^{137}Cs and ^{210}Pb in the San Gabriel Mountains, California: Erosion Rates, Processes And Implications.

by

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ABSTRACT

Numerous studies have examined the interplay of climate, tectonics, biota and erosion and found that these variables are intertwined in a complicated system of feedbacks and as a result, some of these factors are often oversimplified or simply neglected. To understand the interplay of these factors one must understand the processes that transport or inhibit transport of soil. This study uses the short-lived, fallout-derived, radionuclides ^{137}Cs and ^{210}Pb to identify soil transport processes and to quantify soil transport using the profile distribution model for ^{137}Cs. Using five field sites in the San Gabriel Mountains of California, I address four questions: (1) Is there a process transition between high and low gradient slopes observable with short-lived isotopes? (2) Do convex hilltops reflect short-term equilibrium erosion rates? (3) Do linear transects of pits accurately characterize hillslope averaged erosion rates? and (4) What role does fire play on short-term soil transport and isotope distribution? I find no evidence supporting a process transition from low gradient to high gradient slopes but also find that significant spatial variability of erosion rates exist. This spatial variability is the result of sensitivity of the method to small scale variations in isotopes and indicates that small scale processes may dominate broader scale trends. I find that short-term erosion rates are not at equilibrium on a convex hilltop and suggest the possibility of a headward incision signal. Data from a post-fire landscape indicates that fires may create complications in ^{137}Cs and ^{210}Pb distribution that current models for erosion calculation do not account for. I also find that across all my field sites soil transport processes can be identified and quantified using short-lived isotopes and

I suggest high resolution grid sampling be used instead of linear transects so that small scale variability can be averaged out.

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INTRODUCTION

Short-term soil transport rates make up an important part of long-term landscape evolution. As shown by the humped soil production function, if soil depth is too high or too low then soil production can drastically decrease Obviously, soil transport plays a role in the depth of soil and is thus intertwined with soil production. A landscape that finds a balance of soil thickness, soil production and soil transport will denude significantly faster than a landscape where weathering stalls due to no soil cover or too thick soil cover. The rapidly denuded landscape will have a different morphology than the other landscape. Understanding these variables and their interplay requires quantification. Landscape morphology has become increasingly quantifiable with tools such as Light Detection and Ranging (LIDAR) and ArcGIS. Using these tools, researchers can rapidly quantify topographic variables such as the slope of a hill, curvature, or the slope of a stream. With tools such as ^{10}Be researchers can quantify long-term basin wide erosion rates. With these variables constrained, geomorphologists are able to create geomorphic laws and more thoroughly understand relationships between topography and landscape evolution. Despite the progress of quantifying topographic variables and long-term erosion rates, there is limited quantification of the short-term processes on a hillslope. While the processes that move soil such as overland flow and bioturbation are well known, it can be difficult to quantify these processes on a given hillslope.

Fallout derived, short lived nuclides such as ^{137}Cs and ^{210}Pb enable soil transport rates to be quantified on decadal time scales (Zhang et al., 1998; Walling and He, 1999b; Zapata, 2003). ^{137}Cs is a radiogenic isotope with a half-life of 30.2 yr that was released into the atmosphere by nuclear weapons testing. Deposition of ^{137}Cs began in 1954, peaking in 1963 (Cambray et al., 1989). The isotope is known to have a high affinity for fine soil particles (He and Walling, 1995) and once fixed to a soil particle it is not easily removed (Benson, 1960). Similarly, the isotope ^{210}Pb shares this affinity for fine soil particles. ^{210}Pb is a naturally occurring environmental isotope with a half-life of 22.2 yr. It is a byproduct of the decay of $^{222}Rn_{(g)}$. ^{210}Pb from atmospheric ^{222}Rn decay is regarded to be ^{210}Pb excess. ^{210}Pb from decay of ^{222}Rn in the soil is in-situ ^{210}Pb. Given these isotope's affinity for fine soil particles and their chemical immobility it can be assumed that as soil is transported, so are the isotopes. By comparing the inventory, defined here as the sum of sample isotope activities for a soil pit multiplied by the depth increment of sampling, of a non-eroding, non-depositing reference pit to another pit, it is possible to track soil transport since 1963 by assuming that relative gains or losses represent deposition or erosion, respectively (Ritchie et al., 1974). In contrast to the peak deposition of ^{137}Cs in 1963, ^{210}Pb is an isotope that is continually being deposited. This continual deposition means that isotopes were deposited before and after 1963. Since the isotopes move with soil ^{210}Pb can be used to track soil transport earlier than 1963. Using these isotopes and soil transport rates I can answer questions about soil transport and fallout isotopes on a hillslope to understand more about the method and the role of soil transport. Using the isotope distributions and quantified transport rates I will attempt to answer 4 questions: (1) Is there a process transition between high and low gradient slopes observable with short-lived isotopes? (2) Do convex hilltops indicate short-term equilibrium erosion rates? (3) Do linear transects of pits accurately characterize hillslope averaged erosion rates? And (4) What role does fire play on short-term soil transport and isotope distribution? The San Gabriel Mountains (SGM) were chosen as the field site to answer these questions.

The San Gabriel Mountains, located just north of Pasadena, California, provide the ideal field area to explore these questions using field observations and extensive measurements of the short-lived isotopes introduced above. Previous cosmogenic radionuclide (CRN) ^{10}Be work in the SGM quantified basin-averaged erosion rates on the order of thousands of years and identified an erosion gradient that increases from west to east, as well as quantified the topographic controls on long-term erosion rates of the region (DiBiase et al., 2010). Choosing the SGM for this study enables comparisons between short-term and long-term erosion rates. Five sites within the SGM (Figure 1) explore the above four questions.

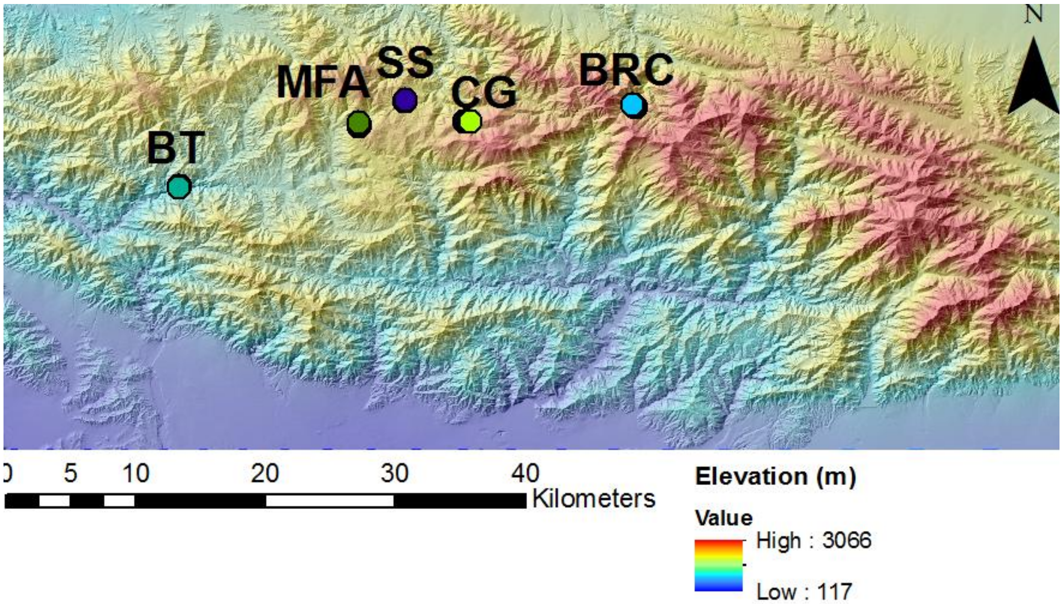


Figure 1. Transect Locations in The San Gabriel Mountains. This figure is a DEM of the San Gabriel Mountains color coded for elevation where blues are low, reds are high. The five studied areas are marked and labeled on the map with circles indicating the general location of the transect.

Sulfur Springs (SS) and Middle Fork of Alder (MFA) were chosen to answer question (1) because of their transition from low gradient to high gradient. Camp Glenwood (CG) was chosen for question (2) because of its convex top. Big Rock Creek (BRC) is used to examine spatial variability between linear transects, and Big Tujunga (BT) was chosen because it was burned recently. The conceptual framework for the questions being asked at these sites as well as the framework for quantifying soil transport rates from fallout isotopes is discussed next.

CONCEPTUAL FRAMEWORK

The concept of using short-lived isotopes to quantify soil transport has been around for decades (Rogowski and Tamura, 1965, Yang et al., 1998). More recently, Kaste et al., 2006 used ^{137}Cs to quantify soil transport on an undisturbed prairie and Dixon et al, 2009 used ^{137}Cs and ^{210}Pb to examine climate-driven processes of hillslope weathering. Through the years different methods for quantifying soil transport with these isotopes have been used but the theory remains the same. Next, I will explain the theory behind using these isotopes to quantify soil transport rates.

As mentioned in the Introduction, these isotopes affinity for soil particles and their chemical immobility makes them very useful for tracking soil transport and identifying processes. Since the isotopes are short-lived, they are useful for tracking soil transport on decadal time scales. If the isotopes were long-lived and in the case of cesium, deposited before 1963, their signals would give soil transport history from further back in time. The theory and the various methods of quantifying a soil transport rate from these isotopes is described in Walling and Quine, 1990. While the methods may vary depending on whether the soil is tilled or is undisturbed, or whether one uses an empirical model or theoretical model, the theory remains the same. It is simply that the immobility of these isotopes after adhering to soil, makes them excellent for tracking soil transport because the isotopes move with the soil after adhesion. Assuming uniform distribution of fallout, one needs only to compare the amount of isotopes from one patch of soil to the amount of isotopes in soil from a non-eroding non-depositing reference soil to quantify a transport rate.

There are a number of factors considered in modern methods which I did not mention as they do not alter the theory but instead, attempt to cope with complications that arise. For example, it is not easy to simply obtain " the amount of isotopes". Complex gamma spectroscopy which includes its own theories must be done to obtain an activity, which is the gamma emissions per second of the isotope in the soil. The sum of activities through a soil profile represents the inventory which represents the amount of isotopes in the soil. Increasing the amount of activity measurements one makes through a given soil profile will yield more accurate data but this relates to the methods, the theory remains unchanged. The particular model I use, the profile distribution model, is described in detail in the Methods section. Next, I will discuss the conceptual framework behind the questions being asked.

The first question, " Is there a process transition between high and low gradient slopes observable with short-lived isotopes?" stems from the concept that different sections of a hillslope have varying dominant processes (Dalrymple, et al., 1968, Ritter et al., 2006). The ability of fallout isotopes to track soil transport on decadal time scales will allow me to try to identify dominant process changes on short-term time scales. I hypothesize that there should be a process change between the low gradient and high gradient slope observable with short-lived isotopes.

The second question is "Do convex hilltops reflect short-term equilibrium erosion rates? This question stems from the following equations which indicate that perfectly convex ridge tops reflect long-term equilibrium erosion rates.

Sediment flux is linearly dependent on slope:

$$Qs = -K\left(\frac{dz}{dx}\right) \tag{1}$$

where Qs denotes sediment flux per unit width (L^2/t), K is a transport coefficient (L^2/t), z is elevation above sea level (L), and x is horizontal distance (L). Erosion rate (E, L/t, positive downward) or change of elevation over change in time is given by the divergence of sediment flux:

$$E = (\frac{dQs}{dx}) \tag{2}$$

Substituting (1) into (2) yields a diffusion equation that states that erosion is equal to the transport coefficient multiplied by hillslope curvature (Carson and Kirkby,1972):

$$E = -K(\frac{d^2z}{dx^2}) \tag{3}$$

Thus, curvature is equal to erosion divided by the transport coefficient:

$$\left(\frac{d^2z}{dx^2}\right) = E/K \tag{4}$$

From equation (4), if a hilltop has well shaped curvature then erosion should be constant across the hilltop meaning long-term erosion rates should be in equilibrium. Using a laser rangefinder survey to measure the curvature of the convex top and fallout isotopes to quantify erosion rates, I can test whether or not short-term erosion rates are also at equilibrium on the hilltop. I hypothesize that the short term erosion rates will be equal across the hilltop.

The third question is, "Do linear transects of pits accurately characterize hillslope averaged erosion rates?" As previously mentioned, fallout isotopes can be used to obtain soil transport rates. It is not clear if averaging the erosion rates from pits of a linear transect down the hillslope will provide accurate hillslope averaged erosion rates. To better understand the limitations of the method it is important to discover how representative of the hillslope a linear transect is. To test this, I will compare the erosion rates and activity vs. depth profiles of the isotopes between two linear transects spaced ~3 m apart at BRC. I hypothesize that linear transects cannot accurately provide a hillslope averaged erosion rate due to spatial variability. My hypothesis will be disproven if the A and B transect have equal erosion rates and activity profiles.

The final question is, "What role does fire play on short-term soil transport and isotope distribution." It has been shown that fire has the ability to resuspend fallout isotopes into the atmosphere (Yoschenko et al., 2006). It is also widely known that ash has high surface area and as shown by (He and Walling, 1995) isotope activity increases with surface area. Thus, in a fire with ash swirling around and resuspended fallout isotopes there may be isotopes concentrating in the ash which can be blow upslope. To examine this, I sampled ashy and non-ashy soil samples from the burnt BT area and hypothesize that the ashy soil will have higher isotope activities. I took 0-2 cm samples from various locations along the ridge and from various dark (burnt organic rich) or light (lack of burnt organics) areas and one intermediate - gray patch of soil to test this hypothesis by comparing isotope activities. Next, I will examine the details of the individual field sites.

FIELD SITES

SULFUR SPRINGS AND MIDDLE FORK OF ALDER

Sulfur Springs and Middle Fork of Alder are both located in a zone of relatively low relief, north of the Chilao Flats area of the San Gabriel Mountains (SGM). Vegetation around the SS transect consists of mostly pine and small patches of grasslike vegetation. The vegetation at MFA consists of mostly Manzanita. Both sites are hillslopes drained by ephemeral channels. I chose these sites to examine the question, " Is there a process transition between high and low gradient slopes observable with short-lived isotopes?" because both localities have low gradient ridge tops that increase in slope away from the crest to a threshold slope of around 30 degrees. The upper slope is convex up and the threshold slope is planar. Examining the soil transport rates of the low gradient convex zone and the high gradient planar zone will give further insight into the transport processes of these two topographically different areas and will confirm if there are process transitions identifiable with the use of short-lived isotopes.

CAMP GLENWOOD

The Camp Glenwood transect is located east of SS and MFA, just north of Los Angeles Crest Highway at Camp Glenwood. Cloudburst Canyon is at the base of the hillside. There is sporadic oak and pine with minimal surface vegetation such as grass. Consequently, much of the exposed surface soil is loose with minimal organics. The CG ridge has a perfectly convex top. Consequently, it is an excellent field site to test the question, "Do convex hilltops reflect short-term equilibrium erosion rates?"

BIG ROCK CREEK

Big Rock Creek is to the east of Camp Glenwood. Two parallel transects of pits, BRC-A and BRC-B were sampled here. The transects are on the northwest facing slope of a hill above the north fork of Big Rock Creek. The topography in this area is very steep and there are visible slope failures within the catchment. The maximum slope measured at a pit on the transect is 40 degrees and there is thick sediment accumulation on the toe slope which has been incised by the ephemeral stream at the base. By choosing this site I can further explore soil transport processes in the zone of critical slope ~ > 30 degrees. I can also use the visual accumulation of sediment on the toe slope as a check for the calculated soil transport rate, by making sure the data yields a deposition rate. This check coupled with sampling twin transects, spaced ~ 3 m apart, will allow me to answer the question, "Do linear transects accurately characterize hillslope averaged erosion rates?" by comparing the erosion rates from the two transects. This information is important for understanding the limits of this method and how much linear transects can be relied on for yielding an accurate hillslope averaged erosion rate.

BIG TUJUNGA

There are eight samples from BT; four organic rich, dark, ashy soils, three light colored , low ash samples, and one intermediate sample. The Big Tujunga samples came from a ridge in Big Tujunga Canyon located on the western side of the SGM. This area was burned during the Station Fire of 2009. This fire created an opportunity to answer the question, "What role does fire play on short-term soil transport and isotope distribution?" by burning an area where I could collect samples. A visual survey of this post-fire landscape indicates a random distribution of dark, burnt, organic-rich soil. The burnt organic material has high surface area and as shown by (He and Walling, 1995), ^{137}Cs and ^{210}Pb have a high affinity for particles with high surface area.

METHODS

SAMPLE COLLECTION

I collected soil samples from BT from visually identified, light and dark colored surface soil (top 0-2 cm) along a ridge in a post fire landscape and I collected samples from MFA, SS, CG, and BRC from vertical profiles in pits that were oriented along linear transects from ridge to base of the slope. In some instances, thick vegetation cover or rock outcrops required deviations from the linear transect. I recorded the location of all the pits with a GPS. I collected soil samples from the pits along these transects in either bulk form or with incremental sampling. For incremental sampling, I took soil from 2 cm increments through the soil column. I took soil from a 15 cm X 15 cm square of ground for every 2 cm of depth up to 30 cm or until I reached saprolite. In some cases, I used bulk sampling. I took bulk samples from a 15 cm X 15 cm area and measured the depth of the bulk sample. I brought collected soil samples back to the lab for further preparation and analysis.

In the lab, I weighed the samples then oven dried them for 12 hours to remove soil moisture and make them more easily sievable, I then weighed them again to have soil moisture mass loss in the event a future study needs this data. I sieved the samples into <2 mm and >2 mm fractions and weighed them. Inclusion of the >2 mm fraction with the sample can create complications with gamma spectroscopy analysis (described below) because the larger >2 mm clasts can absorb gamma emissions. I justify the exclusion of the >2 mm size fraction by acknowledging ^{137}Cs and ^{210}Pb's affinity for fine particles (He and Walling, 1995) which indicates the activity of the >2 mm size fraction is negligible. I packed soil from the <2 mm fraction into Petri dishes and weighed, then wrapped them with black electrical tape to prevent soil escaping. I then brought the packed <2 mm to the Germanium Detector lab for gamma spectroscopy analysis.

GAMMA SPECTROSCOPY

I placed the petri-dishes in a Canberra BE3830 Germanium (Ge) Detector. The lab protocol for running the two germanium detectors (Davis and Penck), their setup, and use of the gamma spectroscopy software, Apex are attached in Appendix A. Appendix A also introduces important vocabulary and gives an in depth walkthrough of the calibrations briefly described below. I allowed the samples to be counted until there were 1000 ^{137}Cs and ^{210}Pb counts or more or it became apparent that there was little to no activity in the sample.

Energy calibrations for the two detectors (Davis and Penck) ensured spectra accuracy for factors such as full-width half-max (FWHM) and energy line. The FWHM is used to make sure the area of any given peak in the spectra is symmetric in shape. The energy line (662 keV for ^{137}Cs, 46.5 keV for ^{210}Pb) is a representation of the energy emitted by the decay photon. Without an energy calibration we could not align the energy level with the proper channel.

I performed efficiency calibrations to assess proper geometries of suites of samples. A geometry is composed of three types of efficiencies; emission efficiency, detector efficiency, sample efficiency as well as the detector background activity. The efficiencies represent the percentage of gamma decays observed compared to the actual gamma decays. The emission efficiency is also known as a branching ratio or emission probability and refers to how often an isotope will actually undergo gamma emission. Detector efficiency is the intrinsic efficiency of a detector or the percentage of gamma emissions that are recorded for a given isotope. For example, if there were 10 gamma decays of ^{210}Pb over some time period and the detector had an intrinsic efficiency of 10% at 46.5 keV, the detector would only record 1 count over that time period. Finally, there is sample efficiency which refers to the sample matrix. A decay photon must actually make it to the detector crystal to be counted. Its path toward the crystal can vary significantly depending on the density of a soil and the photons energy level. A high density soil will attenuate more gammas than a low density soil. However, as a photon energy level increases its ability to penetrate obstructions increases such that an emission at 662 keV will easily penetrate a sample of soil regardless of density.

I ran efficiency calibrations for three days. Due to the number of samples and time consuming nature of efficiency calibrations, I grouped suites of samples into specific geometries based on absorption checks. I ran absorption checks by placing a multinuclide, gamma emission source on top of a packed sample and allowing the sample to run for two minutes. I found a rough estimate of efficiencies by calculating the difference between the observed activity of the sample and the known activity of the radioactive source placed atop the soil sample. I sorted samples by 241Am (60 keV) counts then grouped them into geometries such that the variation in absorption check efficiency was within roughly 1 %. Isotopes with low energy emissions such as ^{210}Pb (46.5 keV) showed decreasing efficiency with increasing sample mass. ^{137}Cs (662 keV) showed a near horizontal line indicating little to no efficiency variation resulting from sample efficiency.

I ran background checks biweekly to subtract background activity from spectra and to assure that there was no detector contamination. I performed background checks for 2 hours using empty detectors. I also ran calibration checks biweekly which were ran by placing a multinuclide source into the detectors and measuring spectra for 2 minutes. I used calibration checks to make sure there wasn't drift of values for FWHM, peak energy, and peak area.

EROSION CALCULATION

Several methods have been developed to calculate erosion rate based on change in inventory of ^{137}Cs for cultivated and uncultivated sites including empirical models, theoretical models, and models of varying complexity (Walling and He, 1999a). At the time of this study I am unaware of any application of these methods to terrain as rugged as the SGM and as such I will not be using an empirical model. For this study I will be using a theoretical model known as the profile distribution model for uncultivated soils (Zhang et al.,1990; Walling and Quine, 1990; Yang et al., 1998; Porto et al., 2001) to quantify soil transport at MFA, SS, CG, and BRC. The profile distribution model is an accepted model (Walling and He, 1999a) which compares the inventory of a reference pit to the inventory of other pits while accounting for the relatively high activity of surface soil due to initial distribution of fallout.

As demonstrated by (Walling and He, 1999a) the activity depth profile is exponential, as given by:

$$\mathrm{A(x)} = \mathrm{A(0)} * \mathrm{e}^{\left(-\frac{\mathrm{x}}{\mathrm{h_o}}\right)} \tag{1}$$

where x denotes mass depth (kg/m^2), A(x) denotes the concentration of ^{137}Cs at depth x (Bq/kg), A(0) denotes the concentration of ^{137}Cs in the surface soil (Bq/kg), and h_o denotes the relaxation depth describing the profile shape
Annual soil loss, Y (tonnes/ha/yr) is given by:

$$Y = \left(\frac{10}{t-1963}\right) * h_0 * \ln\left[1 - \left(\frac{X}{100}\right)\right] \tag{2}$$

where t denotes year of sample collection and X denotes the percentage reduction in ^{137}Cs inventory relative to local reference value. I converted soil loss in tonnes per hectare per year to mm/yr using a representative soil density value of 1.6 g/cm^3.

The value of the relaxation depth, h_o was found as follows. The first step was to plot the natural log of A(X) vs. mass depth for each pit. The second step was to fit a line to the data. From the equation for this line (3) it can be seen that the slope (m) is equal to -1/h_o (4) and h_o is equal to -1/slope (5).

$$\ln[\mathrm{A(x)}] = -\frac{\mathrm{x}}{\mathrm{h_o}} + \ln\left[\mathrm{A(0)}\right] \tag{3}$$

$$m = \left(-\frac{x}{h_o}\right) \tag{4}$$

$$h_o = \left(-\frac{1}{m}\right) \tag{5}$$

The values for h_o and X are listed in Table 1.These values can be used to calculate soil loss (Y) in equation (2) (results listed in Table 1).

GIS MAPS

I smoothed 1 m digital elevation models (DEMs) for SS, MFA, BRC and BT and a 1/3 Arc Second NED for CG by averaging over a three cell radius. These smoothed DEMS were then used to create maps of local curvature resampled using cubic convolution. Sample locations are registered on the DEM maps using GPS coordinates taken in the field. I created 3D renderings by draping a hillshade map and/or curvature map over the DEM.

RESULTS AND DISCUSSION

SULFUR SPRINGS

The objective at SS and MFA is to answer the question, "Is there a process transition between high and low gradient slopes observable with short-lived isotopes?" I will answer this question by observing any notable differences in profile shape, surface activity, and erosion rate between pits 1 through 3 with slopes < 30 degrees and the pits 4 and 5 with slopes > 30 degrees (Figure 2 and Figure 3). The size fractions and sample packed weight can be found in Table 2 and the activities can be found in Table 3. I will examine profile shapes first.

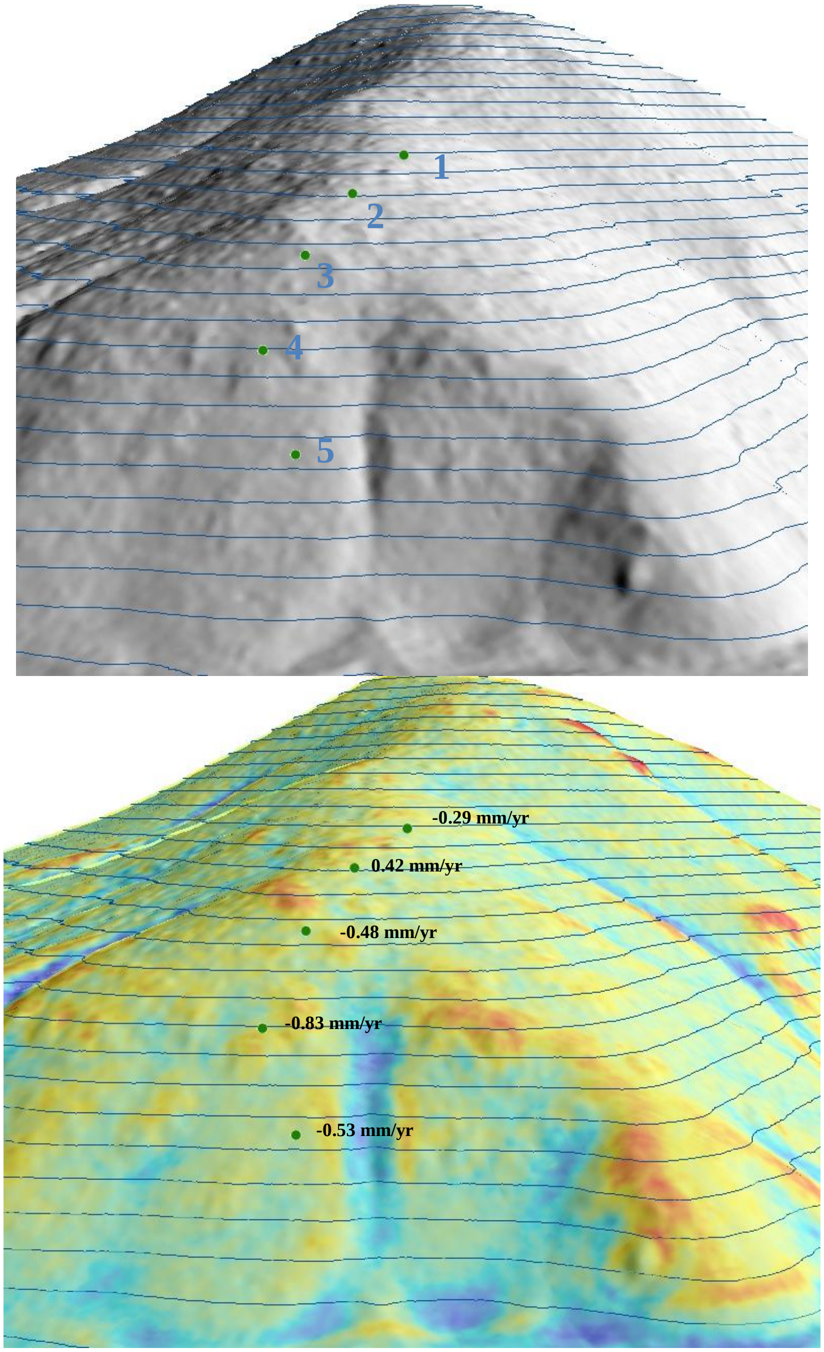


Figure 2. SS - Hillshade Pit Locations, Curvature, and Erosion Rates. The top image is a hillshade made from 1 m DEM looking south illustrating the locations of SS-1 through SS-5 labeled here as 1, 2, 3, etc. This image allows the reader to visualize the transect. The lower image is a curvature map draped over the hillshade where reds represent convex up and blues are convex down. The curvature map is so that the reader can visualize the convexities of the area in relation to the pits and erosion rates.

SS-1

SS-2

SS-3

Figure 3. SS - Pit Images. These images document the SS pits as well as their upslope area. A 12" orange ruler is given for scale. These images allow the reader to more easily visualize the field site.

SS-4

SS-5

Figure 3 continued.

The ^{137}Cs profiles (Figure 4 and Figure 5) are exponential. The ^{210}Pb profiles (Figure 4 and Figure 6) are exponential for SS-1 and SS-2, have a subsurface peak at 6-8 cm for SS-3, are linear for SS-4, and are exponential with subsurface peak at 6-8 cm for SS-5. The ^{210}Pb activities do not reach zero with depth, nor do individual pits activities approach a particular activity, indicating the ^{210}Pb in-situ signal is varying from pit to pit. To account for the in-situ ^{210}Pb I took the lowest activity level from each pit and subtracted it from the other activities from that particular pit creating a rough estimation of the excess ^{210}Pb signal (Figure 7).

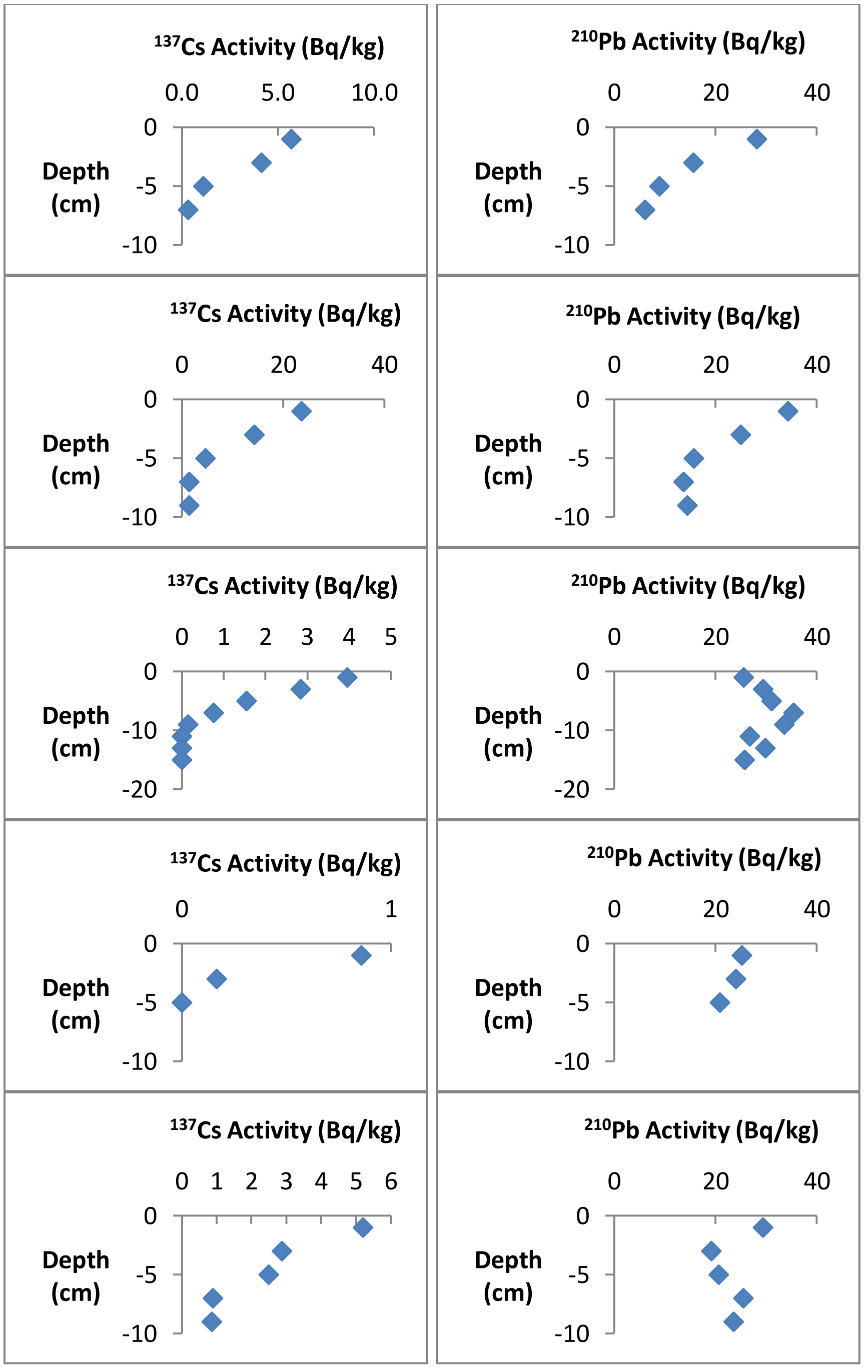


Figure 4. SS - Individual ^{137}Cs and ^{210}Pb Profiles. This image shows the profile shapes of the SS pits. Axes are not on same scale so that profile shape is more clear. The left column is the ^{137}Cs profiles and the right column is the ^{210}Pb profiles. Each row is a new pit starting with SS-1 at the top.

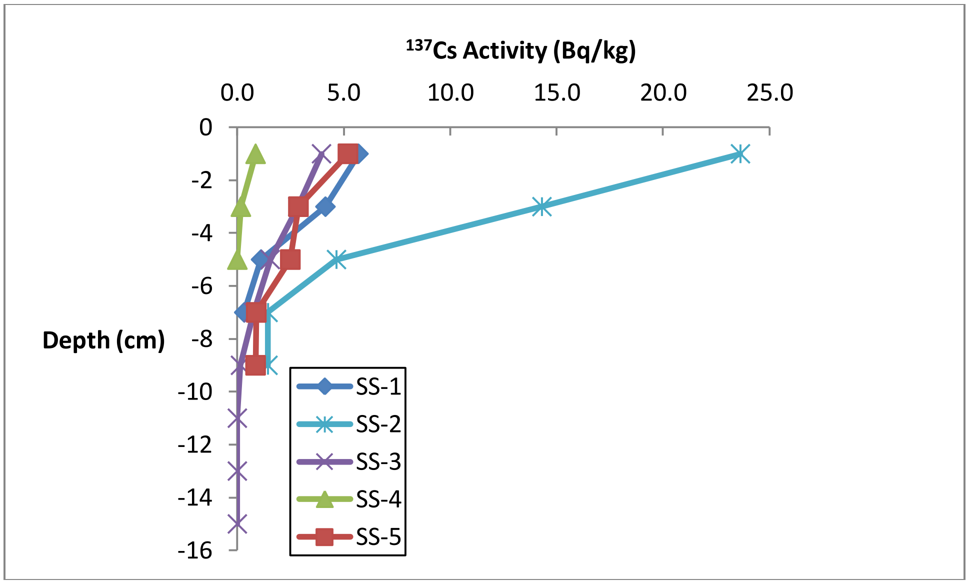


Figure 5. SS - Group ^{137}Cs Profiles. The ^{137}Cs activities vs. depth for all five SS pits. SS-1 through SS-3 are in the low gradient zone and SS-4 and SS-5 are in the high gradient zone. SS-1, SS-3, and SS-5 have similar activity and shape. SS-2 has significantly higher activity and SS-4 has significantly lower activity.

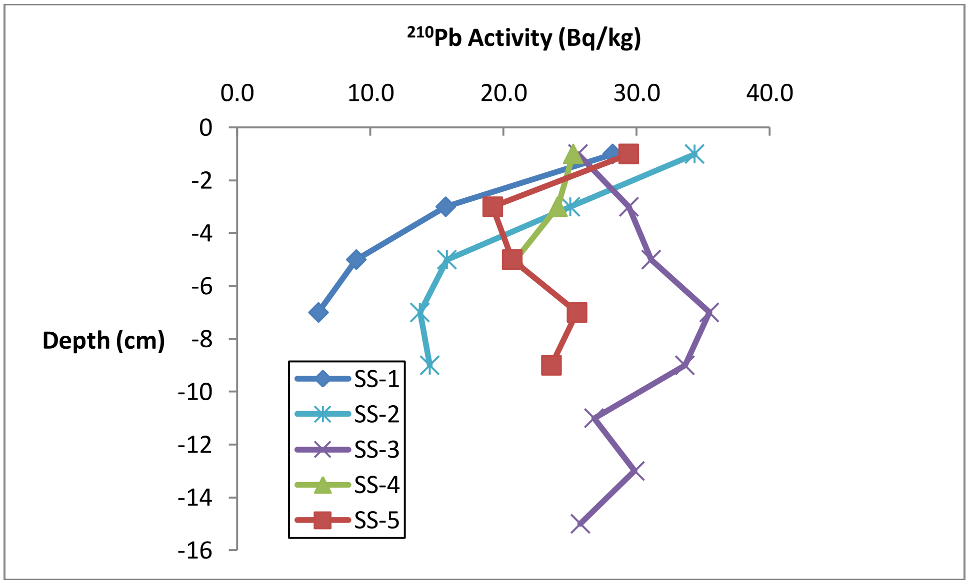


Figure 6. SS - Group ^{210}Pb Profiles. The ^{210}Pb activities vs. depth for all five SS pits. SS-1 through SS-3 are in the low gradient zone and SS-4 and SS-5 are in the high gradient zone. There is no clear pattern between the activities and profile shapes of the low gradient and high gradient pits.

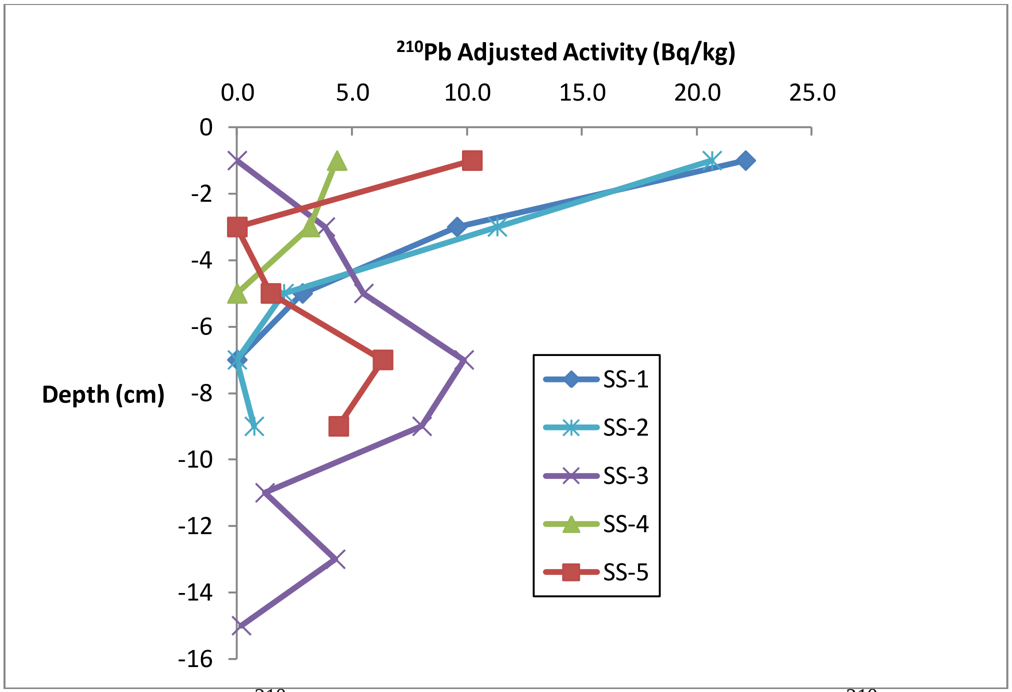


Figure 7. SS - Group ^{210}Pb Adjusted Profiles. This graph illustrates ^{210}Pb activity vs. depth adjusted for in-situ ^{210}Pb by subtracting the lowest activity for a given pit from all other activities for that pit. This assumes, that the lowest activity represents the in-situ ^{210}Pb signal for that pit.

