Hg flux is plotted in Figure 5. As with Pb flux, Hg flux is strongly influenced by bulk density and estimates of sedimentation. As a result, Soldiers and Lyman demonstrate the highest fluxes of about 30 ngHg/cm$^2$/yr, while other lakes show progressively lower fluxes. The high sedimentation rates for Alamo result in Hg delivery more than an order of magnitude higher than the other lakes.

We compared surface sediment Hg concentrations from ADEQ sampling and our study in Table 6. NAU values for Upper Lake Mary were significantly higher than ADEQ values, however ADEQ data show much higher variability. The small number of samples for other sites does not permit statistical comparison, but NAU values were within 10 ng/g Hg for the other three sites. Two likely causes for the differences in the data are spatial heterogeneity in sediment Hg and inter-laboratory differences. ADEQ sampling techniques use a bulk sampling device that samples the top 5 to 10 cm of sediment, vertically integrating the sample. In lakes such as Willow Springs, Hg changes rapidly with depth. Variations in vertical integration would affect the average value. Hg may well be spatially variable across the surface of the lake. The high variability among ADEQ samples for Upper Lake Mary may be related to this spatial variability. Additional analysis of spatial heterogeneity and inter-laboratory analyses of reference sediment samples would address causes for differences between ADEQ and NAU samples.

## Discussion

Total Hg, Total Pb, Pb Isotopes, and Zn all showed changes in sediment concentration, which in some way must be anthropogenic. Possible sources of metals in the sediments of these reservoirs include point sources from discrete releases of the metals, crustal sources that may be detected as changes in concentrations over time due to watershed disturbances, or atmospheric sources. There were no indications of point sources for Hg, Pb, or Zn; any patterns of change detected in one lake were also detected in other lakes, usually in the same geographic area. An exception was the high concentrations of Pb and Zn at the 39-cm position in the Upper Lake

Mary core (Figure 2). This excursion, however was clearly related to organic trapping of metals in peat during the likely pre-impoundment period in the lake.

In principle, it is possible that a significant source of metals is a crustal source that is concentrated by organic matter. Metal ions have a high affinity for organic carbon (Stumm and Morgan 1996), so the organic carbon pools in the terrestrial or aquatic ecosystems may have acted as a sink for metals, as suggested by the high concentrations of Zn and Pb toward the base of the Upper Lake Mary core. Plots of Zn, Hg, and Pb versus LOI, a measure of organic carbon, indicate generally positive correlations between metals and organic carbon on a lake-specific basis (Figure 9). These correlations do not reveal the origins of the metals, but do provide a mechanism to explain how it may be possible for crustal or anthropogenic metals to accumulate in concentrations higher than their original mineral concentration. From a kinetic standpoint, the amount of crustal Hg available for organic uptake is limited by the rate of weathering. It is beyond the scope of this study to assess the relative theoretical contribution of Hg from atmospheric loading sources versus crustal sources through weathering, but the exercise would be straightforward.

Concentration of crustal metals by organic carbon may explain some of the variability in metals, but there are clear indications of anthropogenic sources in the patterns of Pb stable isotope change and in the similarity of changes in metals concentrations over time across watersheds. The Pb isotope record clearly shows variation in Upper Lake Mary and Ashurst between the two end members of coal and leaded gasoline (Figure 6). Only Upper Lake Mary, Ashurst, and Lyman were analyzed at sufficient resolution to detect temporal trends. The trends were similar for Upper Lake Mary and Ashurst. Pb ratio plots (Figure 6b) indicate that all lakes except Alamo, Lyman, and an observation from Stoneman, fall in a straight line between the end members of gasoline and coal. This does not exclude other sources for the Pb in these sediments, but is consistent with a combination of these two. Additionally, a coal combustion source for Pb may also explain some of the sources of Hg loading, as Hg is released with coal combustion (e.g., Yudovich and Ketris, 2005).

Lyman and Alamo have distinctive Pb isotope ratios that did not necessarily plot in a straight line between the gasoline and coal end members (Figure 6b). Clearly there is a missing end member that we did not sample, of either crustal or anthropogenic origin. Alamo is geographically distant from other lakes and may well have different sources of atmospheric

deposition. In the case of Lyman, the unique ratios did not appear in samples from nearby lakes Nelson and Carnero, but we only analyzed a small number of samples from these lakes and the trend may be present but undetected. Other possible end members require investigation and include such sources as cement plants and smelters.

The Pb isotope record points to gasoline combustion as a contributing source which may be related to Zn loading, but not to Hg loading. Hg is not a significant component of gasoline-combusion emissions (Conaway, et al., 2005) so would not be expected to co-vary with Pb. Zn, however, may be linked to gasoline combustion; not through emissions, but through roadway runoff associated with automobiles (e.g., Gualtieri et al., 2005; Blok 2005). Upper Lake Mary would be the likeliest candidate for metals deposition from highway runoff, but shows no clear pattern of increased Zn. Episodes of high Zn concentration occur at about 17, 28, 34 and 39 cm in the core, but all correspond with increases in organic carbon. Each of these may correspond with dry or low-water periods in the lake history when soil or peat may have formed.

Hg concentrations show an even clearer pattern of increase with time than Pb or Zn. As with the other metals, there does not appear to be any point source of Hg. Hg flux calculations (Figure 5) separate the lakes somewhat in terms of their delivery of Hg to the sediments. Lakes with low sedimentation or high bulk density tended to have higher Hg budgets.

Sensitivity of flux to sedimentation rate also points to the importance of crustal concentrations of Pb and Hg. Alamo, for example had Hg flux more than an order of magnitude higher than any other lake. Even corrected for watershed size, the delivery of crustal Hg appears to dominate the total Hg budget of this lake due to its high sedimentation. Crustal Hg is probably far less biologically available than organically-bound Hg, but the analysis for total Hg does not distinguish between the forms. More sophisticated analysis to separate the forms would be appropriate

The focusing of crustal Hg, and metal ions in general, by organic carbon is possible, however the consensus among Hg researchers is that increases in Hg in ecosystems is caused by atmospheric deposition. In a review of Hg sequestration in forests and peatlands, Grigal (2003) states, “Nearly all Hg in vegetation is derived from the atmosphere.” Our observations are consistent with a non-point source of Hg. Upper Lake Mary, Ashurst, and Kinnickinick all have unconnected watersheds, but Hg concentrations varied similarly. In addition, Carnero, which is distant from the other three, showed similar patterns in Hg.

From a lake management standpoint, the question of whether the ultimate source of Hg is atmospheric or crustal may be less relevant than how Hg is stored and released from watersheds. Because surface areas of reservoirs tend to be far smaller than their watersheds, the greatest proportion of an atmospheric Hg load must be transported through terrestrial ecosystems. Studies of Hg in watersheds concluded that the inorganic $Hg^{2+}$ form of mercury has such a high affinity for organic carbon that it is rapidly incorporated into soil litter and living biomass (e.g., Ravichandran 2004 and Grigal 2002). Of great relevance in aquatic ecosystem studies, then, may be how Hg in watersheds is sequestered and released.

A corollary to questions regarding the storage and release of Hg in is how atmospheric-derived Hg behaves after arrival in the reservoir. In reservoirs with high sedimentation rates, such as Alamo and Lyman, most of the Hg is effectively removed from the ecosystem through burial. Most Hg arrives in the inorganic form bound to organic matter (Ravichandran 2004). If that organic carbon is labile and easily dissolved, it may be far more biologically available than Hg incorporated into massive charcoal, associated with fire events (Caldwell et al., 2000). In summary, although the ultimate source of most Hg in aquatic ecosystems may be atmospheric, the proximate processes Hg undergoes in terrestrial watersheds may be of far greater importance in lake management.

## Conclusions and Recommendations

Our analysis of sediment cores from northern- and central-Arizona reservoirs detected patterns of change in Hg, Pb, and Zn delivery to aquatic sediments. Similarities in these patterns of change across watersheds point to non-point sources of the metals, either through concentration of crustal sources of the metals, or more likely through atmospheric deposition. Pb stable isotope analysis indicates a gasoline source for at least some of the Pb deposition. Pb stable isotopes detected in the sediments are also consistent with a coal source, indicating power plants as a possible source of some deposition. Gasoline combustion explains some of the Pb deposition, and perhaps some of the Zn loading, but not the Hg loading. Hg is not a significant component of gasoline combustion. Observed increases in both Hg and Pb point to a coal combustion source, which can deliver both metals through atmospheric deposition.

We observed increases in Hg over time in all lakes except Lower Lake Mary, which has a highly disturbed sediment record, and Willow Springs Reservoir, which appears to have

terrestrial rather than aquatic sediment. As with the other metals, there is no indication of point-sources of Hg in any of the study lakes. The likely non-point sources are geologic or atmospheric. Although it is possible that the ultimate source of Hg in these lakes is geologic from within the watershed, the growing consensus among the scientific community is that the ultimate source of Hg in ecosystems is atmospheric.

Whether the source is geologic or atmospheric, transformations of Hg with organic carbon in the watershed prior to delivery to the reservoir appear to control the Hg budget of lakes. From a lake management standpoint, the most important questions regarding Hg in aquatic ecosystems relate to (1) Hg storage in and release from watersheds and (2) the biological availability of the organic carbon forms associated with the Hg delivered to aquatic ecosystems.

We recommend additional study in two areas: identifying the relative contribution of geologic Hg from within the watershed and characterizing the biological availability of Hg delivered to lakes. Understanding the aquatic Hg budget is an essential early step in determining sources of Hg in the food web. We observed in Alamo Reservoir, for example that although Hg delivery is high, the supply of biologically available Hg may be relatively low due to burial. Similarly, Hg bound in woody biomass delivered to lakes associated with wildfires may be far less biologically available than Hg incorporated into dissolved organic carbon.

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# FIGURES

## Figure 1. Site Location Map.

***To Be Added.***

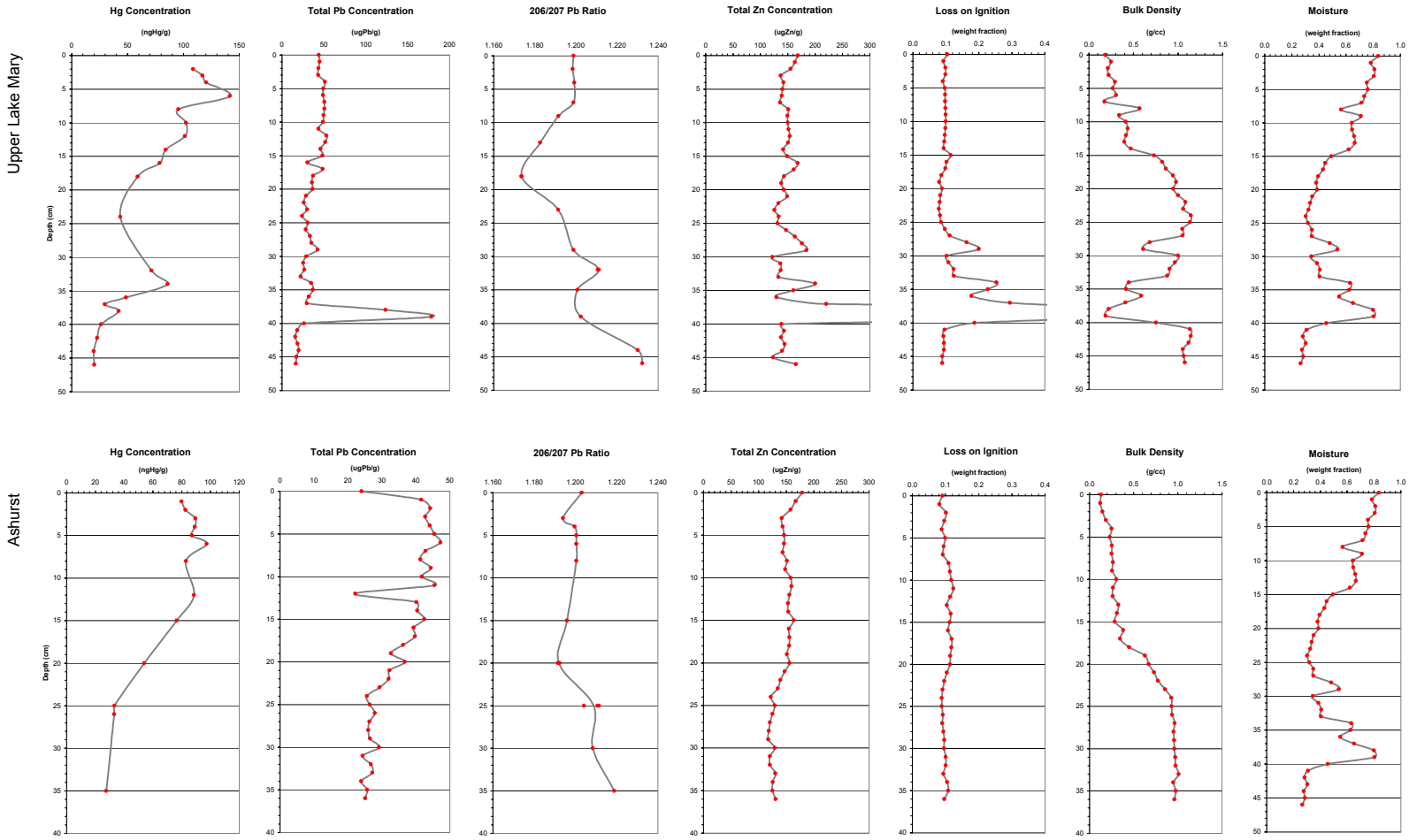


Figure 2a. Data summary for Upper Lake Mary and Ashurst Lake.

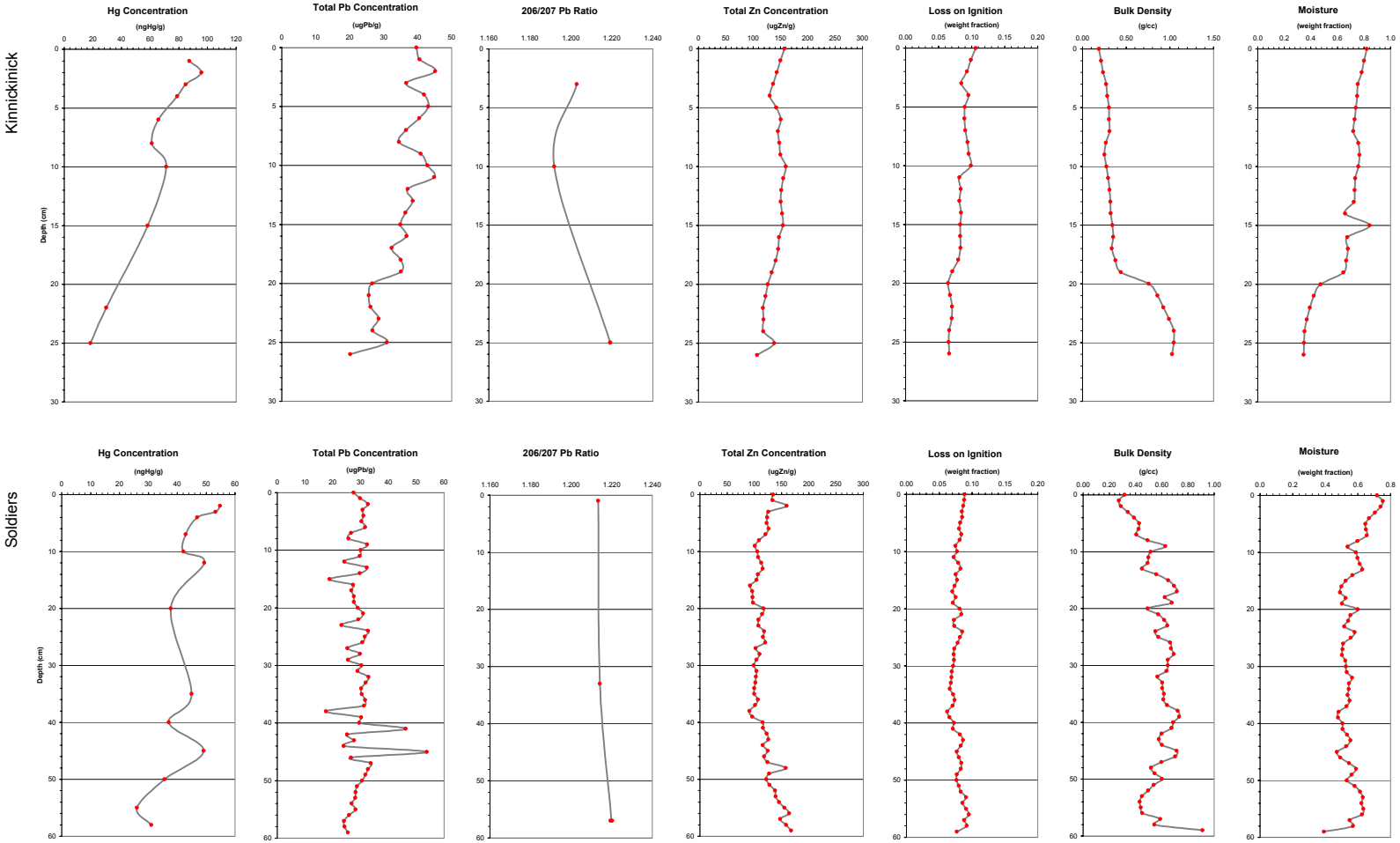


Figure 2b. Data summary for Kinnickinick and Soldiers Lakes.

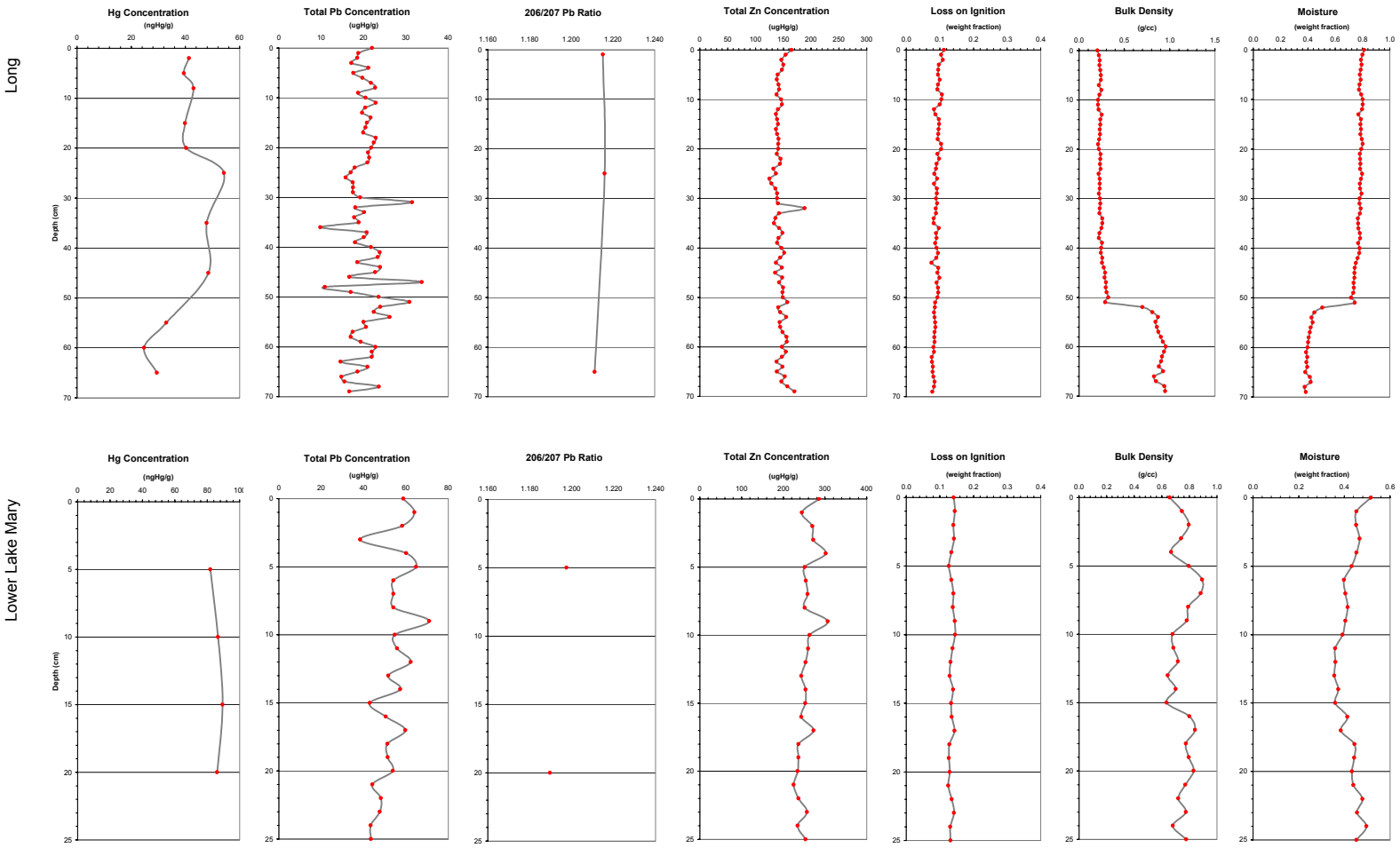


Figure 2c. Data summary for Upper Lake Mary and Ashurst Lake.

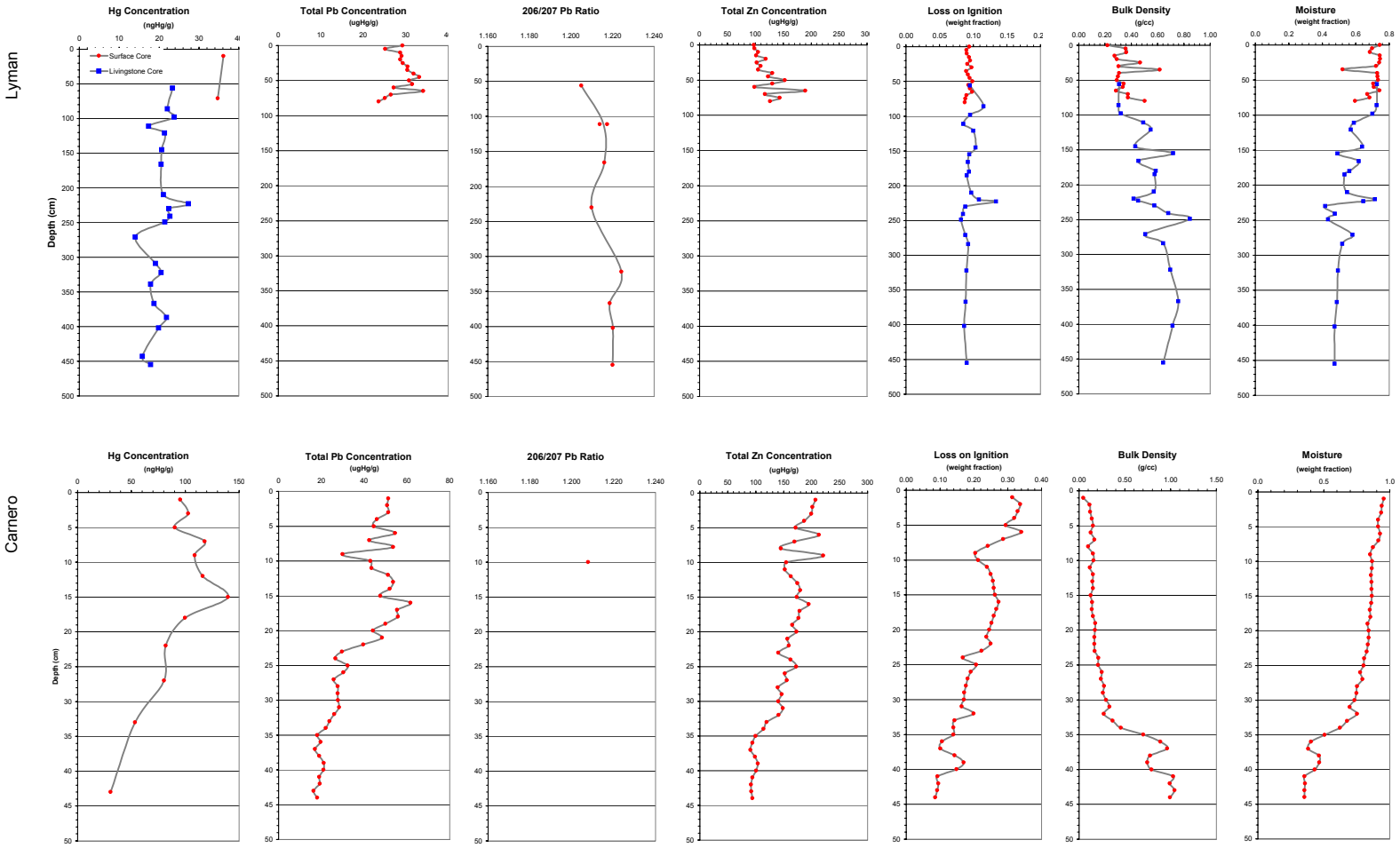


Figure 2d. Data summary for Lyman and Carnero Lakes.

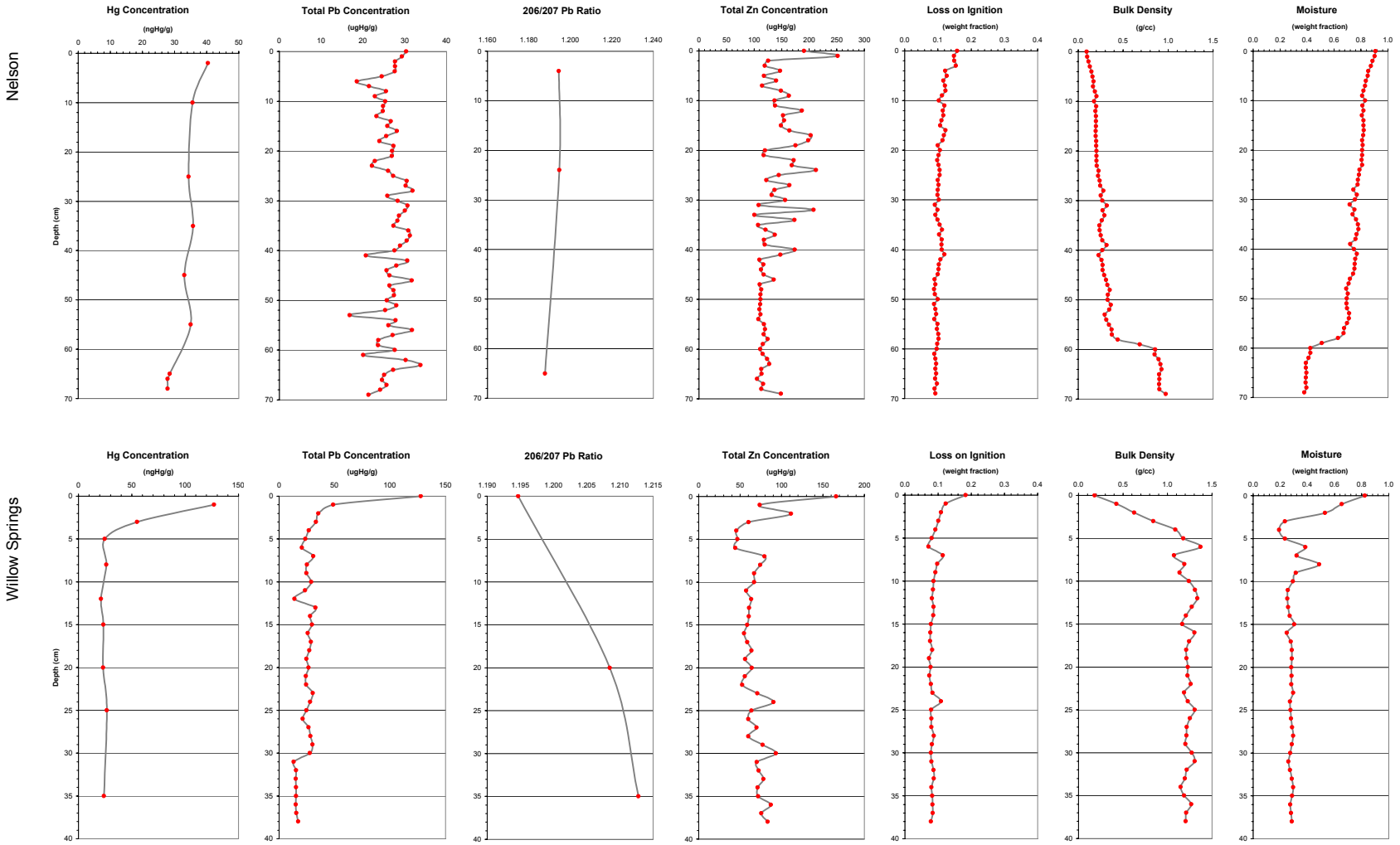


Figure 2e. Data summary for Nelson and Willow Springs Lakes.

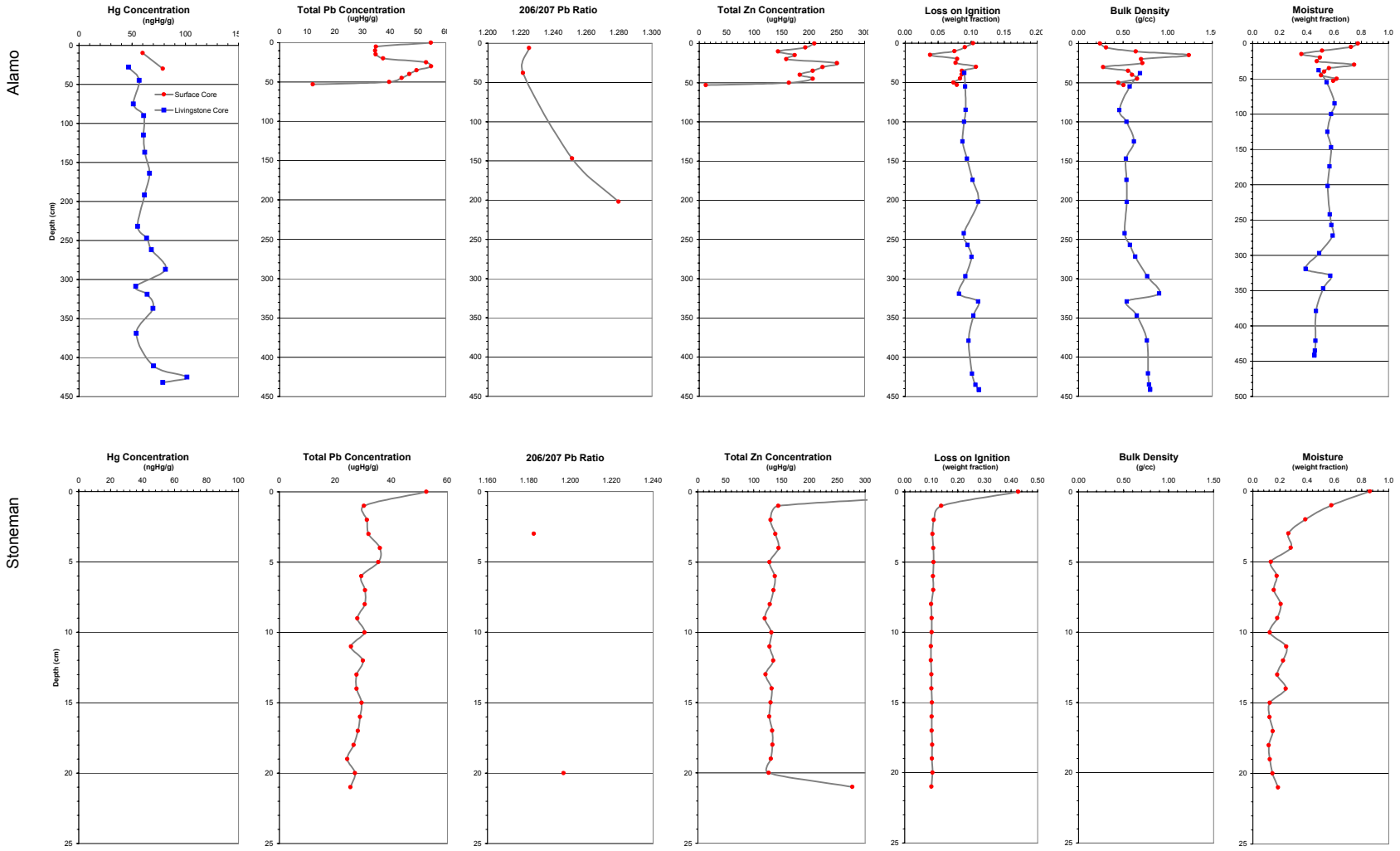


Figure 2f. Data summary for Alamo and Stoneman Lakes.

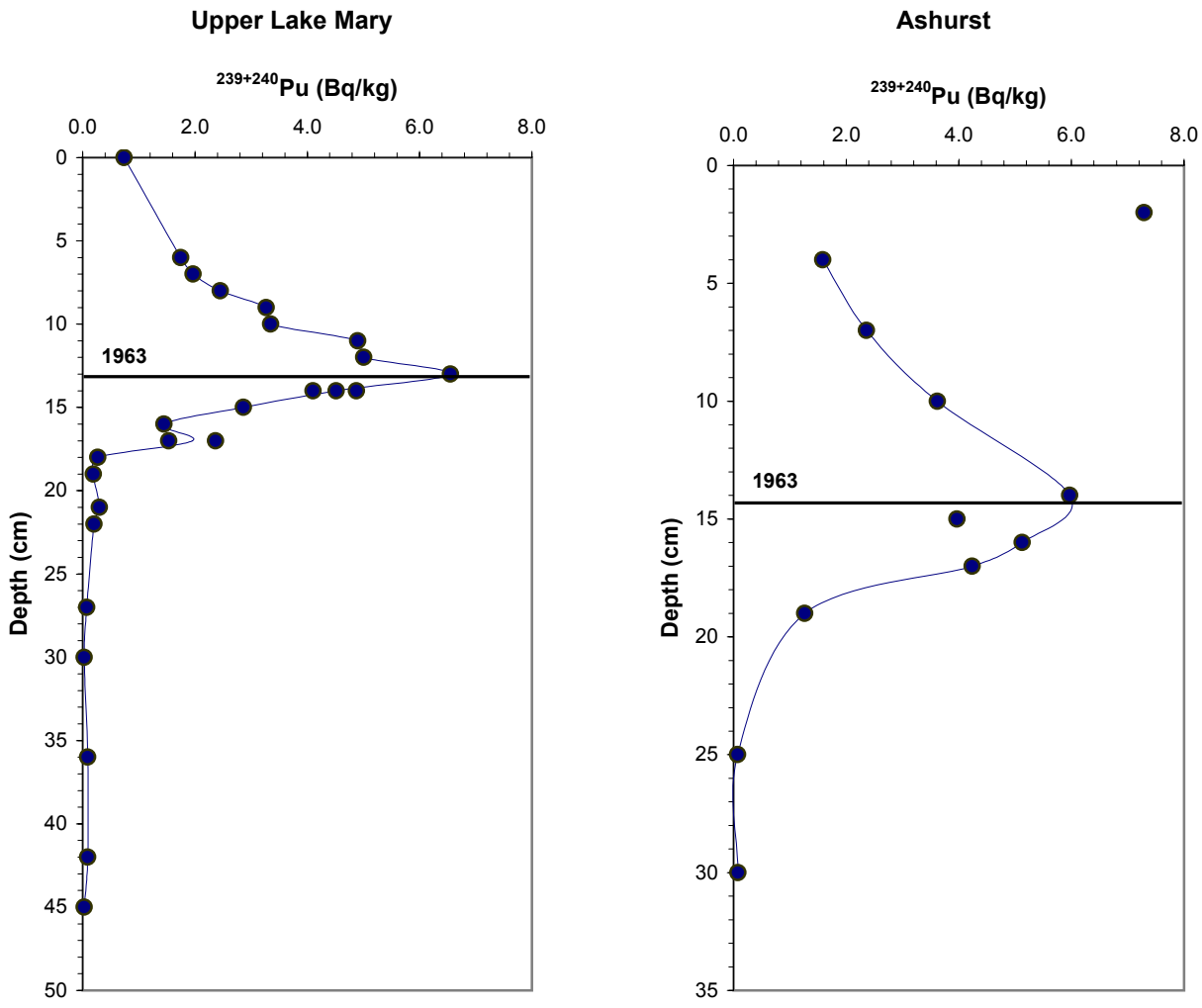


Figure 3a. Plutonium activity for Upper Lake Mary and Ashurst Lake.