From these observations I interpret there to be no remarkable difference in profile shape between the low gradient pits and the high gradient pits for ^{137}Cs. Despite adjusting for in-situ ^{210}Pb, there is no pattern between ^{210}Pb profile shapes for high gradient vs. low gradient slopes. Next, I will examine the surface activity levels of ^{137}Cs and ^{210}Pb and determine any notable difference between low gradient and high gradient pits.

^{137}Cs activity levels for the low gradient pits, SS-1 and SS-3 are nearly identical to activity levels for the high gradient SS-5. The activity levels of the low gradient SS-2 are significantly higher than all other pits. The activity levels of the high gradient SS-4 are notably lower than the other pits. The adjusted ^{210}Pb activities show higher surface activity levels for SS-1 and SS-2 and lower surface activities for SS-3, 4, and 5.

These observations indicate ^{137}Cs is not able to identify any process change occurring between high gradient and low gradient slope affecting the activity levels of all locations because the high slope SS-5 has similar ^{137}Cs activity levels to the low slope SS-1 and SS-3. However, there may be individual examples of process variation related to gradient given the uniquely high ^{137}Cs activity of the low gradient SS-2 and the uniquely low activity of the high gradient SS-4. These two different activity levels indicate spatial variability of process affecting the soil transport rates but this variability cannot yet be linked to gradient. The ^{210}Pb activity levels are higher for the low gradient SS-1 and SS-2 but not for SS-3 which has the lowest surface activity of the pits. This evidence does not support a process transition between high and low gradient slopes. The erosion rates described below may shed some light on this.

The soil transport rates for SS (Table 4, Figure 2) indicate erosion at all pits except SS-2, which has a deposition rate of 0.42 mm/yr. SS-1 has an erosion rate of -0.29 mm/yr and SS-3 has an erosion rate of -0.48 mm/yr. The high gradient pits have erosion rates of -0.83 mm/yr and -0.53 mm/yr at SS-4 and SS-5 respectively.

From these observations, I interpret the unique deposition rate at SS-2 to be from small clumps of grass like vegetation (Figure 8). The SS-2 pit was sampled right through one of these vegetation clumps and while it is widely known that vegetation can prevent soil erosion I have quantified the actual deposition rate of sediment arrested by this vegetation clump. This deposition rate due to vegetation indicates that spatial variability of processes and vegetation may interfere with any general trends I hope to identify. The high gradient pits show higher erosion rates than the low gradient pits however, this cannot be attributed to process change from low to high gradient slope knowing that the method may be so susceptible to small scale variation such as clumps of grass. To further understand the interplay of gradient and process a larger sample set should be used to average out small scale variability. Next, I will examine the profile shapes, surface activities, and erosion rates of MFA and see if this trend of higher erosion rates on high gradient areas is also found at MFA.

Figure 8. SS-2 Vegetation. Vegetation clumps are abundant in this area and my pit was dug through one of these vegetation clumps. Fallout erosion data supports that vegetation clumps are preventing soil erosion and even causing deposition presumably by arresting sediment transported from uphill.

MIDDLE FORK OF ALDER

I took samples from 6 pits at MFA (Figure 9 and Figure 10). The size fractions and packed weights are in Table 5. MFA-1 through MFA-4 have slopes < 30 degrees, while MFA-5 and 6 have slopes > 30 degrees (Table 4). The ^{137}Cs profiles (Table 5, Figure 11 and Figure 12) vary in shape. MFA-1 has a small subsurface peak at 2-4 cm, MFA-2, 3 and 4 are exponential, MFA-5 has a subsurface peak at 2-4 cm, and MFA-6 has a subsurface peak at 10-12 cm. The ^{210}Pb profile shapes are all exponential (Figure 11 and Figure 13).

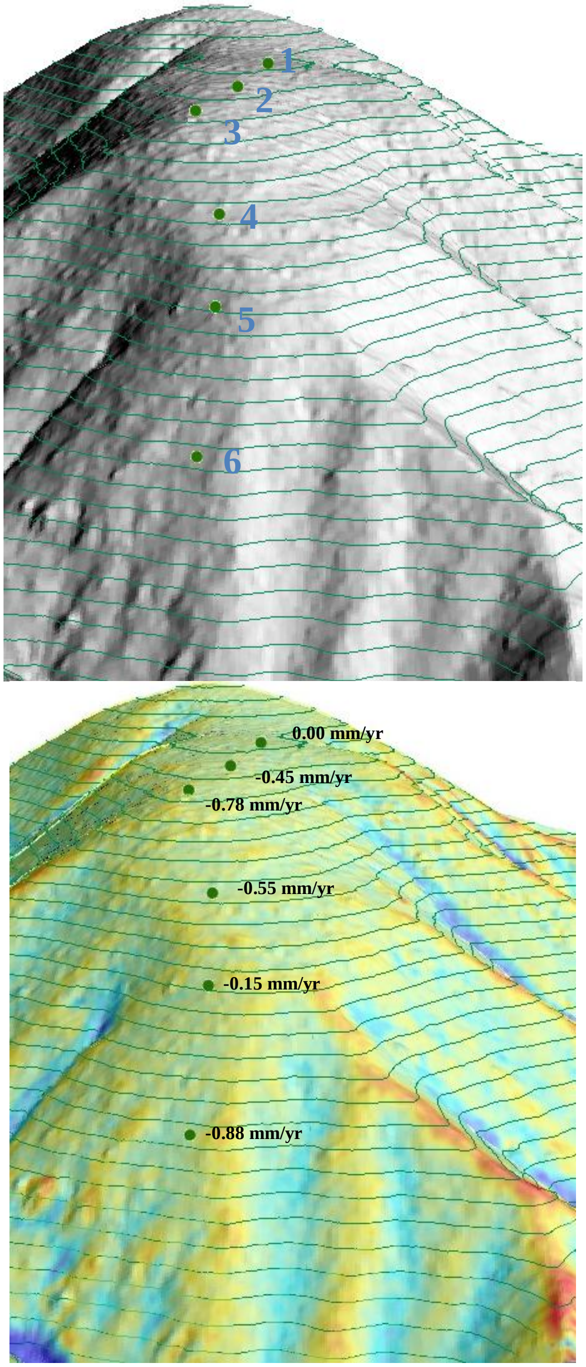
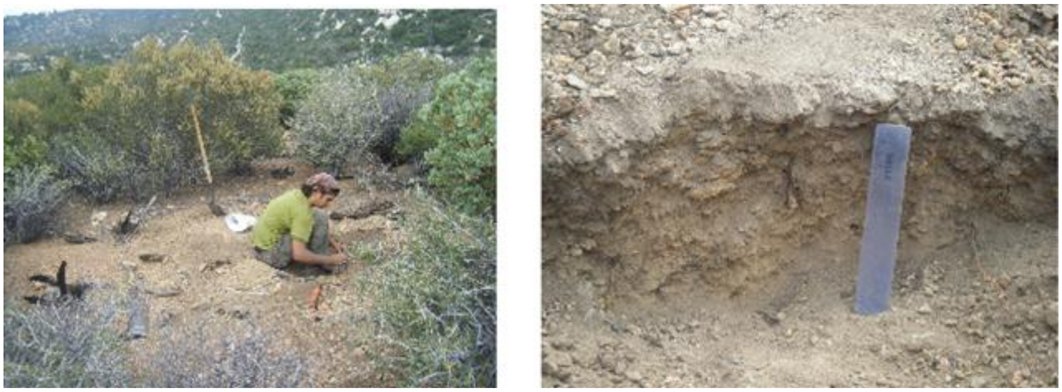


Figure 9. MFA - Hillshade Pit Locations, Curvature, and Erosion Rates. The top image is a hillshade made from 1 m DEM looking south illustrating the locations of MFA-1 through MFA-6 labeled here as 1, 2, 3, etc. This image allows the reader to visualize the transect. The lower image is a curvature map draped over the hillshade where reds represent convex up and blues are convex down. The curvature map is so that the reader can visualize the convexities of the area in relation to the pits and erosion rates.

MFA-1

MFA-2



MFA-3

Figure 10. MFA - Pit Images. These images document the MFA pits as well as their upslope area. A 12" orange ruler or 6" blue ruler are given for scale. These images allow the reader to more easily visualize the field site.

MFA-4

MFA-5

MFA-6

Figure 10 continued.

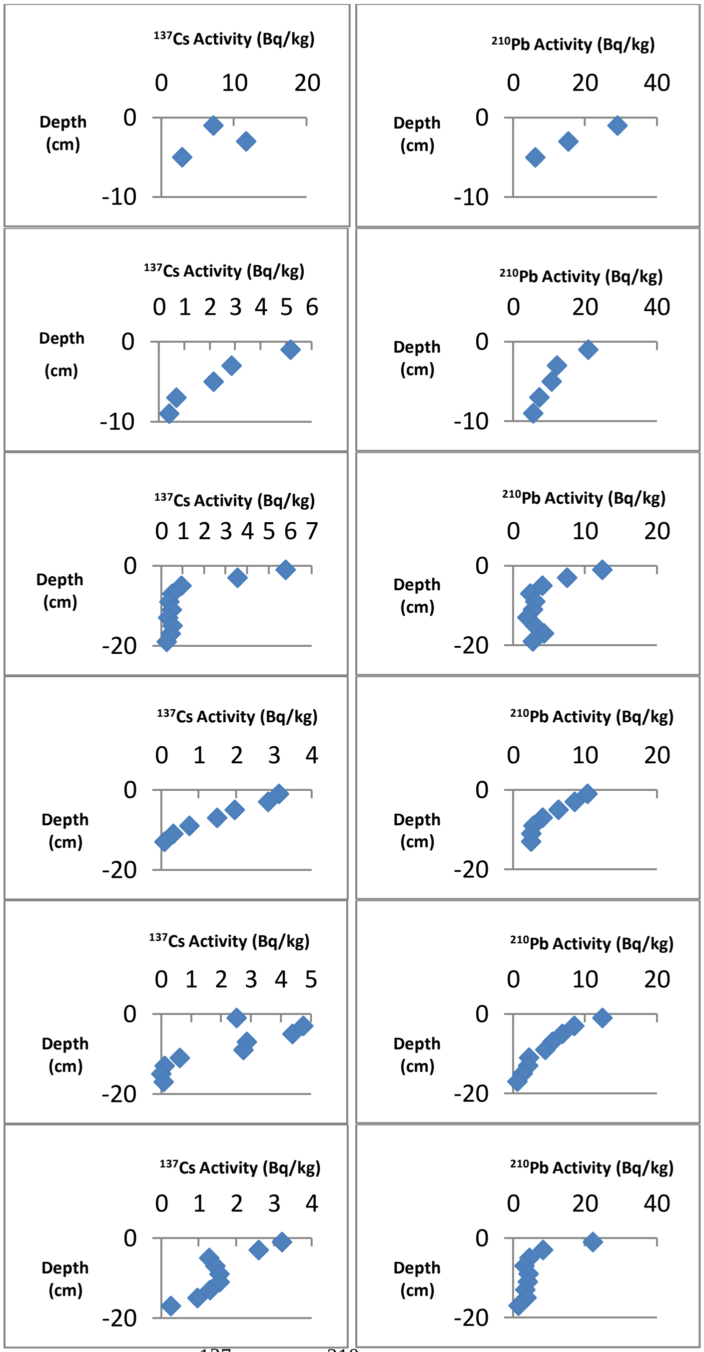


Figure 11. MFA - Individual ^{137}Cs and ^{210}Pb Profiles. This image shows the profile shapes of the MFA pits. Axes are not on same scale so that profile shape is more clear. The left column is the ^{137}Cs profiles and the right column is the ^{210}Pb profiles. Each row is a new pit starting with MFA-1 at the top.

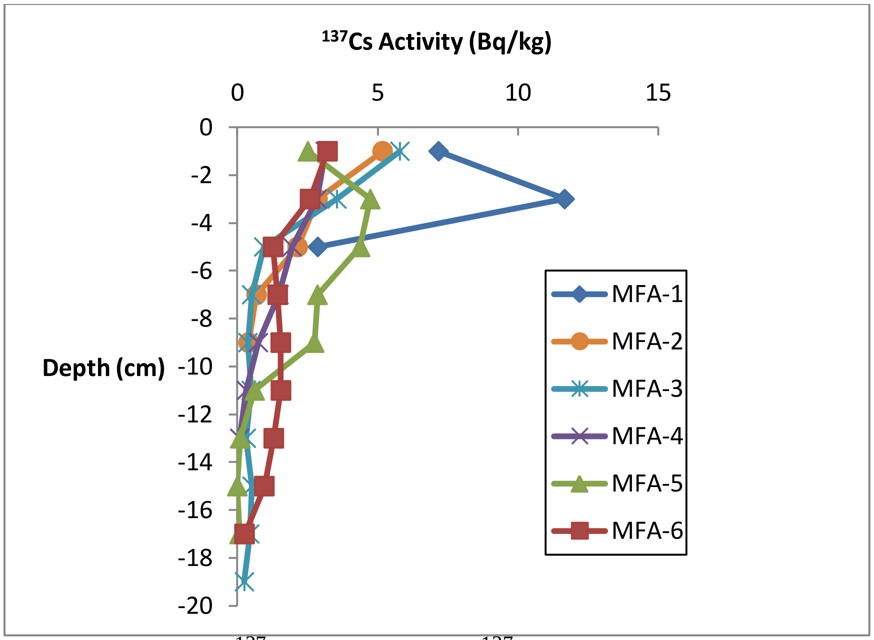


Figure 12. MFA - Group ^{137}Cs Profiles. The ^{137}Cs activities vs. depth for all six MFA pits. MFA-1 through MFA-4 are in the low gradient zone and MFA-5 and MFA-6 are in the high gradient zone. There is no clear pattern between activities or profile shapes of low gradient and high gradient pits.

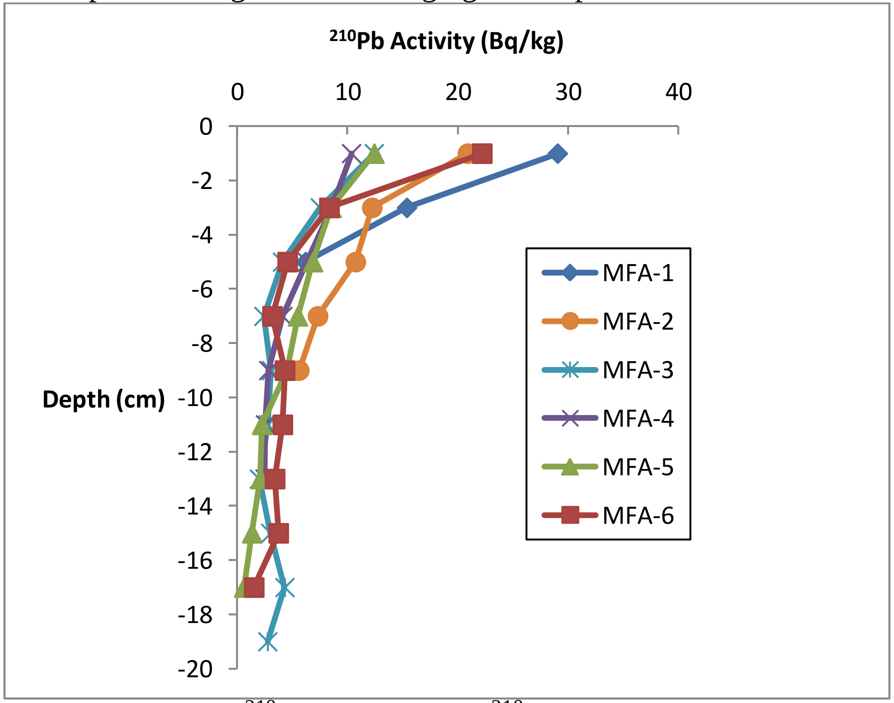


Figure 13. MFA - Group ^{210}Pb Profiles. The ^{210}Pb activities vs. depth for all six MFA pits. MFA-1 through MFA-4 are in the low gradient zone and MFA-5 and MFA-6 are in the high gradient zone. There is no clear pattern between activities or profile shapes of low gradient and high gradient pits.

From these observations there is no distinct process change identified by ^{137}Cs and ^{210}Pb between the low gradient and high gradient pits. The ^{137}Cs profiles indicate subsurface peaks above and below the slope break indicating a process not unique to high or low gradient slopes. The ^{210}Pb profiles all have similar shape also indicating a lack of process change. Next, I will evaluate surface activities for any evidence of process change.

I observe that the ^{137}Cs surface activities for MFA-1, 2 and 3 are higher than the surface activities for MFA-4, 5 and 6. For the ^{210}Pb surface activities, MFA-1 has the highest activity, followed by MFA-6, MFA-2, MFA-3 and 5, and finally MFA-4 with the lowest surface activity. I interpret there to be no distinct difference in processes shown by ^{137}Cs as MFA-4 is above the slope break and has similar activity to MFA-6 which is below the slope break. I interpret that there is no distinct difference in processes shown by the ^{137}Cs data. Similarly, the ^{210}Pb data shows MFA-6, a high gradient pit, having higher activity than MFA-2 through 4, low gradient pits, indicating no clear trend. Perhaps a trend will present itself in the erosion rates.

There is no erosion or deposition at MFA-1 (Table 4, Figure 9). MFA-2 has an erosion rate of -0.45 mm/yr, MFA-3 has an erosion rate of -0.78 mm/yr, MFA-4 is eroding at -0.55 mm/yr, MFA-5 is eroding at -0.15 mm/yr, and MFA-6 is eroding at -0.88 mm/yr. These observations indicate the highest erosion rate is at MFA-6 in the high gradient zone. MFA-5 is also in the high gradient zone but has the second lowest erosion rate after the reference pit. It should also be noted that erosion rates increase with slope and distance from the divide for MFA-1 to MFA-3.

The data from SS hinted that the high gradient slopes may have more erosion than the low gradient slopes but the data from MFA is inconclusive. The highest erosion rate for the transect corresponds to the pit with the steepest slope. This supports the idea that the high gradient zone has more erosion however, contrary to the idea, the second steepest slope has the second lowest erosion rate. The data also shows the second highest erosion rate is located in the low gradient zone. As shown at SS-2, it is possible that small-scale variability can be the dominating signal at these pits. While I was unable to identify any particular reason for the low erosion rate at MFA-5 or the high erosion rate at MFA-3, the possibility remains that there is a small-scale process dominating the soil transport signal and overriding a general process change. It seems that the linear transects from SS and MFA are not enough to accurately identify a transport process change from low gradient to high gradient slopes and thus, my hypothesis has yet to be adequately disproved. To better constrain this question high density grid sampling should be used so that small scale variability can be averaged out, and a clearer picture of the hillside transition from low gradient to high gradient can be obtained.

CAMP GLENWOOD

The objective at Camp Glenwood is to answer the question, "Do convex hilltops reflect short-term equilibrium erosion rates?" I sampled 8 pits at CG (Figure 14 and Figure 15). Size fractions and packed weight are in Table 7 and activities are in Table 8. I sampled pits 1-4 within a linear stretch of 10 m from the crest of the ridge and I used a laser rangefinder survey to capture the curvature of this top (Figure 16). I sampled pits 5-8 further down the hillslope. I made an attempt to keep the transect linear however, obstacles such as torrs, lack of soil mantle, or vegetation cover necessitated diversion of the transect.

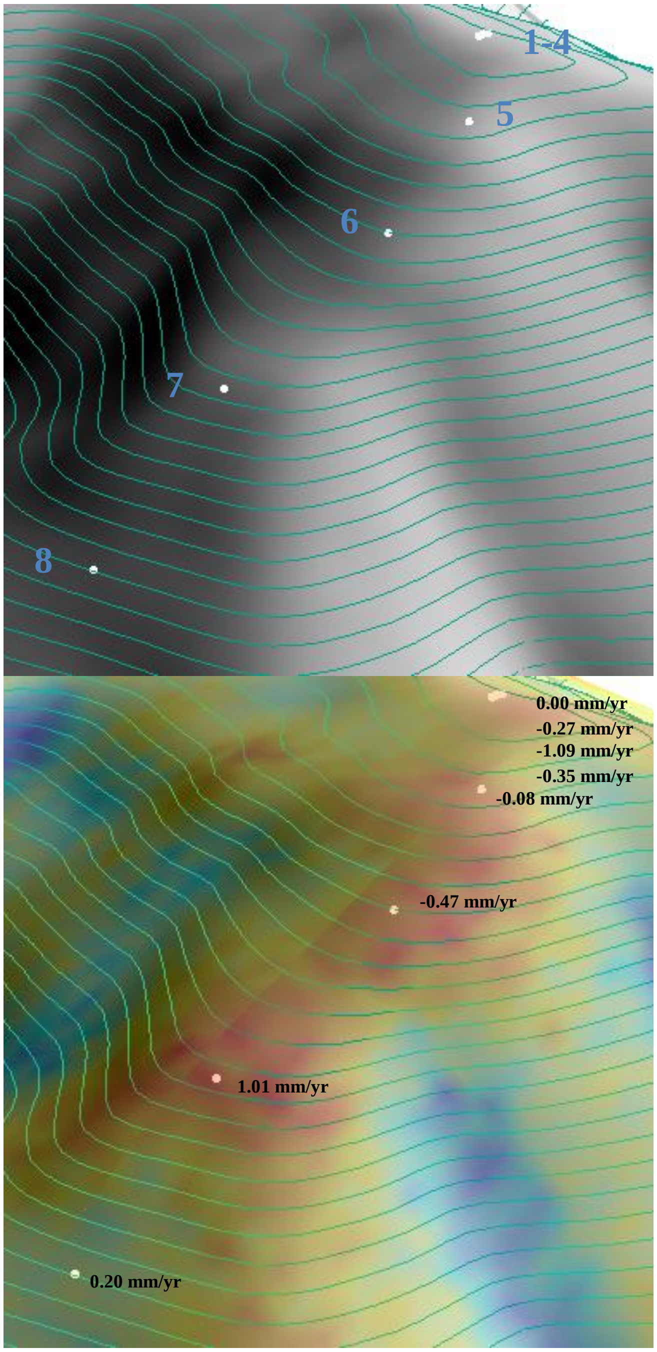


Figure 14. CG - Hillshade Pit Locations, Curvature, and Erosion Rates. The top image is a hillshade made from 1/3 Arc Second NED looking southwest illustrating the locations of CG-1 through CG-8 labeled here as 1, 2, 3, etc. This image allows the reader to visualize the transect. The lower image is a curvature map draped over the hillshade where reds represent convex up and blues are convex down. The curvature map is so that the reader can visualize the convexities of the area in relation to the pits and erosion rates.

CG-1

CG-2

CG-3

CG-4

Figure 15. CG - Pit Images. These images document the CG pits as well as their upslope area. A 12" orange ruler is given for scale. These images allow the reader to more easily visualize the field site.

CG-5

CG-6

CG-7

CG-8

Figure 15 continued.

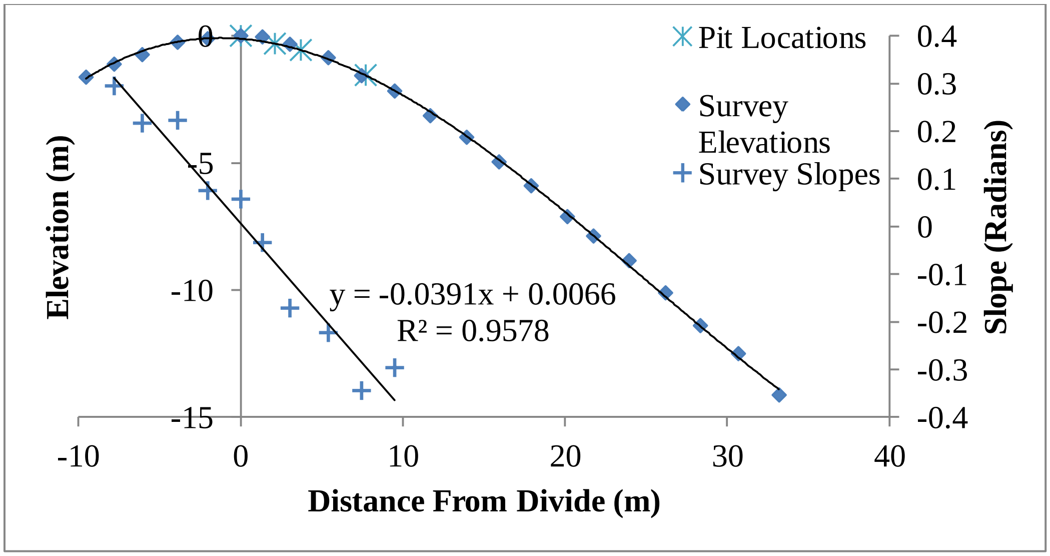


Figure 16. Rangefinder Survey. This image is the laser rangefinder data capturing the convexity of the CG ridge. Blue asterisks indicate pit localities for CG-1 ,2, 3 and 4. Blue diamonds represent survey points. Blue plus signs indicate slope in radians. Note the convex top of the profile. Camp Glenwood erosion rates increase away from the ridge until the zone of semi-planar slope. Thus, erosion rates are not at equilibrium on the convex top.

The erosion rates of the upper 4 pits are not equal (Table 4, Figure 14) indicating that my hypothesis is incorrect. The erosion rates increase away from the ridge with no erosion or deposition at CG-1, an erosion rate of -0.27 mm/yr at CG-2, -0.35 mm/yr at CG-3, and -1.09 mm/yr at CG-4. There is a deposition rate of -0.08 mm/yr at CG-6, an erosion rate of -0.47 mm/yr at CG-6, a deposition rate of 1.01 mm/yr at CG-7 and a deposition rate of 0.20 mm/yr at CG-8.

The 10 m from the ridge crest is convex (Figure 16). The first four pits are located on this convex top. Along this stretch, erosion rates increase with slope and distance from divide. From this data, I interpret that short-term equilibrium rates do not exist on this convex up hilltop. Possible explanations include: spatial variability of processes interfering with longer term erosional signal as seen at SS, disequilibrium in erosion rates from the rates that formed the convex top, and dynamic equilibrium where the long-term rates are in equilibrium and the short-term rates are dynamically changing. I will examine these ideas with the additional data below.

The profile shape data for ^{137}Cs (Figure 17 and Figure 19) indicate shallow subsurface peaks for CG-1, 3, 5, 6, 7, and 8 and deeper subsurface bulges for CG-1, 3, 4, and 8. I adjusted the ^{210}Pb data (Figure 18 and Figure 20) for in-situ ^{210}Pb by subtracting the lowest activity of a pit from all the activities of that pit (Figure 21). Figures 17, 18, and 19 indicate shallow subsurface peaks at CG-1, 3, 7, and 8 and deeper subsurface bulges at CG-1, 2, 3, 4, 6, 7, and 8.

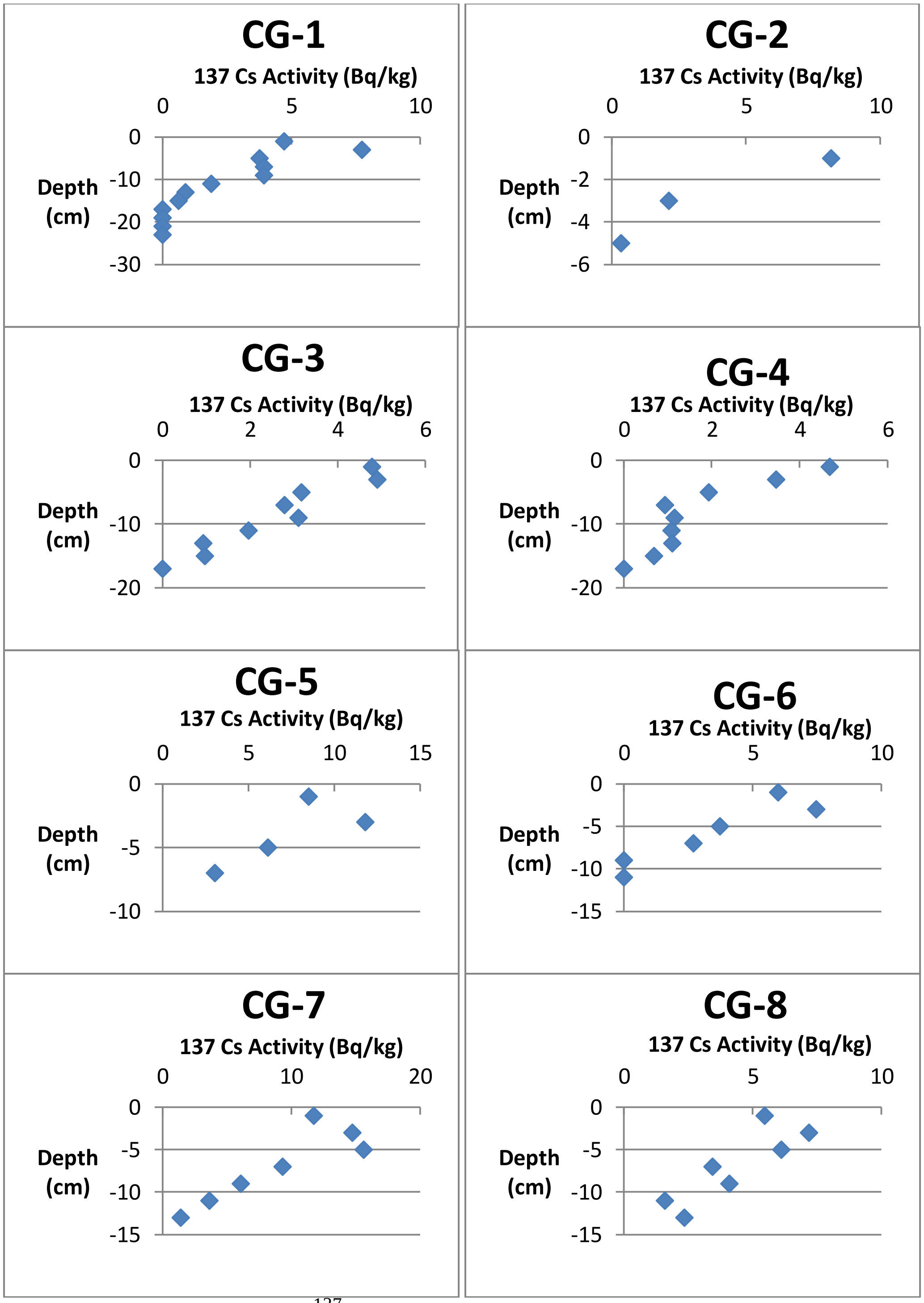


Figure 17. CG - Individual ^{137}Cs Profiles. This image shows the profile shapes of the CG pits. Axes are not on same scale so that profile shape is more clear.

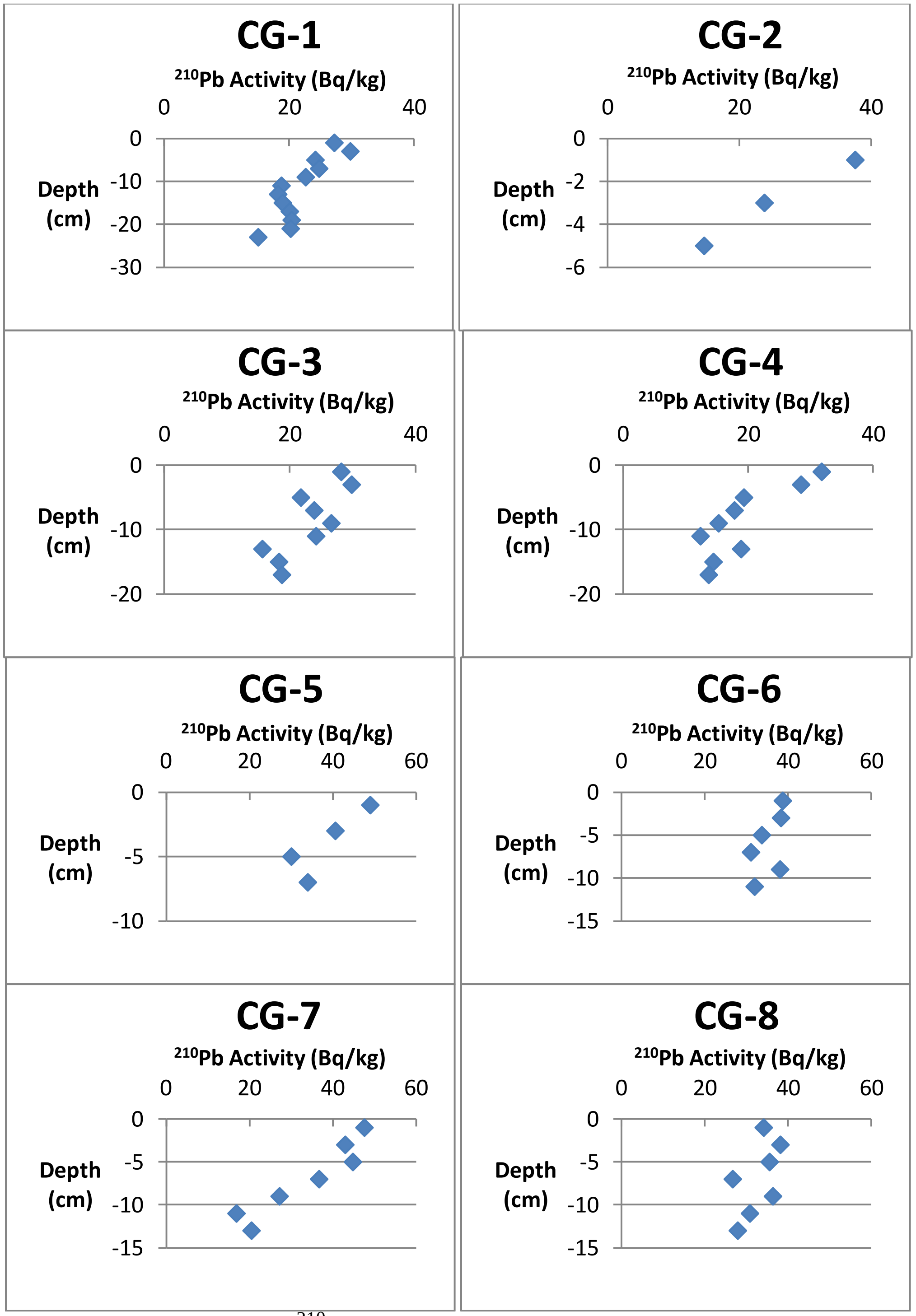


Figure 18. CG - Individual ^{210}Pb Profiles. This image shows the profile shapes of the CG pits. Axes are not on same scale so that profile shape is more clear.

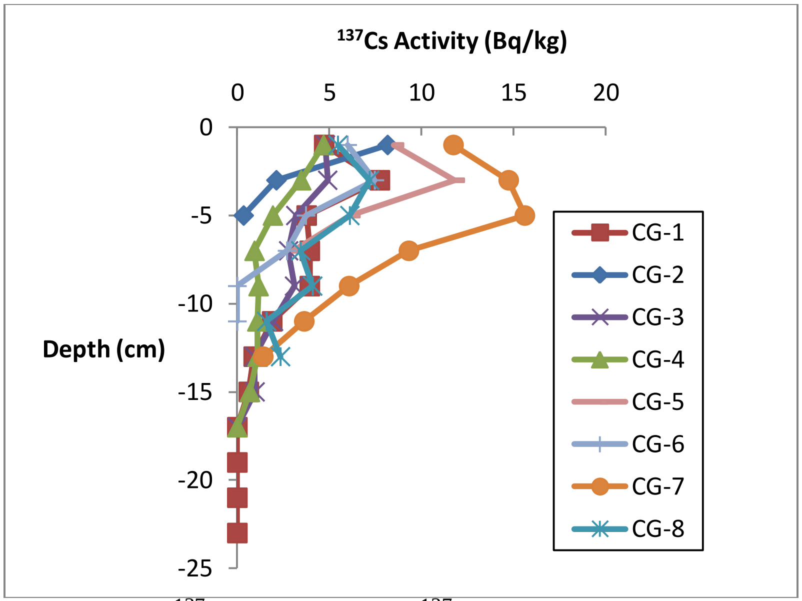


Figure 19. CG - Group ^{137}Cs Profiles. The ^{137}Cs activities vs. depth for all eight CG pits. Profile shapes here have shallow and deep subsurface peaks which are not as dominant at SS or MFA. Possible reasons for the subsurface peaks include preferential erosion of fines, bioturbation, or leaching of fines indicating different dominant processes than at previous sites.

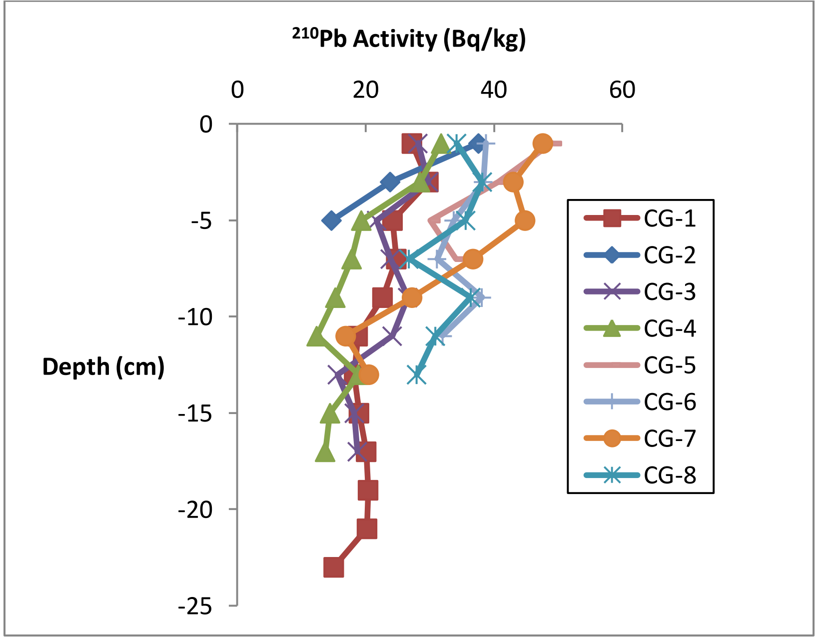


Figure 20. CG - Group ^{210}Pb Profiles. The ^{210}Pb activities vs. depth for all eight CG pits. Profile shapes here have shallow and deep subsurface peaks which are not as dominant at SS or MFA. Possible reasons for the subsurface peaks include preferential erosion of fines, bioturbation, or leaching of fines indicating different dominant processes than at previous sites.

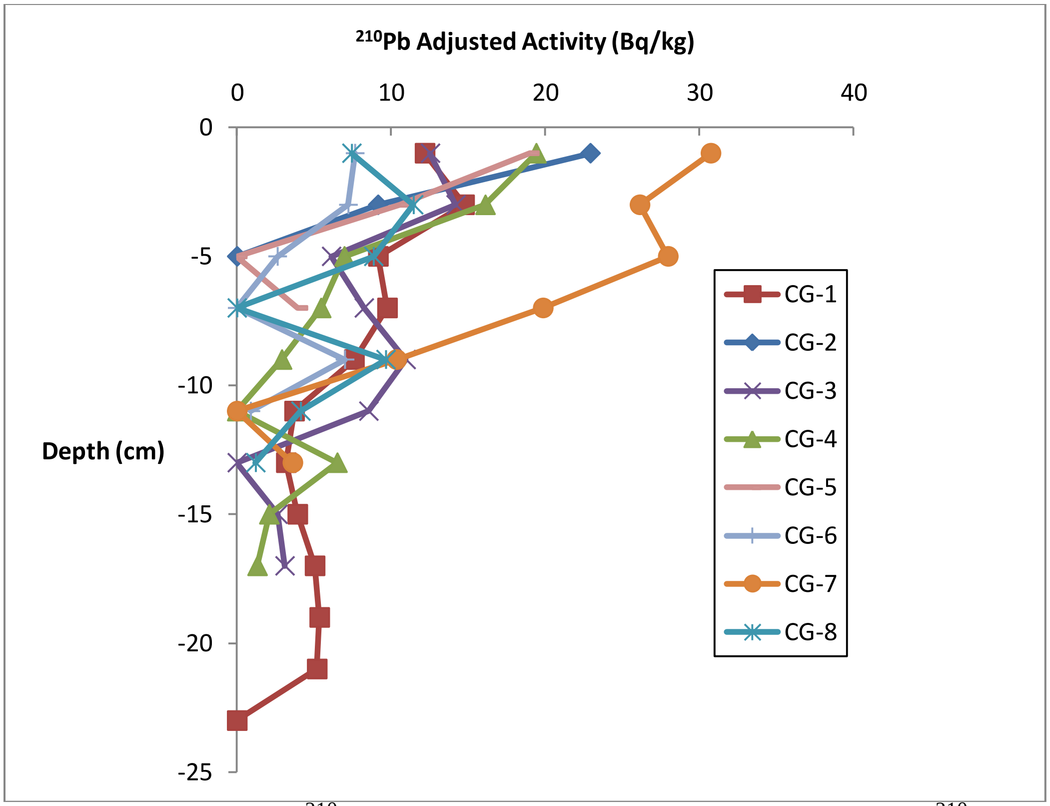


Figure 21. CG - Group ^{210}Pb Adjusted Profiles. This image is a graph of ^{210}Pb activity vs. depth adjusted for in-situ ^{210}Pb by subtracting the lowest activity for a given pit from all other activities for that pit. This assumes, that the lowest activity represents the in-situ ^{210}Pb signal for that pit. Profiles still show shallow and deep subsurface peaks.

These observations indicate processes dominating CG which were not as active or present at MFA and SS. Possible explanations for the shallow subsurface peak include, deposition of depleted material on the surface, downward migration of activity through the profile, and overland erosion depleting surface activity. I believe the reason for these subsurface peaks is a combination of all these factors. There is evidence of active bioturbation in the area from the presence of burrow holes at CG-4 (Figure 15). As these creatures burrow into the ground, highly active surface material can be brought to depth while depleted material is thrown toward the surface creating a shallow subsurface peak and a deeper activity bulge.

I also believe that overland processes are preferentially eroding fines from the surface. There is minimal surface vegetation at CG which means that fine particles can easily be washed or blown away and fine particles as shown by (He and Walling, 1995), carry the majority of activity. To confirm that the majority of activity at CG is in the finer particles I sieved a test sample from CG-6 0-2 cm, and 2-4 cm into a <250um size fraction and a size fraction between 250um and 2 mm. The packed weight of these samples is in Table 9. The fine particles at CG contain most of the activity as seen in Table 10. The depletion of fines is supported by the data from the <2 mm fractions (Table 7) where at CG the < 2 mm faction tends to increase from 0-2 cm to 0-4 cm, while at SS (Table 2) and MFA (Table 5) the <2 mm fraction tends to decrease from 0-2 cm to 0-4 cm. This indicates a loss of the <2 mm fraction at the surface of CG. It should also be mentioned that a mechanism for surface fines depletion is leaching of the fines downward. Fines <250um may be working their way down through the coarser fragments of soil subsequently bringing activity to depth.

These processes indicate spatial as well as temporal variability because these processes aren't occurring at every pit and the burrowers aren't burrowing at all times. Thus, spatial variability may be one reason for the lack of equilibrium in erosion rates. As previously suggested, dynamic equilibrium and disequilibrium could be other reasons for the varying erosion rates. It is unknown if the processes acting on the hill today are the same long-term processes that shaped the convex top, but if they are then the hill would be in dynamic equilibrium because of the disequilibrium in short-term erosion rates but the evidence of long-term equilibrium from the convex top. If the modern processes are different than the long-term processes for example, the burrowers migrated only recently to the region, or headward incision is propagating through the hill, then the hillslope is in disequilibrium. The fact that erosion rates are increasing away from the ridge up until the planar zone may be a coincidence but is interesting and may provide a clue to a headward incision signal. More sampling of the convex / planar interface would shed light on this. Consequently, my hypothesis has not been adequately invalidated.

It also appears that larger scale topography is playing a role on the soil transport signal. Beyond 10 m from the divide, the slope transitions to an area of generally planar topography (Figure 16) with small variations in micro-topography. Further downslope, there is a large bench which can be seen in (Figure 14). I interpret the high depositional signal at CG-7 to be the result of the bench arresting sediment travelling from uphill. There is also a depositional signal at CG-8 which is located in a convex down area. Presumably sediment is accumulating in this convex down area resulting in a depositional signal. These results indicate the method is very sensitive to localized processes which could override general relationships. As suggested at SS and MFA, further study should be done using high resolution grid sampling to average out small scale variability.

BIG ROCK CREEK

The objective at Big Rock Creek is to answer the question, "Do linear transects of pits accurately characterize hillslope averaged erosion rates?" As suggested from the previous sites, spatial variability may be significantly affecting soil transport rates. By using the erosion rates of twin transects spaced 3 m apart I will be able to quantitatively show if a linear transect exhibits similar soil transport rates to other linear transects thus allowing a linear transect to characterize the average soil transport rate for a hillslope. If a linear transect exhibits varying erosion rates from the other proximal linear transect it will indicate the necessity for grid sampling to characterize hillslope averaged erosion rates.

The two transects are labeled BRC-A and BRC-B. BRC-A is on the left, looking upslope, and BRC-B is on the right looking upslope. There are 6 pits in BRC-A and 3 pits in BRC-B (Figure 22 and Figure 23). The mass fractions and packed sample mass can be found in Table 11 and the isotope activities and their errors are in Table 12. ^{137}Cs profiles are displayed in Figures 24, 24, 26 and 27. ^{210}Pb profiles are displayed in Figures 24, 25, 28, and 29.

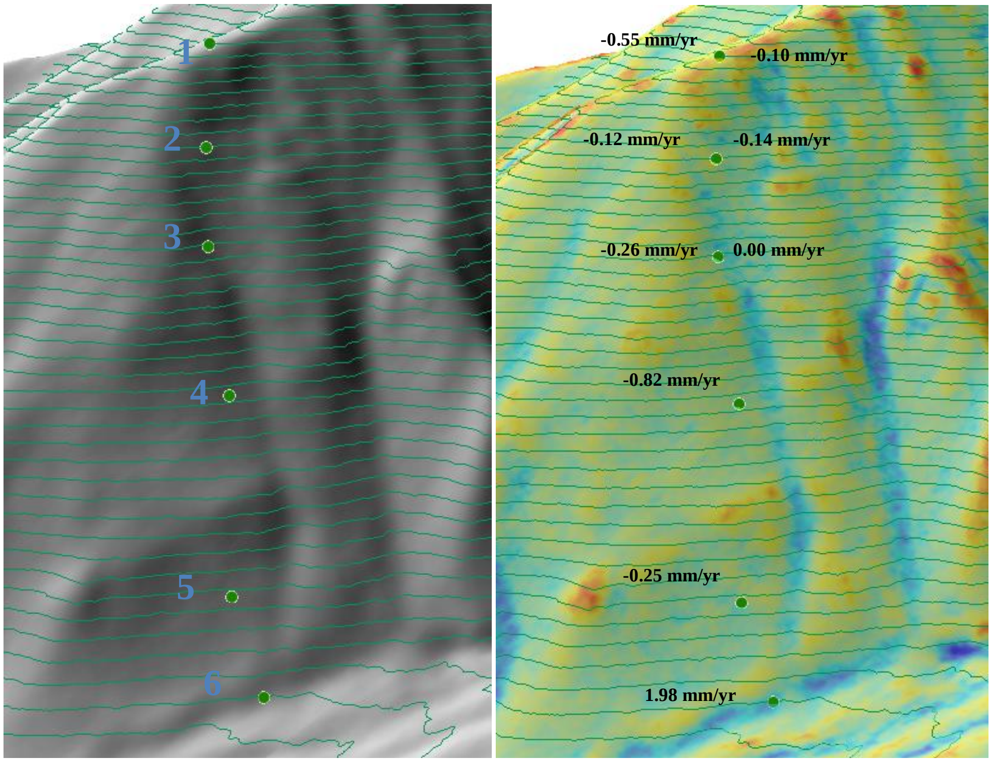


Figure 22. BRC - Hillshade Pit Locations, Curvature, and Erosion Rates. The left image is a hillshade made from 1 m DEM looking southeast illustrating the locations of BRC-1 through BRC-6 labeled here as 1, 2, 3, etc. This image allows the reader to visualize the transect. The right image is a curvature map draped over the hillshade where reds represent convex up and blues are convex down. The curvature map is so that the reader can visualize the convexities of the area in relation to the pits and erosion rates. Erosion rates on the left represent the BRC-A transect and the rates on the right are the BRC-B transect.

BRC-0A

BRC-0B

BRC-1A

BRC-1B

Figure 23. BRC - Pit Images. These images document the BRC pits as well as their upslope area. A 12" orange or 12" silver ruler are given for scale. These images allow the reader to more easily visualize the field site.

BRC-2A

BRC-2B

BRC-3A

BRC-3B

Figure 23 continued.

BRC-4A

BRC-5A

BRC-6A

Figure 23 continued.

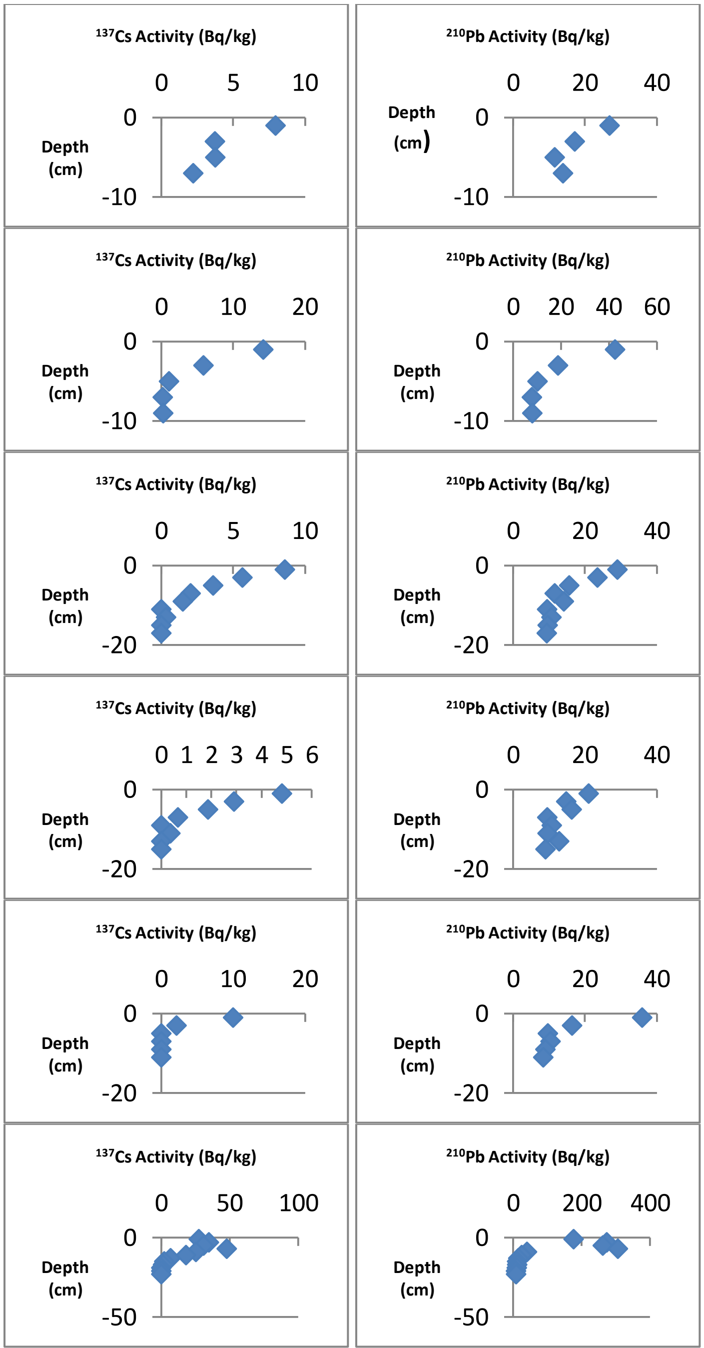


Figure 24. BRC-A - Individual ^{137}Cs and ^{210}Pb Profiles. This image shows the profile shapes of the BRC-A pits. Each row is another pit with BRC-1A at the top and BRC-6A at the bottom. The left row is ^{137}Cs profiles and the right row is ^{210}Pb profiles. Axes are not on same scale so that profile shape is more clear.

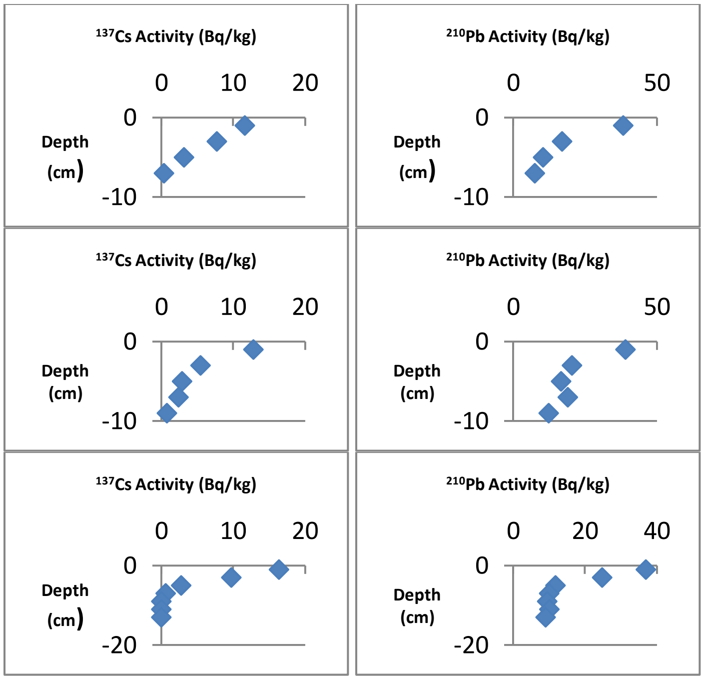


Figure 25. BRC-B - Individual ^{137}Cs and ^{210}Pb Profiles. This image shows the profile shapes of the BRC-A pits. Each row is another pit with BRC-1B at the top and BRC-3B at the bottom. The left row is ^{137}Cs profiles and the right row is ^{210}Pb profiles. Axes are not on same scale so that profile shape is more clear.

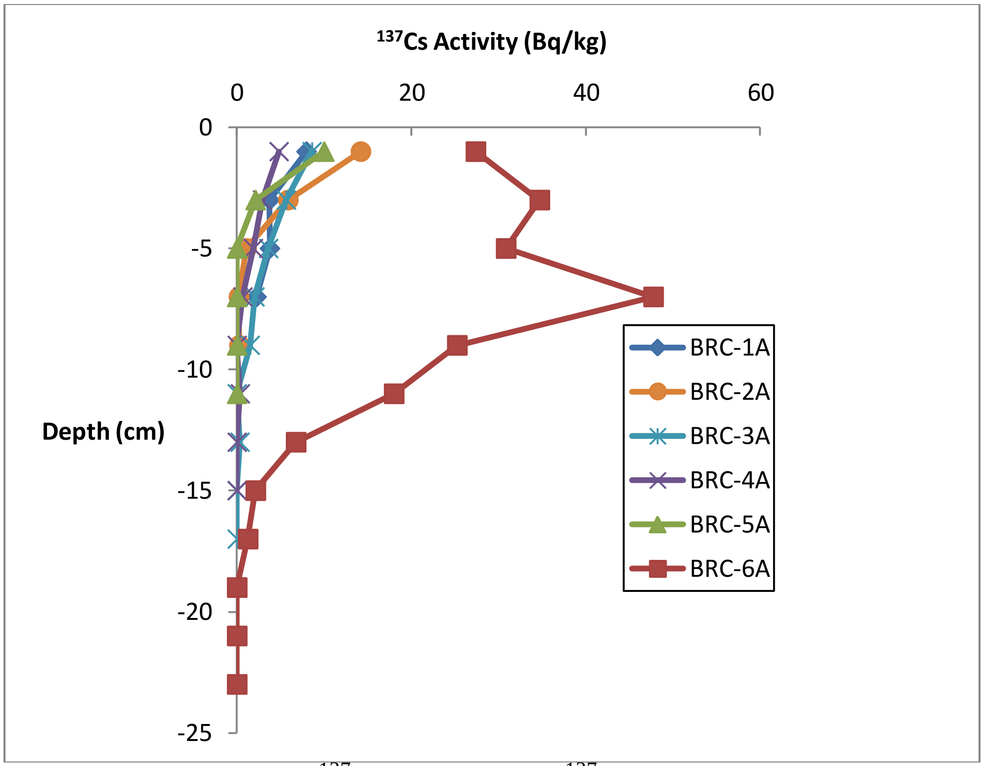


Figure 26. BRC-A - Group ^{137}Cs Profiles. The ^{137}Cs activities vs. depth for all six BRC-A pits. Profile shapes are exponential for BRC-1A through 5A but subsurface peak for 6A.

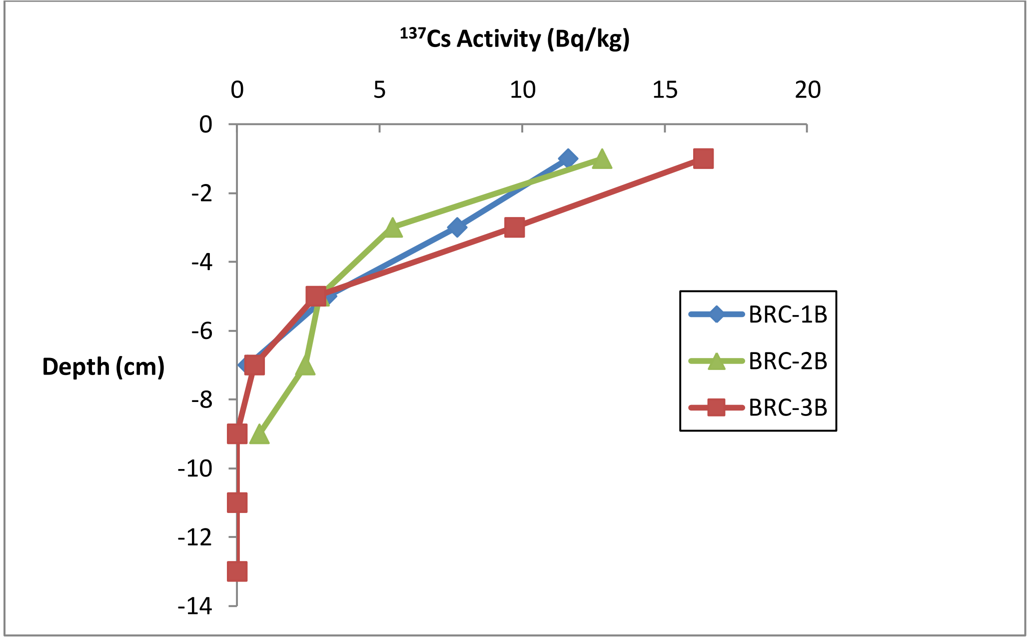


Figure 27. BRC-B - Group ^{137}Cs Profiles. The ^{137}Cs activities vs. depth for all three BRC-B pits. Profile shapes are exponential similarly to corresponding pits for BRC-B however surface activities are different.

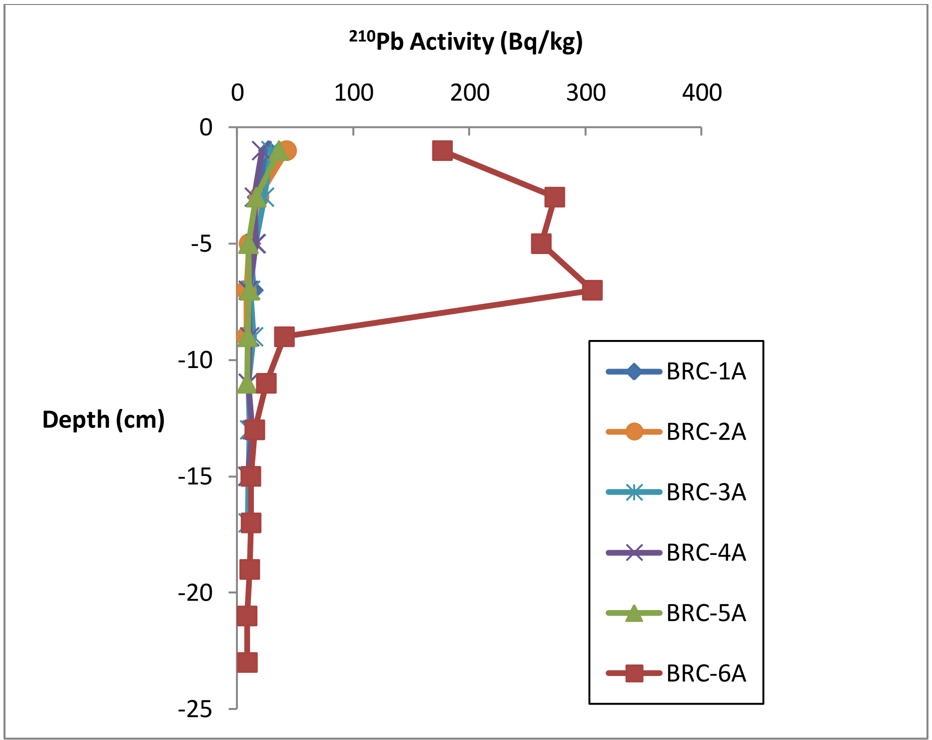


Figure 28. BRC-A - Group ^{210}Pb Profiles. The ^{210}Pb activities vs. depth for all six BRC-A pits. Profile shapes are exponential for BRC-1A through 5A but subsurface peak for 6A.

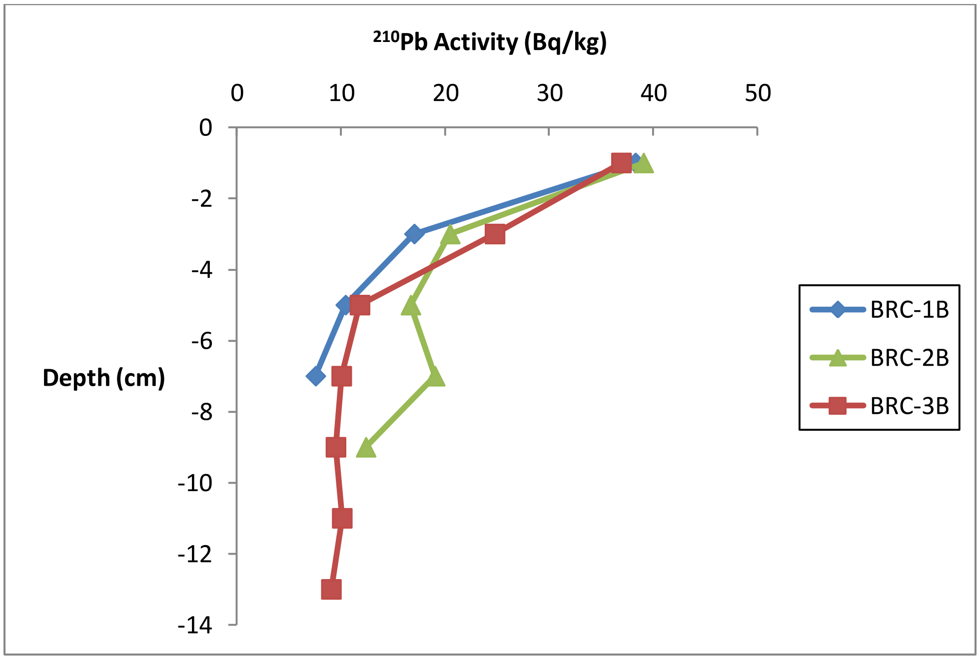


Figure 29. BRC-B - Group ^{210}Pb Profiles. The ^{210}Pb activities vs. depth for all three BRC-B pits. Profile shapes are exponential similarly to corresponding pits for BRC-B however surface activities are different.

The soil erosion rates for BRC-A from BRC-1A at the top to BRC-6A at the bottom are, -0.55 mm/yr, -0.12 mm/yr, -0.26 mm/yr, -0.82 mm/yr, -0.25 mm/yr, and a depositional rate of 1.98 mm/yr. The soil erosion rates for BRC-B are -0.10 mm/yr at BRC-1B, -0.14 mm/yr at BRC-2B, and BRC-3B is neither eroding or depositing (Table 4, Figure 22). From this data one can see that the transects do not have equal erosion rates.

As predicted by my hypothesis, the erosion rates for the two transects are not the same. There is over a 5x increase in erosion rate at BRC-1A compared to BRC-1B. BRC-2A and 2B are almost the same and only off by -0.02 mm/yr. BRC-3A and 3B have a difference in rate of 0.26 mm/yr. I interpret the lack of erosion or deposition at BRC-2B to be from its proximity to the convex down zone (Figure 22). It is unclear why BRC-1A has such a higher erosion rate than BRC-1B.

These findings validate the claim that spatial variability greatly effects the isotope derived erosion rates and indicates that a linear transect is not adequate to quantify hillslope averaged erosion rates. However, the linear transects are useful for identifying site specific erosion rates as evidenced by BRC-6. In the field, I identified BRC-6 as an area with sediment deposition. Isotope derived erosion rates indicate the area has a sediment deposition rate of 1.98 mm/yr.

BIG TUJUNGA

The objective at Big Tujunga is to answer the question "what role does fire play on short-term soil transport and isotope distribution?" There are three light colored samples, BT-1, BT-2A, BT-4, one intermediate sample, BT-4, and four dark samples, BT-2B, BT-3, BT-5, and BT-7 (Figure 30 and Figure 31). The dark samples are rich in burnt organic matter (Figure 32). I hypothesize that the ashy, organic-rich soil patches with high surface area will have high activity relative to neighboring soil patches which lack ashy organic matter. The sample packed weights are in Table 13 and the activities and errors are in Table 14.

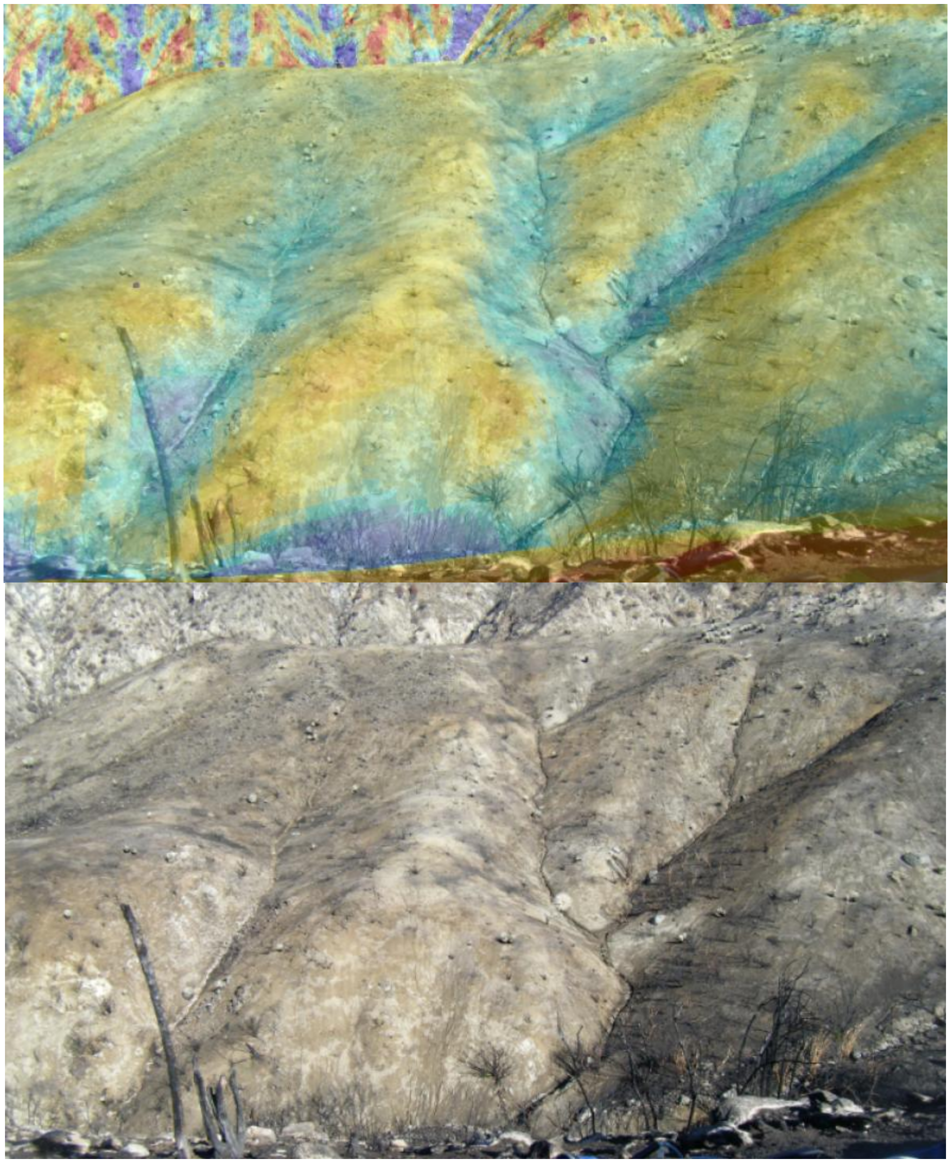


Figure 30. BT - Dark Spots and Curvature. This is the area where BT samples were collected. ArcScene was used to render a 3D environment with curvature colored so that red represents convex up and blue represents convex down. I layered the curvature image over the actual image to create this blended image. Note the dark soil spots across the hillside. It also appears that there is a higher abundance of dark soil in the convex down areas and lighter soil on the convex up areas.

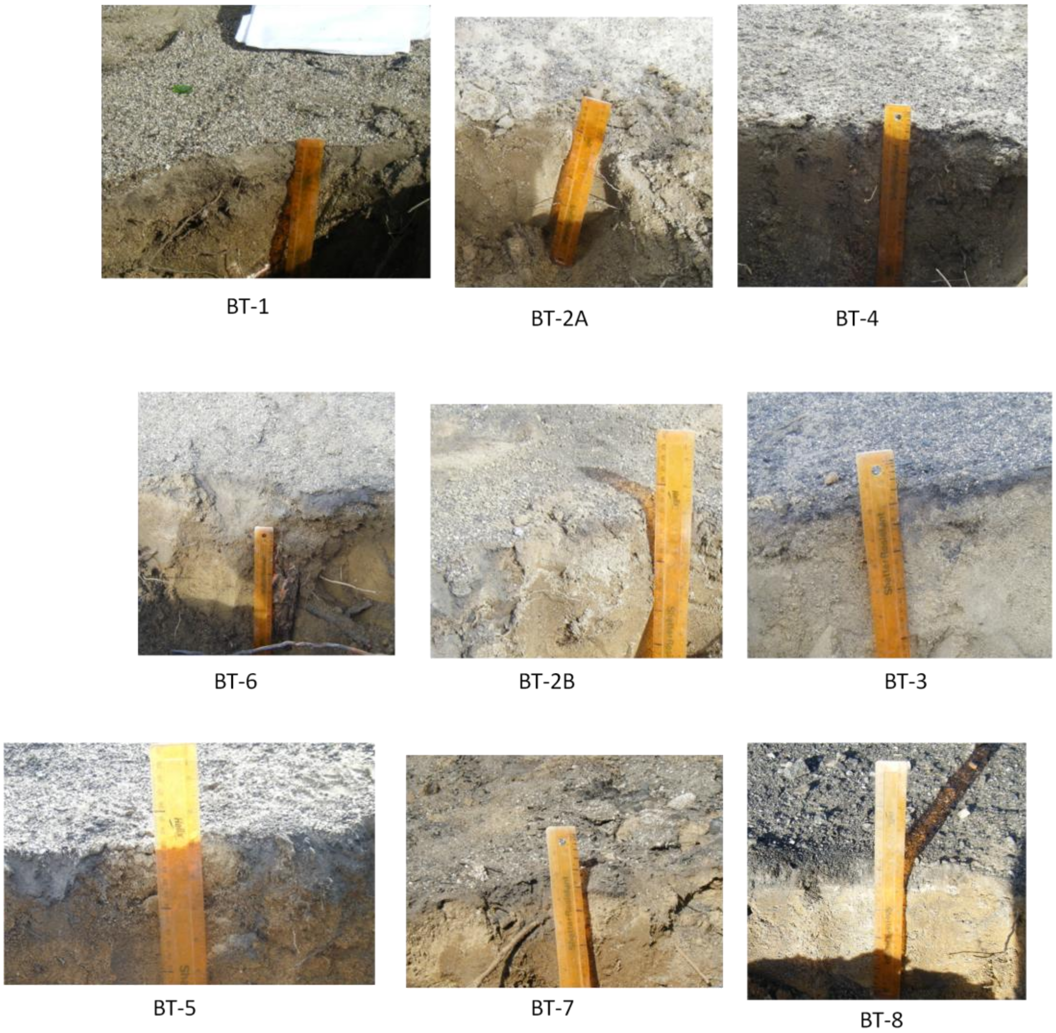

BT-1
BT-2A
BT-4
BT-6
BT-2B
BT-3
BT-5
BT-7
BT-8

Figure 31. BT - Pit Images. Shown are the cross-sections through the ground where various BT samples were taken. There is a 12" orange ruler for scale. Note the predominantly darker color of the surface soil at BT-3, 5, 7, and 8.

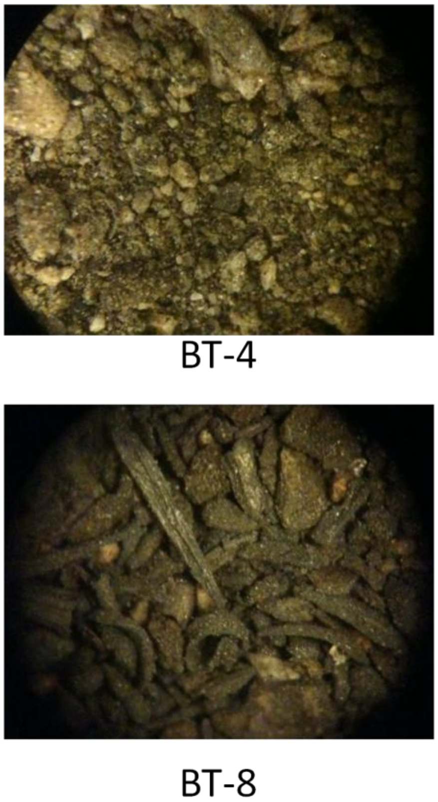


Figure 32. BT - Microscope Image. A visual comparison of dark vs. light soil indicates darker soils have more burnt organics than the light soils. Organics have high surface area and seem to be contributing to increased isotope activity in the darker soil. A microscope was used simply to create more visible images.

I observe that for ^{210}Pb all three of the light samples, BT-1, BT-2A, BT-4 and the intermediate sample BT-6, all have lower activity than the 4 dark samples, BT-2B, BT-3, BT-5, and BT-7 (Figure 33). For ^{137}Cs two of three of the light samples, BT-2A and BT-4, and the intermediate sample BT-6, have lower activity than all the dark samples. The third light sample, BT-1, has lower activity than all of the dark samples except BT-6.

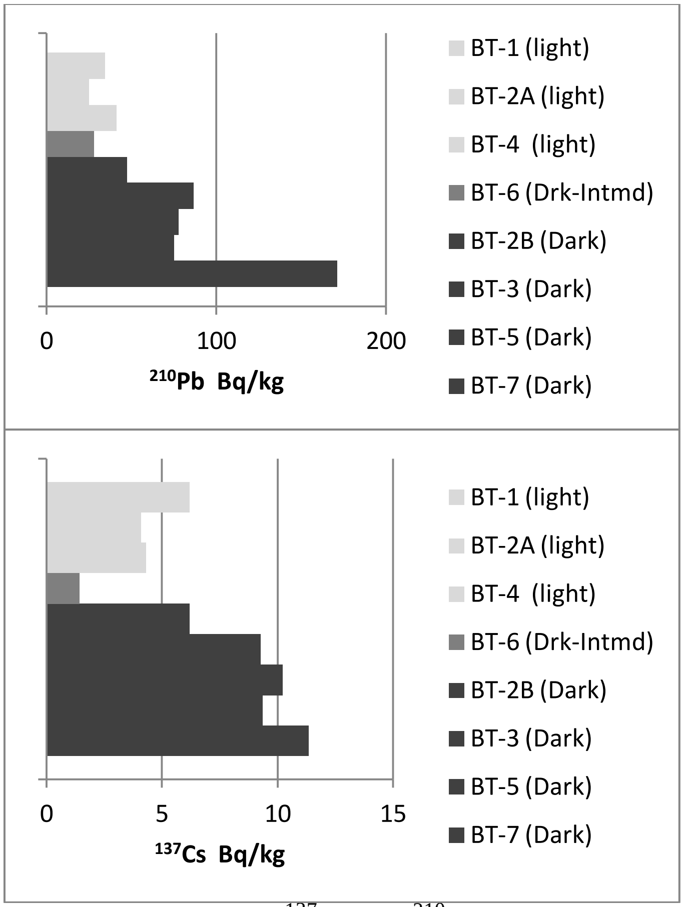


Figure 33. BT - Activity Bar Graph. ^{137}Cs and ^{210}Pb activity for the different Big Tujunga samples is shown. Samples were visually identified as light, dark to intermediate, or dark in color. The data shows that the darker soils are significantly higher in activity.

These observations do not disprove my hypothesis, that the soils with lots of burnt organics have higher activity than the lighter colored soils with few organics. Thus, the sporadic distribution of ashy, burnt organic matter caused by the fire indicates a sporadic distribution of isotopes. While this does not invalidate the fundamental assumption of quantifying soil transport with ^{137}Cs, that ^{137}Cs was uniformly distributed, it does show that ash deposited by the fire may be causing a redistribution of isotopes that is not evenly distributed. This redistribution of isotopes indicates that current 137Cs models which assume uniform distribution of isotopes may be inadequate for quantifying soil transport in post-fire landscapes. While models have been developed for secondary isotope deposition signals in cases such as Chernobyl, these models assume uniform deposition of ^{137}Cs over a particular area and I have shown that ^{137}Cs is not uniformly redeposited during a fire. Rapid homogenization or smoothing of these spots by overland flow or similar processes may create an even distribution which allows the event to fall under a Chernobyl type model. A visual assessment of the area (Figure 30) shows that while the spots are still present, lighter soil is generally on the convex up areas and darker soil is generally in the convex down areas. This seems to indicate that the spots are already being smoothed out as a result of soil transport. A follow up study examining the rate of homogenization of these spots will indicate if there is need for a new model or if the spots are rapidly homogenized to the point that a Chernobyl type model is still applicable.

Further complications arise when considering the resuspension of ^{137}Cs during fire. Control burn studies near Chernobyl indicate that fires can resuspend ^{137}Cs in the air (Yoschenko et al., 2006). If the fire burns a swale with high activity, like BRC-6, and resuspends those isotopes in the air, the loose isotopes may concentrate on aerially suspended, ashy organics as seen at BT. Consequently, there is the potential of depositing activity upslope in a concentrated patch of ashy organics. This would create a depositional signal that is disproportionate to the actual amount of soil deposited, due to a concentrating mechanism, fire.

CONCLUSIONS

I examined the use of ^{137}Cs and ^{210}Pb for identifying soil transport processes and quantifying soil erosion rates in several different contexts. I used the isotopes to look for process change on hillslopes that transition from low gradient to high gradient slopes. I did not find evidence supporting a process transition but showed that spatial variability may be overriding any general trend I hoped to identify.