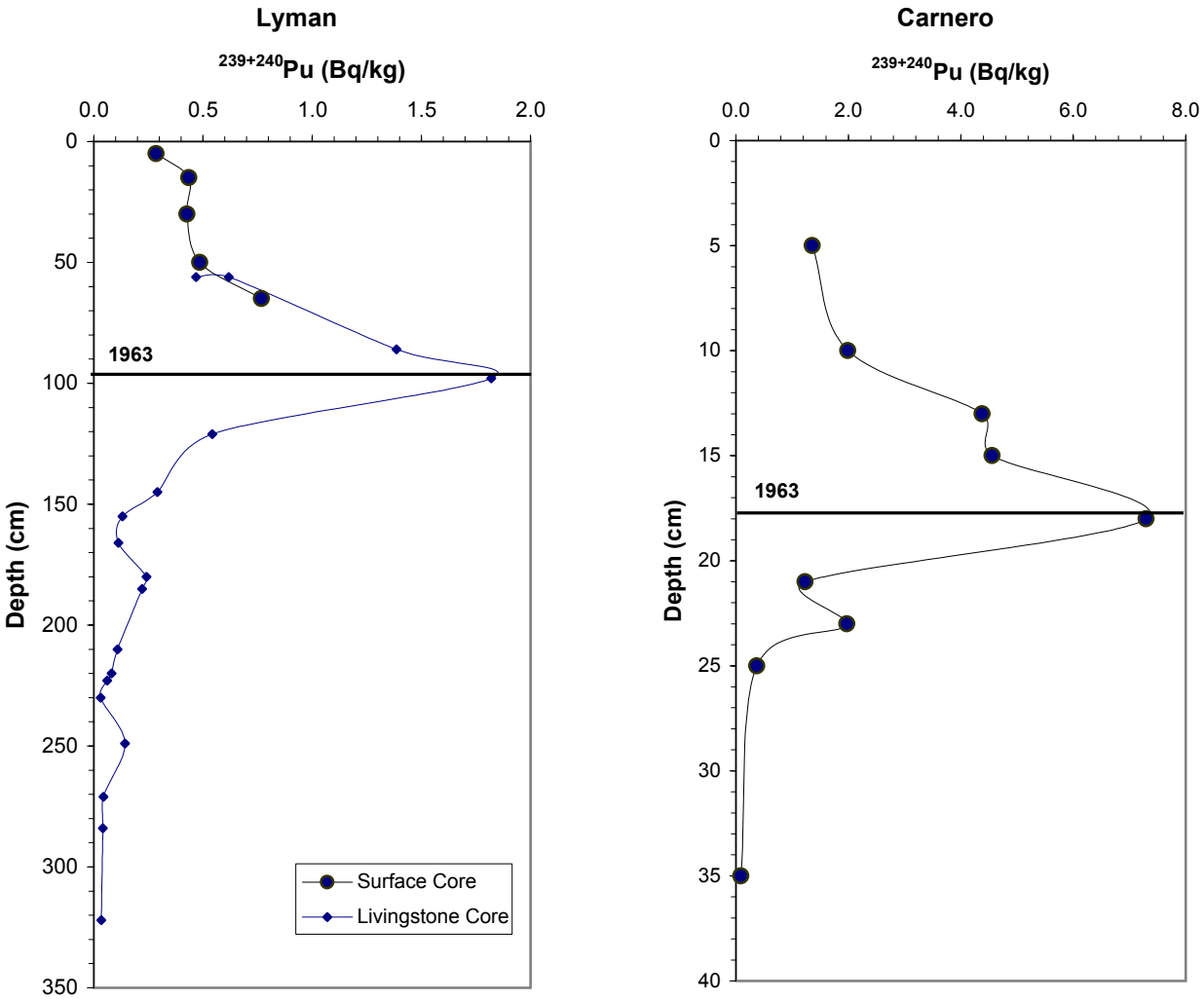


Figure 3b. Plutonium activity for Lyman and Carnero Lakes.

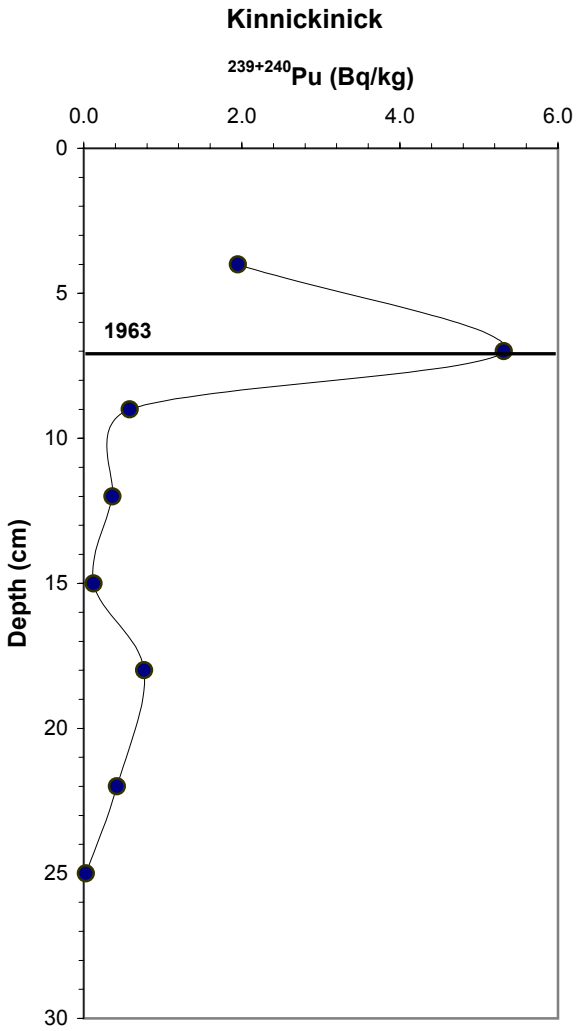


Figure 3c. Plutonium activity for Kinnickinick Lake.

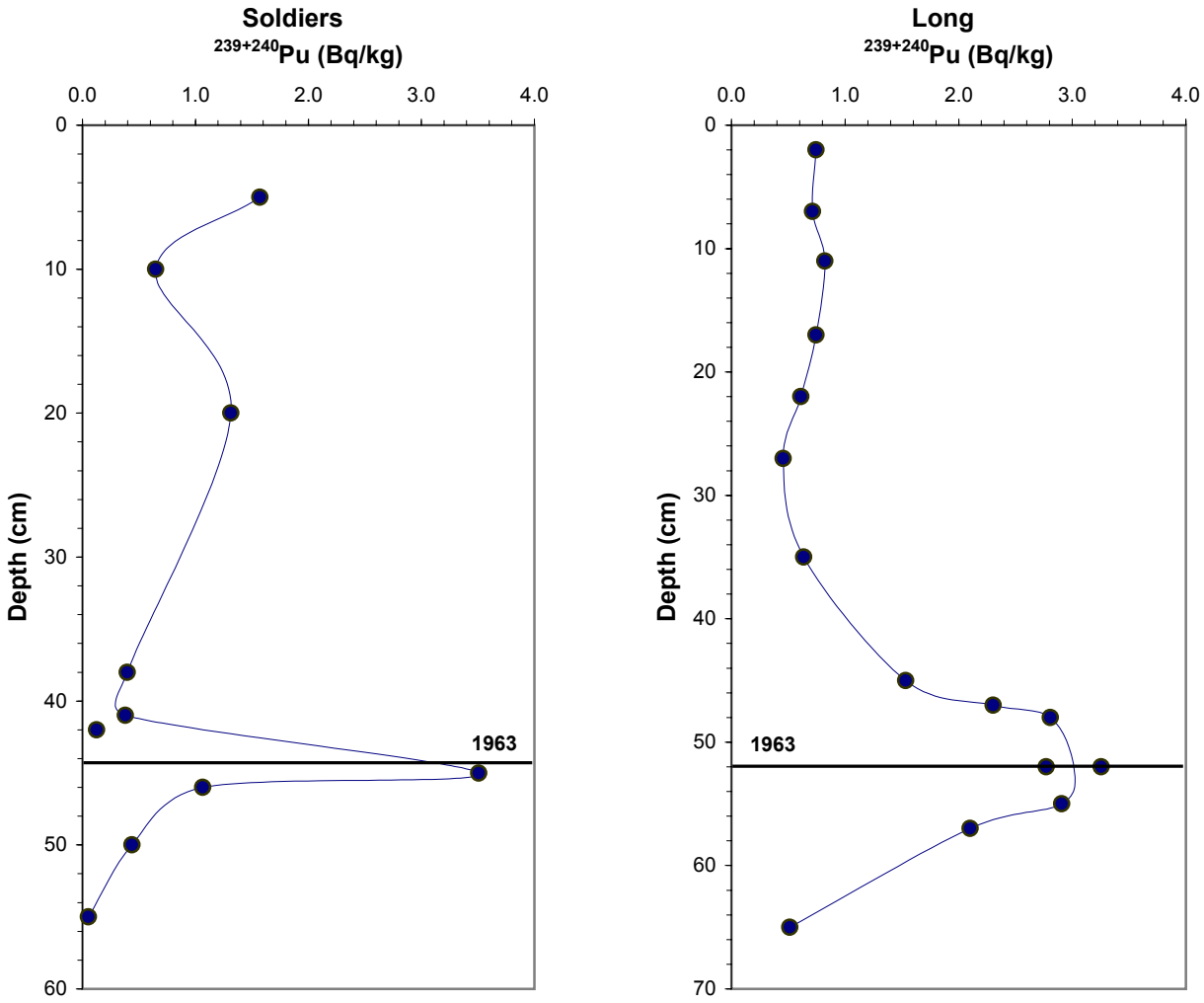


Figure 3d. Plutonium activity for Soldiers and Long Lakes.

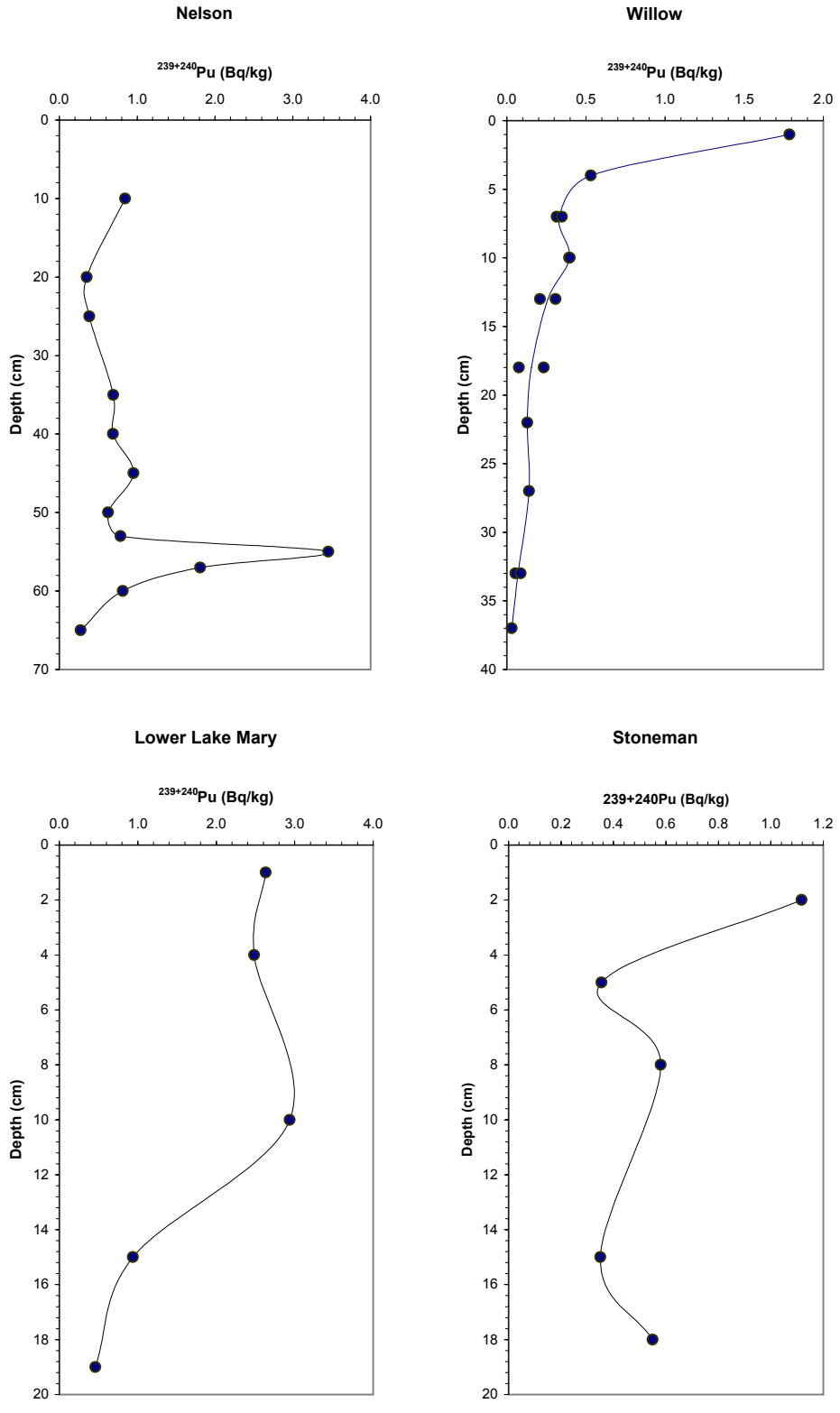


Figure 3e. Plutonium activity for Nelson, Willow Springs, Lower Lake Mary, and Stoneman.

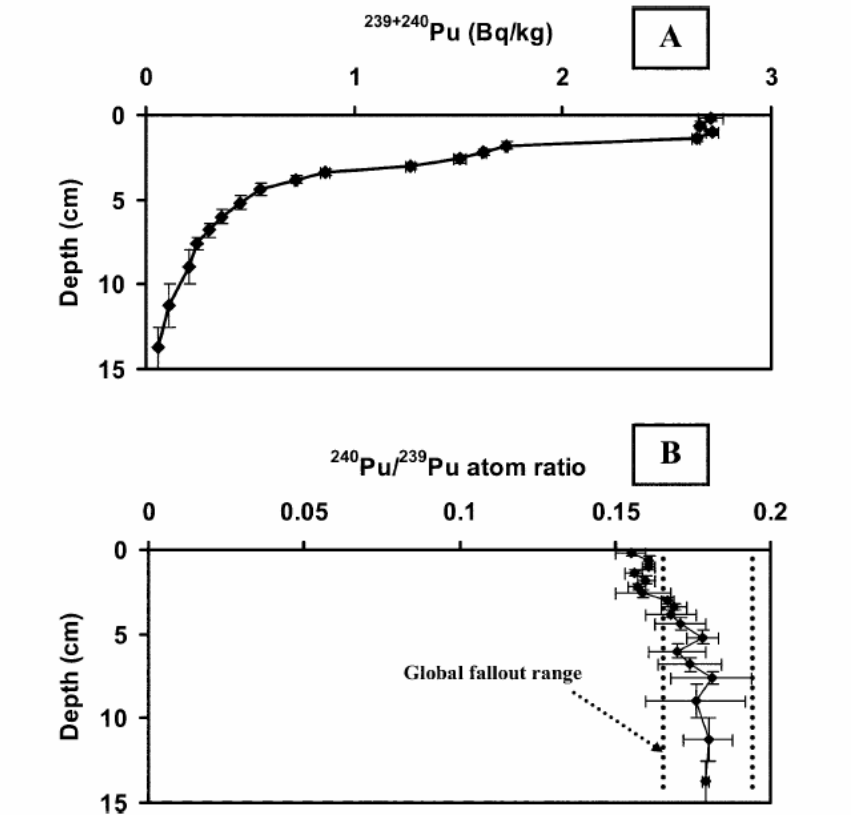


Figure 4. Lockett Meadow, Arizona soil depth profiles. From Ketterer et al., 2003.

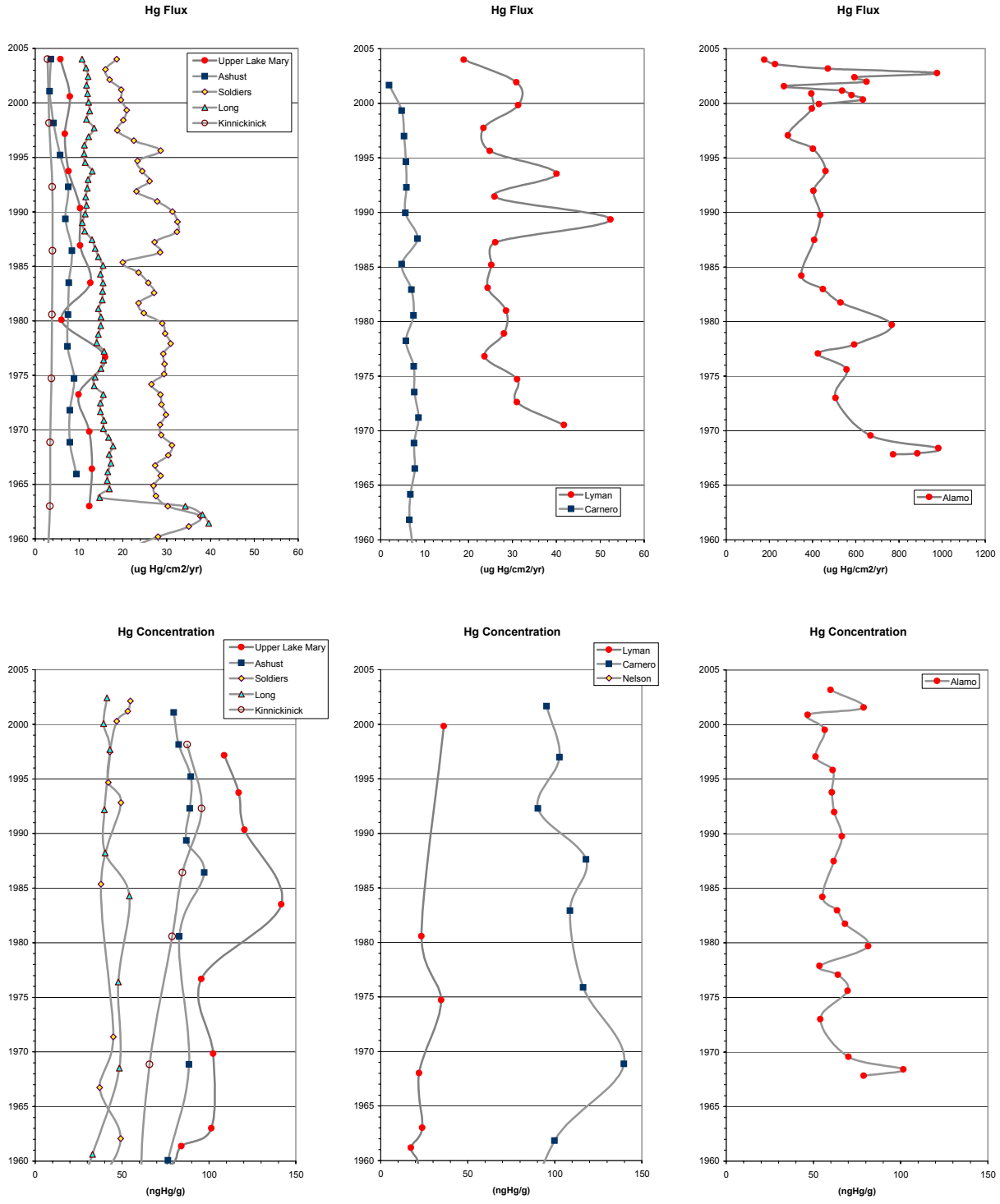


Figure 5a. Mercury flux (top) and concentration (bottom) in post-1963 sediments.