I showed that the short-term erosion rates of a convex top are not at equilibrium and these erosion rates increase with slope and distance from ridgecrest for the upper convex part of the hilltop at CG. I also noted this trend at MFA suggesting that these erosion rates may be capturing an erosion signal from headward incision propogating through the hillslopes. Further sampling of the convex/planar boundary will indicate whether this signal is the result of headward erosion, something else entirely, or simply coincidence resulting from spatial variability.

Data from BRC quantitatively shows the spatial variability that exists just 3 m to the left or right of a transect. From this data I suggest that linear transects cannot yield accurate hillslope averaged erosion rates. In addition to the complication of spatial variability I show that fire may be complicating as well.

Results from BT indicate that fire plays a significant role in isotope distribution. The continued application of fallout isotopes to fire prone landscapes will require further investigations of the exact role fire plays on isotope distribution and consequently, quantified erosion rates. Further investigation in this area could yield a new model for quantifying soil transport with fallout isotopes in post-fire landscapes.

Throughout these transects I combined field observations and fallout isotopes to identify and quantify the processes acting on different areas. I identify shallow subsurface peaks in activity indicating preferential erosion of fines by overland processes, deep subsurface peaks indicating bioturbation, prevention of erosion by vegetation, and deposition of sediment on benches and toe slopes. These rates do not yield fundamental geomorphic relationships. However, these erosion rates give quantification to short-term processes which are important for understanding short-term hillslope evolution.

LONG-TERM VS SHORT TERM EROSION RATES

Choosing the SGM as my field site where long term erosion rates have been found using ^{10}Be allows for the comparison of these long-term rates to the fallout derived short-term rates. A graph of ^{10}Be derived, catchment averaged, long-term erosion rates vs. ^{137}Cs derived, short-term erosion rates shows no correlation (Figure 35). ^{10}Be error bars represent the range of rates for that particular area. ^{137}Cs error bars are based on a typical 20% coefficient of variation (Pennock, 2000). Given the substantial variability of short-term rates observed at several of the locations and shown specifically at Big Rock Creek it is not surprising there is no correlation. It should also be noted that the long-term rates are basin averaged erosion rates so the long-term rates of hillslopes throughout a catchment are being compared to one linear transect from a single hillslope in a catchment. A larger data set from these areas will give a more accurate measure of any correlation between long-term and short-term rates.

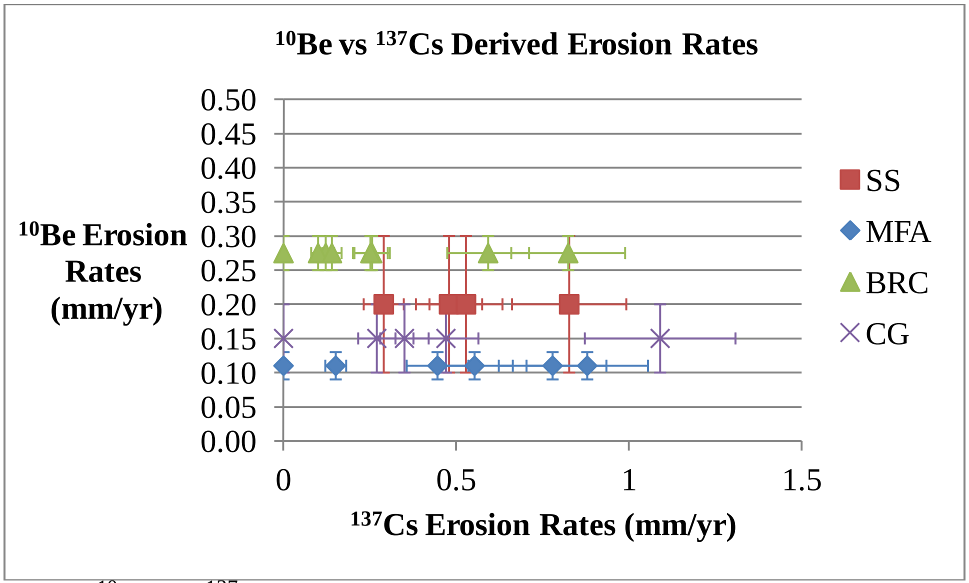


Figure 35. ^{10}Be vs. ^{137}Cs Derived Erosion Rates. There is no correlation between the ^{10}Be derived erosion rates and the ^{137}Cs derived erosion rates which is expected given the high spatial variability observed at several transects. The ^{137}Cs rates have been shown to be highly dependent on sampling location and highly variable. A significantly higher sample set is needed to make a better comparison.

RECOMMENDATIONS FOR FURTHER STUDY

The use of fallout isotopes to quantify soil transport and identify processes can provide lots of useful information however, there are several things to consider and be tested to obtain more accurate results and make better interpretations. I have shown that spatial variability across a hillslope is significant and that very localized processes can dominate the signal at a pit. To better understand the broader role of processes on the hillslope high-density grid sampling should be used. A high density sampling pattern can average out highly localized signals and yield data that is more relevant to the hillslope scale. Such data will allow for more accurate interpretations of the interplay between process transitions and topography. In addition, a larger sample set will give a more accurate hillslope averaged erosion rate. These more accurate hillslope averaged erosion rates can be compared to long term ^{10}Be rates to examine relationships between short-term and long-term erosion rates. The data I have shown indicates there is no trend but a larger sample set may indicate otherwise.

Finally, a better understanding of how ^{137}Cs moves during fires is critical to the use of the method in post-fire landscapes. My results suggest that fire is redistributing isotopes sporadically across the landscape. The role this redistribution plays in quantifying erosion rates should be thoroughly examined. Ideally, a controlled burn of a hillslope with known isotope distribution could be used to quantify isotopes on the hillslope and in the swale pre-fire and post-fire with additional measurements of isotopes resuspended during the fire. With this data, comparisons could be made of activity levels pre and post-fire on the hillslope. This study could identify if isotopes are being redistributed up slope. Additionally, the study could identify the sporadic nature of isotope distribution on the hillslope and observe the time it takes for these highly active spots to disperse and homogenize across the hillslope if they do homogenize.

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APPENDIX A

GAMMA SPECTROSCOPY PROTOCOL

Guideline For Measurement of Short-Lived Nuclides, Primary Fallout ^{137}Cs and ^{210}Pb or Cosmogenic ^{7}Be.

TABLE OF CONTENTS

GENERAL REQUIREMENTS FOR WORK IN THE FALLOUT LAB

All lab workers in the "FALLOUT LAB" must attend the following ASU sponsored classes:

- General Laboratory Safety
- Fire Safety and Prevention
- Radiation Safety

You can enroll in these classes at http://uabf.asu.edu/health_safety_training or through your MyASU links.

Remember: Hope for the best and plan for the worst… Always keep work area clean.

Part 1: APEX INSTALLATION AND SETUP

These instructions walk you through the initial installation and setup of APEX and GENIE 2K.

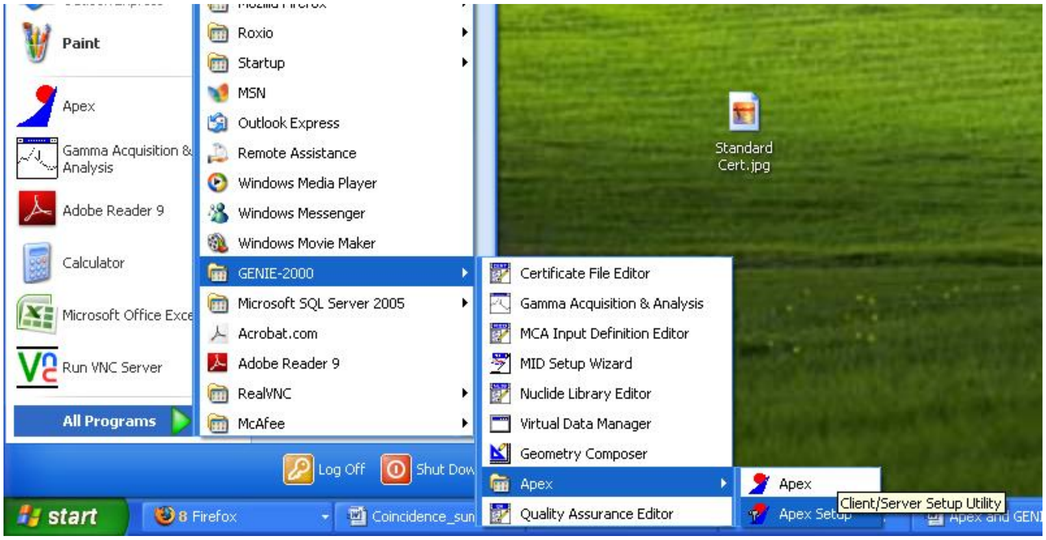
1.1 Software Installation

***** THE COMPUTER NAME MUST BE EQUAL TO OR LESS THAN 8 CHARACTERS.*****

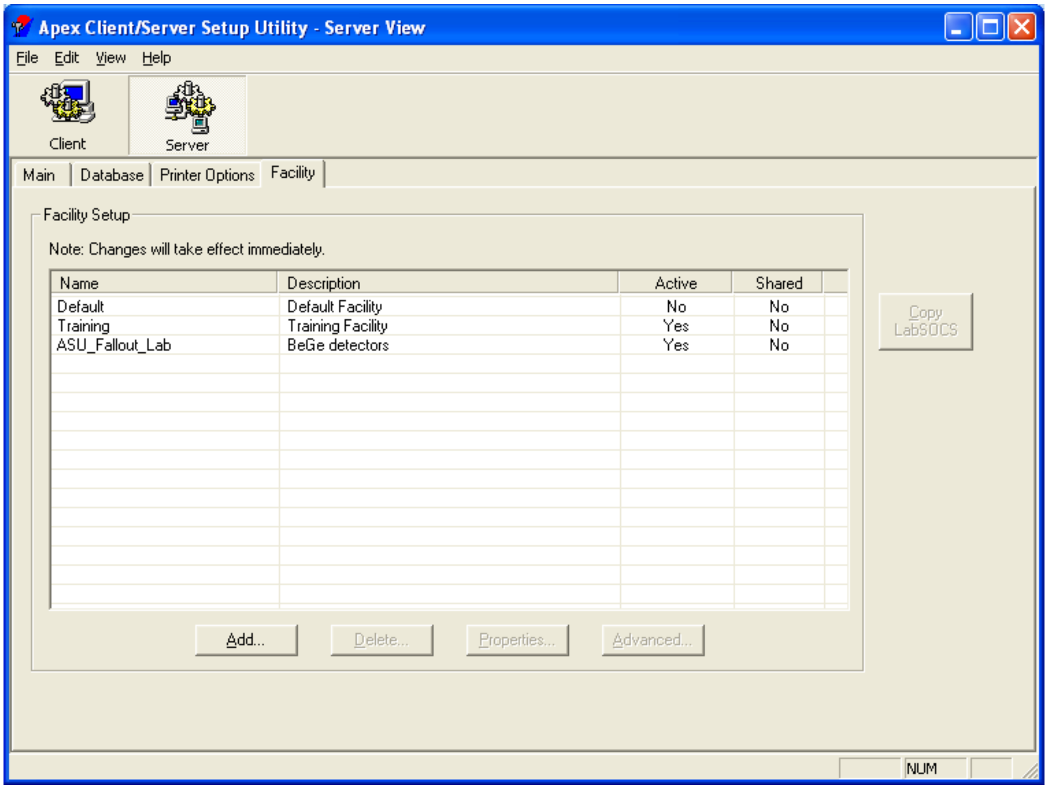
1. Make sure you have a TCP/IP connection and the USB key.
2. Insert Genie 3.1 Basic Spectroscopy CD. Select 'Standard Installation'.
3. Once Genie 3.1 has finished installing, eject the disk and insert the Genie 3.1a CD.
4. Install the Genie 2000 update and install .Net V2.0.
5. Once these are finished installing, eject the disk and insert the Genie 3.1 Gamma Analysis CD. Install the Gamma Analysis Software.
6. Once the Gamma Analysis Software has installed, eject the disk and insert the Genie 2000 Quality Assurance V1.3 floppy drive. It installs automatically, or you can run setup.exe.
7. Eject the Genie 2000 Quality Assurance floppy drive and insert the Genie 2000 Interactive Peak Fit floppy drive. It also installs automatically, or can be manually installed by running setup.exe.
8. Eject the Genie 2000 Interactive Peak Fit floppy drive and insert the Apex 1.2 Desktop Version CD. If you are given a prompt to uninstall Adobe Approval, do so. Install the SQL Server and the Desktop Software and Utilities.
9. If reinstalling from a previous version, you can use an existing directory.
10. Restart computer.

1.2 Facility Setup

1. Double-click the Apex Setup icon on your computer's desktop, or go to Start → All Programs → GENIE-2000 → Apex → Apex Setup.



2. Click the Server button and select the Facility tab.

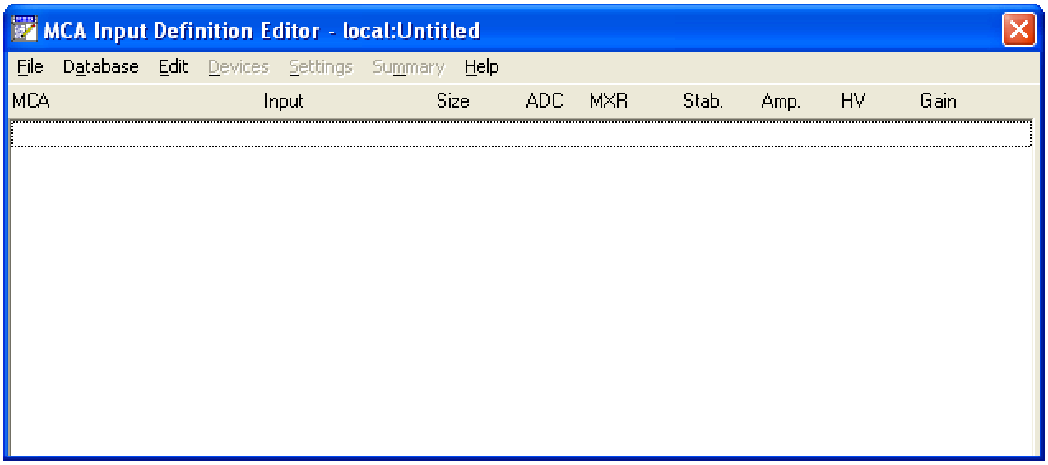


Note: Changes will take effect immediately.

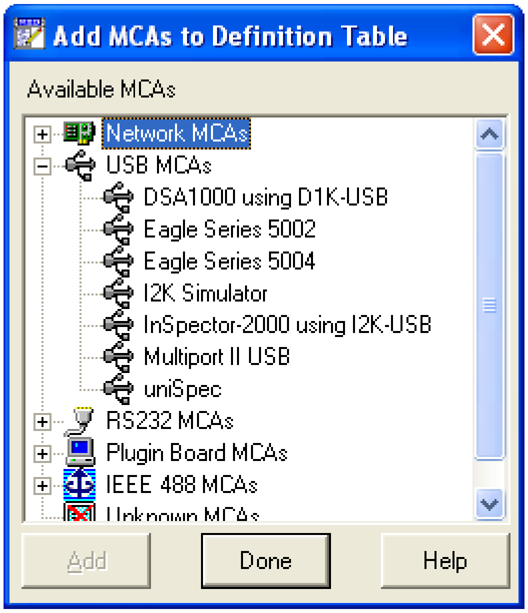
Name	Description	Active	Shared
Default	Default Facility	No	No
Training	Training Facility	Yes	No
ASU_Fallout_Lab	BeGe detectors	Yes	No

   a. Name it “ASU_Fallout_Lab”
   b. Describe it “BeGe detectors”
   c. Select the Default facility, press Properties, make inactive
   d. Select the Training facility, press Properties, make active

3. Go to Start → All Programs → Genie 2000 → MCA Input Definition Editor.
    a. Once you've opened the MCA Input Definition Editor, go to Edit → Add MCA.

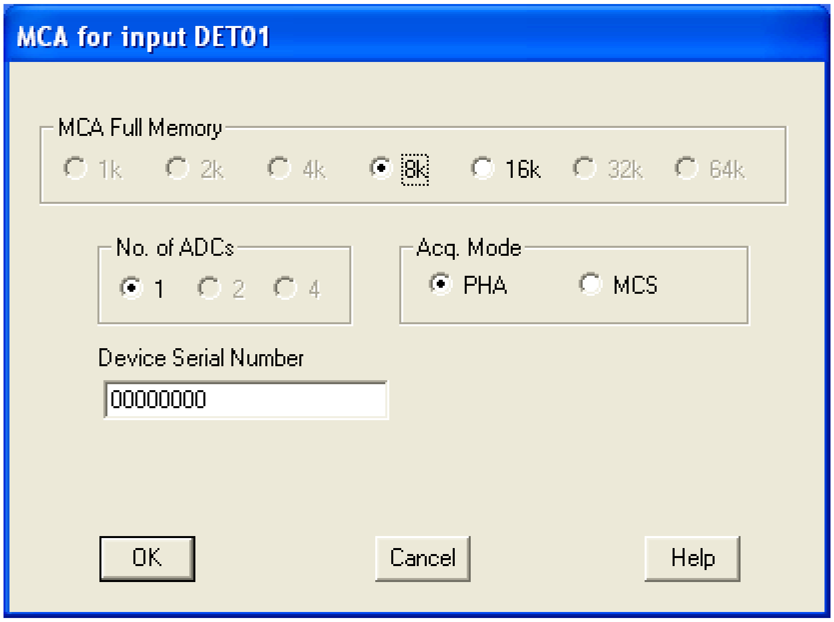


    b. You'll get a screen that looks like this:



    c. Click on USB MCAs and select DSA1000. Press 'Add' for each detector in your facility.
    d. Select the I2k simulator under USB MCAs and press 'Add' as well. This is a simulation detector.
    e. Click 'Done'.

4. In the MCA Input Definition Editor, select Devices → MCA… (after highlighting an MCA in the main window). Enter the device serial number, and then click ‘OK’.



MCA for input DET01

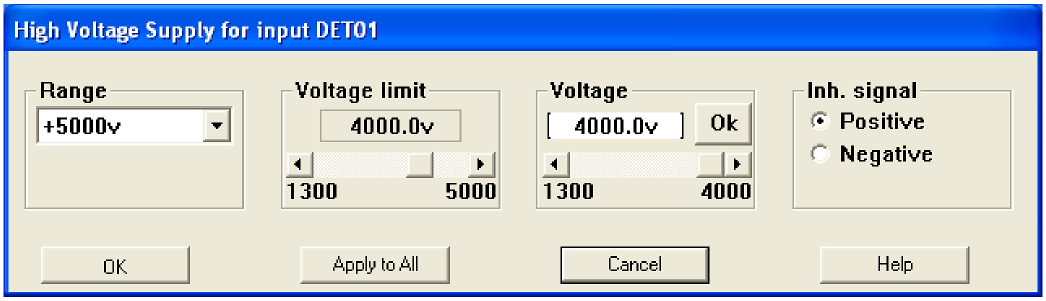
MCA Full Memory: ○ 1k ○ 2k ○ 4k ● 8k ○ 16k ○ 32k ○ 64k

No. of ADCs: ● 1 ○ 2 ○ 4

Acq. Mode: ● PHA ○ MCS

Device Serial Number: 00000000

5. In the MCA Input Definition Editor, select Settings → High Voltage.
    a. Enter the voltage settings: Range +5k, Voltage limit 4000.0v, Voltage 4000.0v. Inherent signal should be positive.



High Voltage Supply for input DET01

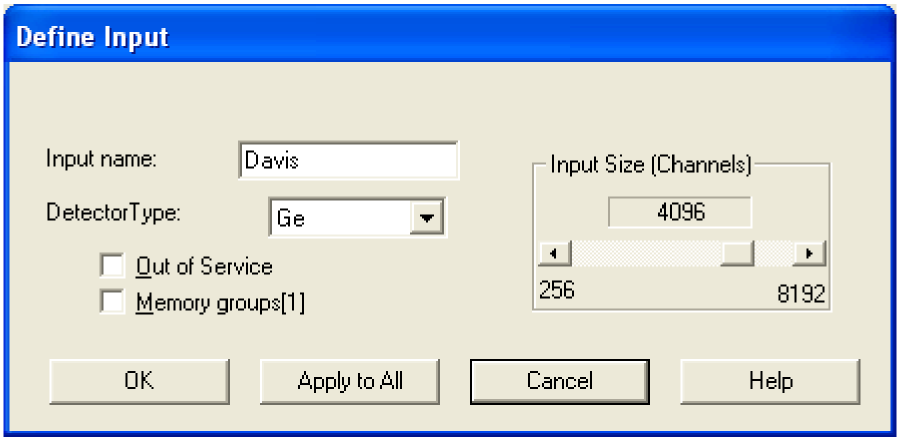
Range: +5000v

Voltage limit: 4000.0v (1300 – 5000)

Voltage: 4000.0v (1300 – 4000)

Inh. signal: ● Positive ○ Negative

6. In the MCA Input Definition Editor, select Settings → Input
    a. Enter the detector name and the number of channels (4096).



Input name: Davis

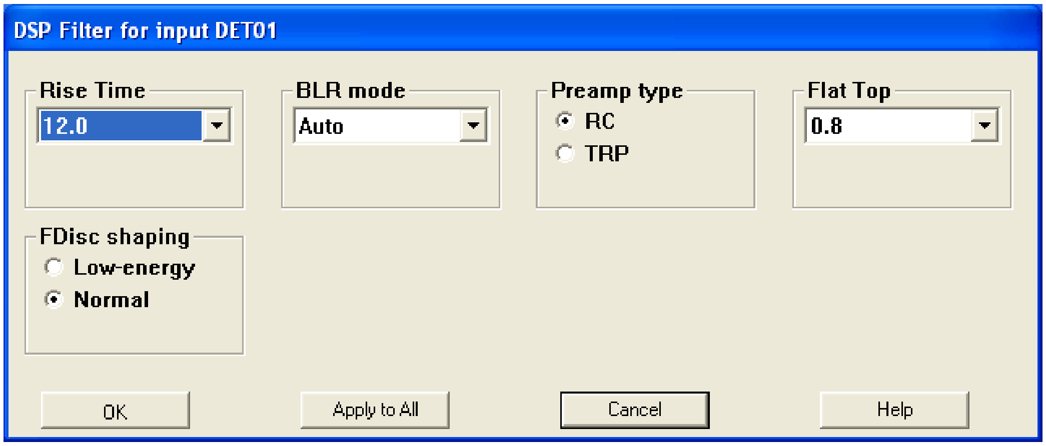
DetectorType: Ge

☐ Out of Service

☐ Memory groups[1]

Input Size (Channels): 4096

7. In the MCA Input Definition Editor, select Settings → DSP Filter.
    a. Set the rise time to 12, everything else should be okay.



Rise Time: 12.0

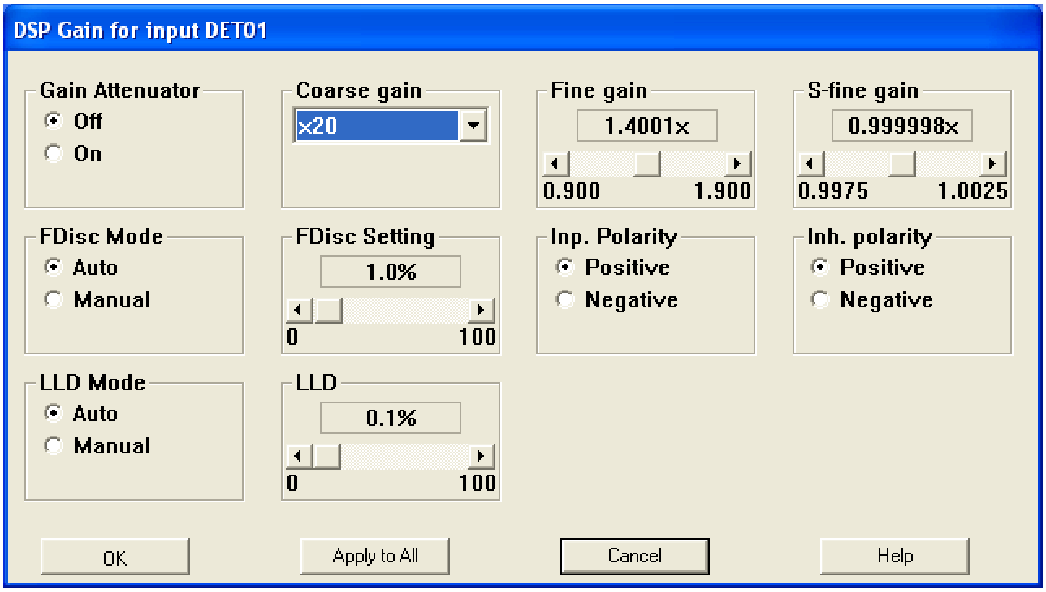
BLR mode: Auto

Preamp type: ● RC ○ TRP

Flat Top: 0.8

FDisc shaping: ○ Low-energy ● Normal

8. In the MCA Input Definition Editor, select Settings → DSP Gain.
    a. Set the coarse gain to 20x.



DSP Gain for input DET01

Gain Attenuator: ● Off ○ On

Coarse gain: x20

Fine gain: 1.4001x (0.900 – 1.900)

S-fine gain: 0.999998x (0.9975 – 1.0025)

FDisc Mode: ● Auto ○ Manual

FDisc Setting: 1.0% (0 – 100)

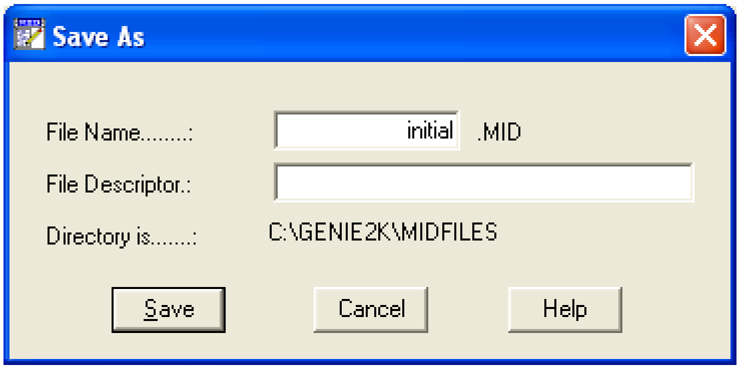
Inp. Polarity: ● Positive ○ Negative

Inh. polarity: ● Positive ○ Negative

LLD Mode: ● Auto ○ Manual

LLD: 0.1% (0 – 100)

9. **Repeat steps 4-8 for each detector in your facility. Leave the simulated detector alone.**
10. In the MCA Input Definition Editor, select File → Save as… call it "initial.mid"



File Name........: initial .MID

File Descriptor.:

Directory is.......: C:\GENIE2K\MIDFILES

11. In the MCA Input Definition Editor, select Database → Load to…
    a. Select "initial" file, click 'load', then click 'done'
12. Exit the MCA Input Definition Editor.

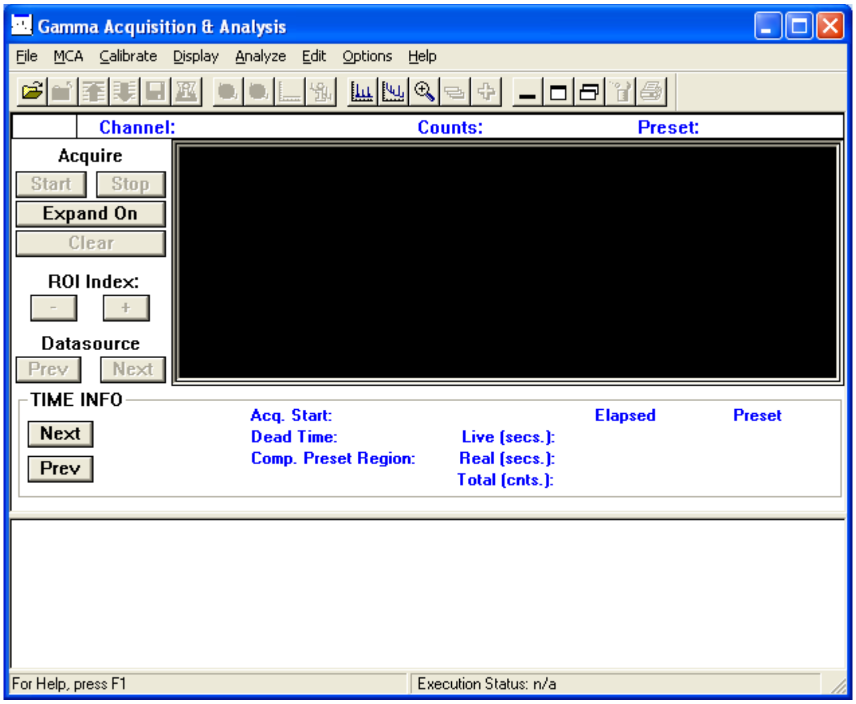
1.3 DSA 1000 and Drivers

1. Make sure the high voltage is off before plugging in the detectors. You can check the voltage status on the front of the DSA 1000.

2. Insert the Genie 2000 3.1 Basic Spectroscopy CD.
3. Connect the DSA 1000 to the computer using the cable labeled “DSA 1000 USB” and make sure everything is powered on. The power switch for the DSA 1000 is located in back, next to the cables.
4. The software installation wizard will pop up and will ask to check for software updates for found hardware. Say yes. Then say ‘proceed anyway’. This installs the drivers for the detectors.

1.4 Checking Detector Availability

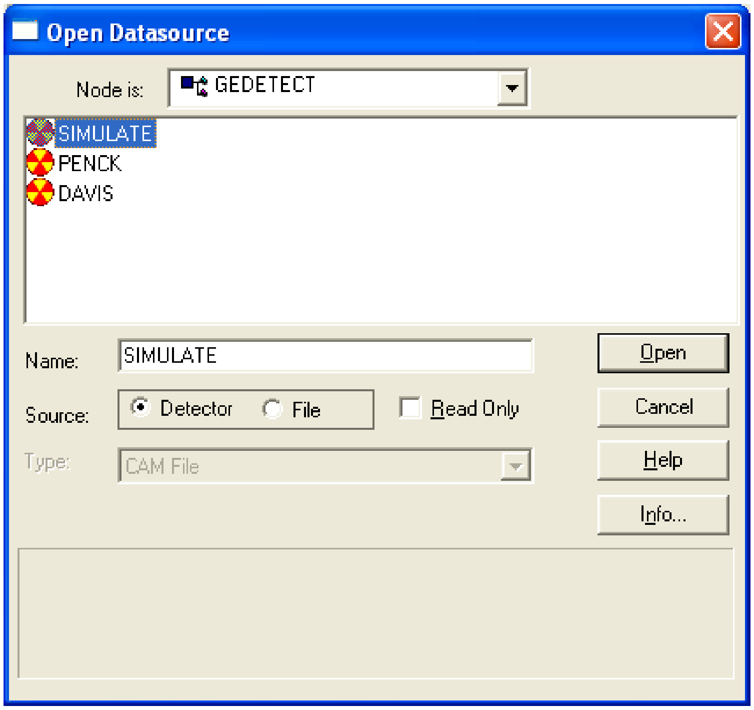
1. Go to Start → All Programs → Genie-2000 → Gamma Acquisition + Analysis. The Gamma Acquisition and Analysis window should appear.



For Help, press F1

Execution Status: n/a

2. Select File → Open Datasource.
    a. Select ‘Detector’ as source, highlight one of the detectors and click ‘Open’.



Node is: GEDETECT

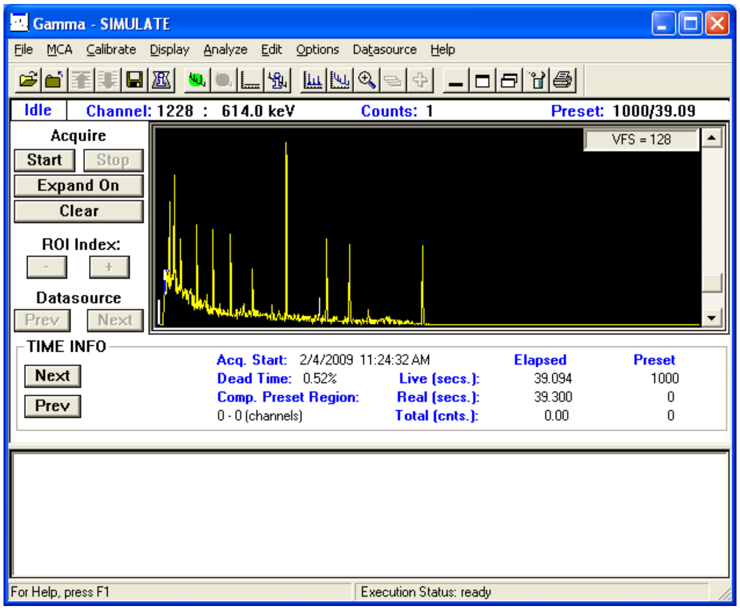
SIMULATE
PENCK
DAVIS

Name: SIMULATE

Source: ● Detector ○ File ☐ Read Only

Type: CAM File

b. You should get a window that looks like this:



Idle | Channel: 1228 : 614.0 keV | Counts: 1 | Preset: 1000/39.09

			Elapsed	Preset
Acq. Start: 2/4/2009 11:24:32 AM				
Dead Time: 0.52%		Live (secs.):	39.094	1000
Comp. Preset Region:		Real (secs.):	39.300	0
0 - 0 (channels)		Total (cnts.):	0.00	0

For Help, press F1

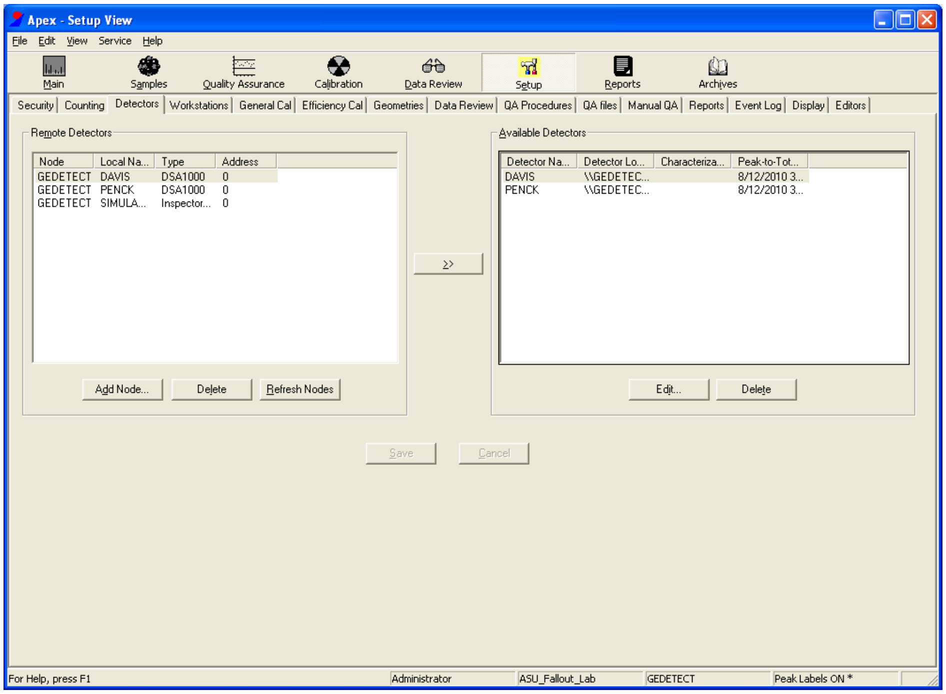
Execution Status: ready

c. Check that you can open the simulated detector and all of the real detectors that you connected to the computer.

NOTE: If you ever need to change the DSA 1000 serial number, you have to unload the initial.mid file before editing it.

1.5 Setting up the Apex Program

1. Go to Start → All Programs → GENIE-2000 → Apex → Apex
2. Select the Setup button, and then select the Detectors tab.



Remote Detectors

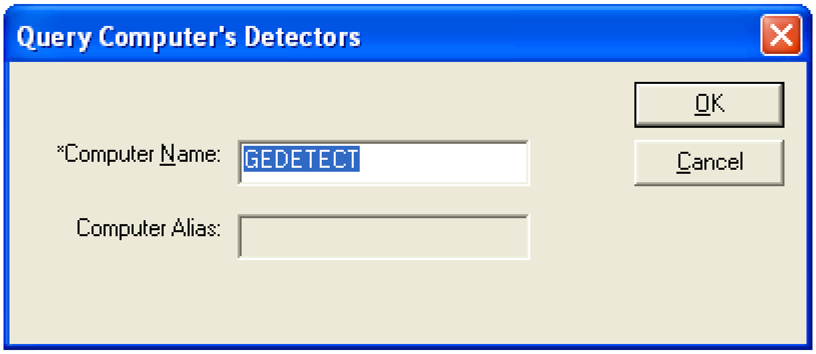
Node	Local Na...	Type	Address
GEDETECT	DAVIS	DSA1000	0
GEDETECT	PENCK	DSA1000	0
GEDETECT	SIMULA...	Inspector...	0

Available Detectors

Detector Na...	Detector Lo...	Characteriza...	Peak-to-Tot...
DAVIS	\\GEDETEC...		8/12/2010 3...
PENCK	\\GEDETEC...		8/12/2010 3...

Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

   a. Click Add Node… give the computer name (in this case, 'gedetect') and click 'OK'.

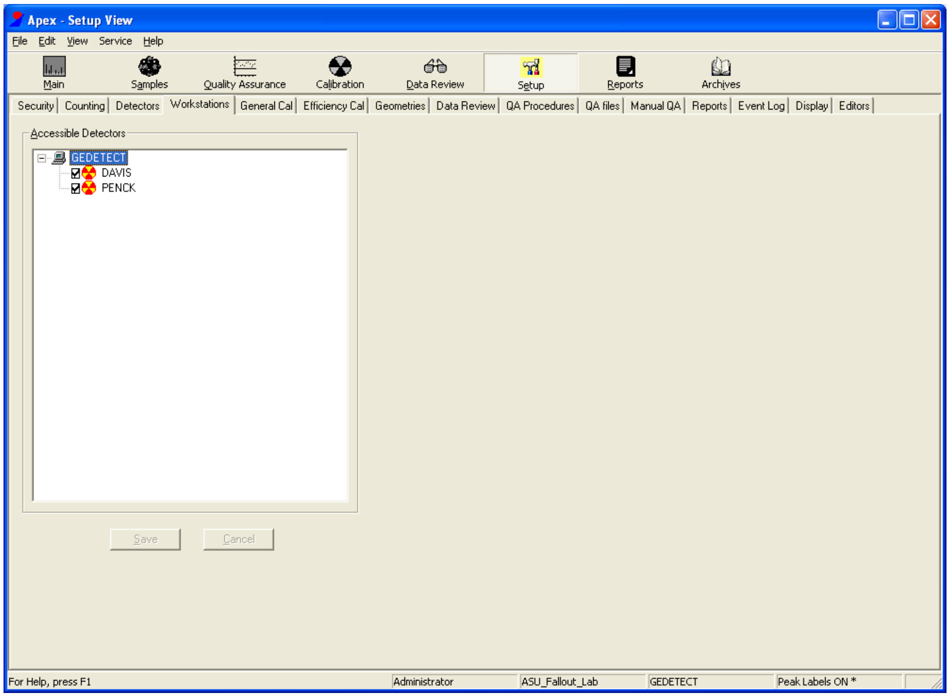


*Computer Name: GEDETECT

Computer Alias:

   b. Move the detectors over to the right-hand window using the arrow key in the center of the screen, then press 'Save'.