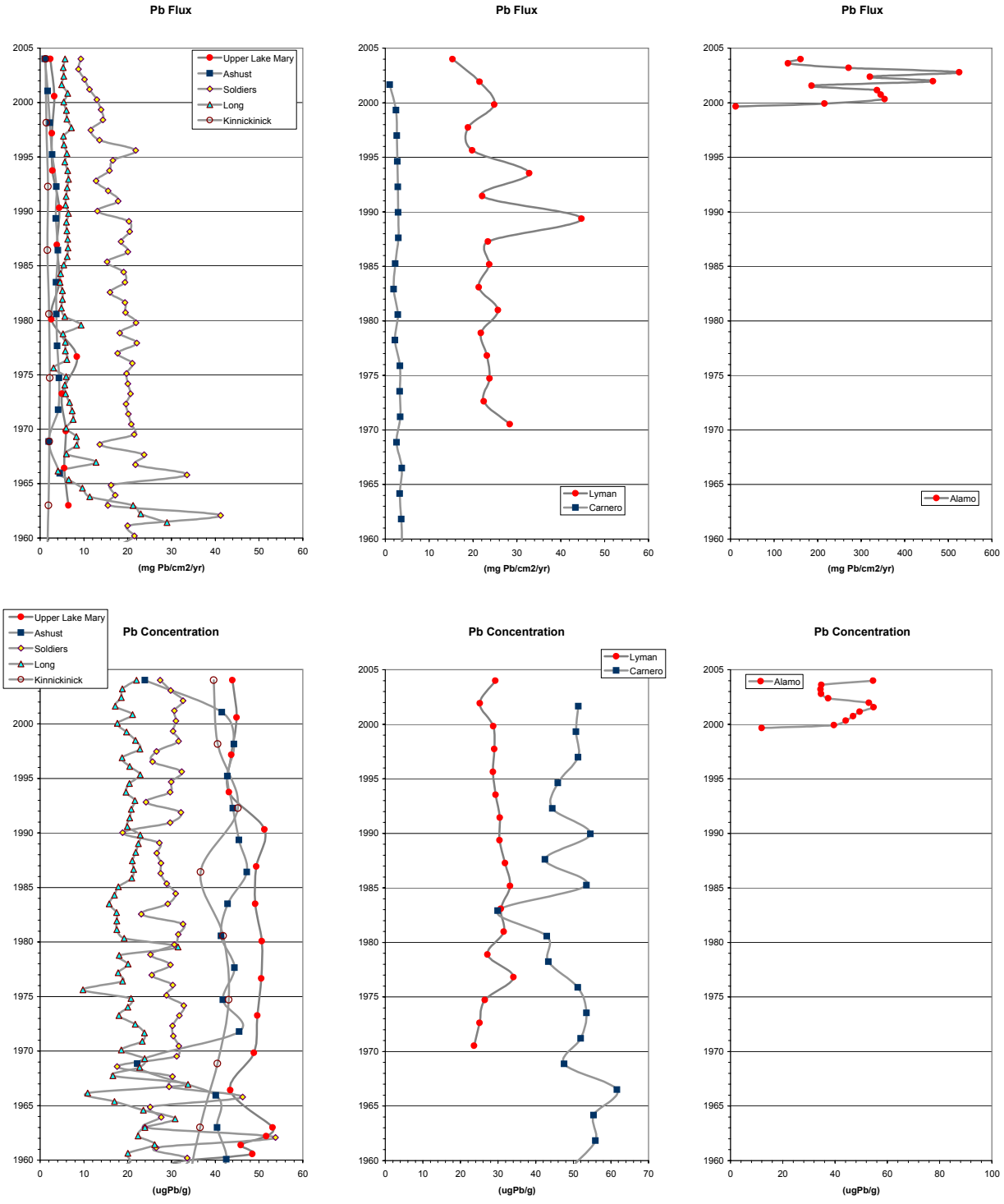


Figure 5b. Lead flux (top) and concentration (bottom) in post-1963 sediments.

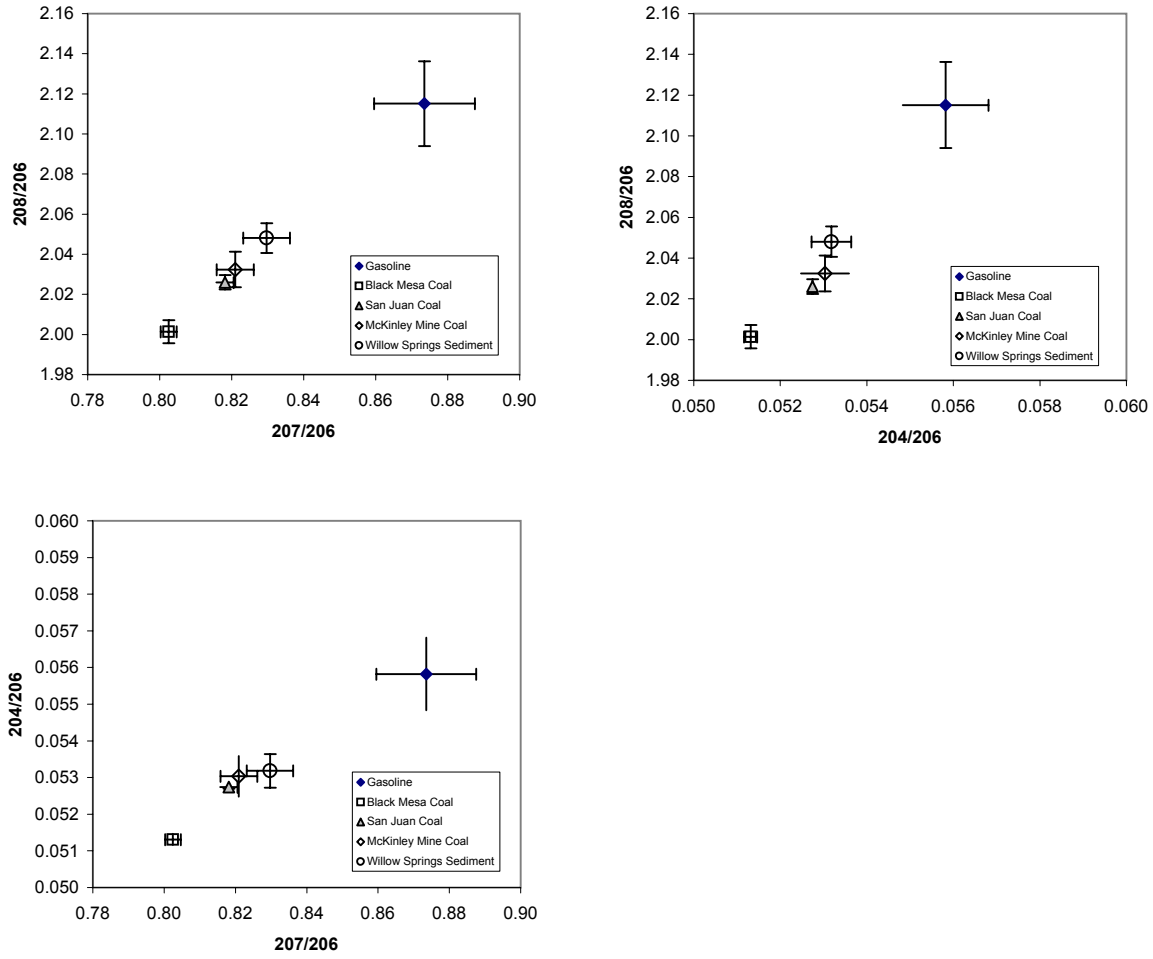


Figure 6a. Pb stable isotope ratios for coal and gasoline potential end members and for Willow Springs Sediments.

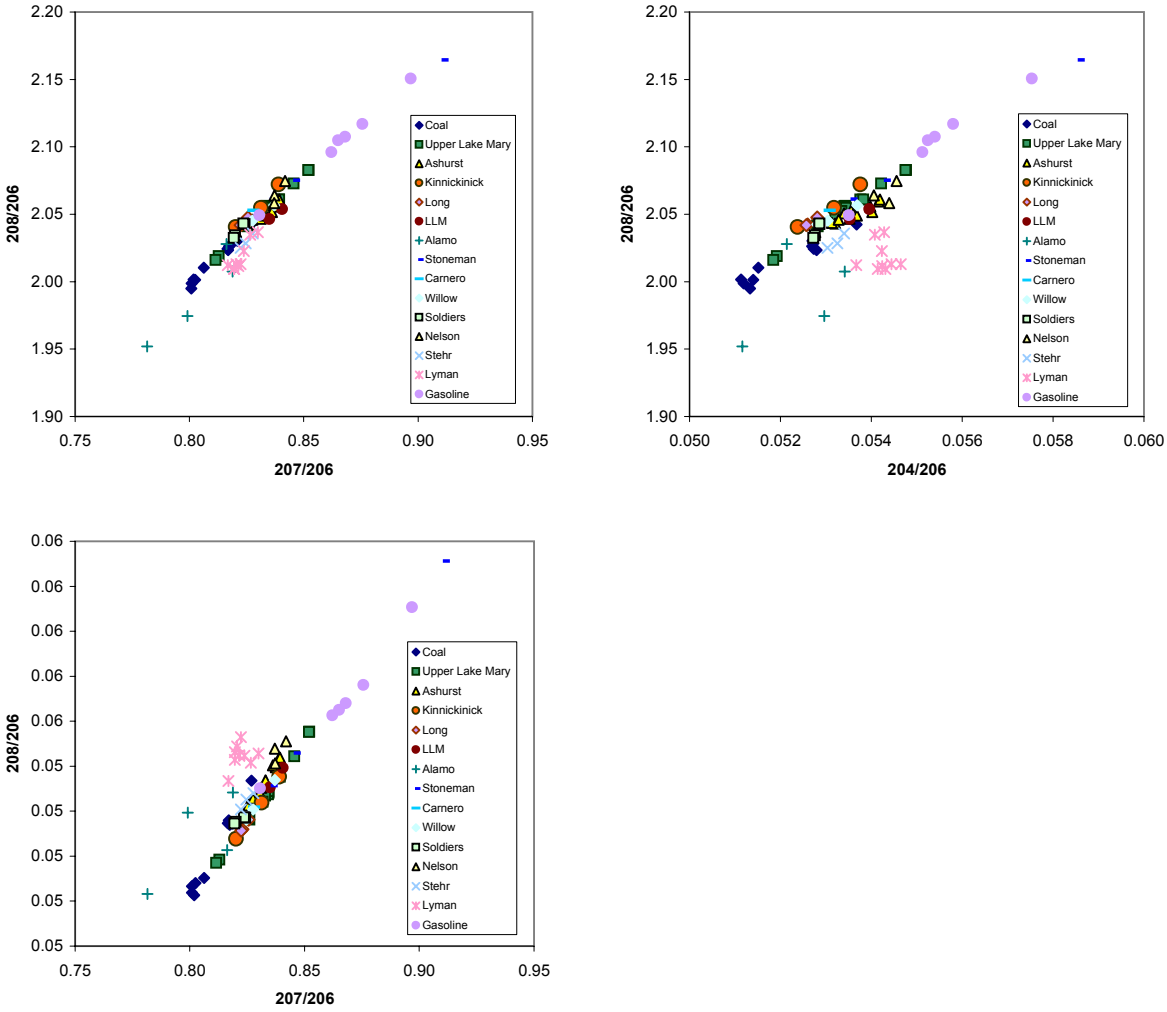


Figure 6b. Pb stable isotope ratios lake sediments and potential end members.

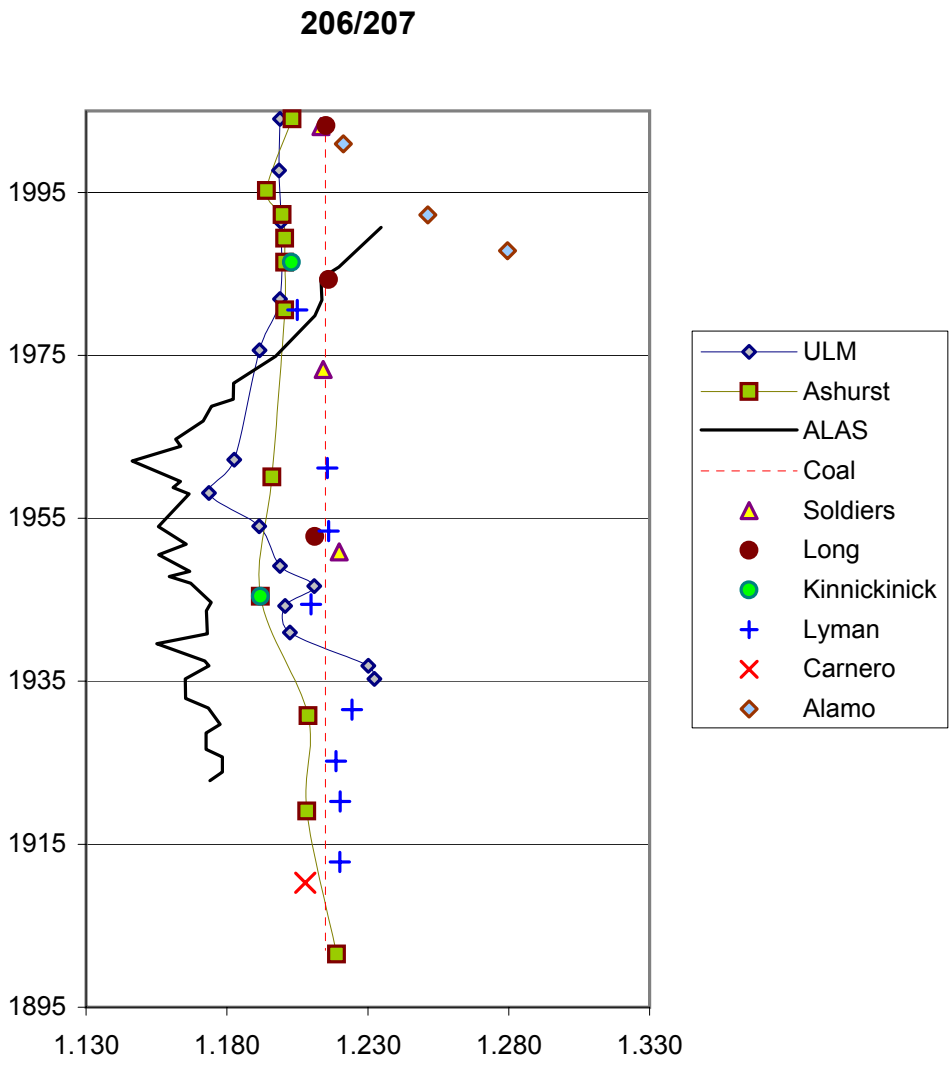


Figure 7. Pb isotope ratio 206/207 versus year for the potential end members and lake sediments.

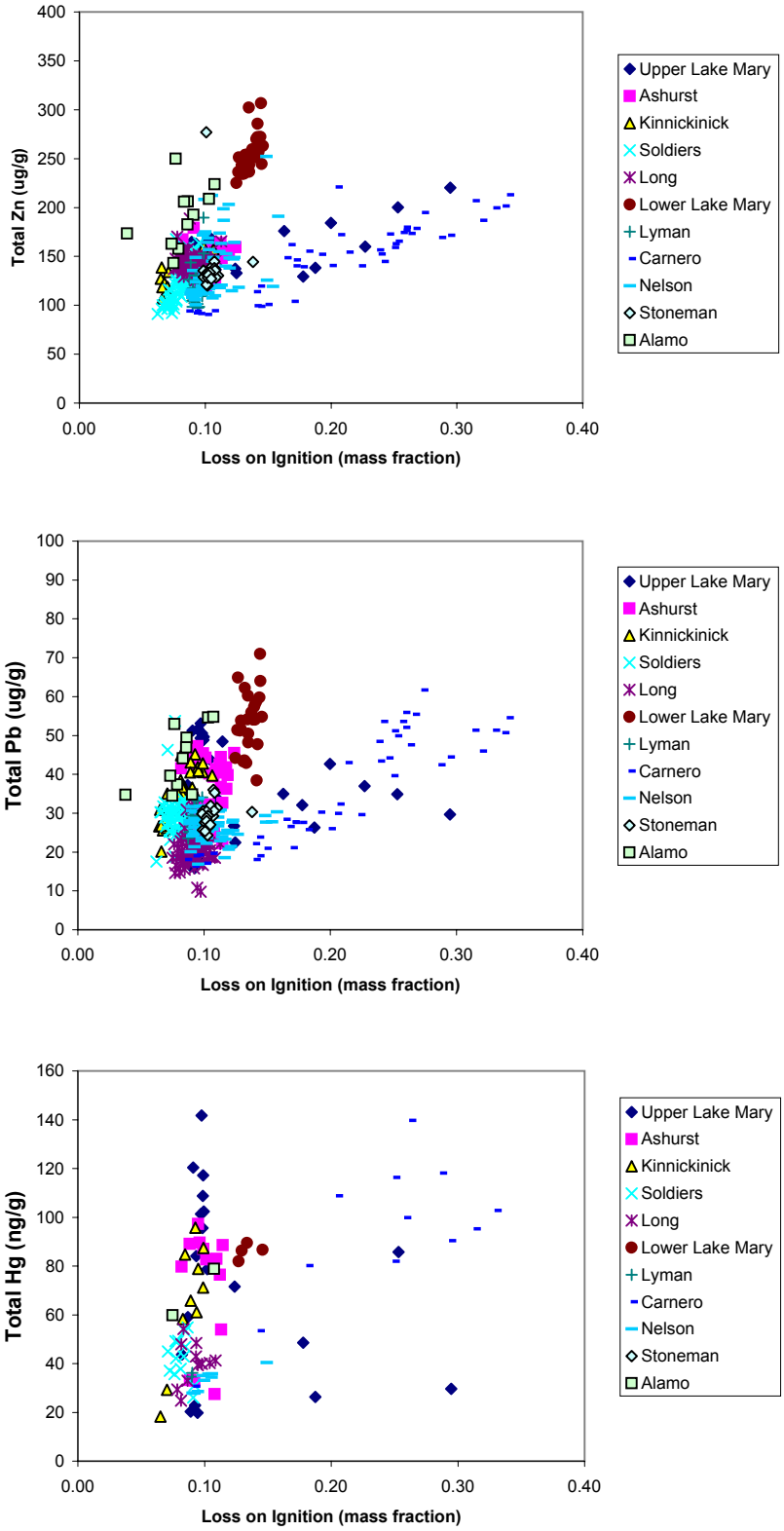


Figure 8. Metals concentrations in lake sediment versus loss-on-ignition.