3. Go to Setup → Workstations, and check to see the detectors are there.

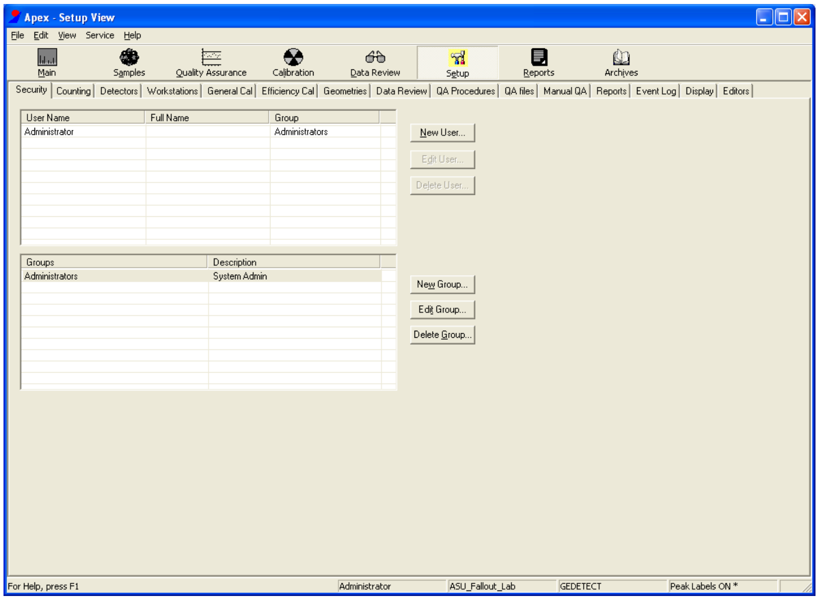


Accessible Detectors

GEDETECT
- ☑ DAVIS
- ☑ PENCK

Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

4. Go to Setup → Security. Here you can create users for Apex, create groups of users, and assign permissions for user groups. This is useful if you have a large laboratory with multiple users, and you want some people to have full permission but other people to just be able to run samples and collect data.

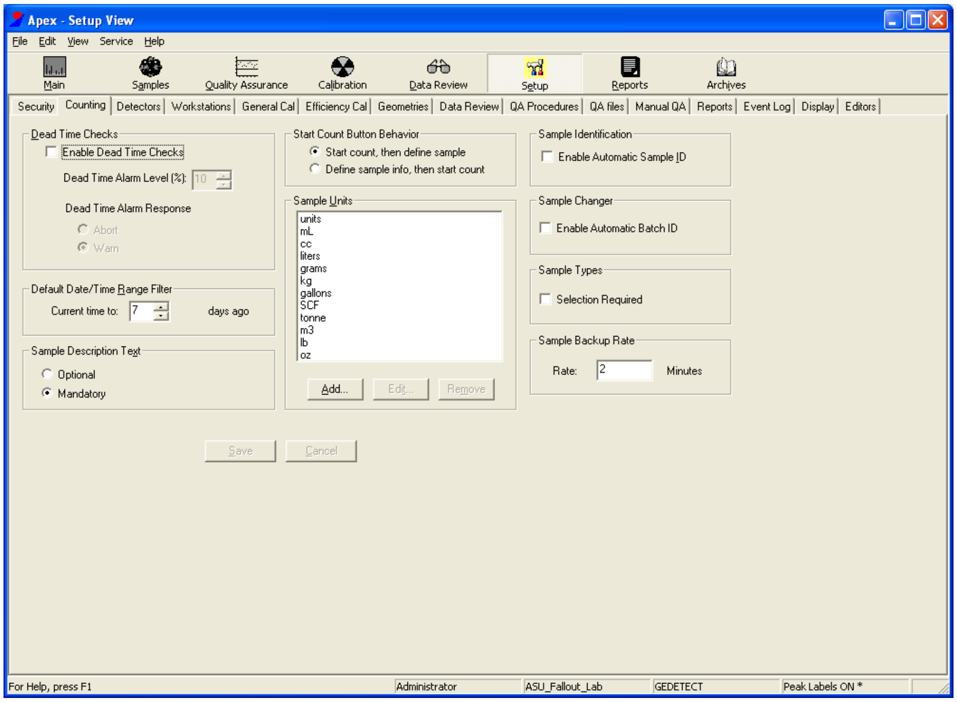


User Name	Full Name	Group
Administrator		Administrators

Groups	Description
Administrators	System Admin

Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

5. Go to Setup → Counting. Here you can modify the settings for counting samples, choose what units to use, set up default search filters, etc.



Dead Time Checks

☐ Enable Dead Time Checks

Dead Time Alarm Level (%): 10

Dead Time Alarm Response

○ Abort

● Warn

Default Date/Time Range Filter

Current time to: 7 days ago

Sample Description Text

○ Optional

● Mandatory

Start Count Button Behavior

● Start count, then define sample

○ Define sample info, then start count

Sample Units

units
mL
cc
liters
grams
kg
gallons
SCF
tonne
m3
lb
oz

Sample Identification

☐ Enable Automatic Sample ID

Sample Changer

☐ Enable Automatic Batch ID

Sample Types

☐ Selection Required

Sample Backup Rate

Rate: 2 Minutes

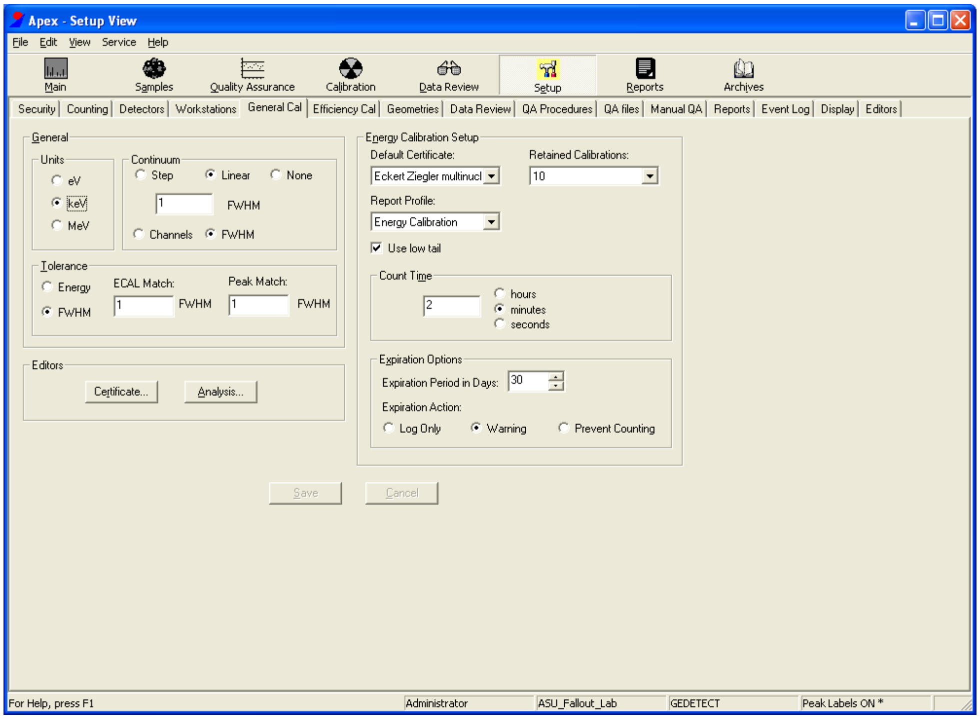
a. Make the Sample Description Text mandatory.

b. Under Sample type, check the box labeled “selection required”.

c. Set the Default date/time range filter to 30 days.

d. Under Start Count Button Behavior, set it to “Define sample, then start count”.

6. Go to Setup → General Calibration. These are the settings for defining which calibration standard to use, what tolerances are set for peak identification, what to do with expired calibrations, etc.



General

Units: ○ eV ● keV ○ MeV

Continuum: ○ Step ● Linear ○ None; 1 FWHM; ○ Channels ● FWHM

Tolerance: ○ Energy ● FWHM; ECAL Match: 1 FWHM; Peak Match: 1 FWHM

Energy Calibration Setup

Default Certificate: Eckert Ziegler multinucl

Retained Calibrations: 10

Report Profile: Energy Calibration

☑ Use low tail

Count Time: 2 ○ hours ● minutes ○ seconds

Expiration Options

Expiration Period in Days: 30

Expiration Action: ○ Log Only ● Warning ○ Prevent Counting

For Help, press F1 | Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

a. Set the Continuum to Linear, FWHM, 0.5 FWHM.

b. Set the Tolerance to FWHM, 1.0 for ECAL Match, 1.0 for Peak Match.

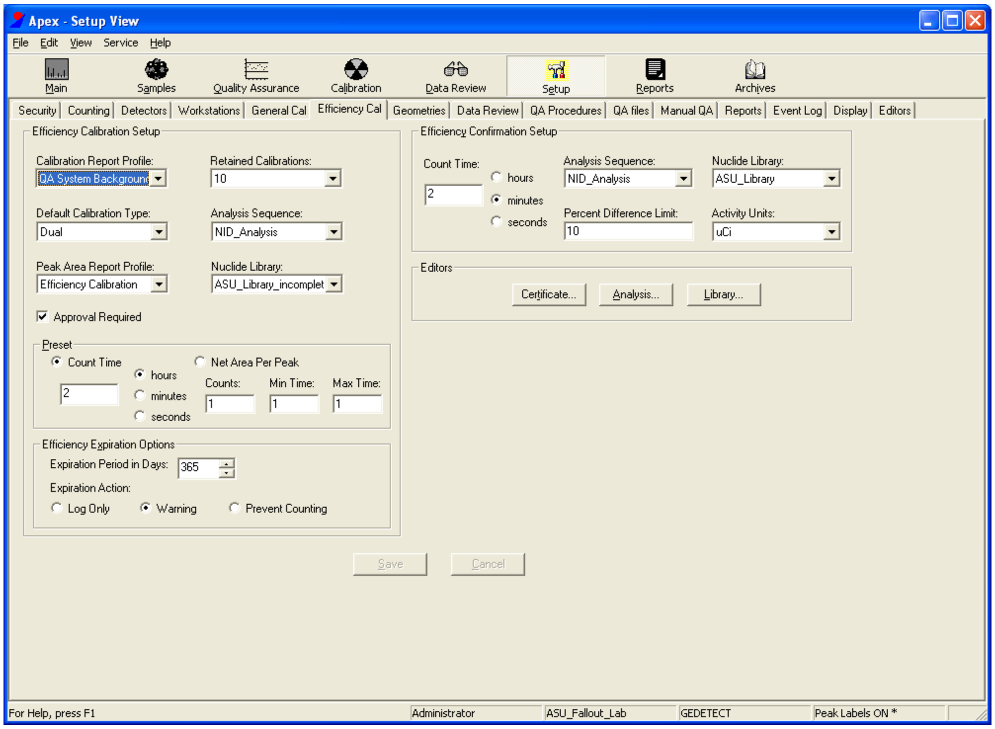
c. For the Energy Calibration Setup section:

   i. Use low tail

   ii. Set the Count time to 5 minutes

d. For the Expiration Options, set it to warning, 30 days expiration period.

7. Go to Setup → Efficiency Calibration. This is similar to the Energy Calibration section, but for Efficiency Calibrations instead.



Efficiency Calibration Setup

Calibration Report Profile: QA System Backgrounc
Retained Calibrations: 10
Default Calibration Type: Dual
Analysis Sequence: NID_Analysis
Peak Area Report Profile: Efficiency Calibration
Nuclide Library: ASU_Library_incomplet
☑ Approval Required

Preset
● Count Time
2
● hours
○ minutes
○ seconds
○ Net Area Per Peak
Counts: 1
Min Time: 1
Max Time: 1

Efficiency Expiration Options
Expiration Period in Days: 365
Expiration Action:
○ Log Only
● Warning
○ Prevent Counting

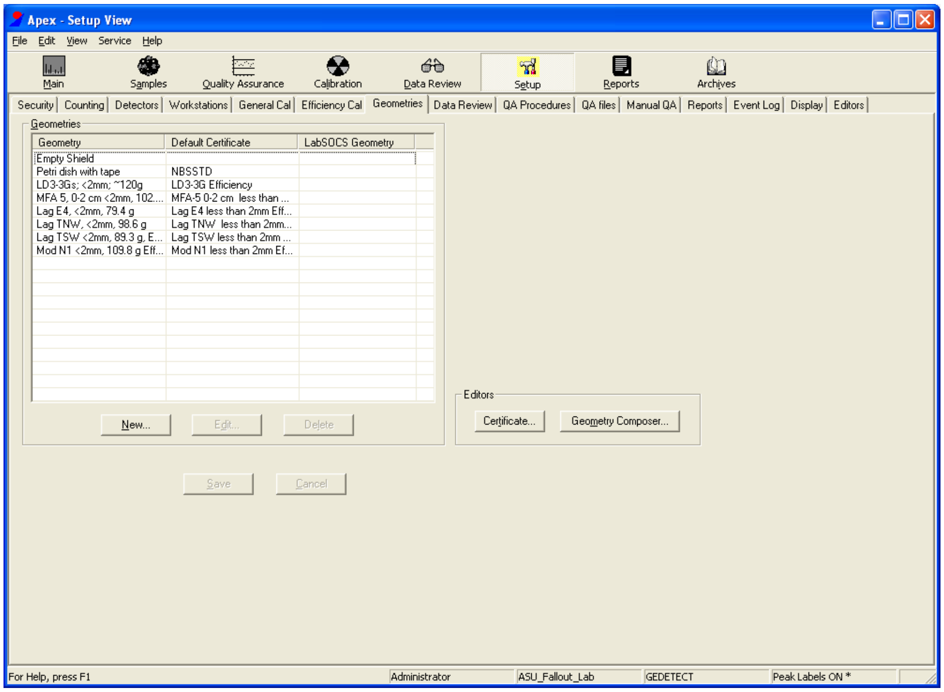
Efficiency Confirmation Setup

Count Time: 2
○ hours
● minutes
○ seconds
Analysis Sequence: NID_Analysis
Nuclide Library: ASU_Library
Percent Difference Limit: 10
Activity Units: uCi

For Help, press F1 | Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

a. In the Efficiency calibration setup section:
   i. Set Analysis sequence to peak analysis
   ii. Set the count time to 2 hours
   iii. Set the Efficiency expiration options to warning, 90 days.
b. In the Efficiency confirmation setup section, give it a 1 hour count time, with NID_Analysis as the Analysis Sequence.

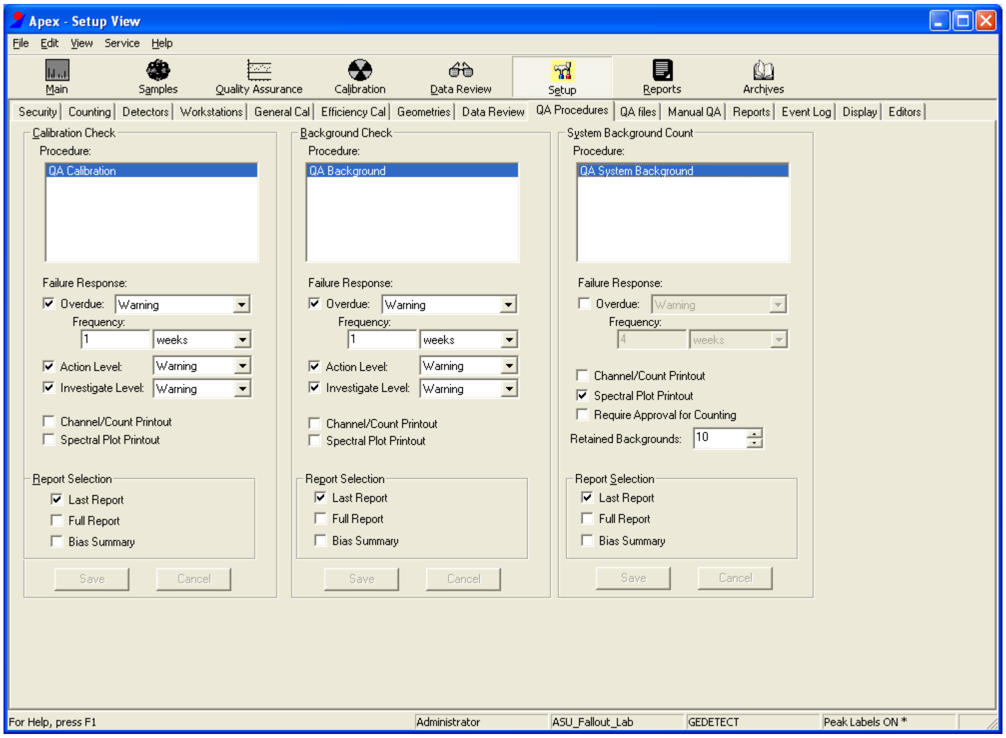
8. Go to Setup → Geometries. Here you can define different geometries, depending on container, density, soil type, etc. You'll need to create new certificates for efficiency calibration of your geometries – see Part 5 of the protocol.



Geometry	Default Certificate	LabSOCS Geometry
Empty Shield		
Petri dish with tape	NBSSTD	
LD3-3Gs; <2mm; ~120g	LD3-3G Efficiency	
MFA 5, 0-2 cm <2mm, 102....	MFA-5 0-2 cm less than ...	
Lag E4, <2mm, 79.4 g	Lag E4 less than 2mm Eff...	
Lag TNW, <2mm, 98.6 g	Lag TNW less than 2mm...	
Lag TSW <2mm, 89.3 g, E...	Lag TSW less than 2mm ...	
Mod N1 <2mm, 109.8 g Eff...	Mod N1 less than 2mm Ef...	

9. Leave the Setup → Data Review section alone for now.

10. Go to Setup → QA Procedures



Calibration Check
Procedure: QA Calibration
Failure Response:
☑ Overdue: Warning
Frequency: 1 weeks
☑ Action Level: Warning
☑ Investigate Level: Warning
☐ Channel/Count Printout
☐ Spectral Plot Printout
Report Selection
☑ Last Report
☐ Full Report
☐ Bias Summary

Background Check
Procedure: QA Background
Failure Response:
☑ Overdue: Warning
Frequency: 1 weeks
☑ Action Level: Warning
☑ Investigate Level: Warning
☐ Channel/Count Printout
☐ Spectral Plot Printout
Report Selection
☑ Last Report
☐ Full Report
☐ Bias Summary

System Background Count
Procedure: QA System Background
Failure Response:
☐ Overdue: Warning
Frequency: 4 weeks
☐ Channel/Count Printout
☑ Spectral Plot Printout
☐ Require Approval for Counting
Retained Backgrounds: 10
Report Selection
☑ Last Report
☐ Full Report
☐ Bias Summary

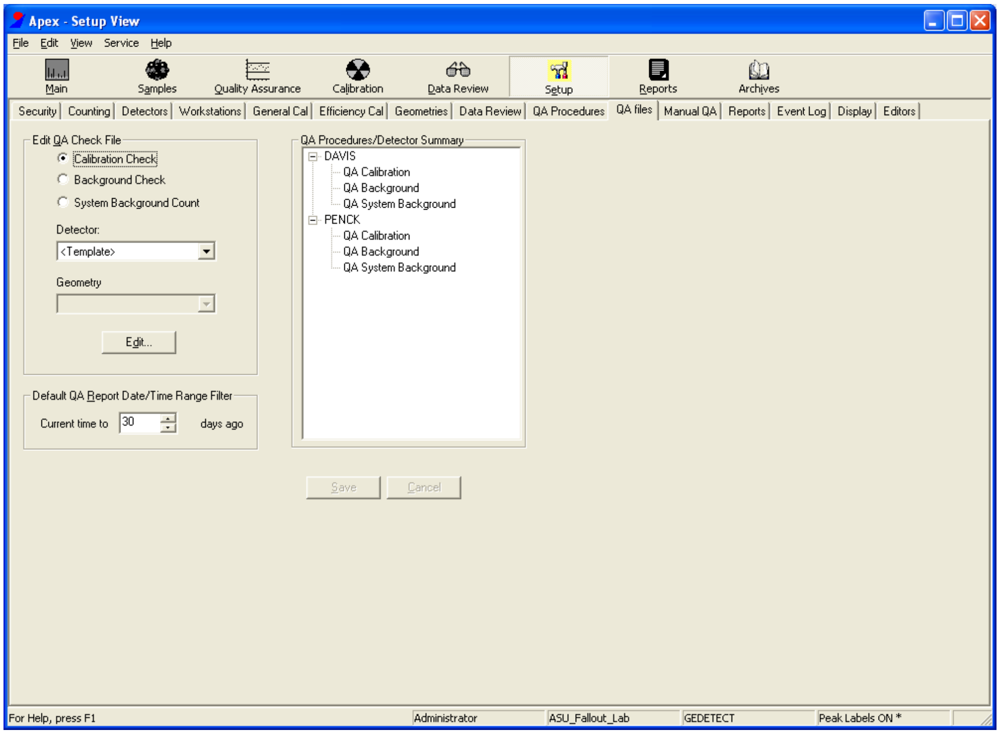
a. Under ‘System Background Count’, deselect the Overdue notice. In general, don’t count the system background unless you suspect contamination from the container.

b. Set the calibration check for every 2 weeks

c. Set the background check for every 2 weeks

d. For both checks: deselect ‘channel/count printout’

11. Go to Setup → QA Files, and select ‘Calibration Check’



● Calibration Check

○ Background Check

○ System Background Count

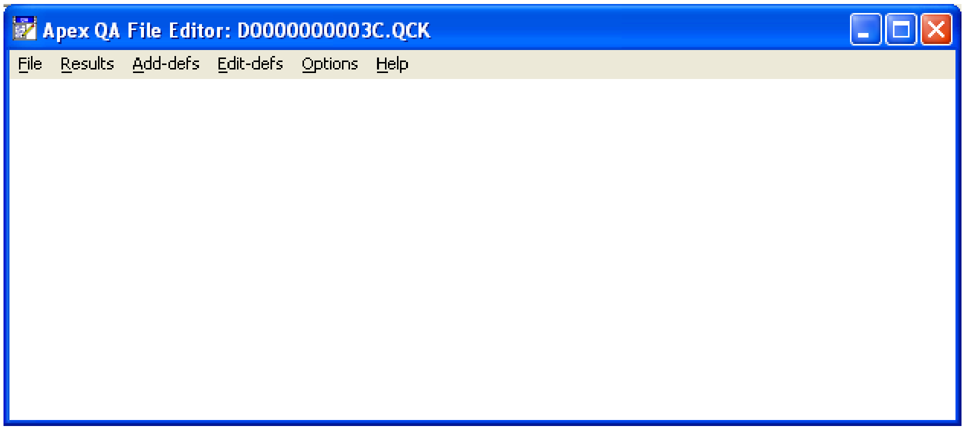
Detector: <Template>

Geometry:

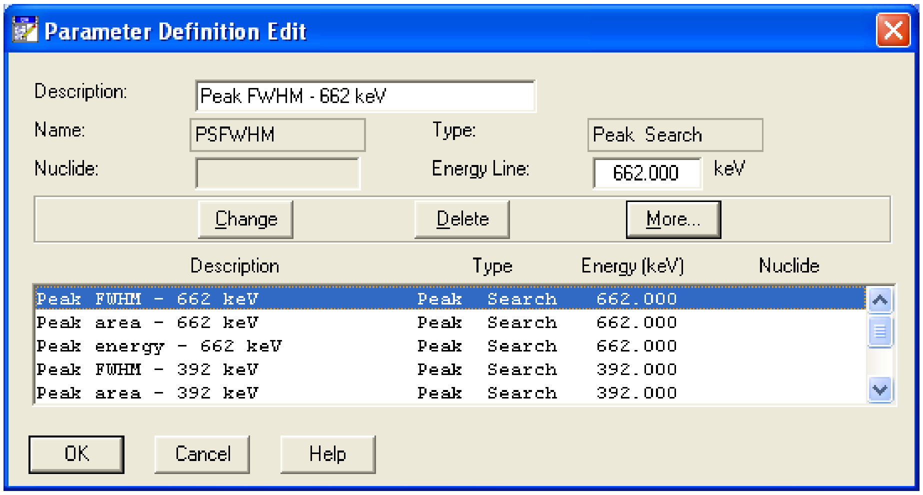
Default QA Report Date/Time Range Filter

Current time to 30 days ago

a. Select a detector in the drop-down menu and press ‘Edit’. This will open the Apex QA File Editor.



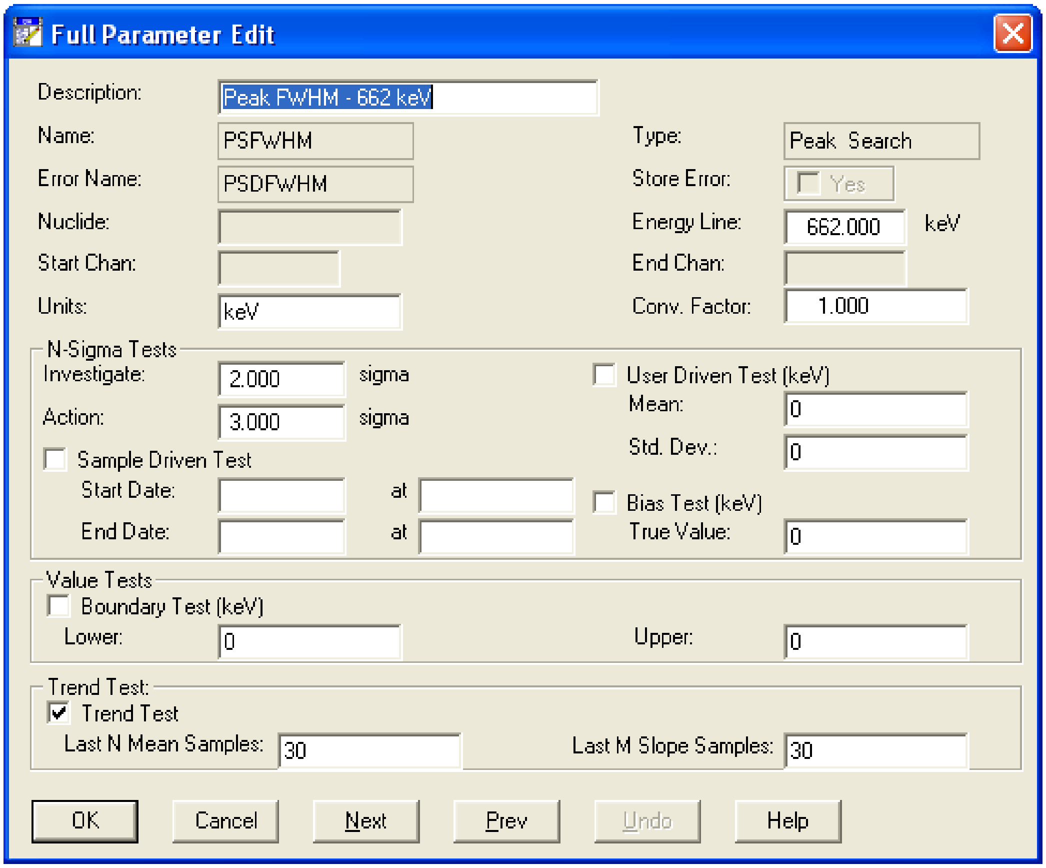
b. Go to Edit-defs → parameter definitions to open the Parameter Definition Edit window.



Description: Peak FWHM - 662 keV
Name: PSFWHM
Type: Peak Search
Nuclide:
Energy Line: 662.000 keV

Description	Type	Energy (keV)	Nuclide
Peak FWHM - 662 keV	Peak Search	662.000	
Peak area - 662 keV	Peak Search	662.000	
Peak energy - 662 keV	Peak Search	662.000	
Peak FWHM - 392 keV	Peak Search	392.000	
Peak area - 392 keV	Peak Search	392.000	

c. Press “More…”.



Description: Peak FWHM - 662 keV
Name: PSFWHM
Type: Peak Search
Error Name: PSDFWHM
Store Error: ☐ Yes
Nuclide:
Energy Line: 662.000 keV
Start Chan:
End Chan:
Units: keV
Conv. Factor: 1.000

N-Sigma Tests
Investigate: 2.000 sigma
Action: 3.000 sigma
☐ User Driven Test (keV)
Mean: 0
Std. Dev.: 0
☐ Sample Driven Test
Start Date: at
End Date: at
☐ Bias Test (keV)
True Value: 0

Value Tests
☐ Boundary Test (keV)
Lower: 0
Upper: 0

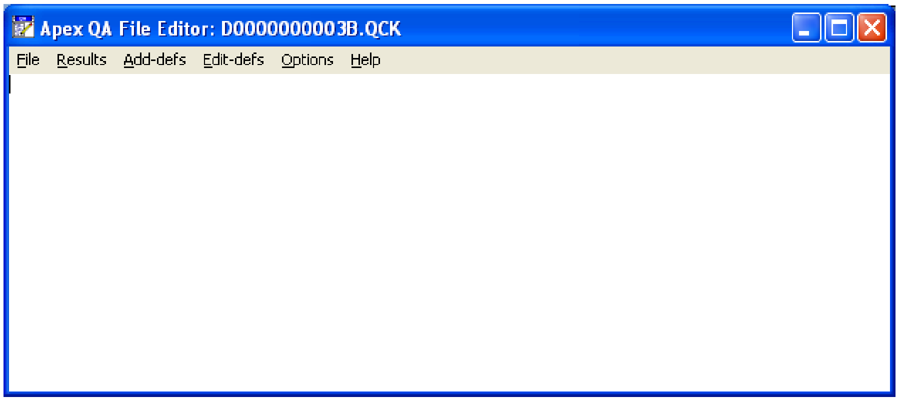
Trend Test:
☑ Trend Test
Last N Mean Samples: 30
Last M Slope Samples: 30

d. Deselect ‘sample driven test’, then press next; keep going, deselecting ‘sample driven test’ and ‘boundary test (keV)’, until you’ve modified all the parameter definitions in the list.

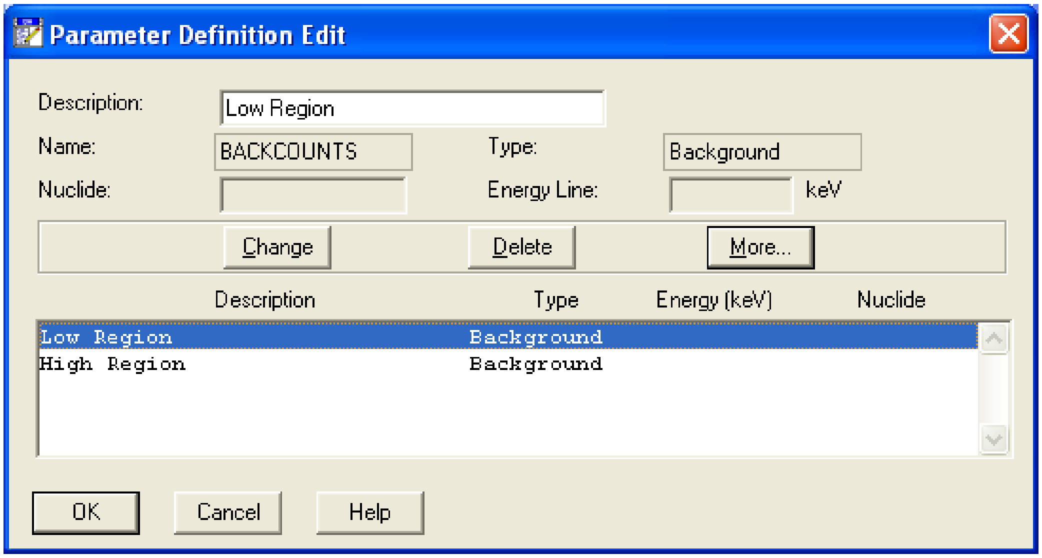
e. Click ‘OK’, exit the Apex QA File Editor, save changes, and get back to the Setup → QA Files window.

f. **Repeat steps a-e for each detector in the facility.**

g. Click the “Background Check” button, and press the “Edit” button. You’ll be back in the Apex QA File Editor, but editing the background check files now.



h. Go to Edit-definitions → parameter definitions. There should be a “Low Region” and “High Region” file.



Description: Low Region
Name: BACKCOUNTS
Type: Background
Nuclide:
Energy Line: keV

Description	Type	Energy (keV)	Nuclide
Low Region	Background		
High Region	Background		

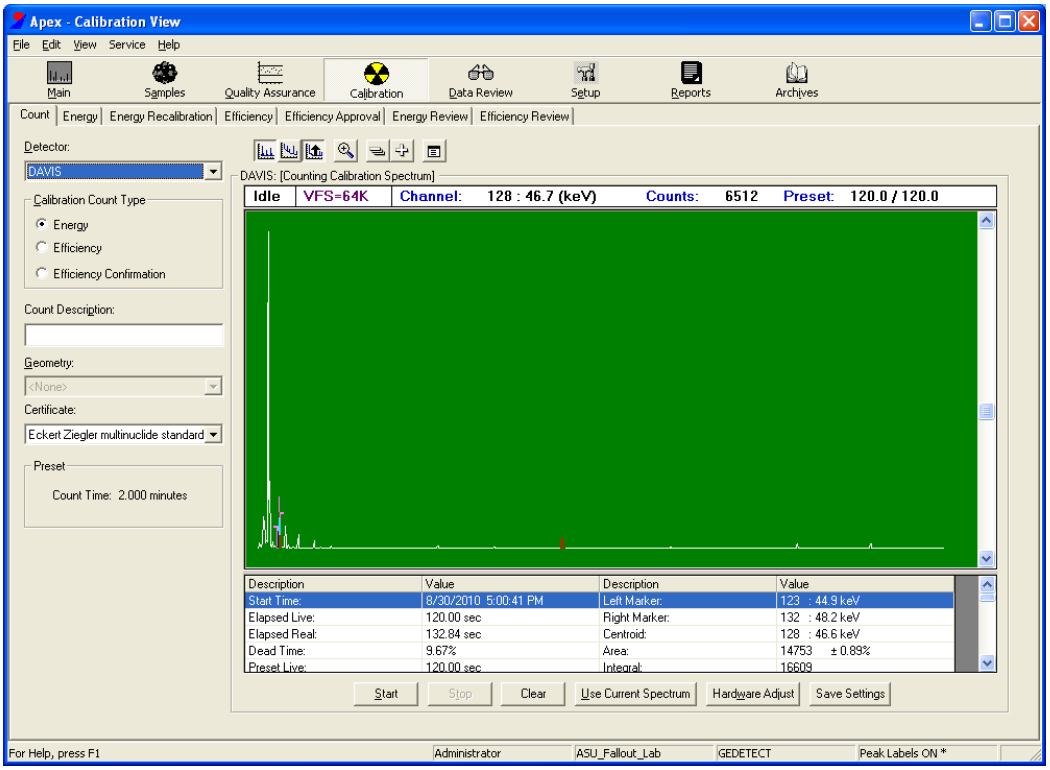
i. Click ‘More…’. In the Low Region, set the Start Channel at 50 and the End Channel at 400. In the High Region, set the Start Channel at 400 and the End Channel at 4096.

j. Click ‘OK’, exit out of the Apex QA File Editor, save your changes.

1.6 Detector Range Adjustment

The germanium crystal picks up a range of high-energy particles. The range of particles that are picked up by the computer and analyzed depends on the hardware settings. These can be changed through Apex. It is highly recommended that you adjust the hardware settings to the desired range of keV values you want to observe BEFORE running any calibration standards or samples.

1. Go to Calibration → Count and select a detector.



Detector: DAVIS

Calibration Count Type
● Energy
○ Efficiency
○ Efficiency Confirmation

Count Description:

Geometry: <None>

Certificate: Eckert Ziegler multinuclide standard

Preset
Count Time: 2.000 minutes

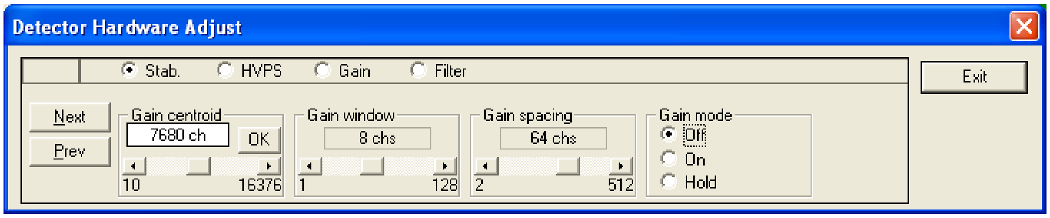
DAVIS: [Counting Calibration Spectrum]

Idle | VFS=64K | Channel: 128 : 46.7 (keV) | Counts: 6512 | Preset: 120.0 / 120.0

Description	Value	Description	Value
Start Time:	8/30/2010 5:00:41 PM	Left Marker:	123 : 44.9 keV
Elapsed Live:	120.00 sec	Right Marker:	132 : 48.2 keV
Elapsed Real:	132.84 sec	Centroid:	128 : 46.6 keV
Dead Time:	9.67%	Area:	14753 ± 0.89%
Preset Live:	120.00 sec	Integral:	16609

Administrator | ASU_Fallout_Lab | GEDETECT | Peak Labels ON *

2. Select "Hardware Adjust". This will open the Detector Hardware Adjust window.



● Stab. ○ HVPS ○ Gain ○ Filter

Gain centroid: 7680 ch (10 – 16376)

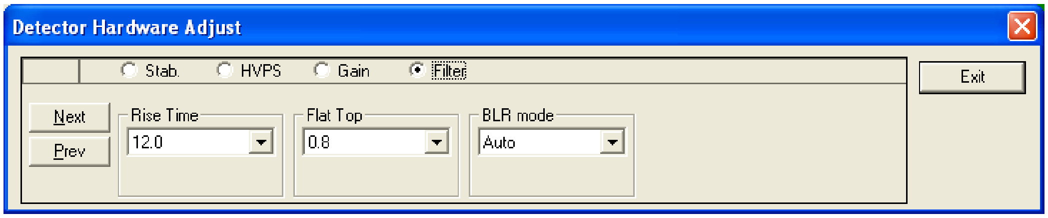
Gain window: 8 chs (1 – 128)

Gain spacing: 64 chs (2 – 512)

Gain mode
● Off
○ On
○ Hold

3. You'll need a point source that releases particles in the range you want to detect. We use an Eckert Zeigler multiline standard. Place your point source in the detector.

4. Click the 'filter' button, change the rise time to 12.0, press previous and do a new pole zero adjustment.

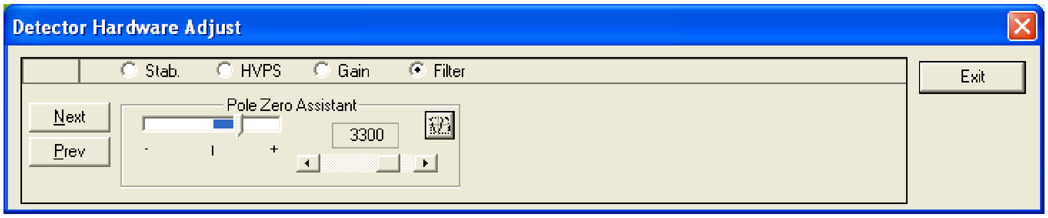


○ Stab. ○ HVPS ○ Gain ● Filter

Rise Time: 12.0

Flat Top: 0.8

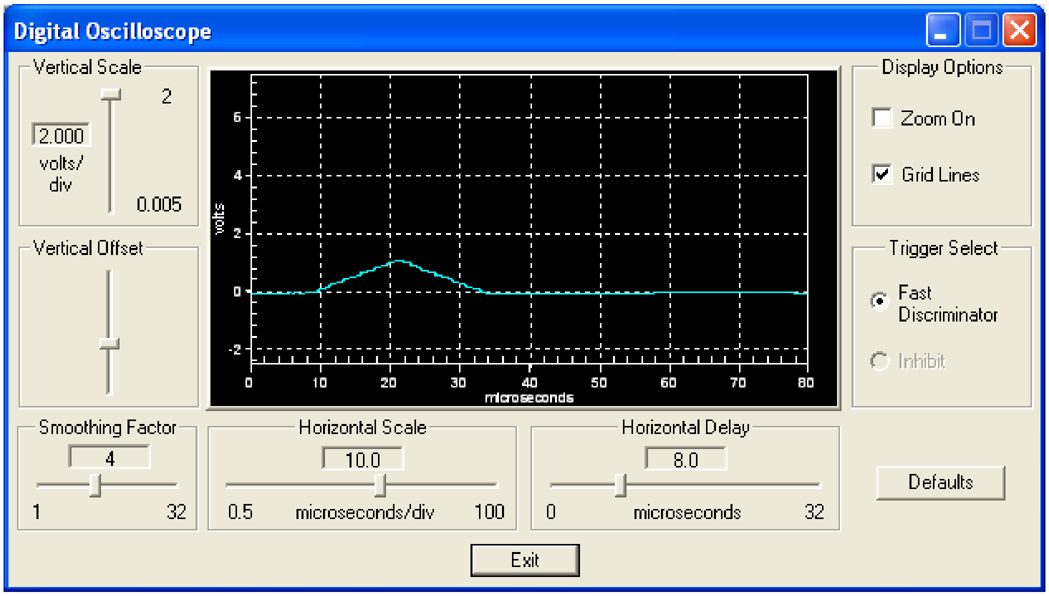
BLR mode: Auto



○ Stab. ○ HVPS ○ Gain ● Filter

Pole Zero Assistant: 3300

a. To make a pole zero adjustment, first press the graph button to the right of the Pole Zero Assistant bar. That will open the Digital Oscilloscope.



Vertical Scale: 2.000 volts/div

Vertical Offset

Smoothing Factor: 4

Horizontal Scale: 10.0 microseconds/div

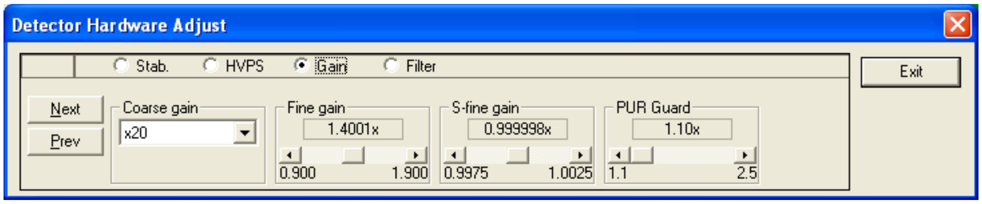
Horizontal Delay: 8.0 microseconds

Display Options: ☐ Zoom On ☑ Grid Lines

Trigger Select: ● Fast Discriminator ○ Inhibit

b. Adjust the Horizontal Scale, Vertical Scale and Vertical Offset until you can clearly picture the oscillating peak in the center of the window. Adjust the sliding bar in the Detector Hardware Adjust window until the Digital Oscilloscope shows a flat line with a single oscillating peak. If the flat line consistently dips below or above the zero voltage line, you'll have to make further adjustments to the Pole Zero Assistant sliding bar. Exit the Digital Oscilloscope.

5. In the Detector Hardware Adjust window, press the gain button. Looking at the Apex Calibration View window, hit 'Start' and look for your peaks. If you don't see all your peaks, change the coarse gain until you do. For our lab, we measure a range of 0-1500 keV and use a coarse gain of 20x.



Detector Hardware Adjust

○ Stab. ○ HVPS ● Gain ○ Filter

Coarse gain: x20

Fine gain: 1.4001x (0.900 – 1.900)

S-fine gain: 0.999998x (0.9975 – 1.0025)

PUR Guard: 1.10x (1.1 – 2.5)

   a. You can further refine the detector range by adjusting the Fine gain and S-fine gain.

6. Press “Exit”, then “Save Settings” once you are satisfied with the detector’s range.

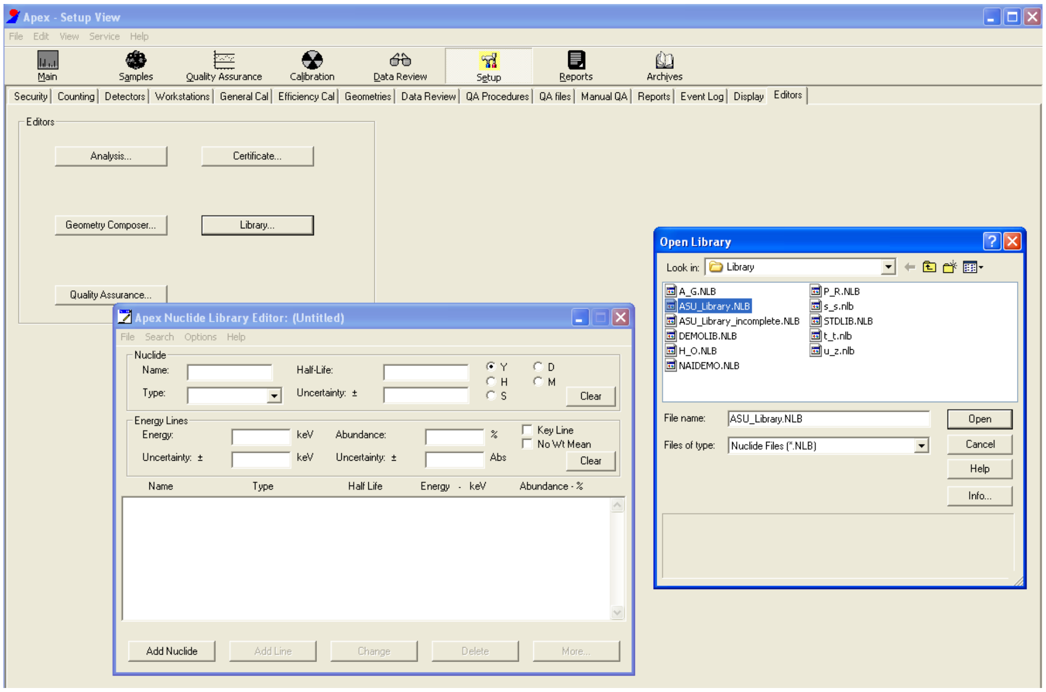
PART 2: THE NUCLIDE LIBRARY

The Nuclide Library is a list of gamma-emitting nuclides that Apex can identify based on their associated energy lines. Much like the original GENIE 2K software, APEX does not need a nuclide library to collect a spectrum; the nuclide library is required so individual peaks in the spectrum can be matched to the nuclide they are associated with. You may have a different library for individual projects or sample types, and generating the appropriate nuclide library requires a balance: Too few nuclides and APEX may fail to correctly identify a nuclide in a sample…too many nuclides and APEX may make false positives in associating energy lines with nuclides not actually present. The following steps lead you through creating and editing a nuclide library.

2.1: Importing Nuclide Information from Other Libraries

1. In APEX, go to **Setup** → **Editors**, and select **Library**

2. Go to **File** → **Open** to edit a current library. Select the Library you want to edit (e.g., ASU_Library.NLB).



Look in: Library

File name: ASU_Library.NLB

Files of type: Nuclide Files (*.NLB)

3. The library will open in the editor window. If you want to IMPORT new nuclide information from a preexisting library, or search other libraries for nuclides, click **Options → Extract.**

4. Select the intended library from which you would like to import information (e.g., A_G.NLB). Then select the nuclides you want to include and click **OK**

5. The nuclide will now be added to the library you are editing. Check to make sure the energy line you want to include is listed. If an energy line of interest is not included, you may need to manually create new energy lines.

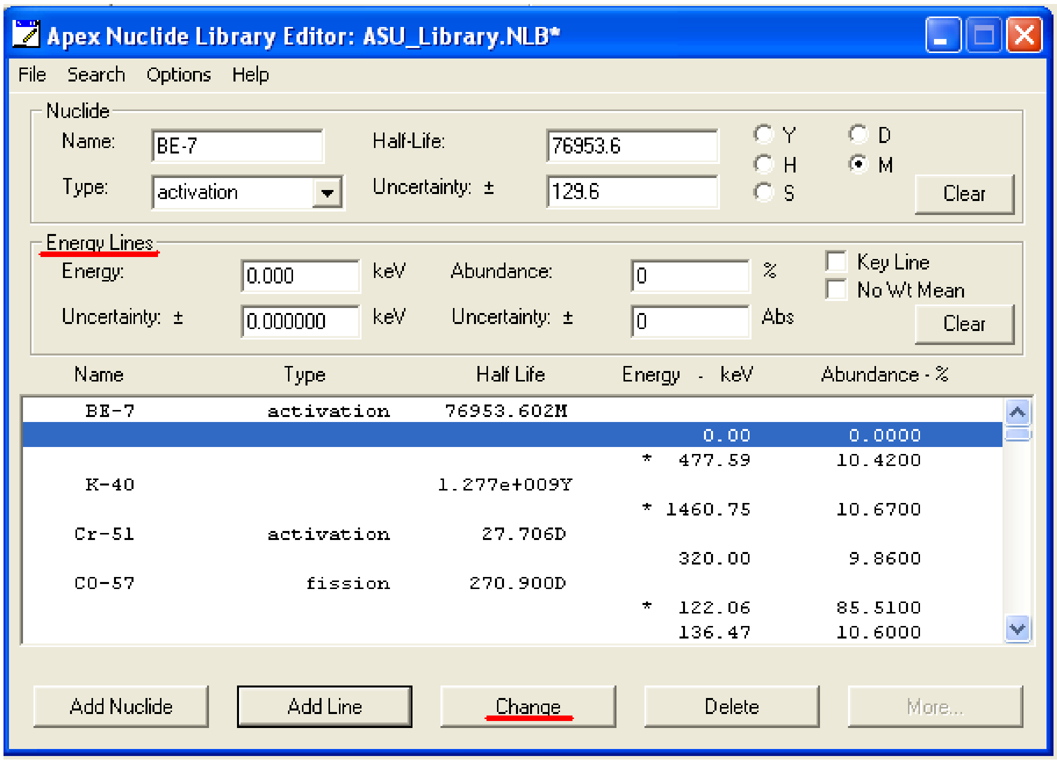
6. **File → Save** the new library, and DO NOT OVERWRITE old libraries unless you are absolutely sure of the changes.

2.2. Manually Entering Nuclide Information

You may need to manually edit a library if the information cannot be imported from preexisting libraries. For example, you may not have a nuclide of interest (e.g., Ac-228), or you may not have an important energy line for that nuclide (e.g., Ac-228 is listed, but the emission line at 129 keV is missing).

2.2.A) ADDING A NEW ENERGY LINE

1. Open the nuclide library you would like to edit following steps 1 and 2 of the previous section 2.1. To add a new energy line to a nuclide already listed, select the nuclide from the list and click "**Add line**."
2. Now select the new line by clicking on it (it will read 0.00 across all values).
3. In the section under "**Energy Lines**", manually enter the **energy** and **abundance** (emission efficiency). If this is the **key line** (the dominant emission line), click the box to the right. If you have the information for uncertainty, enter that information. Otherwise leave blank. When you have added the information, click **Change**.
4. You will now see the blank line (previously showing zero values) updated with the information you entered. Then go to **File →** **Save** or **File → Save As** to update the library or create a new library with the updated information.



Nuclide

Name: BE-7

Type: activation

Half-Life: 76953.6

Uncertainty: ± 129.6

○ Y ○ H ○ S ○ D ● M

Energy Lines

Energy: 0.000 keV

Uncertainty: ± 0.000000 keV

Abundance: 0 %

Uncertainty: ± 0 Abs

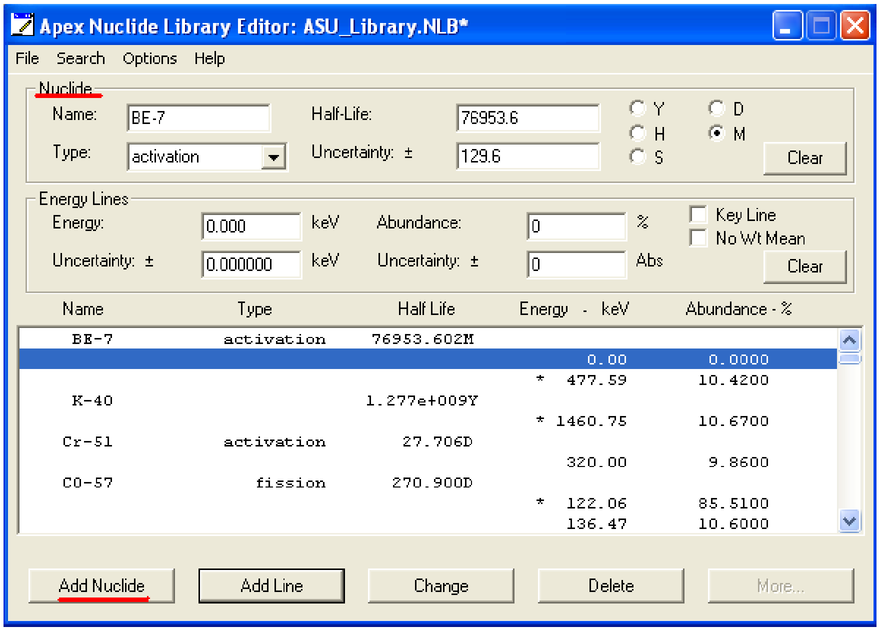
☐ Key Line

☐ No Wt Mean

```
Name           Type          Half Life        Energy  -  keV    Abundance - %
 BE-7        activation     76953.602M
                                                    0.00          0.0000
                                               *  477.59         10.4200
 K-40                      1.277e+009Y
                                               * 1460.75         10.6700
Cr-51        activation        27.706D
                                                  320.00          9.8600
CO-57           fission       270.900D
                                               *  122.06         85.5100
                                                  136.47         10.6000
```

2.2.B) ADDING A NEW NUCLIDE

1. To add a new nuclide that is not listed, enter the appropriate information in the top section under “**Nuclide**.” You need to enter the **name** (e.g., AC-228), the **half-life** and enter the appropriate **half-life units** (years, days, hours, minutes, or seconds). If you know the type or uncertainty about the half-life, also enter that information. Otherwise leave it blank. Then click **Add Nuclide**.



Nuclide
Name: BE-7
Type: activation
Half-Life: 76953.6
Uncertainty: ± 129.6
○ Y ○ H ○ S ○ D ● M

Energy Lines
Energy: 0.000 keV
Uncertainty: ± 0.000000 keV
Abundance: 0 %
Uncertainty: ± 0 Abs
☐ Key Line
☐ No Wt Mean

```
Name           Type           Half Life      Energy  -  keV      Abundance - %
  BE-7         activation     76953.602M
                                                      0.00          0.0000
                                                 *  477.59         10.4200
  K-40                       1.277e+009Y
                                                 * 1460.75         10.6700
 Cr-51         activation        27.706D
                                                    320.00          9.8600
 CO-57            fission       270.900D
                                                 *  122.06         85.5100
                                                    136.47         10.6000
```

2. You will now need to add energy lines following the previous instructions in 2.2.A.

3. **File → Save** or **File → Save As** to update the library or create a new library with the updated information.

PART 3: NUCLIDE STANDARDS

3.1. Types of Standards

3.1.A) SEALED POINT STANDARD

We will use a sealed multi-nuclide standard created by Eckert & Ziegler Isotope Products to perform energy calibrations. This standard provides several nuclides that emit gammas across a broad range of energy lines. You will use this standard for the following steps:

- Energy Calibrations
- QA/QC Calibration Checks
- QA/QC Absorption Checks

This point source is sealed and requires no preparation.

3.1.B) POWDERED 'ORE' STANDARD

We will use a powdered multi-nuclide standard created by Eckert Ziegler Analytics to perform efficiency calibrations. This standard provides several nuclides that emit gammas across a broad range of energy lines. Previously, we used a powdered Uranium Ore from Sasquatchewan Canada (http://www.nrcan-rncan.gc.ca/mmssmm/tect-tech/ccrmp/cer-cer/bl-5-eng.pd), however this sample has proven difficult to obtain. Now, we use an artificial 'soil' multi-nuclide standard created by Eckert & Ziegler Analytics. The powdered standard and a previously packed and run sample will together be used to create a "Packed Efficiency Standard." For each suite of samples (i.e., projects), you will broadly define between one and several textural classes based on material density, particle size and packing geometry. You will need a separate "Packed Efficiency Standard" for each packing geometry used. Using this standard we will calculate the gamma emission efficiency of a material with known activity through a sample of a set geometry and mass.

Begin conservatively, and determine the minimum number of "Packed Efficiency Standards" per project, based on the packing geometry. For example, if samples are packed in both the lid-dish geometry and a falcon-petri geometry, you will need at least two Efficiency Standards.

3.2: **Creating or Editing a Standard Certificate**

When a new standard arrives, the first step is to create or import the certificate. The purpose of the certificate is to specify the known nuclides and gamma-emission energy lines in the standard.

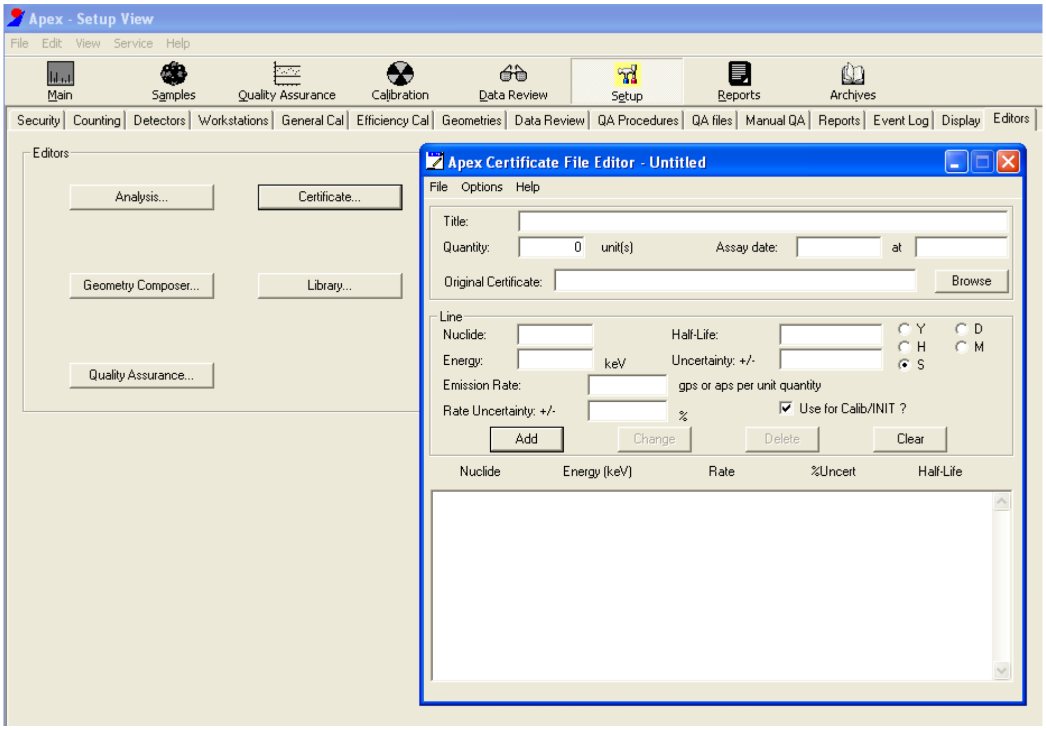
These instructions explain how to set up a certificate for a sealed point standard. To create a certificate for an Efficiency standard (a powdered or liquid standard), see section 5.2 of this protocol.

1. Go to **Setup → Editors → Certificate**
2. A new window will open with the APEX certificate file editor.

3. **Title** – Name of the new standard (e.g., Eckert-Ziegler planchet multiline standard).
4. **Quantity** – Hopefully written on the standard sheet. May be associated with with grams or who knows what. Hopefully this doesn't matter, or becomes clearer later.

5. **Assay Date** – Date the standard was manufactured (will be written on the standard certificate)

6. **Original Certificate** – you can import a '.ctf' file already associated with the standard if available.



Quantity: 0 unit(s)

○ Y ○ D ○ H ○ M ● S

☑ Use for Calib/INIT ?

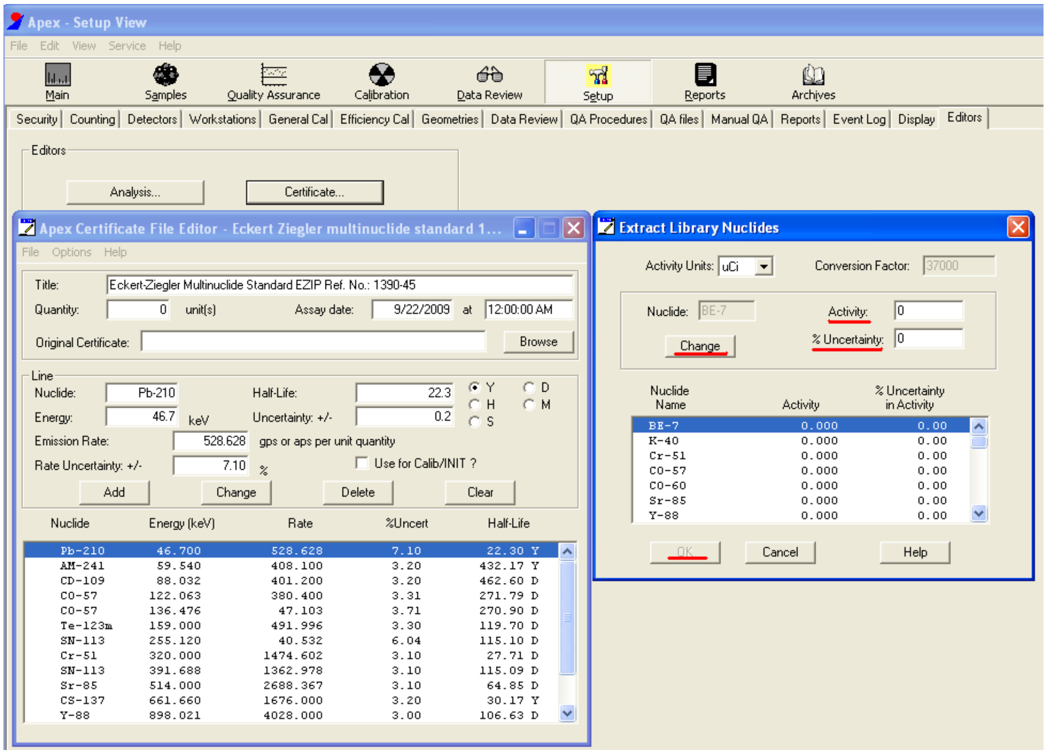
7. You will now need to add the individual nuclides and energy lines associated with the standard. Go to **Options → Library Extract**.

8. Open the nuclide library you would like to choose the nuclides from (e.g, ASU_library.nlb).

9. A new window will open that lists the nuclides included in the selected library. Select the nuclides in each standard. If you do not see a nuclide of interest, you will have to first add the nuclide to the library (see Part 1 of this protocol for how to update a nuclide library).

10. Select a nuclide listed on your standard certificate. In the area on the right hand side of the window, you will enter an **Activity** and **% Uncertainty**. Click **change**.

11. Repeat for all nuclides you have to add to the certificate. When finished, click **ok**.



Title: Eckert-Ziegler Multinuclide Standard EZIP Ref. No.: 1390-45

Quantity: 0 unit(s) Assay date: 9/22/2009 at 12:00:00 AM

Original Certificate:

Nuclide: Pb-210 Half-Life: 22.3 ● Y ○ D ○ H ○ M ○ S

Energy: 46.7 keV Uncertainty: +/- 0.2

Emission Rate: 528.628 gps or aps per unit quantity

Rate Uncertainty: +/- 7.10 % ☐ Use for Calib/INIT ?

Nuclide	Energy (keV)	Rate	%Uncert	Half-Life
Pb-210	46.700	528.628	7.10	22.30 Y
AM-241	59.540	408.100	3.20	432.17 Y
CD-109	88.032	401.200	3.20	462.60 D
CO-57	122.063	380.400	3.31	271.79 D
CO-57	136.476	47.103	3.71	270.90 D
Te-123m	159.000	491.996	3.30	119.70 D
SN-113	255.120	40.532	6.04	115.10 D
Cr-51	320.000	1474.602	3.10	27.71 D
SN-113	391.688	1362.978	3.10	115.09 D
Sr-85	514.000	2688.367	3.10	64.85 D
CS-137	661.660	1676.000	3.20	30.17 Y
Y-88	898.021	4028.000	3.00	106.63 D

Activity Units: uCi Conversion Factor: 37000

Nuclide: BE-7 Activity: 0 % Uncertainty: 0

Nuclide Name	Activity	% Uncertainty in Activity
BE-7	0.000	0.00
K-40	0.000	0.00
Cr-51	0.000	0.00
CO-57	0.000	0.00
CO-60	0.000	0.00
Sr-85	0.000	0.00
Y-88	0.000	0.00

12. You will see an updated list of the nuclides in the standard. Double check that each of them has the appropriate energy, half-life, rate, and % uncertainty listed on the certificate. The emission rate is a function of the activity and the quantity.

PART 4: ENERGY CALIBRATIONS

We will use a multi-nuclide point standard (type M disk) to do energy calibrations. The energy calibration tells the detector which channel is associated with which energy line. **NOTE! Only 10 previous energy calibrations are saved in APEX.** You will need to perform an energy calibration if:

- QA/QC procedures show deviations from the previous calibration
- You manually change any hardware settings (e.g., FOCUS, GAIN)
- You want to use a different point standard for future calibrations.

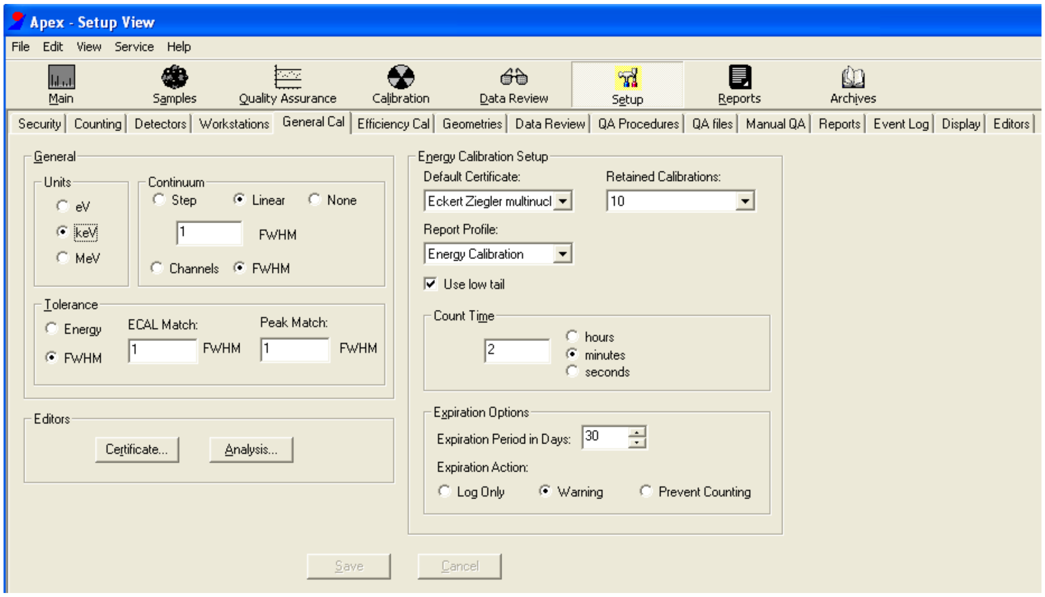
4.1. Adjusting the Default Calibration Settings

1. **Go to** Setup → General Cal
2. **Define the calibration parameters as follows:**
3. **Units** – set at keV
4. **Continuum** – defines the background counts around a peak. We set at linear w/ one FWHM.
5. **Tolerance –** defines the acceptable margin of error about a peak. We set at one FWHM
6. **Default Certificate –** will be set to the multiline point standard (e.g., Eckert Ziegler multiline.ctf)
7. **Retained Calibrations –** 10 is the maximum
8. **Report Profile –** choose energy calibration
9. **Use Low Tail** – keep checked
10. **Count time –** define the time you want each energy cal to run. For standards between 1 and 3 uCi, this will be less than 5

minutes. When you set up these parameters for a new standard, you will want to get around 5000 counts per nuclide within the time allotted. 2 Minutes would be a good default.

11. **Expiration Period in Days –** how often you want a standard run. We will likely perform new energy cals each month, and perform weekly or biweekly Quality Checks.

12. Click **Save** to save the new defaults.



General

Units: ○ eV ● keV ○ MeV

Continuum: ○ Step ● Linear ○ None

1 FWHM

○ Channels ● FWHM

Tolerance: ○ Energy ● FWHM

ECAL Match: 1 FWHM

Peak Match: 1 FWHM

Energy Calibration Setup

Default Certificate: Eckert Ziegler multinucl

Retained Calibrations: 10

Report Profile: Energy Calibration

☑ Use low tail

Count Time: 2 ○ hours ● minutes ○ seconds

Expiration Options

Expiration Period in Days: 30

Expiration Action: ○ Log Only ● Warning ○ Prevent Counting

4.2. Performing a new energy calibration

4.2.A) STARTING THE CALIBRATION

1. Go to **Calibration → Count**

2. Enter the correct parameters:

    a. **Detector** – Select the detector you would like to calibrate

    b. **Calibration Count Type** - select Energy

    c. **Description** - Provide a short description if desired

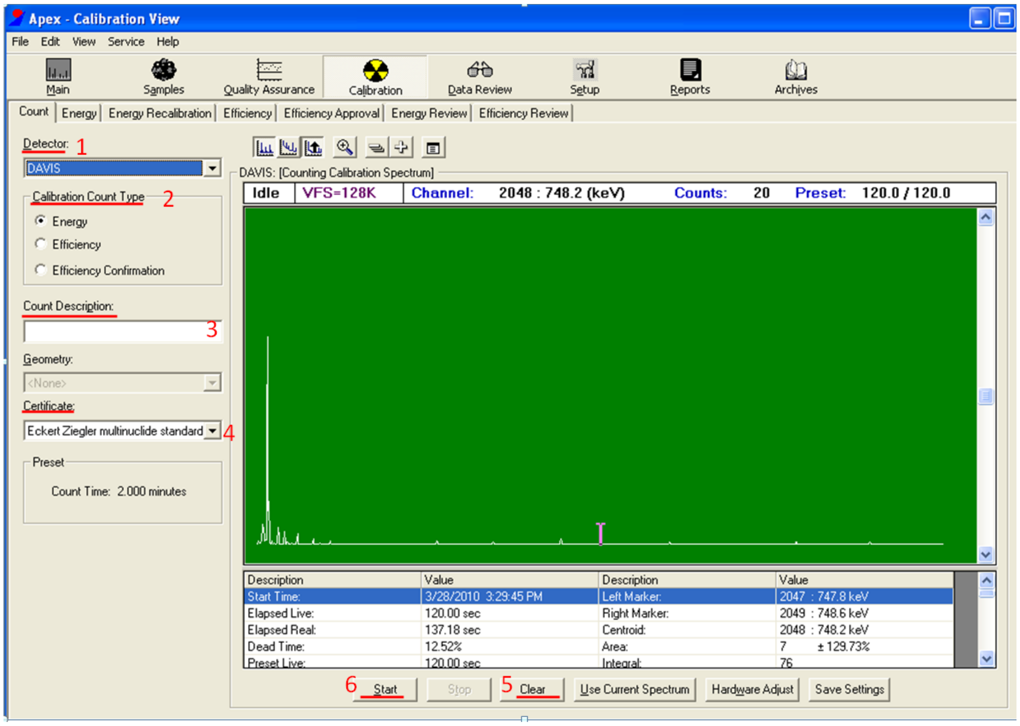
    d. **Certificate** - Select the certificate associated with the standard you will use.

   e. The **count time** is preset (see step #10 in section 4.1).

3. Load the point standard in the appropriate detector

4. Press **Clear** to clear the current spectrum and then press **Start**

5. The calibration will run 2 minutes (or the preset time) and then automatically save the spectrum. If you would like to end the calibration early, press **STOP** and then click **Use Current Spectrum** to save the counts as the new energy cal.



Detector: DAVIS

Calibration Count Type
● Energy
○ Efficiency
○ Efficiency Confirmation

Count Description:

Geometry: <None>

Certificate: Eckert Ziegler multinuclide standard

Preset
Count Time: 2.000 minutes

DAVIS: [Counting Calibration Spectrum]

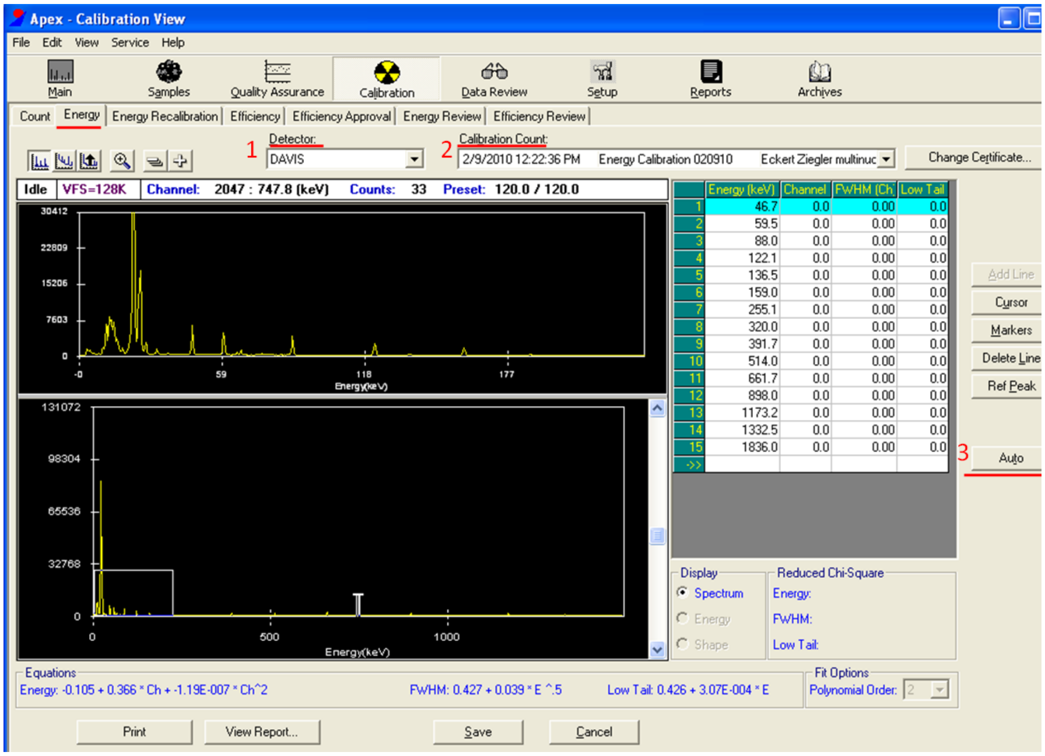
Idle | VFS=128K | Channel: 2048 : 748.2 (keV) | Counts: 20 | Preset: 120.0 / 120.0

Description	Value	Description	Value
Start Time:	3/28/2010 3:29:45 PM	Left Marker:	2047 : 747.8 keV
Elapsed Live:	120.00 sec	Right Marker:	2049 : 748.6 keV
Elapsed Real:	137.18 sec	Centroid:	2048 : 748.2 keV
Dead Time:	12.52%	Area:	7 ± 129.73%
Preset Live:	120.00 sec	Integral:	76

4.2.B) MATCHING PEAKS

1. To view the new calibration, go to **Calibration → Energy**. Select the appropriate detector and then the most recent Calibration Count (by date).

2. You will now need to associate the peaks in the graph with the nuclides and energy lines in the standard certificate. Click **Auto**. Apex will automatically match peaks based on its own algorithms.



Detector: DAVIS

Calibration Count: 2/9/2010 12:22:36 PM Energy Calibration 020910 Eckert Ziegler multinuc

Idle VFS=128K Channel: 2047 : 747.8 (keV) Counts: 33 Preset: 120.0 / 120.0

	Energy (keV)	Channel	FWHM (Ch)	Low Tail
1	46.7	0.0	0.00	0.0
2	59.5	0.0	0.00	0.0
3	88.0	0.0	0.00	0.0
4	122.1	0.0	0.00	0.0
5	136.5	0.0	0.00	0.0
6	159.0	0.0	0.00	0.0
7	255.1	0.0	0.00	0.0
8	320.0	0.0	0.00	0.0
9	391.7	0.0	0.00	0.0
10	514.0	0.0	0.00	0.0
11	661.7	0.0	0.00	0.0
12	898.0	0.0	0.00	0.0
13	1173.2	0.0	0.00	0.0
14	1332.5	0.0	0.00	0.0
15	1836.0	0.0	0.00	0.0
->>				

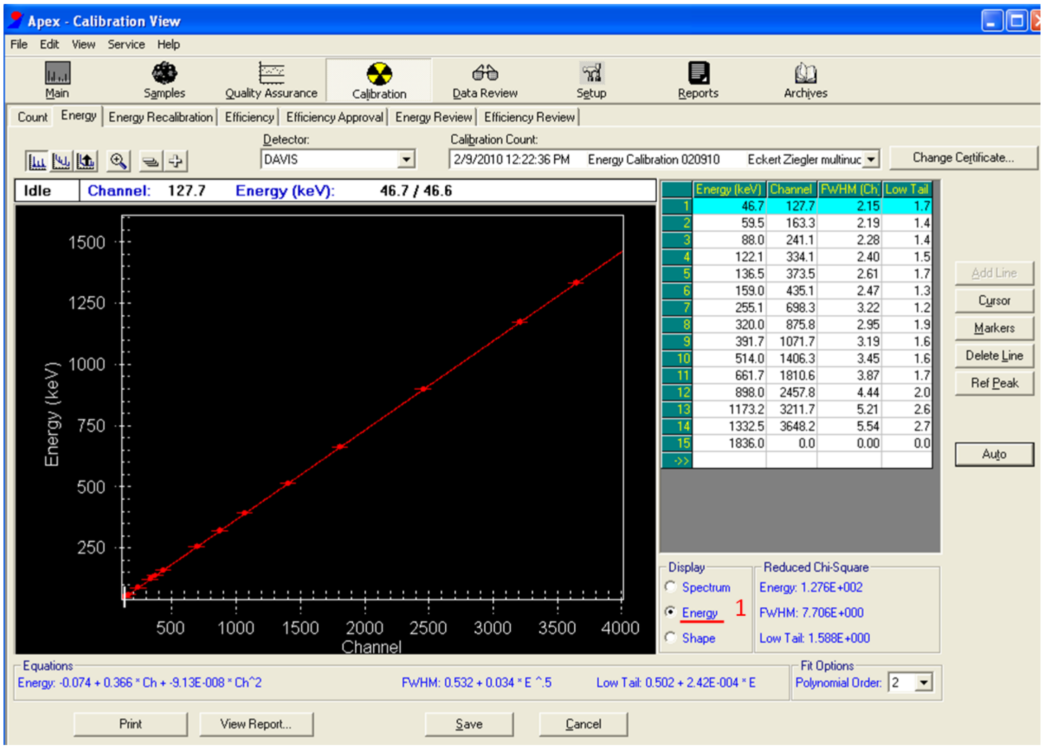
Display
● Spectrum
○ Energy
○ Shape

Reduced Chi-Square
Energy:
FWHM:
Low Tail:

Equations
Energy: -0.105 + 0.366 * Ch + -1.19E-007 * Ch^2
FWHM: 0.427 + 0.039 * E ^.5
Low Tail: 0.426 + 3.07E-004 * E

Fit Options
Polynomial Order: 2

3. In the area underneath the chart, click **ENERGY** under **Display**. The graph will now display the calibration curve for this standard. If the calibration curve is not a line, or shows outlying points, you may need to manually assign energy lines to the peaks (or you may need to double check that the correct certificate is loaded). If the calibration looks good, click Save and skip to step #4.