**Table 1. Reservoir Summary**

| Reservoir | Area (acres) | Average depth (ft) | Elevation (ft) | Year Impounded |
|---|---|---|---|---|
| Upper Lake Mary | 600 | 38 | 6,895 | 1941 |
| Kinnickinick Lake | 229 | 12 | 7,100 | 1954 |
| Soldier Lake | 126 | 22 | 7,040 | n/a |
| Long Lake | 268 | <1 (presently) | 6,700 | n/a |
| Lower Lake Mary | n/a | 3 | 6,800 | 1904 |
| Lyman Lake | 1,400 | 22 | 5,980 | 1915 |
| Carnero Lake | n/a | 14 | 9,000 | 1979 |
| Nelson Reservoir | 60 | 15 | 7,410 | 1892 |
| Stoneman Lake | n/a | 0 (presently) | n/a | Natural |
| Willow Springs Lake | 150 | 60 | 7,520 | 1967 |
| Alamo Lake | n/a | n/a | n/a | 1968 |

**Sources:** Arizona Game and Fish Department Region I Office, Pinetop, AZ and Region II Office, Flagstaff, AZ.

**Table 2. Age Models and Estimated Average Sedimentation Rates**

| Sedimentation Rates | | | | | |
|---|---|---|---|---|---|
| Lake | Age Marker | Accumulation (cm) | Time (yr) | Rate (cm/yr) | Depth Range (cm) |
| Upper Lake Mary | 1963 = 12cm | 12 | 41 | 0.29 | 0 to 12 cm |
| | 1941 = 39cm | 27 | 22 | 1.23 | 12 to 46 cm |
| Ashurst | 1963 = 14cm | 14 | 41 | 0.34 | 0 to 36 cm |
| Kinnickinick | 1963 = 7cm | 7 | 41 | 0.17 | 0 to 26 cm |
| Soldiers | 1963 = 44cm | 44 | 41 | 1.07 | 0 to 59 cm |
| Long | 1963 = 52cm | 52 | 41 | 1.27 | 0 to 69 cm |
| Lyman | 1963 = 98cm | 98 | 41 | 2.39 | 0 to 98 cm |
| | 1910 = 475cm | 377 | 53 | 7.11 | 98 to 475 cm |
| Lower Lake Mary | No Model | | | | 0 to 25 cm |
| Carnero | 1963 = 17.5cm | 17.5 | 41 | 0.43 | 0 to 44 cm |
| Nelson | No Model | | | | 0 to 69 cm |
| Willow Springs | No Model | | | | 0 to 38 cm |
| Stoneman | No Model | | | | 0 to 21 |
| Alamo | 1968 = 440cm | 440 | 36 | 12.22 | 0 to 440 cm |

**Table 3. Comparison of Flux and Parameters Used to Calculate Flux for 1960 to 1965 and 1999 to 2004.**

| Lake | Bulk Density ($g/cm^3$) | | Sedimentation Rate ($g/cm^2/yr$) | | Hg Concentration (ng/g) | | Hg Flux ($ng/cm^2/yr$) | | Pb Concentration (ug/g) | | Pb Flux ($ug/cm^2/yr$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 to 1965 | 1999 to 2004 | 1960 to 1965 | 1999 to 2004 | 1960 to 1965 | 1999 to 2004 | 1960 to 1965 | 1999 to 2004 | 1960 to 1965 | 1999 to 2004 | 1960 to 1965 | 1999 to 2004 |
| Upper Lake Mary | 0.504 | 0.214 | 0.522 | 0.063 | 92.74 | 108.81 | 44.84 | 6.83 | 49.78 | 44.15 | 25.44 | 2.77 |
| Ashurst | 0.307 | 0.127 | 0.105 | 0.043 | 76.48 | 79.79 | 8.47 | 3.46 | 41.05 | 32.76 | 4.30 | 1.41 |
| Kinnickinick | 0.309 | 0.188 | 0.053 | 0.032 | 63.46 | 87.42 | 3.35 | 2.81 | 36.55 | 39.66 | 1.93 | 1.27 |
| Soldiers | 0.639 | 0.339 | 0.686 | 0.364 | 49.18 | 51.64 | 30.61 | 18.61 | 33.84 | 30.33 | 23.60 | 11.05 |
| Long | 0.592 | 0.229 | 0.751 | 0.290 | 32.98 | 40.38 | 27.91 | 11.79 | 23.42 | 19.28 | 17.46 | 5.58 |
| Lyman | 0.453 | 0.313 | 2.720 | 0.747 | 20.90 | 36.18 | 54.22 | 27.04 | . | 27.71 | . | 20.54 |
| Carnero | 0.157 | 0.081 | 0.067 | 0.034 | 99.78 | 95.27 | 6.83 | 3.37 | 53.72 | 51.03 | 3.58 | 1.75 |
| Alamo | n/a | 0.575 | n/a | 7.102 | n/a | 69.37 | n/a | 504.20 | n/a | 43.97 | n/a | 301.04 |

**Table 4. Average concentrations of Hg, Pb, and Zn in lake sediments.**

| | Hg (ng/g) | | | Pb (ug/g) | | | Zn (ug/g) | |
|---|---|---|---|---|---|---|---|---|
| Lake | n | Mean | Std. Dev. | n | Mean | Std. Dev. | n | Mean | Std. Dev. |
| Upper Lake Mary | 20 | 70.99 | 37.98 | 47 | 40.56 | 26.67 | 47 | 196.0 | 236.7 |
| Ashurst | 13 | 70.86 | 24.77 | 37 | 34.31 | 8.14 | 37 | 142.7 | 15.9 |
| Kinnickinick | 10 | 65.07 | 24.91 | 27 | 35.48 | 6.52 | 27 | 140.6 | 14.0 |
| Soldiers | 13 | 42.38 | 8.59 | 60 | 29.25 | 5.13 | 60 | 118.7 | 19.1 |
| Long | 11 | 40.15 | 8.59 | 69 | 20.22 | 3.91 | 70 | 145.0 | 9.4 |
| Lower Lake Mary | 4 | 86.07 | 3.14 | 26 | 53.70 | 7.72 | 26 | 255.8 | 19.9 |
| Lyman | 16 | 23.09 | 5.61 | 17 | 29.10 | 2.89 | 17 | 120.5 | 24.3 |
| Carnero | 12 | 93.10 | 29.36 | 44 | 36.04 | 14.00 | 44 | 150.1 | 37.0 |
| Nelson | 9 | 33.17 | 4.30 | 70 | 26.62 | 3.26 | 70 | 137.2 | 31.3 |
| Willow Springs | 9 | 38.98 | 34.64 | 39 | 27.54 | 17.92 | 39 | 70.2 | 20.8 |
| Stoneman | n/a | n/a | n/a | 22 | 30.27 | 5.75 | 22 | 159.9 | 102.8 |
| Alamo | 21 | 64.99 | 12.42 | 11 | 43.97 | 8.19 | 11 | 191.6 | 31.4 |
| | | | | | | | | | |
| Surface | 24 | 79.97 | 26.29 | 61 | 39.32 | 16.28 | 61 | 166.4 | 76.0 |
| Core Base | 12 | 35.72 | 22.46 | 10 | 22.93 | 8.09 | 10 | 159.8 | 63.8 |

**Notes:** n/a = No samples analyzed.
Samples were not analyzed for Pb or Zn at the base of Lyman or Alamo cores.
Surface samples are the average of the top 4 cm of sample, base samples are the single observation at the lowest point in each core

## Table 5. Pb Stable Isotope Analysis of Potential End Members.

| **Chow and Johnstone 1965 Gasoline** | | | | |
|---|---|---|---|---|
| **Sample** | **204/206** | **207/206** | **208/206** | |
| Wilshire D | 0.055127 | 0.862069 | 2.09599665 | |
| Wilshire Regular | 0.055249 | 0.865052 | 2.10482004 | |
| Douglas | 0.055402 | 0.868056 | 2.10748156 | |
| Standard Oil Regular | 0.055804 | 0.875657 | 2.11685013 | |
| Shell Oil Regular | 0.057537 | 0.896861 | 2.15053763 | |
| 1947 Tetraetlhyl Lead | 0.053505 | 0.830565 | 2.04918033 | |
| **NAU Analyses** | | | | |
| **Sample** | **204/206** | **207/206** | **208/206** | |
| Black Mesa 1 | 0.051191 | 0.800935 | 1.99868773 | |
| Black Mesa 2 | 0.051134 | 0.801832 | 2.00152727 | |
| Black Mesa 3 | 0.051329 | 0.800842 | 1.99498943 | |
| Black Mesa 4 | 0.051512 | 0.806266 | 2.01045717 | |
| Black Mesa 5 | 0.051401 | 0.802489 | 2.0014383 | |
| San Juan 1 | 0.052704 | 0.820926 | 2.03018897 | |
| San Juan 2 | 0.052795 | 0.816939 | 2.0234464 | |
| San Juan 3 | 0.052732 | 0.816588 | 2.02442787 | |
| McKinley Mine 1 | 0.053676 | 0.826863 | 2.04249197 | |
| McKinley Mine 2 | 0.052726 | 0.818679 | 2.02841067 | |
| McKinley Mine 3 | 0.052697 | 0.817354 | 2.02635513 | |
| **Pre-Impoundment Soil (Willow Springs Sediment)** | | | | |
| **Sample** | **204/206** | **207/206** | **208/206** | |
| 0-1 cm | 0.053692 | 0.837039 | 2.05653997 | |
| 20-21 cm | 0.05304 | 0.827487 | 2.04529663 | |
| 35-36 cm | 0.05281 | 0.824548 | 2.0424113 | |
| | | | | |
| **Statistics: 204/206** | **N** | **Mean** | **Stdev** | **RSD** |
| Gasoline* | 5 | 0.055824 | 0.00099142 | 1.78 |
| Black Mesa Coal | 5 | 0.051313 | 0.00015392 | 0.30 |
| San Juan Coal | 3 | 0.052744 | 4.7013E-05 | 0.09 |
| McKinley Mine Coal | 3 | 0.053033 | 0.00055704 | 1.05 |
| Willow Springs | 3 | 0.053181 | 0.00045748 | 0.86 |
| **Statistics: 207/206** | **N** | **Mean** | **Stdev** | **RSD** |
| Gasoline* | 5 | 0.873539 | 0.01398267 | 1.60 |
| Black Mesa Coal | 5 | 0.802473 | 0.00222606 | 0.28 |
| San Juan Coal | 3 | 0.818151 | 0.00240982 | 0.29 |
| McKinley Mine Coal | 3 | 0.820965 | 0.00515008 | 0.63 |
| Willow Springs | 3 | 0.829691 | 0.00653061 | 0.79 |
| **Statistics: 208/206** | **N** | **Mean** | **Stdev** | **RSD** |
| Gasoline* | 5 | 2.115137 | 0.02113964 | 1.00 |
| Black Mesa Coal | 5 | 2.00142 | 0.00571182 | 0.29 |
| San Juan Coal | 3 | 2.026021 | 0.0036427 | 0.18 |
| McKinley Mine Coal | 3 | 2.032419 | 0.00878356 | 0.43 |
| Willow Springs | 3 | 2.048083 | 0.007465 | 0.36 |

**Notes:** Gasoline statistics do not include 1947 sample.

**Table 6. Comparison of Surface Sediment Hg Collected and Analyzed by ADEQ versus NAU.**

| | Upper Lake Mary | Lower Lake Mary | Willow Springs | Soldier |
|---|---|---|---|---|
| **ADEQ Surface Sediment Hg (ng/g)** | | | | |
| | 28.20 | 61.80 | 73.80 | 35.59 |
| | 29.63 | 65.00 | | |
| | 34.70 | 72.50 | | |
| | 37.97 | 80.29 | | |
| | 40.90 | | | |
| | 43.24 | | | |
| | 44.30 | | | |
| | 46.15 | | | |
| | 50.30 | | | |
| | 76.60 | | | |
| | 80.92 | | | |
| | 80.92 | | | |
| n | 12 | 4 | 1 | 1 |
| Mean | 49.49 | 69.90 | 73.80 | 35.59 |
| Std. Dev. | 19.22 | 8.25 | | |
| RSD | 39% | 12% | | |
| **NAU Surface Sediment Hg (ng/g)** | | | | |
| | 108.81 | 81.91 | 127.11 | 54.78 |
| | 117.14 | | 55.06 | 53.25 |
| | 120.44 | | 24.62 | 46.89 |
| n | 3 | 1 | 3 | 3 |
| Mean | 115.46 | 81.91 | 68.93 | 51.64 |
| Std. Dev. | 3.34 | | 3.34 | 3.34 |
| RSD | 3% | | 5% | 6% |

# Appendix A.

## Quality Assurance Project Plan

***Submitted as a separate PDF File***

## Anderson Mesa

### Upper Lake Mary

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.837 | 0.182 | 0.104 | 168.3 | 43.90 | | 0.05343 | 0.83418 | 2.0562 | 0.7405 |
| 1 | 0.784 | 0.249 | 0.093 | 163.0 | 44.87 | | | | | |
| 2 | 0.810 | 0.213 | 0.099 | 155.2 | 43.69 | 108.81 | 0.05341 | 0.83440 | 2.0559 | |
| 3 | 0.806 | 0.222 | 0.099 | 137.2 | 43.16 | 117.14 | | | | |
| 4 | 0.755 | 0.292 | 0.091 | 142.2 | 51.25 | 120.44 | 0.05338 | 0.83388 | 2.0530 | |
| 5 | 0.760 | 0.267 | 0.097 | 140.2 | 49.36 | | | | | |
| 6 | 0.735 | 0.304 | 0.098 | 139.1 | 49.14 | 141.68 | | | | 1.7451 |
| 7 | 0.715 | 0.174 | 0.098 | 136.3 | 50.63 | | 0.05337 | 0.83414 | 2.0515 | 1.9663 |
| 8 | 0.564 | 0.570 | 0.098 | 151.2 | 50.51 | 95.60 | | | | 2.4551 |
| 9 | 0.711 | 0.342 | 0.100 | 149.3 | 49.63 | | 0.05376 | 0.83921 | 2.0609 | 3.2713 |
| 10 | 0.643 | 0.413 | 0.099 | 149.8 | 48.84 | 102.42 | | | | 3.3488 |
| 11 | 0.646 | 0.435 | 0.099 | 151.5 | 43.45 | | | | | 4.8994 |
| 12 | 0.660 | 0.417 | 0.097 | 153.5 | 53.12 | 101.37 | | | | 5.0052 |
| 13 | 0.664 | 0.399 | 0.095 | 150.5 | 51.68 | | 0.05422 | 0.84558 | 2.0728 | 6.5515 |
| 14 | 0.620 | 0.470 | 0.094 | 141.5 | 45.85 | 84.11 | | | | 4.4990 |
| 15 | 0.493 | 0.732 | 0.115 | 148.7 | 48.47 | | | | | 2.8613 |
| 16 | 0.446 | 0.823 | 0.102 | 168.2 | 30.42 | 78.69 | | | | 1.4506 |
| 17 | 0.430 | 0.864 | 0.098 | 161.0 | 48.57 | | | | | 1.9499 |
| 18 | 0.395 | 0.945 | 0.087 | 143.3 | 37.20 | 59.05 | 0.05476 | 0.85206 | 2.0828 | 0.2720 |
| 19 | 0.379 | 0.979 | 0.080 | 138.1 | 35.87 | | | | | 0.1930 |
| 20 | 0.386 | 0.948 | 0.089 | 142.7 | 36.43 | | | | | |
| 21 | 0.351 | 0.999 | 0.084 | 149.1 | 28.75 | | | | | 0.2976 |
| 22 | 0.336 | 1.084 | 0.081 | 133.1 | 25.91 | | | | | 0.2031 |
| 23 | 0.324 | 1.059 | 0.079 | 125.5 | 29.97 | | 0.05382 | 0.83932 | 2.0609 | |
| 24 | 0.302 | 1.145 | 0.082 | 133.4 | 23.90 | 43.65 | | | | |
| 25 | 0.319 | 1.134 | 0.086 | 131.2 | 30.62 | | | | | |
| 26 | 0.348 | 1.048 | 0.097 | 146.7 | 28.52 | | | | | |
| 27 | 0.349 | 1.053 | 0.111 | 162.7 | 33.52 | | | | | 0.0757 |
| 28 | 0.481 | 0.682 | 0.163 | 175.8 | 34.98 | | | | | |
| 29 | 0.537 | 0.611 | 0.200 | 184.4 | 42.68 | | 0.05344 | 0.83419 | 2.0547 | |
| 30 | 0.345 | 1.002 | 0.103 | 121.9 | 29.15 | | | | | 0.0302 |
| 31 | 0.386 | 0.966 | 0.108 | 136.3 | 25.24 | | | | | |
| 32 | 0.407 | 0.905 | 0.124 | 137.3 | 26.69 | 71.53 | 0.05282 | 0.82581 | 2.0413 | |
| 33 | 0.406 | 0.881 | 0.125 | 132.8 | 22.45 | | | | | |
| 34 | 0.631 | 0.448 | 0.253 | 200.2 | 34.91 | 85.77 | | | | |
| 35 | 0.624 | 0.416 | 0.227 | 160.1 | 36.93 | | 0.05335 | 0.83285 | 2.0524 | |
| 36 | 0.549 | 0.589 | 0.178 | 129.5 | 32.12 | 48.58 | | | | 0.0898 |
| 37 | 0.652 | 0.410 | 0.295 | 220.3 | 29.69 | 29.67 | | | | |
| 38 | 0.799 | 0.222 | 0.695 | 1585.2 | 123.58 | 42.01 | | | | |
| 39 | 0.803 | 0.188 | 0.707 | 925.5 | 178.46 | | 0.05321 | 0.83170 | 2.0488 | |
| 40 | 0.455 | 0.753 | 0.187 | 138.5 | 26.33 | 26.33 | | | | |
| 41 | 0.308 | 1.136 | 0.096 | 143.5 | 18.16 | | | | | |
| 42 | 0.283 | 1.143 | 0.093 | 137.5 | 15.88 | 22.83 | | | | 0.0904 |
| 43 | 0.303 | 1.118 | 0.094 | 144.2 | 18.53 | | | | | |
| 44 | 0.276 | 1.054 | 0.094 | 139.5 | 19.87 | 19.75 | 0.05192 | 0.81291 | 2.0189 | |
| 45 | 0.285 | 1.065 | 0.089 | 123.1 | 17.20 | | | | | 0.0271 |
| 46 | 0.265 | 1.078 | 0.089 | 164.9 | 16.41 | 20.37 | 0.05185 | 0.81151 | 2.0162 | |