Detector: DAVIS

Calibration Count: 2/9/2010 12:22:36 PM Energy Calibration 020910 Eckert Ziegler multinuc

Idle Channel: 127.7 Energy (keV): 46.7 / 46.6

	Energy (keV)	Channel	FWHM (Ch	Low Tail
1	46.7	127.7	2.15	1.7
2	59.5	163.3	2.19	1.4
3	88.0	241.1	2.28	1.4
4	122.1	334.1	2.40	1.5
5	136.5	373.5	2.61	1.7
6	159.0	435.1	2.47	1.3
7	255.1	698.3	3.22	1.2
8	320.0	875.8	2.95	1.9
9	391.7	1071.7	3.19	1.6
10	514.0	1406.3	3.45	1.6
11	661.7	1810.6	3.87	1.7
12	898.0	2457.8	4.44	2.0
13	1173.2	3211.7	5.21	2.6
14	1332.5	3648.2	5.54	2.7
15	1836.0	0.0	0.00	0.0
->>				

Display
○ Spectrum
● Energy
○ Shape

Reduced Chi-Square
Energy: 1.276E+002
FWHM: 7.706E+000
Low Tail: 1.588E+000

Equations
Energy: -0.074 + 0.366 * Ch + -9.13E-008 * Ch^2
FWHM: 0.532 + 0.034 * E ^.5
Low Tail: 0.502 + 2.42E-004 * E

Fit Options
Polynomial Order: 2

a. To manually assign energy lines to the peaks, go to **Calibration → Energy** and select the detector and most recent Calibration Count (by date). Click **SPECTRUM** under **Display** and move the cursor over the graph. Click on one of the peaks and use the arrow keys to center the cursor bar at the top of the peak. In the table on the right, select the energy line that corresponds to this peak and press the **Cursor** button. Check the standard certificate ahead of time to see what the pattern of peaks is so that you can identify the peaks on a non-calibrated spectrum. Apex usually only needs one or two manually submitted correlations to produce the correct energy calibration. Double-check that the calibration is correct by repeating step #3.

4. Repeat for all detectors.

PART 5: EFFICIENCY CALIBRATIONS

We will use a powdered ‘ore’ multinuclide standard to perform efficiency calibrations. The efficiency calibration checks to find out how many gammas from a standard of known activity are actually recorded by the detector. The actual recorded COUNTS are influenced by:

The **activity** of the sample (the amount of nuclides w/in a sample)

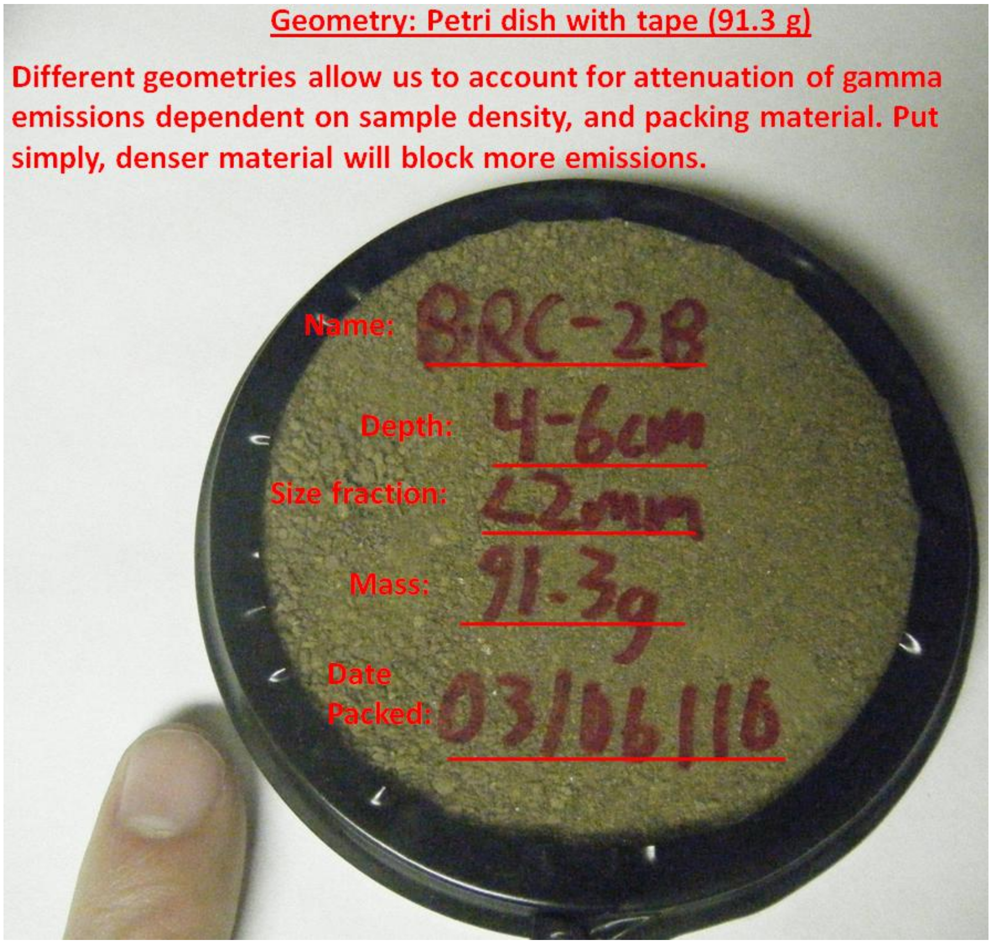
The **emission efficiency** of the nuclide (what percentage of gammas are actually emitted at a specific energy line)

The **efficiency of the detector** (how many of the emitted gammas interface with the germanium crystal and are recorded by the detector)

The **efficiency of the packing geometry and material** (whether any gammas are attenuated through the sample due to the packing geometry, mass, or sample container).

5.1. Creating a New Efficiency Standard

5.1.A) MIXING STANDARD AND SAMPLE IN THE LAB



Geometry: Petri dish with tape (91.3 g)

Different geometries allow us to account for attenuation of gamma emissions dependent on sample density, and packing material. Put simply, denser material will block more emissions.

Name: BRC-2B

Depth: 4-6cm

Size fraction: <2mm

Mass: 91.3g

Date Packed: 03/06/16

1. Take a representative sample that has already been run for fallout analysis. By ‘representative’, I mean that it should have a mass, packing geometry, and density that reflects a suite of other samples.

2. Put on the magic radiation ring and badge. Each user must have radiation training, and you will obtain these items from the Radiation Office once training is complete.

3. Grab the powdered ‘ORE’ standard from its storage place. You will need a clean surface and space with which to work. Lay down paper towels, clean paper, or kim-wipes on the work surface. The powdered ore standard has a much higher total activity >500 uCi (Unfortunately, the ore we are currently using is far less active ~3.0uCi which is resulting in painfully long calibrations or the use of a couple grams of ore) than the soil

samples, and therefore you want to avoid contamination of your work space.

4. Grab a weigh boat from the drawer and place on the analytical balance. Tare the weight to zero.

5. Using a clean spatula (specifically for fallout work), weigh out ~1 gram (+/- .01) of the powdered 'Ore' Standard and place into the weigh boat. Record the weight.

6. Using a second weigh boat, separate the 1 g standard into two roughly equal fractions. Place the soil sample on a kim-wipe or clean sheet of paper and remove the lid. Pour roughly equal halves of the soil sample into each boat.

7. Carefully mix the "ore" and the soil together so as not to lose any of either.

8. When mixed, carefully pack ALL of the soil (plus extra gram of standard) back into the sample container.

9. Replace the lid and re-tape the container.

10. It is very important that you do not contaminate the fallout lab with powdered standard, therefore carefully clean the outside of the container using a kim-wipe and water and make sure no 'sample or standard' can escape through the tape.

11. Label the outside lid with "**MULTINUCLIDE EFFICIENCY STANDARD**" and the **mass** of ore added (e.g., "added 1.001 g ORE").

12. The standard contains multiple nuclides, each with a set 'nuclide activity' per gram of sample (^{210}Pb = 1uCi/g; ^{137}Cs= 1uCi/g; etc.) Double check the standard certificate for this activity. The sum of these individual activities will equal the 'total activity'. Multiply the 'nuclide activity' by the mass of ore added (e.g., 1 uCi/g * 1.001 gram standard). Record this activity (in units uCi) on the outside of the sample.

13. Carefully clean the lab and record your actions in the appropriate lab book.

5.2. Efficiency Standard Certificates

Each efficiency standard will require a new certificate based on the mass of the ‘ore’ included in the packed sample. This certificate will then be associated with all samples associated with this sample geometry and texture. Each time you generate a new Efficiency Standard, you will create a new certificate based on a default certificate file already stored in APEX.

5.2.A) GENERATING A TEMPLATE CERTIFICATE

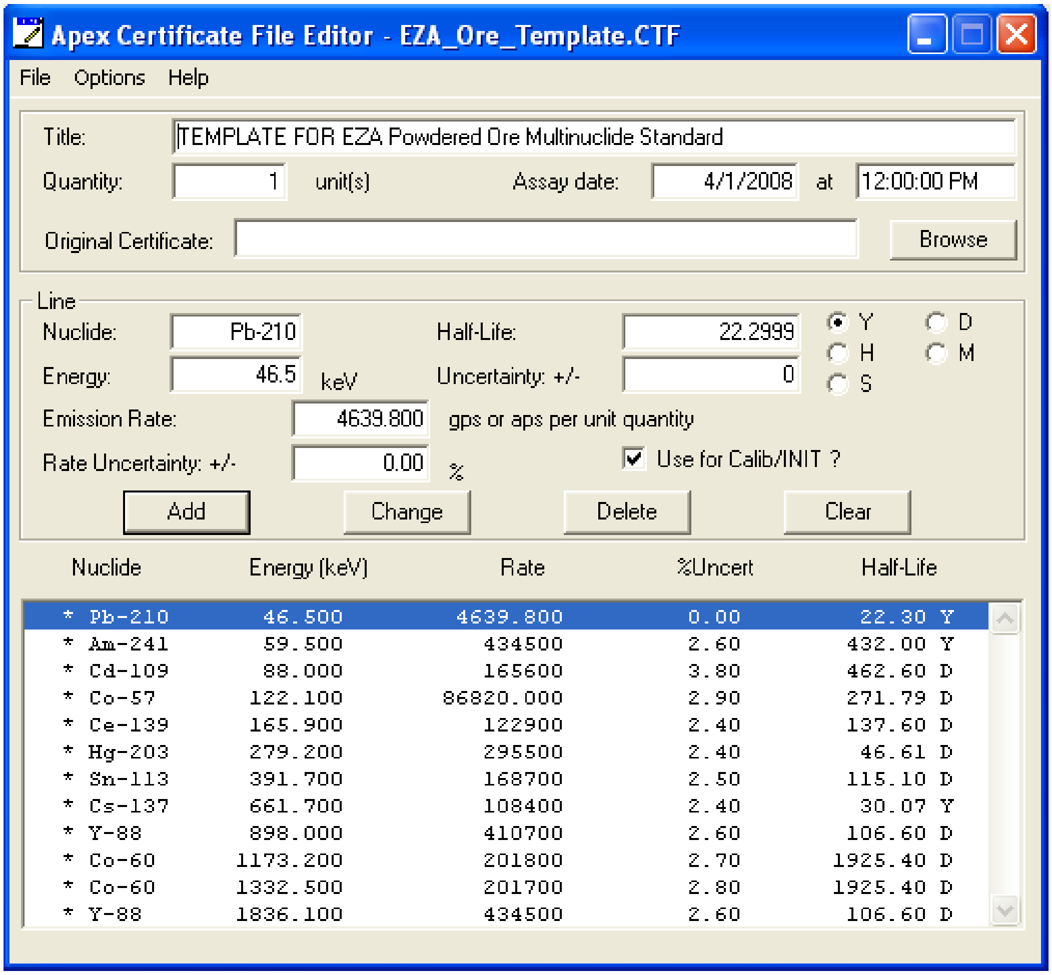
1. We will use the template certificate every time we create a new Efficiency Standard. You should only need to update it once, after the standard and certificate have arrived in the mail. The default certificate can be found by going to **Setup → Editors** and then selecting **Certificate.**
2. **File → Open** and then select “EZA_Ore_Template”
3. You will now see the dummy default certificate file for the ore standard. Change the **Assay Date** and Time to the one listed on the certificate.
4. The **Quantity** should read “**1 Units**.” Here, the units we are using are grams.

   A brief primer on radioactivity. The becquerel (Bq) is the SI unit for nuclide activity, and it equals one disintegration per second. Activities can also be described as Curies (Ci), which is an older measure standardized to the decay of Radium. Don’t worry too much about that; all you really need to know is that One Curie = 3.7 x 10^{10} Bq. In your standard, you are interested in the ACTIVITY PER GRAM of material. This quantity may be the same across all nuclides depending on the standard, but not necessarily! The important thing to note is that we are interested in the Activity PER ONE GRAM.

   In the Default Certificate you are now editing, the quantity is currently listed as ‘1 Unit(s)’, which means that the emission rates you enter are calculated per one unit quantity (or per one gram of material).

Emission Rates on this digital certificate will need to be updated based on the nuclide activity w/in the standard. Be sure to convert the emission rate given for the standard into units of becquerels per gram before entering it into the digital certificate.

5. In the lower half of the certificate editor window, you will see a list of the nuclides included in the standard. Check the standard certificate from Eckert & Ziegler to see if these match what is actually included in the standard.
6. If you need to add more nuclides or energy lines, you can do this manually by entering the information under **LINE** and clicking **ADD**. If you would like to add a nuclide by extracting the information from a library, you can go to **Options → Library Extract** and then selecting the appropriate library and nuclide.
7. Now that you have the correct nuclides and energy lines listed in the table, individually select a nuclide by clicking on it. You will see the **nuclide** name (e.g., Pb-^{210}), the **Half-Life**, the **Energy Line**, and the **uncertainty** about this line. Double check all of these parameters match those given in the standard certificate. *IMPORTANT* When entering half-life Apex will do the unit correction for you. For example, if the half life currently says 1 Hr and you want it to be 60 seconds, DO NOT enter “60” then click seconds. Apex will interpret this as 60 hours and convert it to seconds when you click seconds.
8. You will now need to update the **Emission Rate** and **Uncertainty** based on the activity of the nuclide (given in Becquerels or microCuries).
9. Make sure the box “**Use for Calib/INIT**” is checked.
10. **File → Save**, when everything is correct.



Title: TEMPLATE FOR EZA Powdered Ore Multinuclide Standard

Quantity: 1 unit(s)

Assay date: 4/1/2008 at 12:00:00 PM

Original Certificate:

Line

Nuclide: Pb-210

Half-Life: 22.2999 ● Y ○ H ○ S ○ D ○ M

Energy: 46.5 keV

Uncertainty: +/- 0

Emission Rate: 4639.800 gps or aps per unit quantity

Rate Uncertainty: +/- 0.00 %

☑ Use for Calib/INIT ?

	Nuclide	Energy (keV)	Rate	%Uncert	Half-Life
*	Pb-210	46.500	4639.800	0.00	22.30 Y
*	Am-241	59.500	434500	2.60	432.00 Y
*	Cd-109	88.000	165600	3.80	462.60 D
*	Co-57	122.100	86820.000	2.90	271.79 D
*	Ce-139	165.900	122900	2.40	137.60 D
*	Hg-203	279.200	295500	2.40	46.61 D
*	Sn-113	391.700	168700	2.50	115.10 D
*	Cs-137	661.700	108400	2.40	30.07 Y
*	Y-88	898.000	410700	2.60	106.60 D
*	Co-60	1173.200	201800	2.70	1925.40 D
*	Co-60	1332.500	201700	2.80	1925.40 D
*	Y-88	1836.100	434500	2.60	106.60 D

5.2.B) CREATING OR EDITING NEW EFFICIENCY CERTIFICATES

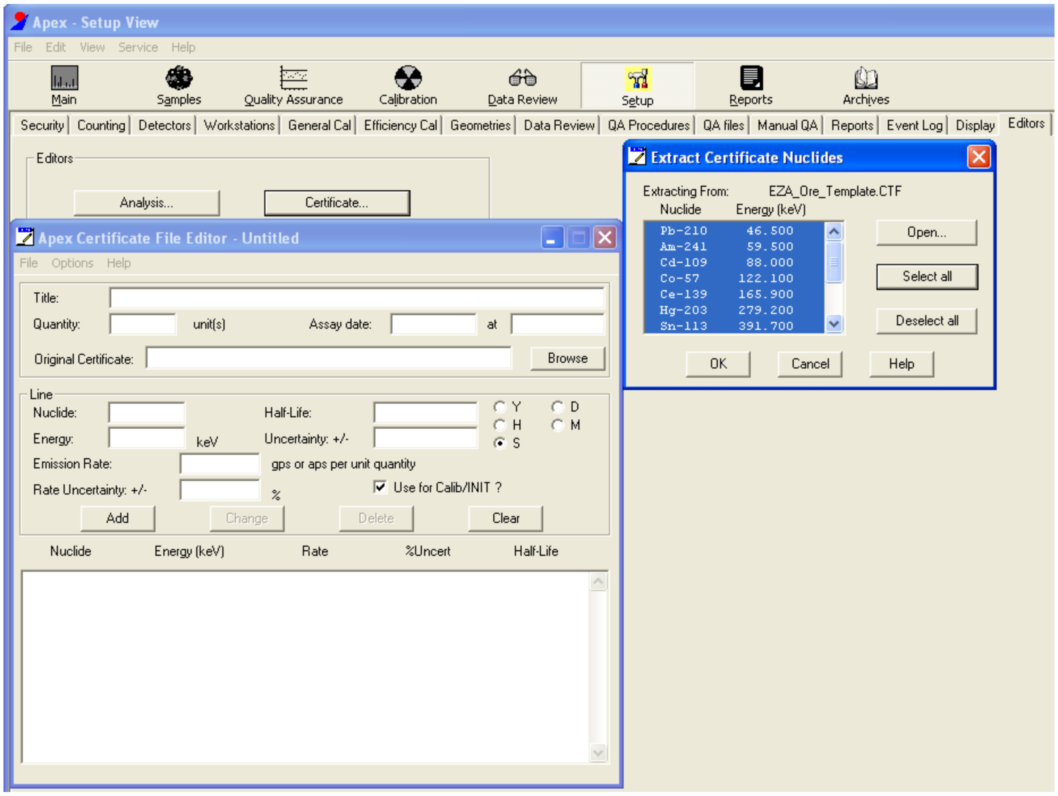
1. Each time you create a new EFFICIENCY Standard (by mixing the 'Ore' Standard with a previously run soil), you will have to create a new standard certificate. Open the Default Certificate by going to **Setup → Editors** and then selecting **Certificate.** Then go to **File → New*.**
   *** If you've already made a certificate and the efficiency ore is the same, <u>and your sample has the same amount of ore (1.0g) </u>, it is a lot easier to go to File -> Open and open up a previous sample based on the same efficiency ore. Once you have that sample open, simply change the title to reflect the sample name and mass. **MAKE SURE YOU USE !<u>SAVE AS!</u>** AND SAVE THE CERTIFICATE WITH THE NEW SAMPLES ID. This is EXTREMELLY IMPORTANT!! Do not overwrite a certificate!!**
2. Go to **Options → Certificate Extract** and Open the Default Certificate named *EZA_ORE_Template 052010.CTF*".
3. Click **Select All** and then **OK** to import the nuclides and energy lines into the new standard certificate.
4. Create a **Title** based on the sample you have used to create this new standard. Supposedly, this sample is representative of a suite of other samples, and is therefore representative of a geometry. Recall that each 'geometry' has a distinct packing container and sample texture. For example, there may be several Geometries for soils from the San Gabriel Mountains (possible one for fine soils at Sulpher springs, one for >2mm soils, and one for clay rich soils).
5. An example title might be: "EFF Standard MFA1 0-2cm; <2mm soil; 93.5 grams soil and 1.006g Ore Standard; Petri dish geometry".
6. This would denote a new efficiency standard created by mixing 1.006g of the "ore" standard in with 93.5g of previous run soil, named MFA 1 0-2cm <2mm.

7. Under **Quantity**, enter the mass of Ore standard packed with the soil. The template certificate was generated with **“units”** defined as grams. The ore packed should be approximately one gram. (in the example above, this quantity would read 1.006 units)

8. The Assay Date should not be changed, and should be the date the original ore standard was created by Eckert Ziegler, **NOT** the date you packed the new emission standard.

9. Assuming the Template Certificate was created correctly, no other information will need to be updated in this Standard Certificate.

10. **Save** the Certificate using an appropriate name such as “**MFA1 <2mm Efficiency.ctf**”.

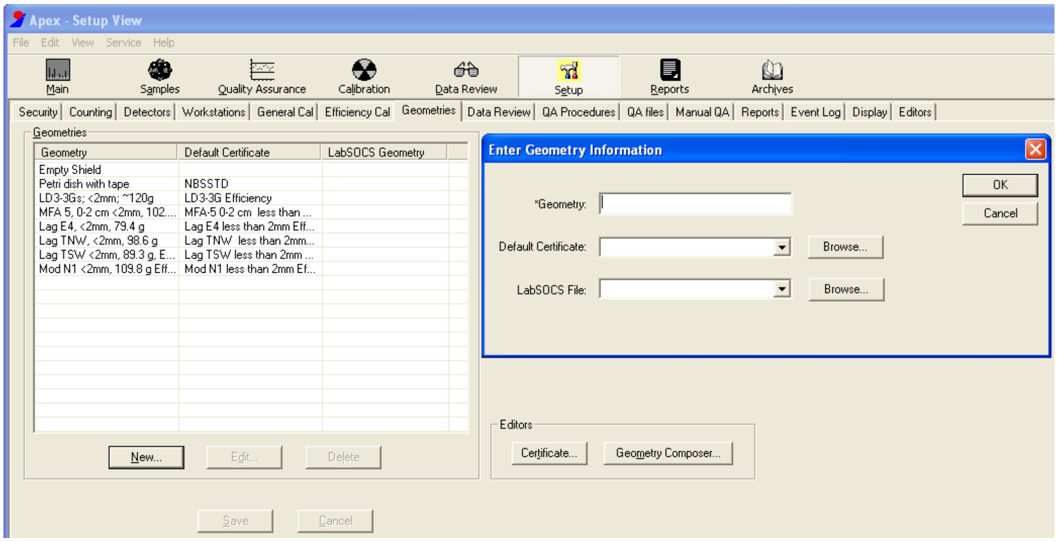


Extracting From: EZA_Ore_Template.CTF

Nuclide	Energy (keV)
Pb-210	46.500
Am-241	59.500
Cd-109	88.000
Co-57	122.100
Ce-139	165.900
Hg-203	279.200
Sn-113	391.700

5.2.C) CREATING A NEW GEOMETRY BASED ON THE EFFICIENCY STANDARD

1. You now need to create a new geometry based on the new efficiency standard. Go to **Setup → Geometries** and select **New**.
2. Under **Default Certificate**, select the Efficiency Standard you have just created (e.g., “MFA1 <2mm Efficiency”).
3. Under **Geometry**, generate a name based on the name of the efficiency standard (e.g., “MFA1 <2mm 93.5g”).
4. Leave **LabSOCS File** blank, and click **OK**.
5. The new geometry should now show up in the list. Click **Save**. You are finally ready to perform the efficiency calibration!



Geometry	Default Certificate	LabSOCS Geometry
Empty Shield		
Petri dish with tape	NBSSTD	
LD3-3Gs; <2mm; ~120g	LD3-3G Efficiency	
MFA 5, 0-2 cm <2mm, 102....	MFA-5 0-2 cm less than ...	
Lag E4, <2mm, 79.4 g	Lag E4 less than 2mm Eff...	
Lag TNW, <2mm, 98.6 g	Lag TNW less than 2mm...	
Lag TSW <2mm, 89.3 g, E...	Lag TSW less than 2mm ...	
Mod N1 <2mm, 109.8 g Eff...	Mod N1 less than 2mm Ef...	

*Geometry:

Default Certificate:

LabSOCS File:

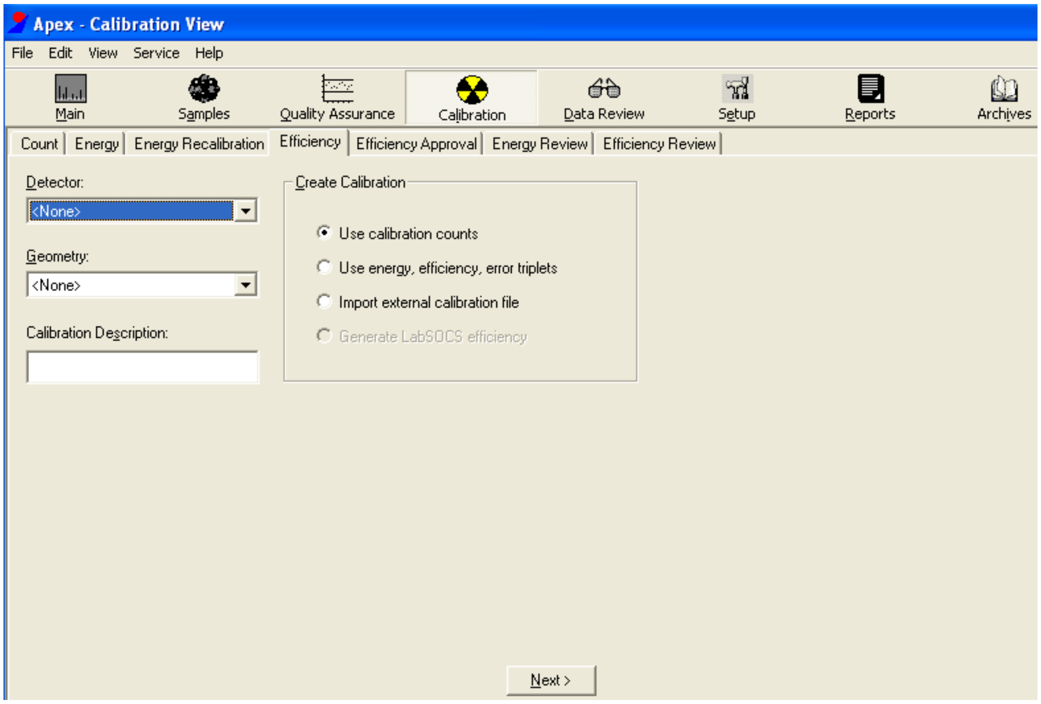
5.3. Performing an Efficiency Calibration

5.3.A) COUNTING AN EFFICIENCY STANDARD

1. Clean the surface of the new efficiency standard with DI water and a kimwipe. This is an incredibly important step. It is ***critical*** that you do not contaminate the INSIDE of the shield with this powdered standard.
2. Select a detector and place the *clean* standard inside the shield atop the detector. Close the shield lid.
3. In Apex, go to **Calibration → Count**.
4. Select the **detector** you just loaded and select **Efficiency**.
5. Under **Count Description**, list the important information you want to remember (e.g., Efficiency Standard from MFA 1 <2mm 93.5g soil).
6. Under **Geometry**, select the Geometry you defined in the previous step (e.g., “MFA 1 <2mm 93.5g”).
7. Under **Certificate**, double check that the certificate matches the Efficiency Standard you created (e.g., “MFA1_<2mm_Efficiency.ctf”).
8. In the area beneath the green spectrum, click **Clear** and then **Start**. The count time is preset (this parameter and others are defined in **Setup → Efficiency Cal**).
9. When the count finishes, the spectrum will be saved automatically.
10. Repeat for each detector.

5.3.B) CALIBRATING A GEOMETRY

1. You now need to apply the efficiency counts to a specific geometry. Go to **Calibration → Efficiency**.
2. Select the Appropriate **Detector** and the **Geometry** recently defined (e.g., “MFA 1 <2mm 93.5g”).
3. Enter a **calibration description** if desired. If the geometries, efficiency standards, and efficiency calibrations all used a similar name, a description is not necessary.



Detector: <None>

Geometry: <None>

Calibration Description:

Create Calibration

● Use calibration counts

○ Use energy, efficiency, error triplets

○ Import external calibration file

○ Generate LabSOCS efficiency

4. Under Create Calibration, select Use Calibration Counts, and click NEXT.
5. Click the box for the Calibration Count you just performed. A check mark should appear next to this count. Click **NEXT**.
6. The calibration curve should now appear. Feel free to play around with the settings for the model. Different Model Types (under Description) and Polynomial Fits will change the modeled curve slightly, but will likely not have a large difference. You want to be consistent with the model types you choose and apply, therefore I recommend using a **DUAL Calibration Model**

with a **4 Poly Order**. *Note it will look like the graph in the screen shot shown below. The screenshot is taken from the approval screen.

7. If you are happy with the calibration, click **Save**. You will now have to Approve the Calibration before it can be applied.

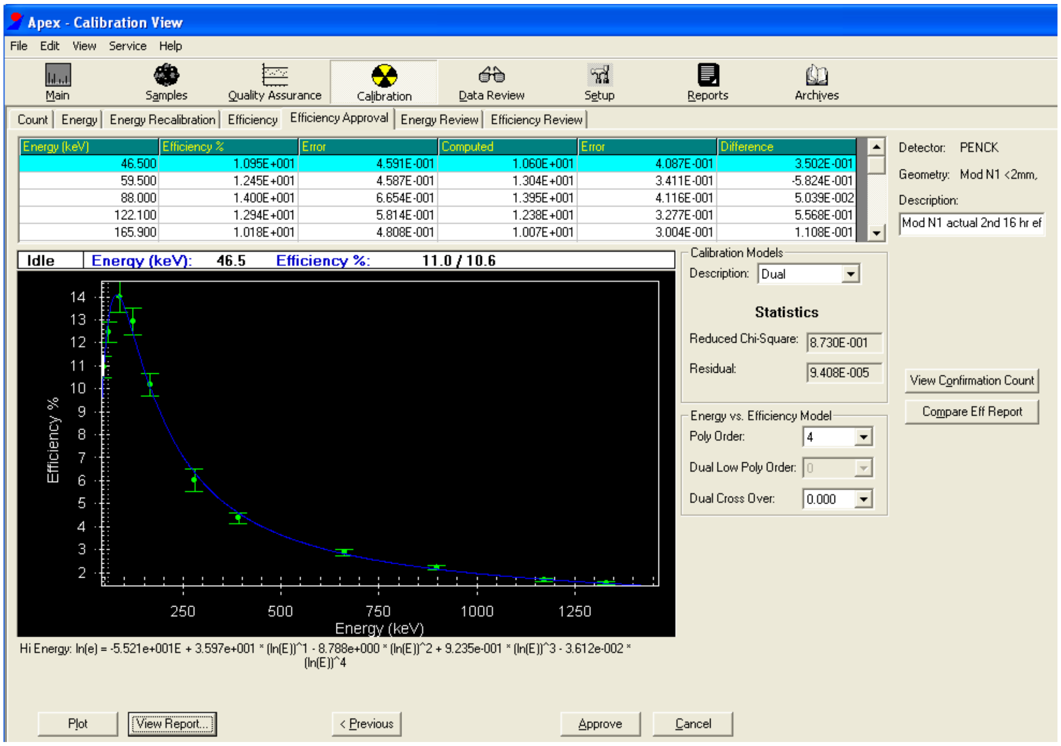
5.2.D) APPROVING AN EFFICIENCY CALIBRATION

1. The final step in creating an efficiency calibration is approving the model and report. Go to **Calibration → Efficiency Approval**.

2. Select the **Detector** and the **Geometry**. Select the **Calibration** with status listed as “Pending Approval”. Click **Next**.

3. This is essentially the same step you went through in the previous section. Here you can view the report or change the model settings. Click **Approve**.

4. At any point, if you would like to review previous efficiency calibrations, you can go to **Calibration → Efficiency Review**.



Energy (keV)	Efficiency %	Error	Computed	Error	Difference
46.500	1.095E+001	4.591E-001	1.060E+001	4.087E-001	3.502E-001
59.500	1.245E+001	4.587E-001	1.304E+001	3.411E-001	-5.824E-001
88.000	1.400E+001	6.654E-001	1.395E+001	4.116E-001	5.039E-002
122.100	1.294E+001	5.814E-001	1.238E+001	3.277E-001	5.568E-001
165.900	1.018E+001	4.808E-001	1.007E+001	3.004E-001	1.108E-001

Detector: PENCK

Geometry: Mod N1 <2mm,

Description: Mod N1 actual 2nd 16 hr ef

Idle Energy (keV): 46.5 Efficiency %: 11.0 / 10.6

Calibration Models

Description: Dual

Statistics

Reduced Chi-Square: 8.730E-001

Residual: 9.408E-005

Energy vs. Efficiency Model

Poly Order: 4

Dual Low Poly Order: 0

Dual Cross Over: 0.000

Hi Energy: ln(e) = -5.521e+001E + 3.597e+001 * (ln(E))^1 - 8.788e+000 * (ln(E))^2 + 9.235e-001 * (ln(E))^3 - 3.612e-002 * (ln(E))^4

PART 6: QUALITY ANALYSIS AND QUALITY CONTROL

6.1: Quality Assurance Parameters

Click **Quality Assurance** in the APEX menu. Under **Charts and Reports** you will note a list of parameters that we use to check that APEX and our lab are working correctly. These include background checks (measurement of background lab radiation) and calibration checks.

QA/QC Programs check for problems that could influence the **quality of the data generated in this lab**. Several different factors could negatively influence the accuracy of our measured counts:

- Lab or detector contamination that affects or alters the *measured* nuclide activities
- Hardware or software issues that affect the accuracy of decay counts or peak identification
- Changes in lab conditions over extended periods of time

The following QA parameters will be checked regularly:

1. **Background Check –** Measures the background gamma emission for the room or shield. This is a natural base level and should be low and non-changing. This check can detect *environmental problems* or *hardware problems*. In this lab we will perform 2 background checks:
    - Low Region (up to ~ 661 keV) <- This parameter we define
    - High Region (~661keV to ~1500 keV) <- This parameter we define

   Changes in the background radiation may indicate contamination of either the lead shield or the room/facility.

2. **Calibration Check –** Measures the accuracy and precision of detected gamma radiation using a known standard of known activity. This check can detect *hardware problems.* In this lab,

we will perform three tests at several energy lines (e.g., 46.5, 382, 1332 keV):

- **Peak Energy –** Checks to make sure that gamma emissions from a known source are accurately recorded at the correct energy line (keV).
- **Peak Area -** Checks to make sure that the counts per second (c/s) measured from a known source with a known activity are correct.
- **Peak FWHM –** Checks that the shape of a peak from a known standard with a known activity is not changing over time (for any reason other than known nuclide decay).

3. **System Background Check-** Measures the background of anything not included in the **Background Check**. This may include introduced background gamma emissions associated with a new soil geometry or sample container. We don't typically do system background checks since we do not expect any contamination from sample geometry. An example of sample geometry contamination may include a glass or metal container that contains gamma emitting nuclides.
4. **Absorption Check –** We will also use QA/QC parameters to perform **ABSORPTION CHECKS** that check for the appropriateness of efficiency calibrations for different sample types of geometries. These checks are custom for our lab and will rely on 'calibration check' programs in APEX.

6.2. Calibration Checks

You will need to redefine QA procedures based on the nuclides w/in your standard. For example, the PEAK AREA, FWHM, and Peak ENERGY calibration files are written for specific nuclides. If you have a new standard, you will need to update these files to reference nuclides and energy lines that are contained in you new standard. See section __ for editing a QA file.

6.2.A) GENERAL INFO ON QA/QC CALIBRATION FILES

You will set up three tests (FWHM, Peak Area and Peak Energy) at each of 3-4 Energy Lines. You will choose these energy lines based on the ones available in your standard. For example, using the borrowed EZ Planchet Standard, we defined these tests at 88 kev, 661.7 kev and 1332.5 kev. Edit these files appropriately.

1. In Apex go to **Setup → Editors** , click **Quality Assurance.** Click **File → Open**

2. Click *QACALCHK.QAF.* To view the parameters currently being checked by this file, click **Edit-defs**, click **parameter definitions.**

3. You should see 9 tests listed (peak area, FWHM, and Peak Energy tests) each at 3 different energy lines. Pick 3-4 nuclide lines from the standard certificate for the Eckert & Ziegler Isotope Products sealed point standard. These energies should be spread across a range of energy lines, and should include the 46.5 keV line for Pb-^{210} and the 661.7 keV line for Cs-^{137}. Select one parameter (e.g. lower region) and click **more**.

4. **Description**- (e.g. Peak FWHM- 661.6 keV) This is the name of the parameter to be checked.

5. Name, Error Name, Nuclide, Type, Store Error, Start Channel, End Channel – Cannot be edited.

6. **Energy Line**- (e.g. 661.6 keV) This defines the energy line that will be repeatedly checked for the defined parameter (e.g. FWHM, Peak Energy, or Peak Count)

7. **Units**: (counts)

8. Conversion factor- Should always be 1.

9. **N-Sigma Tests** – This is where you define the acceptable values for your test.

10. **Investigate sigma**- This means if your background check moves outside a given number of standard deviations the software will give you an alert. If your count moves outside a specified level you will be prompted to respond. Recommend setting to 2 or 3 unless needing more accuracy.

11. You have a choice of the following three N-sigma tests:

    - **Sample Driven Test**- The mean and standard deviation for acceptable data are defined by previously run samples. You can use this to have a test that is defined by all previous data. Danger with this is you may miss slow instrument drift over time because your mean can be slowly changing over time and you may miss it

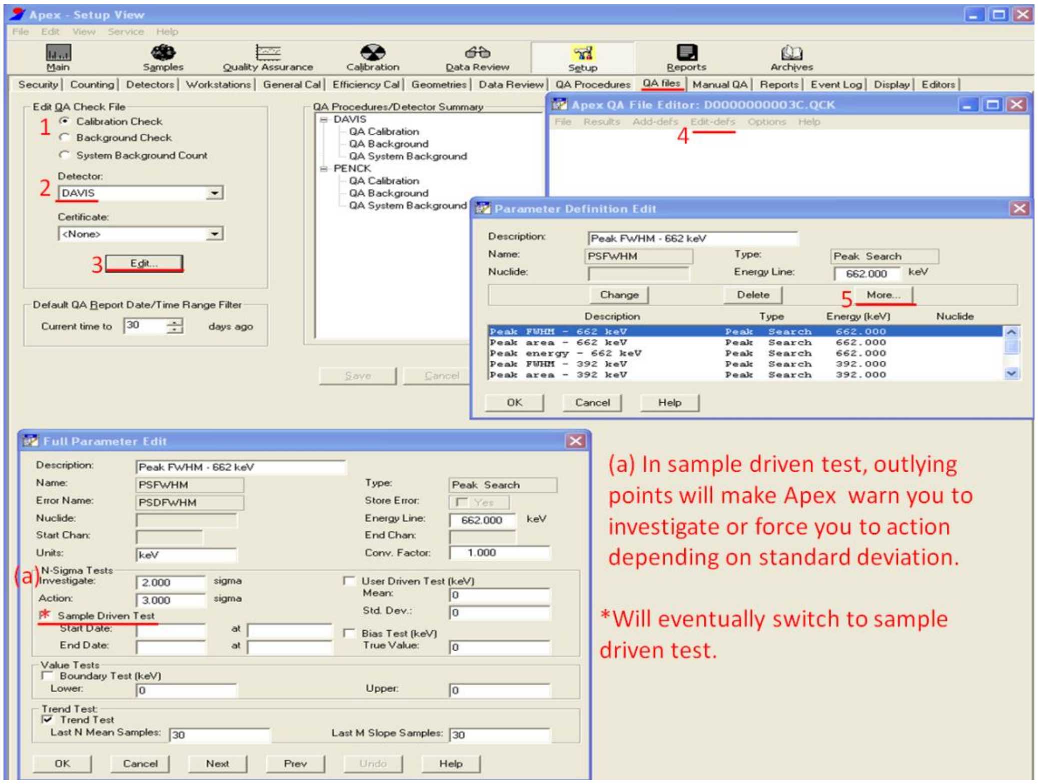
    - **User Driven Test**- You manually enter in the appropriate mean and standard deviation.