### Ashurst Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.874 | 0.132 | 0.091 | 179.1 | 23.96 | | 0.05352 | 0.83116 | 2.0467 | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.880 | 0.122 | 0.082 | 167.4 | 41.55 | 79.79 | | | | |
| 2 | 0.856 | 0.148 | 0.101 | 158.0 | 44.28 | 82.71 | | | | 7.2938 |
| 3 | 0.813 | 0.187 | 0.096 | 142.0 | 42.77 | 89.57 | 0.05398 | 0.83750 | 2.0556 | |
| 4 | 0.775 | 0.249 | 0.088 | 143.7 | 44.05 | 89.02 | 0.05355 | 0.83361 | 2.0529 | 1.5832 |
| 5 | 0.784 | 0.232 | 0.099 | 146.0 | 45.43 | 87.06 | 0.05365 | 0.83300 | 2.0502 | |
| 6 | 0.769 | 0.253 | 0.095 | 146.4 | 47.23 | 97.31 | 0.05361 | 0.83298 | 2.0502 | |
| 7 | 0.769 | 0.250 | 0.092 | 143.6 | 42.84 | | | | | 2.3585 |
| 8 | 0.759 | 0.265 | 0.109 | 151.2 | 41.32 | 82.95 | 0.05368 | 0.83297 | 2.0490 | |
| 9 | 0.761 | 0.256 | 0.113 | 148.4 | 44.39 | | | | | |
| 10 | 0.734 | 0.303 | 0.118 | 158.1 | 41.78 | | | | | 3.6177 |
| 11 | 0.761 | 0.266 | 0.124 | 159.3 | 45.50 | | | | | |
| 12 | 0.763 | 0.262 | 0.115 | 155.9 | 22.19 | 88.51 | | | | |
| 13 | 0.713 | 0.326 | 0.104 | 153.2 | 40.17 | | | | | |
| 14 | 0.727 | 0.311 | 0.116 | 153.9 | 40.45 | | | | | 5.9709 |
| 15 | 0.744 | 0.285 | 0.112 | 163.4 | 42.53 | 76.48 | 0.05402 | 0.83614 | 2.0517 | 4.1723 |
| 16 | 0.678 | 0.382 | 0.107 | 154.9 | 39.36 | | | | | 5.1271 |
| 17 | 0.703 | 0.345 | 0.119 | 155.8 | 39.76 | | | | | 4.2394 |
| 18 | 0.633 | 0.450 | 0.118 | 155.2 | 36.25 | | | | | |
| 19 | 0.529 | 0.628 | 0.115 | 151.4 | 32.65 | | | | | 1.2638 |
| 20 | 0.513 | 0.671 | 0.113 | 155.7 | 36.74 | 53.95 | 0.05418 | 0.83898 | 2.0603 | |
| 21 | 0.481 | 0.731 | 0.104 | 147.0 | 32.25 | | | | | |
| 22 | 0.460 | 0.777 | 0.097 | 139.4 | 31.99 | | | | | |
| 23 | 0.434 | 0.857 | 0.091 | 134.9 | 29.32 | | | | | |
| 24 | 0.402 | 0.925 | 0.089 | 122.0 | 25.58 | | 0.05325 | 0.82728 | 2.0457 | |
| 25 | 0.388 | 0.930 | 0.088 | 129.3 | 26.39 | 33.29 | | | | 0.0753 |
| 26 | 0.380 | 0.935 | 0.092 | 125.3 | 27.88 | 32.98 | | | | |
| 27 | 0.374 | 0.964 | 0.090 | 120.3 | 26.34 | | | | | |
| 28 | 0.374 | 0.951 | 0.094 | 118.4 | 26.04 | | | | | |
| 29 | 0.378 | 0.957 | 0.096 | 117.3 | 26.53 | | | | | |
| 30 | 0.378 | 0.962 | 0.095 | 129.4 | 29.17 | | 0.05328 | 0.82756 | 2.0459 | 0.0766 |
| 31 | 0.366 | 0.972 | 0.101 | 120.6 | 24.31 | | | | | |
| 32 | 0.375 | 0.973 | 0.101 | 120.6 | 26.77 | | | | | |
| 33 | 0.354 | 1.011 | 0.094 | 130.1 | 27.20 | | | | | |
| 34 | 0.384 | 0.950 | 0.105 | 125.9 | 23.90 | | | | | |
| 35 | 0.375 | 0.977 | 0.108 | 125.2 | 25.65 | 27.52 | 0.05277 | 0.82040 | 2.0368 | |
| 36 | 0.375 | 0.963 | 0.097 | 130.6 | 25.05 | | | | | |

## Kinnickinick Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.821 | 0.188 | 0.106 | 157.2 | 39.66 | | | | | |
| 1 | 0.801 | 0.212 | 0.099 | 150.0 | 40.57 | 87.42 | | | | |
| 2 | 0.783 | 0.237 | 0.093 | 143.4 | 45.16 | 95.75 | | | | |
| 3 | 0.754 | 0.272 | 0.085 | 136.8 | 36.67 | 84.77 | 0.05319 | 0.83134 | 2.0546 | |
| 4 | 0.748 | 0.284 | 0.095 | 130.6 | 41.83 | 78.82 | | | | 1.9516 |
| 5 | 0.739 | 0.302 | 0.089 | 142.1 | 43.09 | | | | | |
| 6 | 0.731 | 0.303 | 0.089 | 150.4 | 40.49 | 65.79 | | | | |
| 7 | 0.719 | 0.309 | 0.091 | 145.5 | 36.55 | | | | | 5.3157 |
| 8 | 0.757 | 0.267 | 0.094 | 148.0 | 34.53 | 61.13 | | | | |
| 9 | 0.767 | 0.251 | 0.096 | 149.8 | 40.89 | | | | | 0.5838 |
| 10 | 0.758 | 0.273 | 0.099 | 159.6 | 42.84 | 71.16 | 0.05376 | 0.83901 | 2.0722 | |
| 11 | 0.735 | 0.294 | 0.082 | 154.9 | 44.89 | | | | | |
| 12 | 0.730 | 0.311 | 0.084 | 151.7 | 37.08 | | | | | 0.3645 |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 0.725 | 0.319 | 0.082 | 150.3 | 38.53 | | | | | |
| 14 | 0.659 | 0.322 | 0.084 | 153.2 | 36.41 | | | | | |
| 15 | 0.844 | 0.343 | 0.083 | 154.4 | 34.92 | 58.26 | | | | 0.1246 |
| 16 | 0.676 | 0.351 | 0.083 | 147.2 | 36.72 | | | | | |
| 17 | 0.679 | 0.337 | 0.083 | 145.7 | 32.34 | | | | | |
| 18 | 0.667 | 0.377 | 0.080 | 141.2 | 34.99 | | | | | 0.7650 |
| 19 | 0.645 | 0.438 | 0.071 | 134.1 | 35.05 | | | | | |
| 20 | 0.473 | 0.759 | 0.065 | 127.0 | 26.62 | | | | | |
| 21 | 0.423 | 0.859 | 0.068 | 122.8 | 25.61 | | | | | |
| 22 | 0.394 | 0.925 | 0.070 | 117.9 | 26.13 | 29.31 | | | | 0.4218 |
| 23 | 0.368 | 0.989 | 0.070 | 118.9 | 28.56 | | | | | |
| 24 | 0.353 | 1.046 | 0.066 | 118.5 | 26.67 | | | | | |
| 25 | 0.347 | 1.046 | 0.065 | 138.6 | 30.89 | 18.31 | 0.05239 | 0.82019 | 2.0404 | 0.0293 |
| 26 | 0.347 | 1.027 | 0.066 | 107.0 | 20.16 | | | | | |

## Soldier's Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.717 | 0.316 | 0.089 | 134.7 | 27.45 | | 0.05286 | 0.82414 | 2.0426 | 1.5700 |
| 1 | 0.753 | 0.273 | 0.088 | 133.6 | 29.83 | | | | | |
| 2 | 0.739 | 0.289 | 0.087 | 159.6 | 32.65 | 54.78 | | | | |
| 3 | 0.705 | 0.343 | 0.085 | 125.7 | 30.68 | 53.25 | | | | |
| 4 | 0.668 | 0.389 | 0.085 | 123.6 | 31.04 | 46.89 | | | | |
| 5 | 0.647 | 0.427 | 0.082 | 122.7 | 30.34 | | | | | |
| 6 | 0.649 | 0.423 | 0.080 | 126.3 | 31.59 | | | | | |
| 7 | 0.655 | 0.406 | 0.084 | 120.8 | 26.59 | 42.92 | | | | |
| 8 | 0.598 | 0.492 | 0.081 | 108.6 | 25.65 | | | | | |
| 9 | 0.538 | 0.629 | 0.075 | 101.0 | 32.36 | | | | | |
| 10 | 0.588 | 0.517 | 0.077 | 105.3 | 29.96 | 42.11 | | | | 0.6493 |
| 11 | 0.597 | 0.498 | 0.072 | 107.2 | 29.67 | | | | | |
| 12 | 0.612 | 0.493 | 0.079 | 112.6 | 24.17 | 49.34 | | | | |
| 13 | 0.628 | 0.449 | 0.082 | 115.5 | 32.19 | | | | | |
| 14 | 0.567 | 0.559 | 0.075 | 106.7 | 29.68 | | | | | |
| 15 | 0.525 | 0.649 | 0.077 | 103.8 | 18.82 | | | | | |
| 16 | 0.500 | 0.694 | 0.073 | 92.2 | 27.27 | | | | | |
| 17 | 0.491 | 0.716 | 0.070 | 96.2 | 26.65 | | | | | |
| 18 | 0.525 | 0.624 | 0.075 | 96.8 | 27.61 | | | | | |
| 19 | 0.503 | 0.677 | 0.071 | 97.7 | 27.54 | | | | | |
| 20 | 0.599 | 0.492 | 0.081 | 116.9 | 28.95 | 37.79 | | | | 1.3136 |
| 21 | 0.555 | 0.574 | 0.084 | 114.6 | 30.93 | | | | | |
| 22 | 0.540 | 0.620 | 0.073 | 107.6 | 29.17 | | | | | |
| 23 | 0.516 | 0.644 | 0.073 | 107.5 | 23.11 | | | | | |
| 24 | 0.580 | 0.553 | 0.085 | 117.7 | 32.63 | | | | | |
| 25 | 0.557 | 0.575 | 0.082 | 115.6 | 31.55 | | | | | |
| 26 | 0.509 | 0.665 | 0.078 | 120.2 | 30.65 | | | | | |
| 27 | 0.506 | 0.672 | 0.073 | 102.6 | 25.21 | | | | | |
| 28 | 0.504 | 0.692 | 0.072 | 109.4 | 29.77 | | | | | |
| 29 | 0.524 | 0.647 | 0.073 | 103.9 | 25.48 | | | | | |
| 30 | 0.526 | 0.647 | 0.071 | 99.0 | 30.32 | | | | | |
| 31 | 0.532 | 0.637 | 0.069 | 104.0 | 28.85 | | | | | |
| 32 | 0.565 | 0.568 | 0.069 | 102.7 | 32.83 | | | | | |
| 33 | 0.547 | 0.605 | 0.068 | 101.7 | 31.79 | | 0.05286 | 0.82365 | 2.0432 | |
| 34 | 0.544 | 0.604 | 0.066 | 100.1 | 30.25 | | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 0.537 | 0.618 | 0.071 | 99.9 | 30.39 | 44.93 | | | | |
| 36 | 0.549 | 0.613 | 0.073 | 106.7 | 31.67 | | | | | |
| 37 | 0.530 | 0.641 | 0.070 | 101.3 | 31.22 | | | | | |
| 38 | 0.481 | 0.723 | 0.062 | 91.0 | 17.56 | | | | | 0.3970 |
| 39 | 0.479 | 0.733 | 0.065 | 96.1 | 30.24 | | | | | |
| 40 | 0.506 | 0.688 | 0.073 | 115.1 | 29.48 | 37.05 | | | | |
| 41 | 0.506 | 0.676 | 0.071 | 116.0 | 46.26 | | | | | 0.3800 |
| 42 | 0.533 | 0.601 | 0.082 | 122.6 | 25.14 | | | | | 0.1268 |
| 43 | 0.554 | 0.579 | 0.086 | 125.6 | 27.64 | | | | | |
| 44 | 0.528 | 0.603 | 0.083 | 115.2 | 23.95 | | | | | |
| 45 | 0.471 | 0.714 | 0.077 | 124.6 | 53.77 | 49.18 | | | | 3.5072 |
| 46 | 0.492 | 0.703 | 0.080 | 117.7 | 26.52 | | | | | 1.0649 |
| 47 | 0.547 | 0.597 | 0.084 | 124.1 | 33.60 | | | | | |
| 48 | 0.589 | 0.519 | 0.083 | 157.9 | 32.66 | | | | | |
| 49 | 0.562 | 0.547 | 0.077 | 127.3 | 31.71 | | | | | |
| 50 | 0.531 | 0.603 | 0.076 | 121.9 | 30.49 | 35.65 | | | | 0.4390 |
| 51 | 0.581 | 0.539 | 0.080 | 127.6 | 28.71 | | | | | |
| 52 | 0.614 | 0.496 | 0.083 | 138.0 | 28.14 | | | | | |
| 53 | 0.630 | 0.450 | 0.091 | 139.4 | 28.11 | | | | | |
| 54 | 0.622 | 0.433 | 0.085 | 145.2 | 26.80 | | | | | |
| 55 | 0.634 | 0.440 | 0.091 | 154.9 | 28.22 | 26.02 | | | | 0.0540 |
| 56 | 0.626 | 0.452 | 0.095 | 163.8 | 25.84 | | | | | |
| 57 | 0.550 | 0.590 | 0.088 | 147.4 | 23.99 | | 0.05274 | 0.81975 | 2.0334 | |
| 58 | 0.570 | 0.544 | 0.092 | 158.4 | 24.21 | 31.05 | | | | |
| 59 | 0.393 | 0.912 | 0.077 | 167.8 | 25.44 | | | | | |

## Long Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.814 | 0.204 | 0.113 | 165.3 | 22.05 | | 0.05260 | 0.82292 | 2.0424 | 0.7436 |
| 1 | 0.799 | 0.221 | 0.104 | 154.3 | 18.76 | | | | | |
| 2 | 0.791 | 0.230 | 0.109 | 146.5 | 18.56 | 41.34 | | | | |
| 3 | 0.794 | 0.227 | 0.097 | 150.5 | 17.15 | | | | | |
| 4 | 0.788 | 0.235 | 0.096 | 147.9 | 21.11 | | | | | |
| 5 | 0.781 | 0.243 | 0.095 | 140.3 | 17.62 | 39.42 | | | | |
| 6 | 0.787 | 0.241 | 0.100 | 138.4 | 19.72 | | | | | |
| 7 | 0.779 | 0.221 | 0.095 | 141.7 | 21.77 | | | | | 0.7141 |
| 8 | 0.775 | 0.247 | 0.093 | 142.6 | 22.78 | 43.00 | | | | |
| 9 | 0.792 | 0.226 | 0.106 | 137.9 | 18.71 | | | | | |
| 10 | 0.803 | 0.210 | 0.105 | 146.0 | 20.45 | | | | | |
| 11 | 0.802 | 0.211 | 0.100 | 147.5 | 22.88 | | | | | 0.8217 |
| 12 | 0.798 | 0.218 | 0.083 | 140.5 | 20.42 | | | | | |
| 13 | 0.770 | 0.252 | 0.087 | 137.1 | 19.64 | | | | | |
| 14 | 0.789 | 0.236 | 0.097 | 139.1 | 21.65 | | | | | |
| 15 | 0.786 | 0.235 | 0.098 | 140.3 | 20.81 | 39.81 | | | | |
| 16 | 0.790 | 0.228 | 0.096 | 136.9 | 20.49 | | | | | |
| 17 | 0.786 | 0.231 | 0.095 | 139.1 | 19.92 | | | | | 0.7455 |
| 18 | 0.797 | 0.224 | 0.094 | 141.6 | 22.86 | | | | | |
| 19 | 0.802 | 0.211 | 0.104 | 141.0 | 22.45 | | | | | |
| 20 | 0.792 | 0.221 | 0.104 | 141.3 | 21.84 | 40.27 | | | | |
| 21 | 0.782 | 0.237 | 0.093 | 138.5 | 21.06 | | | | | |
| 22 | 0.782 | 0.235 | 0.098 | 145.3 | 21.38 | | | | | 0.6121 |
| 23 | 0.786 | 0.233 | 0.090 | 144.4 | 20.93 | | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 0.783 | 0.237 | 0.089 | 132.6 | 17.91 | | | | | |
| 25 | 0.798 | 0.216 | 0.083 | 137.1 | 17.00 | 54.21 | 0.05257 | 0.82234 | 2.0420 | |
| 26 | 0.789 | 0.228 | 0.092 | 125.4 | 15.78 | | | | | |
| 27 | 0.782 | 0.229 | 0.083 | 129.0 | 17.47 | | | | | 0.4567 |
| 28 | 0.783 | 0.231 | 0.091 | 135.7 | 17.49 | | | | | |
| 29 | 0.793 | 0.220 | 0.091 | 139.1 | 17.54 | | | | | |
| 30 | 0.780 | 0.231 | 0.089 | 138.9 | 19.18 | | | | | |
| 31 | 0.779 | 0.234 | 0.092 | 140.3 | 31.48 | | | | | |
| 32 | 0.788 | 0.228 | 0.088 | 188.7 | 18.04 | | | | | |
| 33 | 0.780 | 0.225 | 0.089 | 142.8 | 20.11 | | | | | |
| 34 | 0.767 | 0.256 | 0.082 | 135.9 | 17.80 | | | | | |
| 35 | 0.769 | 0.257 | 0.082 | 133.5 | 18.86 | 47.86 | | | | 0.6357 |
| 36 | 0.771 | 0.247 | 0.097 | 142.5 | 9.78 | | | | | |
| 37 | 0.780 | 0.225 | 0.089 | 148.8 | 20.75 | | | | | |
| 38 | 0.784 | 0.221 | 0.090 | 141.5 | 20.05 | | | | | |
| 39 | 0.769 | 0.255 | 0.086 | 139.0 | 18.01 | | | | | |
| 40 | 0.779 | 0.244 | 0.090 | 146.6 | 21.72 | | | | | |
| 41 | 0.777 | 0.243 | 0.095 | 152.0 | 23.80 | | | | | |
| 42 | 0.765 | 0.256 | 0.090 | 144.6 | 23.33 | | | | | |
| 43 | 0.752 | 0.253 | 0.075 | 137.1 | 18.53 | | | | | |
| 44 | 0.744 | 0.273 | 0.095 | 147.8 | 23.91 | | | | | |
| 45 | 0.741 | 0.289 | 0.093 | 135.5 | 22.74 | 48.47 | | | | 1.5336 |
| 46 | 0.742 | 0.283 | 0.099 | 148.1 | 16.64 | | | | | |
| 47 | 0.736 | 0.299 | 0.090 | 142.4 | 33.78 | | | | | 2.3042 |
| 48 | 0.737 | 0.296 | 0.095 | 149.9 | 10.86 | | | | | 2.8065 |
| 49 | 0.733 | 0.303 | 0.096 | 148.7 | 16.99 | | | | | |
| 50 | 0.717 | 0.323 | 0.093 | 149.1 | 23.56 | | | | | |
| 51 | 0.745 | 0.290 | 0.086 | 157.5 | 30.87 | | | | | |
| 52 | 0.506 | 0.700 | 0.086 | 141.2 | 23.95 | | | | | 3.0137 |
| 53 | 0.448 | 0.810 | 0.083 | 144.8 | 22.38 | | | | | |
| 54 | 0.426 | 0.873 | 0.085 | 155.6 | 26.18 | | | | | |
| 55 | 0.435 | 0.844 | 0.086 | 143.6 | 20.01 | 32.98 | | | | 2.9067 |
| 56 | 0.422 | 0.859 | 0.087 | 144.8 | 20.61 | | | | | |
| 57 | 0.414 | 0.877 | 0.084 | 148.6 | 17.44 | | | | | 2.1027 |
| 58 | 0.406 | 0.905 | 0.084 | 156.0 | 16.98 | | | | | |
| 59 | 0.402 | 0.925 | 0.084 | 156.4 | 19.31 | | | | | |
| 60 | 0.398 | 0.958 | 0.081 | 147.5 | 22.81 | 24.81 | | | | |
| 61 | 0.388 | 0.938 | 0.083 | 154.8 | | | | | | |
| 62 | 0.396 | 0.916 | 0.076 | 147.5 | 21.96 | | | | | |
| 63 | 0.390 | 0.908 | 0.077 | 138.0 | 14.56 | | | | | |
| 64 | 0.396 | 0.881 | 0.079 | 148.7 | 20.91 | | | | | |
| 65 | 0.380 | 0.929 | 0.079 | 138.4 | 18.60 | 29.44 | 0.05281 | 0.82562 | 2.0477 | 0.5153 |
| 66 | 0.415 | 0.829 | 0.081 | 152.7 | 14.77 | | | | | |
| 67 | 0.421 | 0.849 | 0.085 | 146.5 | 15.48 | | | | | |
| 68 | 0.377 | 0.942 | 0.083 | 157.4 | 23.61 | | | | | |
| 69 | 0.385 | 0.951 | 0.078 | 170.1 | 16.63 | | | | | |

## Lower Lake Mary

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.516 | 0.657 | 0.142 | 285.6 | 58.80 | | | | | |
| 1 | 0.453 | 0.746 | 0.145 | 244.3 | 64.02 | | | | | 2.6314 |
| 2 | 0.452 | 0.796 | 0.141 | 269.8 | 58.23 | | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.467 | 0.741 | 0.142 | 271.9 | 38.44 | | | | | |
| 4 | 0.453 | 0.668 | 0.135 | 302.0 | 60.20 | | | | | 2.4824 |
| 5 | 0.432 | 0.796 | 0.127 | 251.2 | 64.87 | 81.91 | 0.05353 | 0.83499 | 2.0465 | |
| 6 | 0.398 | 0.892 | 0.135 | 254.2 | 54.12 | | | | | |
| 7 | 0.405 | 0.883 | 0.140 | 258.4 | 54.06 | | | | | |
| 8 | 0.414 | 0.791 | 0.139 | 251.2 | 54.04 | | | | | |
| 9 | 0.405 | 0.782 | 0.145 | 306.6 | 70.97 | | | | | |
| 10 | 0.392 | 0.679 | 0.146 | 263.0 | 54.80 | 86.65 | | | | 2.9355 |
| 11 | 0.360 | 0.684 | 0.137 | 259.3 | 55.88 | | | | | |
| 12 | 0.361 | 0.718 | 0.132 | 253.8 | 62.24 | | | | | |
| 13 | 0.356 | 0.643 | 0.129 | 243.0 | 51.67 | | | | | |
| 14 | 0.374 | 0.701 | 0.140 | 253.7 | 57.34 | | | | | |
| 15 | 0.360 | 0.636 | 0.134 | 253.0 | 42.94 | 89.52 | | | | 0.9386 |
| 16 | 0.413 | 0.801 | 0.135 | 243.2 | 50.46 | | | | | |
| 17 | 0.385 | 0.841 | 0.144 | 272.3 | 59.76 | | | | | |
| 18 | 0.445 | 0.776 | 0.129 | 236.1 | 51.21 | | | | | |
| 19 | 0.444 | 0.795 | 0.126 | 236.3 | 51.43 | | | | | 0.4608 |
| 20 | 0.433 | 0.830 | 0.129 | 234.4 | 53.78 | 86.20 | 0.05396 | 0.84055 | 2.0537 | |
| 21 | 0.439 | 0.771 | 0.125 | 224.9 | 44.21 | | | | | |
| 22 | 0.479 | 0.719 | 0.135 | 236.4 | 48.22 | | | | | |
| 23 | 0.456 | 0.776 | 0.142 | 256.7 | 47.70 | | | | | |
| 24 | 0.497 | 0.680 | 0.131 | 234.5 | 43.30 | | | | | |
| 25 | 0.454 | 0.777 | 0.132 | 253.8 | 43.52 | | | | | |

## White Mountains

### Lyman Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Surface Core** | | | | | | | | | | |
| 0 | 0.745 | 0.219 | 0.094 | 97.4 | 29.26 | | | | | |
| 5 | 0.698 | 0.357 | 0.090 | 98.4 | 25.17 | | | | | 0.2857 |
| 10 | 0.685 | 0.362 | 0.090 | 104.9 | 28.70 | 36.18 | | | | |
| 15 | 0.745 | 0.272 | 0.094 | 101.3 | 29.01 | | | | | 0.4350 |
| 20 | 0.746 | 0.289 | 0.096 | 118.7 | 28.67 | | | | | |
| 25 | 0.741 | 0.468 | 0.091 | 102.2 | 29.31 | | | | | |
| 30 | 0.723 | 0.304 | 0.098 | 109.4 | 30.43 | | | | | 0.4267 |
| 35 | 0.522 | 0.616 | 0.090 | 104.9 | 30.36 | | | | | |
| 40 | 0.729 | 0.308 | 0.092 | 130.5 | 31.83 | | | | | |
| 45 | 0.730 | 0.299 | 0.095 | 122.7 | 33.19 | | | | | |
| 50 | 0.733 | 0.290 | 0.099 | 153.0 | 30.74 | | | | | 0.4847 |
| 55 | 0.706 | 0.341 | 0.093 | 130.3 | 31.51 | | | | | |
| 60 | 0.708 | 0.336 | 0.095 | 98.5 | 27.17 | | | | | |
| 65 | 0.742 | 0.284 | 0.099 | 189.6 | 34.11 | | | | | 0.7682 |
| 70 | 0.669 | 0.375 | 0.090 | 117.3 | 26.50 | 34.69 | | | | |
| 75 | 0.682 | 0.374 | 0.088 | 143.7 | 25.09 | | | | | |
| 80 | 0.596 | 0.503 | 0.087 | 126.3 | 23.58 | | | | | |
| **Livingstone Core** | | | | | | | | | | |
| 56 | 0.727 | 0.308 | 0.095 | | | 23.40 | 0.05428 | 0.82988 | 2.0368 | 0.4686 |
| 86 | 0.726 | 0.304 | 0.115 | | | 22.10 | | | | 1.3858 |
| 98 | 0.699 | 0.320 | 0.096 | | | 23.85 | | | | 1.8206 |
| 111 | 0.590 | 0.492 | 0.085 | | | 17.42 | 0.05424 | 0.82260 | 2.0171 | |
| 121 | 0.571 | 0.548 | 0.100 | | | 21.42 | | | | 0.5426 |
| 145 | 0.638 | 0.430 | 0.104 | | | 20.69 | | | | 0.2908 |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 155 | 0.491 | 0.720 | 0.094 | | | | | | | 0.1315 |
| 166 | 0.618 | 0.454 | 0.092 | | | 20.53 | 0.05465 | 0.82230 | 2.0129 | 0.1126 |
| 180 | 0.562 | 0.587 | 0.094 | | | | | | | 0.2405 |
| 185 | 0.533 | 0.577 | 0.091 | | | | | | | 0.2216 |
| 210 | 0.548 | 0.571 | 0.097 | | | 21.12 | | | | 0.1091 |
| 220 | 0.715 | 0.418 | 0.109 | | | | | | | 0.0819 |
| 223 | 0.646 | 0.453 | 0.134 | | | 27.37 | | | | 0.0614 |
| 230 | 0.419 | 0.576 | 0.089 | | | 22.48 | 0.05408 | 0.82652 | 2.0348 | 0.0312 |
| 241 | 0.476 | 0.682 | 0.085 | | | 22.78 | | | | |
| 249 | 0.435 | 0.846 | 0.082 | | | 21.49 | | | | 0.1433 |
| 271 | 0.581 | 0.507 | 0.089 | | | 14.05 | | | | 0.0443 |
| 284 | 0.519 | 0.642 | 0.092 | | | | | | | 0.0411 |
| 322 | 0.494 | 0.697 | 0.090 | | | | 0.05367 | 0.81677 | 2.0123 | 0.0343 |
| 367 | 0.487 | 0.758 | 0.089 | | | | 0.05444 | 0.82052 | 2.0131 | |
| 402 | 0.474 | 0.714 | 0.087 | | | 19.92 | 0.05431 | 0.81955 | 2.0095 | |
| 455 | 0.474 | 0.642 | 0.090 | | | | 0.05414 | 0.81962 | 2.0094 | |

## Carnero Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.955 | 0.047 | 0.313 | 207.0 | 51.36 | 95.27 | | | | |
| 2 | 0.939 | 0.114 | 0.337 | 201.5 | 50.71 | | | | | |
| 3 | 0.936 | 0.121 | 0.330 | 199.5 | 51.30 | 102.79 | | | | |
| 4 | 0.912 | 0.140 | 0.319 | 186.8 | 45.92 | | | | | |
| 5 | 0.913 | 0.152 | 0.294 | 171.5 | 44.45 | 90.29 | | | | 1.3606 |
| 6 | 0.926 | 0.127 | 0.341 | 213.0 | 54.53 | | | | | |
| 7 | 0.914 | 0.167 | 0.286 | 169.2 | 42.45 | 118.03 | | | | |
| 8 | 0.873 | 0.099 | 0.241 | 144.8 | 53.54 | | | | | |
| 9 | 0.852 | 0.151 | 0.204 | 220.9 | 29.89 | 108.74 | | | | |
| 10 | 0.866 | 0.158 | 0.213 | 154.4 | 42.95 | | | | | 1.9885 |
| 11 | 0.863 | 0.119 | 0.238 | 152.2 | 43.41 | | | | | |
| 12 | 0.857 | 0.153 | 0.250 | 162.8 | 51.18 | 116.25 | | | | |
| 13 | 0.862 | 0.145 | 0.256 | 174.5 | 53.54 | | | | | 4.3803 |
| 14 | 0.862 | 0.153 | 0.259 | 179.7 | 52.01 | | | | | |
| 15 | 0.865 | 0.128 | 0.262 | 173.2 | 47.59 | 139.74 | | | | 4.5554 |
| 16 | 0.861 | 0.144 | 0.273 | 194.8 | 61.63 | | | | | |
| 17 | 0.848 | 0.140 | 0.266 | 178.6 | 55.41 | | | | | |
| 18 | 0.853 | 0.153 | 0.258 | 176.4 | 55.86 | 99.78 | | | | 7.2956 |
| 19 | 0.832 | 0.177 | 0.252 | 165.3 | 49.90 | | | | | |
| 20 | 0.840 | 0.172 | 0.245 | 172.6 | 44.17 | | | | | |
| 21 | 0.840 | 0.166 | 0.237 | 156.5 | 48.42 | | | | | 1.2324 |
| 22 | 0.833 | 0.167 | 0.249 | 159.0 | 39.61 | 81.96 | | | | |
| 23 | 0.824 | 0.172 | 0.223 | 140.3 | 29.60 | | | | | 1.9741 |
| 24 | 0.805 | 0.211 | 0.167 | 162.0 | 26.55 | | | | | |
| 25 | 0.802 | 0.209 | 0.206 | 172.2 | 32.32 | | | | | 0.3742 |
| 26 | 0.775 | 0.248 | 0.191 | 152.1 | 30.25 | | | | | |
| 27 | 0.794 | 0.238 | 0.181 | 155.4 | 25.77 | 80.15 | | | | |
| 28 | 0.753 | 0.273 | 0.177 | 139.4 | 27.58 | | | | | |
| 29 | 0.747 | 0.261 | 0.171 | 146.2 | 27.58 | | | | | |
| 30 | 0.733 | 0.294 | 0.171 | 140.3 | 27.75 | | | | | |
| 31 | 0.697 | 0.333 | 0.164 | 148.6 | 28.37 | | | | | |
| 32 | 0.753 | 0.270 | 0.200 | 140.7 | 26.02 | | | | | |
| 33 | 0.677 | 0.368 | 0.143 | 119.4 | 23.81 | 53.47 | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 0.622 | 0.458 | 0.139 | 113.9 | 22.09 | | | | | |
| 35 | 0.507 | 0.703 | 0.140 | 99.6 | 18.02 | | | | | 0.0882 |
| 36 | 0.402 | 0.890 | 0.106 | 94.2 | 19.62 | | | | | |
| 37 | 0.381 | 0.962 | 0.101 | 90.5 | 17.07 | | | | | |
| 38 | 0.463 | 0.776 | 0.143 | 98.9 | 19.04 | | | | | |
| 39 | 0.465 | 0.747 | 0.169 | 103.9 | 21.11 | | | | | |
| 40 | 0.431 | 0.791 | 0.149 | 100.9 | 20.95 | | 0.05308 | 0.82794 | 2.0529 | |
| 41 | 0.353 | 1.028 | 0.092 | 94.0 | 18.97 | | | | | |
| 42 | 0.358 | 0.990 | 0.095 | 91.5 | 19.23 | | | | | |
| 43 | 0.354 | 1.044 | 0.092 | 92.1 | 16.39 | 30.70 | | | | |
| 44 | 0.354 | 0.995 | 0.086 | 94.1 | 18.03 | | | | | |

## Nelson Reservoir

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.907 | 0.095 | 0.158 | 190.9 | 30.34 | | | | | |
| 1 | 0.902 | 0.101 | 0.149 | 252.0 | 29.36 | | | | | |
| 2 | 0.885 | 0.114 | 0.149 | 125.5 | 27.67 | 40.39 | | | | |
| 3 | 0.874 | 0.130 | 0.154 | 119.2 | 27.71 | | | | | |
| 4 | 0.854 | 0.147 | 0.122 | 147.3 | 27.63 | | 0.05406 | 0.83724 | 2.0639 | |
| 5 | 0.850 | 0.158 | 0.127 | 118.1 | 24.53 | | | | | |
| 6 | 0.838 | 0.172 | 0.116 | 139.9 | 18.54 | | | | | |
| 7 | 0.831 | 0.165 | 0.121 | 114.8 | 21.44 | | | | | |
| 8 | 0.819 | 0.187 | 0.123 | 148.8 | 25.51 | | | | | |
| 9 | 0.809 | 0.204 | 0.113 | 163.1 | 22.88 | | | | | |
| 10 | 0.832 | 0.178 | 0.103 | 137.2 | 25.32 | 35.63 | | | | 0.8455 |
| 11 | 0.812 | 0.201 | 0.119 | 138.1 | 24.80 | | | | | |
| 12 | 0.818 | 0.192 | 0.115 | 186.8 | 24.78 | | | | | |
| 13 | 0.808 | 0.197 | 0.117 | 152.6 | 23.22 | | | | | |
| 14 | 0.819 | 0.198 | 0.111 | 154.8 | 26.69 | | | | | |
| 15 | 0.818 | 0.197 | 0.107 | 148.8 | 25.82 | | | | | |
| 16 | 0.820 | 0.195 | 0.123 | 164.2 | 28.13 | | | | | |
| 17 | 0.817 | 0.194 | 0.119 | 202.9 | 25.57 | | | | | |
| 18 | 0.809 | 0.201 | 0.114 | 198.5 | 23.94 | | | | | |
| 19 | 0.812 | 0.200 | 0.100 | 175.1 | 27.30 | | | | | |
| 20 | 0.810 | 0.203 | 0.106 | 119.7 | 26.98 | | | | | 0.3532 |
| 21 | 0.810 | 0.205 | 0.102 | 117.5 | 26.91 | | | | | |
| 22 | 0.806 | 0.204 | 0.098 | 171.7 | 22.87 | | | | | |
| 23 | 0.809 | 0.206 | 0.102 | 168.7 | 22.18 | | | | | |
| 24 | 0.790 | 0.228 | 0.105 | 212.3 | 26.06 | | 0.05439 | 0.83700 | 2.0583 | |
| 25 | 0.786 | 0.220 | 0.106 | 145.1 | 27.23 | 34.42 | | | | 0.3860 |
| 26 | 0.777 | 0.240 | 0.100 | 122.4 | 30.46 | | | | | |
| 27 | 0.775 | 0.245 | 0.102 | 164.2 | 30.24 | | | | | |
| 28 | 0.743 | 0.281 | 0.100 | 137.4 | 31.87 | | | | | |
| 29 | 0.770 | 0.252 | 0.099 | 131.9 | 25.86 | | | | | |
| 30 | 0.757 | 0.268 | 0.103 | 156.7 | 28.32 | | | | | |
| 31 | 0.717 | 0.320 | 0.091 | 108.3 | 30.64 | | | | | |
| 32 | 0.753 | 0.272 | 0.099 | 208.0 | 30.03 | | | | | |
| 33 | 0.739 | 0.292 | 0.092 | 100.4 | 28.63 | | | | | |
| 34 | 0.765 | 0.262 | 0.099 | 173.5 | 28.27 | | | | | |
| 35 | 0.779 | 0.235 | 0.106 | 107.5 | 27.29 | 35.76 | | | | 0.6924 |
| 36 | 0.781 | 0.239 | 0.113 | 120.6 | 30.83 | | | | | |
| 37 | 0.768 | 0.251 | 0.104 | 137.7 | 31.27 | | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 0.760 | 0.269 | 0.112 | 117.9 | 30.49 | | | | | |
| 39 | 0.720 | 0.315 | 0.111 | 119.2 | 28.91 | | | | | |
| 40 | 0.748 | 0.270 | 0.111 | 173.9 | 27.54 | | | | | 0.6916 |
| 41 | 0.770 | 0.226 | 0.119 | 148.1 | 20.68 | | | | | |
| 42 | 0.758 | 0.260 | 0.108 | 109.7 | 30.59 | | | | | |
| 43 | 0.755 | 0.272 | 0.103 | 116.8 | 28.02 | | | | | |
| 44 | 0.752 | 0.273 | 0.103 | 112.7 | 25.65 | | | | | |
| 45 | 0.743 | 0.289 | 0.100 | 117.3 | 26.35 | 33.05 | | | | 0.9532 |
| 46 | 0.719 | 0.310 | 0.090 | 135.6 | 31.70 | | | | | |
| 47 | 0.709 | 0.325 | 0.092 | 110.2 | 26.32 | | | | | |
| 48 | 0.692 | 0.350 | 0.089 | 113.1 | 27.28 | | | | | |
| 49 | 0.703 | 0.331 | 0.091 | 111.6 | 27.44 | | | | | |
| 50 | 0.696 | 0.327 | 0.100 | 111.8 | 25.69 | | | | | 0.6281 |
| 51 | 0.693 | 0.362 | 0.088 | 111.1 | 28.00 | | | | | |
| 52 | 0.696 | 0.345 | 0.093 | 109.8 | 25.36 | | | | | |
| 53 | 0.713 | 0.294 | 0.095 | 111.6 | 16.83 | | | | | 0.7852 |
| 54 | 0.711 | 0.312 | 0.090 | 108.0 | 27.81 | | | | | |
| 55 | 0.697 | 0.343 | 0.099 | 118.1 | 26.09 | 35.07 | | | | 3.4599 |
| 56 | 0.674 | 0.371 | 0.097 | 119.7 | 31.73 | | | | | |
| 57 | 0.672 | 0.376 | 0.101 | 117.7 | 27.09 | | | | | 1.8123 |
| 58 | 0.629 | 0.440 | 0.102 | 124.7 | 23.67 | | | | | |
| 59 | 0.511 | 0.684 | 0.098 | 116.2 | 23.65 | | | | | |
| 60 | 0.426 | 0.855 | 0.097 | 111.5 | 27.59 | | | | | 0.8175 |
| 61 | 0.425 | 0.850 | 0.089 | 115.6 | 20.07 | | | | | |
| 62 | 0.412 | 0.895 | 0.093 | 123.8 | 30.20 | | | | | |
| 63 | 0.391 | 0.914 | 0.095 | 127.5 | 33.75 | | | | | |
| 64 | 0.392 | 0.926 | 0.093 | 113.4 | 27.23 | | | | | |
| 65 | 0.396 | 0.902 | 0.095 | 113.5 | 25.07 | 28.54 | 0.05456 | 0.84188 | 2.0747 | 0.2756 |
| 66 | 0.392 | 0.903 | 0.092 | 105.5 | 24.57 | 27.89 | | | | |
| 67 | 0.390 | 0.901 | 0.098 | 116.4 | 25.66 | | | | | |
| 68 | 0.396 | 0.905 | 0.091 | 113.3 | 24.15 | 27.81 | | | | |
| 69 | 0.380 | 0.974 | 0.092 | 148.9 | 21.36 | | | | | |

## Mogollon Rim

### Willow Springs Lake

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.824 | 0.182 | 0.183 | 165.9 | 127.63 | | 0.05369 | 0.83704 | 2.0565 | |
| 1 | 0.654 | 0.426 | 0.123 | 73.6 | 48.80 | 127.11 | 0.05304 | 0.82749 | 2.0453 | 1.7872 |
| 2 | 0.531 | 0.627 | 0.108 | 111.4 | 35.31 | | 0.05281 | 0.82455 | 2.0424 | |
| 3 | 0.235 | 0.842 | 0.101 | 60.3 | 33.29 | 55.06 | | | | |
| 4 | 0.192 | 1.089 | 0.092 | 45.6 | 26.88 | | | | | 0.5307 |
| 5 | 0.235 | 1.178 | 0.081 | 46.7 | 23.60 | 24.62 | | | | |
| 6 | 0.386 | 1.372 | 0.071 | 44.1 | 20.69 | | | | | |
| 7 | 0.320 | 1.075 | 0.115 | 79.5 | 30.83 | | | | | 0.3320 |
| 8 | 0.487 | 1.189 | 0.097 | 74.2 | 25.07 | 26.07 | | | | |
| 9 | 0.316 | 1.135 | 0.092 | 67.0 | 24.65 | | | | | |
| 10 | 0.293 | 1.240 | 0.086 | 66.9 | 29.01 | | | | | 0.3961 |
| 11 | 0.256 | 1.309 | 0.085 | 57.4 | 23.33 | | | | | |
| 12 | 0.252 | 1.336 | 0.082 | 63.5 | 13.86 | 21.13 | | | | |
| 13 | 0.258 | 1.275 | 0.086 | 61.0 | 32.83 | | | | | 0.2591 |
| 14 | 0.271 | 1.208 | 0.086 | 60.6 | 28.06 | | | | | |
| 15 | 0.304 | 1.167 | 0.078 | 58.6 | 29.60 | 23.29 | | | | |

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 0.249 | 1.304 | 0.077 | 54.9 | 25.77 | | | | | |
| 17 | 0.279 | 1.244 | 0.076 | 58.5 | 28.76 | | | | | |
| 18 | 0.287 | 1.210 | 0.083 | 63.8 | 27.23 | | | | | 0.1551 |
| 19 | 0.285 | 1.215 | 0.073 | 56.0 | 24.73 | | | | | |
| 20 | 0.282 | 1.229 | 0.078 | 64.2 | 26.54 | 23.15 | 0.05304 | 0.82749 | 2.0453 | |
| 21 | 0.285 | 1.226 | 0.074 | 55.8 | 24.18 | | | | | |
| 22 | 0.281 | 1.260 | 0.078 | 52.5 | 24.30 | | | | | 0.1293 |
| 23 | 0.296 | 1.188 | 0.083 | 70.8 | 30.45 | | | | | |
| 24 | 0.272 | 1.229 | 0.109 | 90.4 | 27.92 | | | | | |
| 25 | 0.276 | 1.305 | 0.079 | 63.9 | 24.58 | 26.55 | | | | |
| 26 | 0.280 | 1.251 | 0.080 | 60.1 | 21.39 | | | | | |
| 27 | 0.289 | 1.217 | 0.080 | 70.0 | 26.57 | | | | | 0.1400 |
| 28 | 0.295 | 1.213 | 0.087 | 59.8 | 28.14 | | | | | |
| 29 | 0.287 | 1.202 | 0.082 | 77.3 | 30.06 | | | | | |
| 30 | 0.274 | 1.274 | 0.078 | 93.3 | 27.82 | | | | | |
| 31 | 0.261 | 1.305 | 0.080 | 70.1 | 13.21 | | | | | |
| 32 | 0.272 | 1.216 | 0.086 | 72.5 | 15.39 | | | | | |
| 33 | 0.286 | 1.197 | 0.087 | 78.1 | 14.98 | | | | | 0.0711 |
| 34 | 0.296 | 1.149 | 0.080 | 71.2 | 15.19 | | | | | |
| 35 | 0.288 | 1.187 | 0.082 | 71.8 | 15.40 | 23.83 | 0.05281 | 0.82455 | 2.0424 | |
| 36 | 0.274 | 1.268 | 0.083 | 87.3 | 15.18 | | | | | |
| 37 | 0.281 | 1.211 | 0.084 | 75.6 | 15.49 | | | | | 0.0307 |
| 38 | 0.285 | 1.204 | 0.079 | 83.5 | 17.32 | | | | | |

**Stoneman Lake**

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.862 | | 0.427 | 598.2 | 52.56 | | | | | |
| 1 | 0.579 | | 0.138 | 144.5 | 30.28 | | | | | |
| 2 | 0.388 | | 0.110 | 130.4 | 31.32 | | | | | 1.1171 |
| 3 | 0.262 | | 0.105 | 139.1 | 31.89 | | 0.05643 | 0.87819 | 2.1198 | |
| 4 | 0.279 | | 0.107 | 144.5 | 35.97 | | | | | |
| 5 | 0.133 | | 0.108 | 128.5 | 35.32 | | | | | 0.3547 |
| 6 | 0.175 | | 0.107 | 138.1 | 29.26 | | | | | |
| 7 | 0.154 | | 0.108 | 135.8 | 30.60 | | | | | |
| 8 | 0.206 | | 0.099 | 129.1 | 30.52 | | | | | 0.5799 |
| 9 | 0.179 | | 0.102 | 120.0 | 27.87 | | | | | |
| 10 | 0.125 | | 0.102 | 132.1 | 30.44 | | | | | |
| 11 | 0.246 | | 0.099 | 128.7 | 25.62 | | | | | |
| 12 | 0.222 | | 0.098 | 135.4 | 29.82 | | | | | |
| 13 | 0.179 | | 0.101 | 121.3 | 27.56 | | | | | |
| 14 | 0.242 | | 0.101 | 132.2 | 27.56 | | | | | |
| 15 | 0.126 | | 0.103 | 130.2 | 29.34 | | | | | 0.3501 |
| 16 | 0.122 | | 0.102 | 128.2 | 28.78 | | | | | |
| 17 | 0.146 | | 0.102 | 133.3 | 28.02 | | | | | |
| 18 | 0.116 | | 0.104 | 133.7 | 26.57 | | | | | 0.5490 |
| 19 | 0.126 | | 0.103 | 131.1 | 24.26 | | | | | |
| 20 | 0.144 | | 0.105 | 127.1 | 27.05 | | 0.05356 | 0.83558 | 2.0613 | |
| 21 | 0.185 | | 0.101 | 277.1 | 25.36 | | | | | |

**Central Arizona**

**Alamo Reservoir**

| Depth (cm) | Moisture (wt f) | Bulk density (g/cc) | Loss on Ignition (wt f) | Zinc (mg/kg) | Total Pb (mg/kg) | Hg (ng/g) | Pb Isotope Mass Ratio 204/206 | Pb Isotope Mass Ratio 207/206 | Pb Isotope Mass Ratio 208/206 | Plutonium 239+240 (Bq/kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Surface Core** | | | | | | | | | | |
| 0 | 0.776 | 0.241 | 0.103 | 208.9 | 54.59 | | | | | |
| 5 | 0.725 | 0.310 | 0.091 | 192.5 | 34.81 | | | | | |
| 10 | 0.512 | 0.644 | 0.075 | 143.1 | 34.46 | 59.83 | 0.05214 | 0.81627 | 2.0279 | |
| 15 | 0.359 | 1.238 | 0.038 | 173.5 | 34.70 | | | | | |
| 20 | 0.497 | 0.701 | 0.079 | 157.7 | 37.36 | | | | | |
| 25 | 0.472 | 0.718 | 0.076 | 249.9 | 52.95 | | | | | |
| 30 | 0.748 | 0.278 | 0.107 | 223.7 | 54.76 | 78.91 | | | | |
| 35 | 0.562 | 0.557 | 0.086 | 206.2 | 49.44 | | | | | |
| 40 | 0.528 | 0.602 | 0.086 | 182.6 | 46.91 | | | | | |
| 45 | 0.504 | 0.657 | 0.083 | 206.0 | 44.10 | | | | | |
| 50 | 0.620 | 0.446 | 0.073 | 162.9 | 39.58 | | | | | |
| 53 | 0.594 | 0.505 | 0.078 | | | | | | | |
| **Livingstone Core** | | | | | | | | | | |
| 38 | 0.487 | 0.690 | 0.090 | | | 46.75 | 0.05341 | 0.81879 | 2.0076 | |
| 55 | | | | | | 56.54 | | | | |
| 85 | 0.604 | 0.458 | 0.092 | | | 51.25 | | | | |
| 100 | | | | | | 60.98 | | | | |
| 125 | 0.550 | 0.622 | 0.087 | | | 60.57 | | | | |
| 147 | 0.578 | 0.534 | 0.094 | | | 61.92 | 0.05296 | 0.79914 | 1.9745 | |
| 174 | | | | | | 66.34 | | | | |
| 202 | 0.553 | 0.542 | 0.111 | | | 61.61 | 0.05116 | 0.78148 | 1.9519 | |
| 242 | 0.569 | 0.518 | 0.089 | | | 55.13 | | | | |
| 257 | | | | | | 63.59 | | | | |
| 272 | 0.591 | 0.636 | 0.101 | | | 68.20 | | | | |
| 297 | | | | | | 81.44 | | | | |
| 319 | 0.391 | 0.906 | 0.082 | | | 53.53 | | | | |
| 329 | 0.573 | 0.542 | 0.111 | | | 64.12 | | | | |
| 347 | | | | | | 69.69 | | | | |
| 379 | 0.467 | 0.768 | 0.096 | | | 53.96 | | | | |
| 421 | | | | | | 70.15 | | | | |
| 435 | | | | | | 101.60 | | | | |
| 441 | 0.455 | 0.804 | 0.112 | | | | | | | |
| 442 | | | | | | 78.78 | | | | |

| Date | Lake | Elevation (ft) | GPS Position | Corer | Core # | Drive # | Water Depth (cm) | Start Depth (cm) | Driven (cm) | Recovered (cm) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N35°04.794', | | | | | | | | |
| 1-May-04 | Lake Mary | 7297 | W111°32.007' | Anderson | 1 | x | 680 | 0 | x | 23 | Lost ~15cm out the bottom at natural change in sediment |
| | | | | Anderson | 2 | x | 670 | 0 | x | 50 | |
| | | | | Livingston | 3 | 1 | 670 | 20 | 57 | 54.5 | |
| | | | | | 3 | 2 | x | x | 38 | 38 | |
| | | | N34°21.853', | | | | | | | | |
| 27-May-04 | Stehr Lake | 3705 | W111°40.143' | Anderson | 1 | x | 565 | 0 | x | 47.5 | |
| | | | | Livingston | 2 | 1 | 561 | 29 | 100 | 71 | |
| | | | | Livingston | 3 | 1 | 560 | 29 | 104 | 59 | |
| | | | | Livingston | 3 | 2 | x | x | 82 | 82 | |
| | Kinnickinick | | N34°53.904', | | | | | | | | |
| 29-May-04 | Lake | 7037 | W111°18.376' | Anderson | 1 | x | 670 | 0 | x | | |
| | | | N34°47.784', | | | | | | | | |
| 11-Jul-04 | Soldiers Lake | ???? | W111°14.045' | Anderson | SC1 | x | 430 | 0 | x | | |
| | | | | Livingston | 1 | 1 | 492 | 30 | 49.5 | 45 | compressed b/t 16-20cm |
| | | | | Livingston | 1 | 2 | x | x | 15 | 15 | |
| 11-Jul-04 | Long Lake | | | | | | | | | | |
| | Lower Lake | | | | | | | | | | |
| 12-Jul-04 | Mary | | | | | | | | | | |
| | | | N35°01.256', | | | | | | | | |
| 13-Jul-04 | Ashurst Lake | ???? | W111°24.220' | Anderson | SC1 | x | 238 | 0 | x | 40.5 | transition to darker sediment at ~20cm |
| | Nelson | | N34°04.558', | | | | | | | | filamentous algae suspended in water column, abrupt |
| 7-Aug-04 | Reservoir | 7578 | W109°11.634' | Anderson | SC1 | x | 515 | 0 | x | 69 | change from dark gyttja to lighter at 57cm |
| | | | N34°22.250', | | | | | | | | |
| 7-Aug-04 | Lyman Lake | 5964 | W109°22.913' | Anderson | SC1 | x | 360 | 0 | x | | water very turbid |
| | | | N34°22.251', | | | | | | | | |
| | | | W109°22.914' | Livingston | 1 | 1 | 359 | 20 | 100 | 104 | extra 4cm was sticking out of the end of the corer |
| | | | | Livingston | 1 | 2 | x | x | 100 | 100 | extra 2cm was sticking out of the end of the corer |
| | | | | Livingston | 1 | 3 | x | x | 100 | 99 | |
| | | | | Livingston | 1 | 4 | x | x | 100 | 93 | |
| | | | | Livingston | 1 | 5 | x | x | 37 | 36 | extra 3cm was sticking out of the end of the corer |
| | | | N34°07.010', | | | | | | | | |
| 8-Aug-04 | Carnero Lake | 9003 | W109°31.708' | Anderson | SC1 | x | 210 | 0 | x | 45 | 38-45cm is pink clay |
| | | | N34°18.851', | | | | | | | | |
| 9-Aug-04 | Willow Springs | 7534 | W110°52.549' | | | | 1860 | | | | no core recovered |
| | | | N34°14.701', | | | | | | | | 0-3cm dark, organic; 3-31cm reddish, gray, light; 31-41 dark; |
| 17-Aug-04 | Alamo Lake | 1060 | W113°35.312' | Foust | SC1 | x | 1700 | 0 | x | 54 | 41-45 light; 45-59 dark; 49-54 dark |
| | | | | | | | | | | | lost ~4cm out the bottom; sediment degassed on the way up; |
| | | | | Livingston | 1 | 1 | 1680 | 15 | 100 | 89 | air pockets evident in the sediment column |
| | | | | Livingston | 1 | 2 | x | x | 100 | 89 | lost ~4cm out the bottom |
| | | | | | | | | | | | corer got stuck on casing joint, could not push drive farther; storm rolls in w/strong wind, moved from initial coring |
| | | | | Livingston | 1 | 3 | x | x | 74 | 76 | location |
| | | | N34°14.575', | | | | | | | | lost ~8cm out the bottom, but sediment degassed on the way |
| 18-Aug-04 | | | W113°35.257' | Livingston | 2 | 1 | 1706 | 20 | 100 | 106 | up and expanded |
| | | | | Livingston | 2 | 2 | x | x | 77 | 80 | corer got stuck on casing; lost ~4cm out the bottom |
| | | | | Livingston | 2 | 3 | x | x | 100 | 103.5 | |
| | | | | | | | | | | | lost ~4cm out the bottom, 52-57cm got compressed during |
| | | | | Livingston | 2 | 4 | x | x | 96 | 77 | extrusion |
| | | | | Livingston | 2 | 5 | x | x | 65 | 53 | lost ~1cm out the bottom |
| | | | N34°18.822', | | | | | | | | |
| 19-Aug-04 | Willow Springs | 7526 | W110°52.577' | Foust | SC1 | x | 1910 | 0 | x | 24 | |
| | | | | | | | | | | | sediment is dark, organic, sandy with fibrous structures-possibly roots, but there is no branching like typical root structure. Pine needles present. Sediment is dry toward the |
| | | | N34°18.860', | | | | | | | | |
| | | 7484 | W110°52.594' | Foust | SC2 | x | 1770 | 0 | x | 39 | base of the core and crumbly.* |