    - **Bias Test**- You enter in a known true value.

12. **Value Test-** Perhaps the most appropriate for calibration check. Defines the upper and lower most acceptable bounds for the measured peak energy (e.g. 660 keV and 662 keV for a peak of interest).

13. Trend Test- used the most recent samples as defined by N-sample mean or M-sample slope.

14. Click **OK** to update the calibration check file.



Edit QA Check File
● Calibration Check
○ Background Check
○ System Background Count
Detector: DAVIS
Certificate: <None>

Default QA Report Date/Time Range Filter
Current time to 30 days ago

QA Procedures/Detector Summary
- DAVIS
  - QA Calibration
  - QA Background
  - QA System Background
- PENCK
  - QA Calibration
  - QA Background
  - QA System Background

Parameter Definition Edit
Description: Peak FWHM - 662 keV
Name: PSFWHM
Type: Peak Search
Nuclide:
Energy Line: 662.000 keV

Description	Type	Energy (keV)	Nuclide
Peak FWHM - 662 keV	Peak Search	662.000	
Peak area - 662 keV	Peak Search	662.000	
Peak energy - 662 keV	Peak Search	662.000	
Peak FWHM - 392 keV	Peak Search	392.000	
Peak area - 392 keV	Peak Search	392.000	

Full Parameter Edit
Description: Peak FWHM - 662 keV
Name: PSFWHM
Error Name: PSDFWHM
Nuclide:
Start Chan:
Units: keV
Type: Peak Search
Store Error: ☐ Yes
Energy Line: 662.000 keV
End Chan:
Conv. Factor: 1.000
N-Sigma Tests
Investigate: 2.000 sigma
Action: 3.000 sigma
☐ User Driven Test (keV)
Mean: 0
Std. Dev.: 0
* Sample Driven Test
Start Date: at
End Date: at
☐ Bias Test (keV)
True Value: 0
Value Tests
☐ Boundary Test (keV)
Lower: 0
Upper: 0
Trend Test:
☑ Trend Test
Last N Mean Samples: 30
Last M Slope Samples: 30

(a) In sample driven test, outlying points will make Apex warn you to investigate or force you to action depending on standard deviation.

*Will eventually switch to sample driven test.

6.2.B) PEAK ENERGY CALIBRATION FILES

1. Follow the instructions in the preceding section to access the calibration file editor.

2. Select the Energy Calibration File you would like to edit (e.g., Peak energy – 88.0 keV) and click **More**.

3. The following settings should be selected and edited:

   - Edit the **Description** and **Energy Line** to reflect the keV emission line you would like to use.

   - **Units** should read ‘ keV ‘

   - **Conv. Factor** is = 1

   - Under **N-Sigma Tests**: Check **Bias Test** and enter the **energy line** in the box. We will not do sample driven or user-driven tests for energy QA because we will be regularly calibrating the detectors!

    - Set the **Investigate** level **to 2 sigma** and the **action** level to **3 sigma**.
    - Check **Value Tests** and enter a lower and upper boundary +/- 1.5 keV about the emission line
    - **Trend test** should be unchecked

6.2.C) PEAK AREA CALIBRATION FILES

1. Follow the instructions in the preceding section to access the calibration file editor.
2. Select the Energy Calibration File you would like to edit (e.g., Peak area – 88.0 keV) and click **More**.
3. The following settings should be selected and edited:
    - Edit the **Description** and **Energy Line** to reflect the keV emission line you would like to use.
    - **Units** should read ‘ keV ‘
    - **Conv. Factor** is = 1
    - Under **N-Sigma Tests**:
        - For <u>the first 1-2 months</u> of running samples, all tests w/in one sigma will be UNCHECKED. This is because we do not have enough data to set up this type of test.
        - <u>After 1-2 months</u>, we will switch to a Sample Driven test with a date range equal to the first month or two of data. Although this first month will be relatively subjective in a year or two, it provides a necessary base-line for comparison. If “slow drift” Check **Bias Test** and enter the **energy line** in the box.
    - Set the **Investigate** level **to 2 sigma** and the **action** level to **3 sigma**.
    - Uncheck **Value Tests**
    - Under **Trend test** :

        - For the first 1-2 months of running samples, check this selection and enter 30 next to Last N Mean Samples and Last M Slope Samples.
        - After 1-2 months, unckeck this selection and switch to a sample driven test.

6.2.D) Peak FWHM CALIBRATION FILES

1. Follow the instructions in the preceding section to access the calibration file editor.
2. Select the Energy Calibration File you would like to edit (e.g., Peak FWHM – 88.0 keV) and click **More**.
3. The following settings should be selected and edited:
    - Edit the **Description** and **Energy Line** to reflect the keV emission line you would like to use.
    - **Units** should read ‘ keV ‘
    - **Conv. Factor** is = 1
    - Under **N-Sigma Tests**:
        - For the first 1-2 months of running samples, all tests w/in one sigma will be UNCHECKED. This is because we do not have enough data to set up this type of test.
        - After 1-2 months, we will switch to a Sample Driven test with a date range equal to the first month or two of data. Although this first month will be relatively subjective in a year or two, it provides a necessary base-line for comparison. If “slow drift” Check **Bias Test** and enter the **energy line** in the box.
    - Set the **Investigate** level **to 2 sigma** and the **action** level to **3 sigma**.
    - Uncheck **Value Tests**
    - Under **Trend test** :

- For <u>the first 1-2 months</u> of running samples, check this selection and enter 30 next to Last N Mean Samples and Last M Slope Samples.
- <u>After 1-2 months</u>, unckeck this selection and switch to a sample driven test.

6.2.E) CREATING .QCK FILES FROM .QAF FILES

1. Once the '.caf' (**Think this should be .qaf)** file is created, you will need to create a '.qck' file.
2. Go to **Setup→QA Files**
3. Select **Calibration Check** and the appropriate **detector**.
4. Now you will need to define the parameters for the .qck file based on those established in the .qal (**Think this should be qaf)** file. Click **Edit** and go to **Add defs → Extract.**
5. Select QACALCHECK.qal (**again I think qaf)** and click extract.
6. Select **all** and say **OK**.
7. Now go to **edit defs → Parameter definitions**
8. Double check that all of the tests you want to perform are listed.
9. Perform these steps for both detectors.
10.

6.2.F) Performing a QA test

I don't think the steps below are correct. From the main tab for each detectors spectrum box there are 2 small boxes in the top right corner. One box is start, the other is QA check. Click QA check and you will be able to run QA tests. If you try to run a check and you are told that the procedures don't exist you can consult pg. 136 of the manual. This will tell you to go to the

samples tab. From here you can change the group drop down menu to QA procedures group. The various QA procedures are listed but will not show you their information unless you click edit! If you were trying to run a calibration check and were told there were no procedures, then click calibration check and click edit. On the right side you will see a next button, click it. On this page you will be able to select the detectors that the procedure should apply to. Once you've clicked the boxes, save what you have done and the procedure should work.

1. Quality Assurance
2. Select the Detector
3. Select Calibration Check
4. Select all tests

6.3 Absorption Check

1. The absorption check is a simple QA file that tracks the efficiency calibrations for different sample types of geometries.
2. You will need to update the QA file with the information appropriate for the new efficiency standard (powdered multinuclide standard).
3. Go to Setup → Editors → Quality Assurance
4. **File → Open**. Select ABSCHECK.QAF
5. Go to **Edit-Defs → Parameter Definitions** to view the tests currently included in the QA checks.
6. If you neo add new QA tests (defs), click **OK** and go to **Add Defs**.
7. To edit currently defined tests, go back to **Edit-Defs → Parameter Definitions.** Click **More**. For the Peak Area tests, we

will perform trend tests that record the trend of peak energy across a pre-defined number of samples.

Creating a QA Procedure

Currently (as of 08/23/10), to do an absorption check, place the multiline source on top of the sample in the detector. This sample should not have ore added to it. Put the sample information into Apex like you are going to run a normal sample. For the procedure, choose the 2 minute test run option. This will give you a 120 second count. Once you have completed this count you will have a file in the Data folder of Apex. This file will have a number assigned by Apex. ****WARNING**-** If you do anything to this file in data review the number will change, this can be incredibly inconvenient and confusing, make sure you are aware that any changes made in the Data Review window will give your sample a new number in the data folder. In order to figure out what number is your sample you can view the report in apex and it will tell you the number of the sample or you can figure it out by the time stamp on the file and when you ran the sample. Once you think you know the number of the file, you can double check by starting G2K and dragging the file into the G2K window. The sample information will be displayed once you go to Analyze -> Execute Sequence -> Peak Analysis W/ Report. The sample information will now be displayed along with the area for each keV. Now you will need to get this data into excel. Select the data, go to options -> Report Window-> Copy Highlighted to Window, now you can paste your data into excel. Once in Excel, you can grab the proper data points (areas corresponding to the keVs in the point source). Now that you have the counts you can compare them to the expected and get the rough % efficiency for the sample. (See Joe_Fallout.xlsx) Absorption Check Tab. Once you've done this for several samples you can begin to see what the comparative efficiencies are. ****WARNING**-** If you are doing the absorption checks on different dates don't forget you will have to recalculate the expected counts (due to decay).

6.4. Background Checks

1. In Apex go to **Setup → Editors** , click **Quality Assurance.** Click **File → Open**
2. Click *QABKGCHK.QAF.* To view the parameters currently being checked by this file, click **Edit-defs**, click **parameter definitions.** Select the parameter (e.g. lower region) and click **more**.

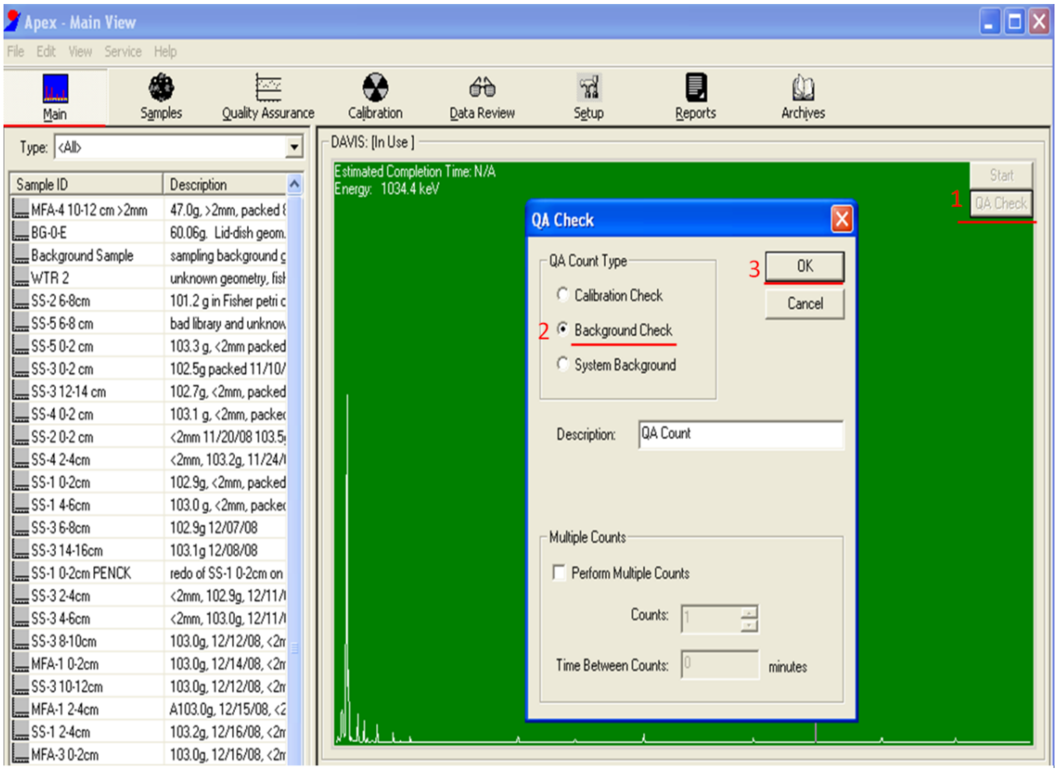
3. **Description**- (e.g. Low Region) this is the name of the parameter to be checked.
4. Name, Error Name, Nuclide, Type, Store Error Energy Line, - Cannot be edited in background checks
5. **Start Channel-** The lowest keV you want investigated. To view which channel corresponds to which keV you can go to the **Calibration** tab, then **Energy** tab. Set the detector drop down menu to the appropriate detector and the calibration count drop down menu to the appropriate calibration. This will show you a spectrum where you can look at the relationship between channel and keV.
6. **End Channel**- The uppermost keV you want investigated. Units: (counts). Conversion factor should always be 1.
7. **Units**: (counts)
8. **Conversion factor-** Should always be 1.
9. *Conversion factor would change if you changed units (e.g. if you wanted Becquerels you change the conversion factor to whatever it needs to be).
10. **N-Sigma Tests** – This is where you define the acceptable values for your test.
11. **Investigate sigma**- This means if your background check moves outside a given number of standard deviations the software will give you an alert. If your count moves outside a specified level you will be prompted to respond. Recommend setting to 2 or 3 unless needing more accuracy.
12. Choose one of the following 3 tests:

    Sample Driven Test- The mean and standard deviation for acceptable data are defined by previously run samples. You can use this to have a test that is defined by all previous data. Danger with this is you may miss slow instrument drift over time because your mean can be slowly changing over time and you may miss it

User Driven Test- You manually enter in the appropriate mean and standard deviation.

Bias Test- You enter in a known true value.

13. **Value Test-** Not appropriate. Defines the upper and lower most acceptable bounds for the measured peak energy (e.g. 660 keV and 662 keV for a peak of interest).
14. Trend Test- Unknown.
15. Click **OK** to update background check file.
16. To run the background checks make sure that the detector is empty. Go to the Main page and click QA Check in the upper right corner of the spectrum window. Select Background Check and click ok.



Type: <All>

Sample ID	Description
MFA-4 10-12 cm >2mm	47.0g, >2mm, packed
BG-0-E	60.06g. Lid-dish geom.
Background Sample	sampling background
WTR 2	unknown geometry, fis
SS-2 6-8cm	101.2 g in Fisher petri
SS-5 6-8 cm	bad library and unknow
SS-5 0-2 cm	103.3 g, <2mm packed
SS-3 0-2 cm	102.5g packed 11/10/
SS-3 12-14 cm	102.7g, <2mm, packed
SS-4 0-2 cm	103.1 g, <2mm, packe
SS-2 0-2 cm	<2mm 11/20/08 103.5
SS-4 2-4cm	<2mm, 103.2g, 11/24/
SS-1 0-2cm	102.9g, <2mm, packed
SS-1 4-6cm	103.0 g, <2mm, packe
SS-3 6-8cm	102.9g 12/07/08
SS-3 14-16cm	103.1g 12/08/08
SS-1 0-2cm PENCK	redo of SS-1 0-2cm on
SS-3 2-4cm	<2mm, 102.9g, 12/11/
SS-3 4-6cm	<2mm, 103.0g, 12/11/
SS-3 8-10cm	103.0g, 12/12/08, <2
MFA-1 0-2cm	103.0g, 12/14/08, <2
SS-3 10-12cm	103.0g, 12/12/08, <2
MFA-1 2-4cm	A103.0g, 12/15/08, <
SS-1 2-4cm	103.2g, 12/16/08, <2
MFA-3 0-2cm	103.0g, 12/16/08, <2

DAVIS: [In Use]

Estimated Completion Time: N/A
Energy: 1034.4 keV

QA Check

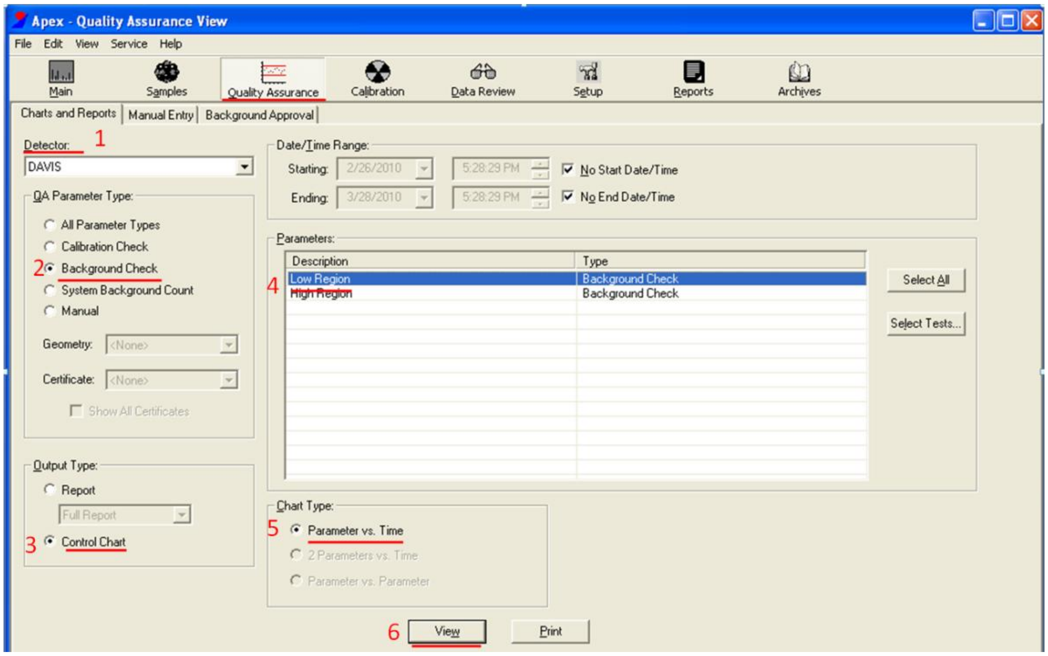
QA Count Type
○ Calibration Check
● Background Check
○ System Background

Description: QA Count

Multiple Counts
☐ Perform Multiple Counts
Counts: 1
Time Between Counts: 0 minutes

17. Background checks can be examined by going to Quality Assurance, Charts and Reports, and selecting the appropriate detector. Then choose background check. You can now choose what kind of output type you would like, report or control chart.

Report will allow you to see any flags noted by Apex. Control chart will give a convenient graph that shows the plotting of all previous background checks as well as the investigate and action boundaries. Now select which region of the spectrum you want to examine (low region or high region) and click view.



1 Detector: DAVIS

QA Parameter Type:
○ All Parameter Types
○ Calibration Check
2 ● Background Check
○ System Background Count
○ Manual

Geometry: <None>
Certificate: <None>
☐ Show All Certificates

Output Type:
○ Report
Full Report
3 ● Control Chart

Date/Time Range:
Starting: 2/26/2010 5:28:29 PM ☑ No Start Date/Time
Ending: 3/28/2010 5:28:29 PM ☑ No End Date/Time

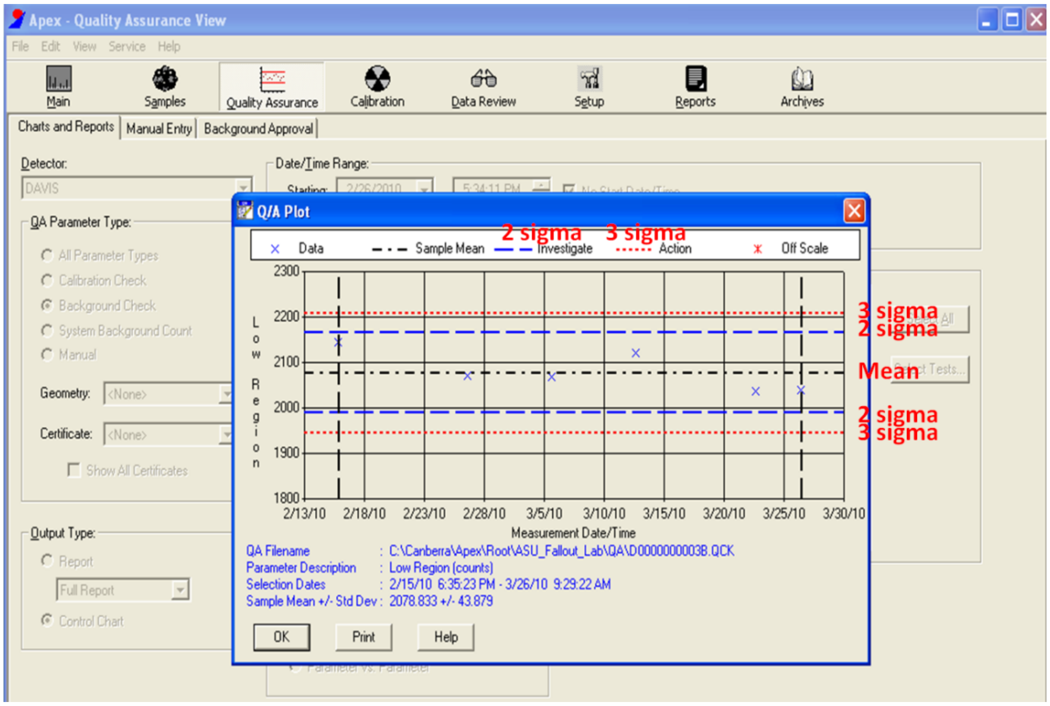
Parameters:

Description	Type
Low Region	Background Check
High Region	Background Check

4

Chart Type:
5 ● Parameter vs. Time
○ 2 Parameters vs. Time
○ Parameter vs. Parameter

6 View



Detector: DAVIS

Date/Time Range:

Starting: 2/26/2010 5:34:11 PM

☑ No Start Date/Time

QA Parameter Type:

○ All Parameter Types
○ Calibration Check
● Background Check
○ System Background Count
○ Manual

Geometry: <None>

Certificate: <None>

☐ Show All Certificates

Output Type:

○ Report

Full Report

● Control Chart

○ Parameter vs. Parameter

QA Filename : C:\Canberra\Apex\Root\ASU_Fallout_Lab\QA\D0000000003B.QCK
Parameter Description : Low Region (counts)
Selection Dates : 2/15/10 6:35:23 PM - 3/26/10 9:29:22 AM
Sample Mean +/- Std Dev : 2078.833 +/- 43.879

PART 7: PREPARING SOIL SAMPLES FOR SHORT LIVED RADIONUCLIDES

7.1. Sample Preparation

7.1.A) DRYING SAMPLES

18. Dry for 12-48 hours at 105 deg C.

7.1.B) SIEVING SAMPLES

19. Sieve <2 and >2mm fractions. Weigh each and record in book.

7.2 Sample Packing

7.2.A) PACKING SAMPLES INTO CONTAINERS

20. Pick a geometry.
21. Record appropriate information in the lab book.
22. Let sample sit for several days before measuring to build up Radon inside the sealed container.

PART 8: RUNNING SAMPLES IN APEX

8.1. A Primer to Apex Jargon

This section details a bit of what you need to know about Samples, Sample Types, Geometries and Procedures.
Samples: (each individual soil sample that we will count)
Sample Types: (e.g., soil or water)
Procedures :The set of commands that will be performed. Specific to a sample type or even a subset of each sample type. For example, if one researcher would like to use a peak area algorithm for their Sierra Nevada soils that differs from that used on Chilean soils, they would define two different sets of procedures (Sierra Soils and Chile Soils) within one Sample Type (Soils).
Geometry: In the lab, we use this term to describe the container in which we pack the soil; However, in APEX this term has a much more nuanced meaning. Samples with a different geometry may have different packing containers, textures, densities, grain size, or mineralogy. Each of these factors may influence the efficiency of gammas emitted from the sample.
Standard:
Energy Calibration:
Efficiency Calibration:
Nuclide Library:

8.2 Uploading New Samples

8.2.A) CREATING A SAMPLE TYPE IN APEX

1. You can skip this step if your sample type is soil. If someone were two run clay fractions, sand, or water, the sample type may change if associated procedures were different.

2. Samples → Sample Type

8.2.B) CREATING A NEW SAMPLE IN APEX

1. Samples → Samples

2. Use a generic geometry based on a course classification of your soils. This Geometry will later be changed based on the Absorption Checks you perform with the QA/QC software.

8.3 Counting a Sample

8.3.A) LOADING A SAMPLE AND COUNTING

1. Select Main from the Apex Menu
2. View samples ready for upload.
3. Load. Remove.

8.3.B) PERFORMING AN ABSORPTION CHECK

1. When finished. You need to collect an absorption spectrum associated w/ the sample. See section ____ for this QA/QC protocol.

8.4 Finalizing Data

8.4.A) APPROVING A SPECTRUM

2. Initial Approval. BEN, does a sample now require 1 or 2 approvals?

8.4.B) APPLYING A GEOMETRY

3. You will need to apply a geometry based on absorption checks and your own classification system. This geometry will be associated with an emission standard you have created using a similar soil sample and the “Ore” Standard.
4. Reanalyze using the new geometry. This is your final data!

PART 9: General Information

9.1 (Tips)

1) Efficiency standard ore should have high activities. ANSI suggests that for an efficiency calibration there should be 10,000 counts for each peak after background subtract. If the ore is too weak you will have to use up more ore for an efficiency standard or you will have to count for a long time. The length of time counting may be absurdly long so if you have this problem it is most likely best to add more ore.

2) SAD- This is the spectroscopy applications manager, it works with the VDM.

3) VDM- Virtual Data Manger. This is described in the Genie operations manual page 2. Basically, it is a program that runs in the background that helps with computer/detector communications. If windows is restarted, goes to sleep or hibernates the VDM connection may be severed and a VDM/SAD error may result. As if 07/26/10 our USB root hubs have been set to not conserve power. This should help prevent the VDM error that has been occurring lately. To access this area go to Control panel, System, Hardware, Device Manager, Universal Serial Bus controllers, right click USB Root Hubs, Properties, Power Management. If you are counting, do not shut down the computer or let it shut itself down (windows update- automatic restart).

4) As of 07/14/2010 this lab does efficiency calibrations with the use of radioactive ore. It has been recommended by Canberra that we use either their ISOCS or LABSOCS software for determining geometries/ efficiencies.

Pros: The “SOCS” software will allow input of various parameters (soil moisture, density, etc.) to obtain geometry and thus, get rid of the need for ore. This would get rid of problems such as having to “craft” an ore for Eckert Ziegler to make, as well as eliminating the possibility that we are sent an ore that doesn’t meet our requirements, extremely delayed shipping and miscommunication between ASU/ SESE, Eckert Ziegler, our lab, and Radiation Safety. All of these problems take up significant amounts of time and subsequently money. Money would also be saved in the long-term because the ore expires after a year which means that the lab will have to continually purchase ore. If there is a period when the lab is not running samples the efficiency ore will be going to waste.

Cons: According to Canberra "SOCS” software is very expensive. Currently I am unaware of the full cost. Canberra has also mentioned that with the software, it helps to have a “characterized” detector. We do not have a characterized detector. It would be absolutely critical to make sure that this software is compatible with our detectors before purchase. Finally, no one in our lab has any experience with this software. The hurdles of learning it without any continual on site assistance may be extremely time consuming and there is no guarantee that the software would be implemented effectively. Canberra offers several classes for their products which tend to cost ~$2000 each. If our lab was to obtain this software then someone may find this class beneficial.

5) At some point you may want to review the spectrum/counts for an efficiency calibration. It is not possible to get this data in Apex unless you have JUST done the calibration and the spectrum is on screen OR you ran the efficiency calibration as a sample and you look at it in Data Review. A simpler method is to open the efficiency calibration in Genie. To do this, first locate the efficiency calibration you want to examine by opening My Computer and looking in C:\Canberra\Apex\Root\ASU_Fallout_Lab\Data you will have to identify the file based on the Date Modified. If the date modified is not displayed, right click in the window, go to view, and then choose details. In order to know which Date Modified file you are looking for, go into Apex, Calibration, Efficiency Review, choose the appropriate detector, geometry, and efficiency calibration, then click View Report. In the description of the sample you will see a date and time for efficiency calibration ran on that you can match to the file. Once you have honed in on the file, run "Gamma Acquisition and Analysis", now drag the file from the data folder into the Gamma Acquisition and Analysis window. Doing so should give you a spectrum. Now, to look at the actual counts go to, Analyze, Reporting, Standard, set the Section Name to peak analysis and click Exectue. Note that you should go to Analyze, C, 1, and set the ROI Limit Determinations to 5, 2, and 2. This was recommended by Canberra. It has helped to alleviate a problem where a peak was being split into 2 nuclides and it shouldn't have been. Canberra recommends that these values be at 5, 2, and 2. This was changed in Apex by going to, Setup, Editors, Analysis, File, Open, NID Analysis and NID Bkg_Analysis and Peak Analysis (note these 3 areas need to be changed), open, peak area – Sum/Non-Linear LSQ Fit, Setup Algorithm, and changed the Limit Determination values from 4, 4, 4, to 5, 2, 2.

APPENDIX B

TABLES

Pit	**ho**	**X (%)**	**Y (t/ha/yr)**
SS-1	32.3	-48.1	-4.7
SS-2	40.6	109.7	6.7
SS-3	40.4	-57.4	-7.7
SS-4	19.5	-95.3	-13.2
SS-5	67.0	-43.3	-8.4
MFA-1	69.8	0.0	0.0
MFA-2	48.9	-48.1	-7.1
MFA-3	112.7	-39.2	-12.5
MFA-4	55.4	-51.3	-8.8
MFA-5	58.8	-16.9	-2.4
MFA-6	147.8	-34.9	-14.1
BRC-1A	83.8	-40.6	-9.5
BRC-2A	28.2	-27.3	-2.0
BRC-3A	60.2	-26.9	-4.1
BRC-4A	58.8	-64.3	-13.2
BRC-5A	20.6	-59.2	-4.0
BRC-6A	77.7	553.6	31.7
BRC-1B	28.4	-23.0	-1.6
BRC-2B	49.8	-18.1	-2.2
BRC-3B	28.7	-0.7	0.0
CG-1	99.3	0.0	0.0
CG-2	20.2	61.3	-4.2
CG-3	129.0	17.8	-5.5
CG-4	129.8	45.3	-17.0
CG-5	85.7	-7.3	1.3
CG-6	103.8	27.7	-7.3
CG-7	88.7	-127.4	15.8
CG-8	150.6	-10.0	3.1

Table 1. Profile Distribution Model Values. Pit values for the profile distribution model. Negative values for X indicate a decrease in inventory relative to reference pit, positive values indicate an increase in inventory relative to reference pit. Negative values for Y indicate erosion, positive values indicate deposition.

Sample Name	Mass (g) < 2mm	Mass (g) > 2mm	Fraction < 2mm	Fraction > 2mm	Packed Weight (g) <2 mm
SS-1 0-2 cm	312.3	100.8	0.76	0.24	102.9
SS-1 2-4 cm	212.2	94.3	0.69	0.31	103.2
SS-1 4-6 cm	171.6	115.8	0.60	0.40	103
SS-1 6-8 cm	171.3	125.2	0.58	0.42	103.1
SS-2 0-2 cm	167.6	66.2	0.72	0.28	103.5
SS-2 2-4 cm	168.8	49.3	0.77	0.23	102.9
SS-2 4-6 cm	159.5	49.3	0.76	0.24	102.4
SS-2 6-8 cm	196.3	77	0.72	0.28	101.2
SS-2 8-10 cm	167.5	54.6	0.75	0.25	103.1
SS-3 0-2 cm	210.8	188	0.53	0.47	102.5
SS-3 2-4 cm	207.3	130.9	0.61	0.39	102.9
SS-3 4-6 cm	233.9	112.5	0.68	0.32	103
SS-3 6-8 cm	218.9	83.2	0.72	0.28	102.9
SS-3 8-10 cm	201.5	88.2	0.70	0.30	103
SS-3 10-12 cm	160.4	98.7	0.62	0.38	103
SS-3 12-14 cm	151.4	97.3	0.61	0.39	102.7
SS-3 14-16 cm	197.4	145.8	0.58	0.42	103.1
SS-4 0-2 cm	202.2	160.2	0.56	0.44	103.1
SS-4 2-4 cm	170.5	182.3	0.48	0.52	103.2
SS-4 4-6 cm	134.1	136	0.50	0.50	103.2
SS-5 0-2 cm	176.7	123.5	0.59	0.41	103.3
SS-5 2-4 cm	193.4	161.2	0.55	0.45	103
SS-5 4-6 cm	200.8	156.4	0.56	0.44	103.2
SS-5 6-8 cm	176.2	108.5	0.62	0.38	102.7
SS-5 8-10 cm	190.7	96.6	0.66	0.34	103.2

Table 2. SS - Size Fraction and Packed Weight. SS mass of size fraction, size fraction, and <2 mm packed weight

Sample Name	137Cs Activity Bq/kg	137Cs Error	210Pb Activity Bq/kg	210Pb Error
SS-1 0-2 cm	5.7	1.7%	28.2	2.21%
SS-1 2-4 cm	4.1	2.7%	15.7	4.51%
SS-1 4-6 cm	1.1	4.8%	8.9	5.07%
SS-1 6-8 cm	0.3	9.6%	6.1	5.86%
SS-2 0-2 cm	23.6	0.8%	34.4	1.93%
SS-2 2-4 cm	14.3	1.0%	25.0	2.53%
SS-2 4-6 cm	4.7	2.7%	15.8	4.76%
SS-2 6-8 cm	1.4	4.1%	13.7	3.98%
SS-2 8-10 cm	1.4	5.2%	14.5	5.26%
SS-3 0-2 cm	4.0	1.8%	25.6	2.19%
SS-3 2-4 cm	2.8	4.3%	29.4	4.06%
SS-3 4-6 cm	1.5	4.9%	31.1	2.70%
SS-3 6-8 cm	0.8	10.3%	35.5	3.16%
SS-3 8-10 cm	0.1	32.3%	33.6	4.01%
SS-3 10-12 cm	0.0	-	26.8	4.57%
SS-3 12-14 cm	0.0	-	29.9	2.46%
SS-3 14-16 cm	0.0	-	25.8	4.36%
SS-4 0-2 cm	0.9	6.1%	25.3	2.44%
SS-4 2-4 cm	0.2	18.6%	24.1	2.28%
SS-4 4-6 cm	0.0	-	20.9	4.30%
SS-5 0-2 cm	5.2	1.7%	29.4	2.16%
SS-5 2-4 cm	2.9	3.9%	19.2	4.83%
SS-5 4-6 cm	2.5	3.2%	20.7	3.37%
SS-5 6-8 cm	0.9	6.2%	25.5	2.84%
SS-5 8-10 cm	0.9	8.8%	23.6	4.18%

- Error not reported for 0 activity

Table 3. SS - Activities. SS ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Pit	**Slope**	**Erosion**	**Avg. Erosion**
	Degrees	**mm/yr**	**mm/yr**
SS-1	10.0	-0.29	
SS-2	13.0	0.42	
SS-3	27.0	-0.48	
SS-4	34.0	-0.83	
SS-5	37.0	-0.53	-0.34
MFA-1	3.5	0.00	
MFA-2	7.5	-0.45	
MFA-3	12.0	-0.78	
MFA-4	26.0	-0.55	
MFA-5	34.0	-0.15	
MFA-6	37.5	-0.88	-0.46
BRC-1A	13	-0.59	
BRC-2A	40	-0.12	
BRC-3A	33	-0.26	
BRC-4A	35	-0.82	
BRC-5A	38	-0.25	1A-5A: -0.34
BRC-6A	28.5	1.98	1A-6A: -0.01
BRC-1B	13.0	-0.10	
BRC-2B	40.0	-0.14	
BRC-3B	33.0	0.00	-0.08
CG-1	0	0.00	
CG-2	7	-0.27	
CG-3	12	-0.35	
CG-4	22	-1.09	
CG-5	24	0.08	
CG-6	28	-0.47	
CG-7	22	1.01	
CG-8	32	0.20	-0.11

Table 4. Slope, Erosion, and Average Erosion. Table showing slope, erosion rates, and average erosion rate for SS, MFA, BRC and CG.

Sample	**Mass (g)**	**Mass (g)**	**Fraction**	**Fraction**	**Packed Weight (g)**
Name	**< 2mm**	**> 2mm**	**< 2mm**	**> 2mm**	**<2 mm**
MFA-1 0-2 cm	231.2	57	0.80	0.20	103
MFA-1 2-4 cm	254.9	76.6	0.77	0.23	103
MFA-1 4-6 cm	191.2	115.8	0.62	0.38	103.1
MFA-2 0-2 cm	210.3	73.6	0.74	0.26	102.4
MFA-2 2-4 cm	205.7	93.4	0.69	0.31	103
MFA-2 4-6 cm	282.3	88.5	0.76	0.24	102.6
MFA-2 6-8 cm	186.3	78.2	0.70	0.30	103.1
MFA-2 8-10 cm	165	87.3	0.65	0.35	103.1
MFA-3 0-2 cm	282.5	93.5	0.75	0.25	103
MFA-3 2-4 cm	280.1	99.2	0.74	0.26	106.4
MFA-3 4-6 cm	422.6	141.8	0.75	0.25	110.8
MFA-3 6-8 cm	238.1	70.6	0.77	0.23	120.4
MFA-3 8-10 cm	262.6	76	0.78	0.22	104.5
MFA-3 10-12 cm	270.9	92.2	0.75	0.25	107.4
MFA-3 12-14 cm	278.3	105.3	0.73	0.27	107.1
MFA-3 14-16 cm	257.2	80	0.76	0.24	110.5
MFA-3 16-18 cm	231.5	49.5	0.82	0.18	103.2
MFA-3 18-20 cm	269	95.3	0.74	0.26	103.7
MFA-4 0-2 cm	203.9	92.7	0.69	0.31	103.4
MFA-4 2-4 cm	283	96	0.75	0.25	103.2
MFA-4 4-6 cm	326	99	0.77	0.23	103.2
MFA-4 6-8 cm	253.6	67	0.79	0.21	103.1
MFA-4 8-10 cm	353.3	86.7	0.80	0.20	102.7
MFA-4 10-12 cm	270.7	47.1	0.85	0.15	103.4
MFA-4 12-14 cm	220.4	35.2	0.86	0.14	103
MFA-5 0-2 cm	151.5	137.5	0.52	0.48	102.8
MFA-5 2-4 cm	246.5	100.5	0.71	0.29	106.2
MFA-5 4-6 cm	203.5	95.3	0.68	0.32	106.5
MFA-5 6-8 cm	232.7	106.7	0.69	0.31	107.2
MFA-5 8-10 cm	259	97.1	0.73	0.27	108.5
MFA-5 10-12 cm	256.2	102.4	0.71	0.29	110
MFA-5 12-14 cm	243.2	58.2	0.81	0.19	111.6
MFA-5 14-16 cm	245.4	69.8	0.78	0.22	102.7
MFA-5 16-18 cm	186.9	71.4	0.72	0.28	113.9

Table 5. MFA - Size Fraction and Packed Weight. MFA mass of size fraction, size fraction, and <2 mm packed weight

Sample **Name**	**Mass (g)** **< 2mm**	**Mass (g)** **> 2mm**	**Fraction** **< 2mm**	**Fraction** **> 2mm**	**Packed Weight (g)** **<2 mm**
MFA-6 0-2 cm	159.5	129	0.55	0.45	88.2
MFA-6 2-4 cm	172.1	94.8	0.64	0.36	103
MFA-6 4-6 cm	212.1	94.3	0.69	0.31	111.2
MFA-6 6-8 cm	249.2	147.1	0.63	0.37	110
MFA-6 8-10 cm	289.7	131.2	0.69	0.31	114.6
MFA-6 10-12 cm	222.6	115.3	0.66	0.34	113.6
MFA-6 12-14 cm	249.4	101.2	0.71	0.29	106.7
MFA-6 14-16 cm	273.9	111.2	0.71	0.29	103
MFA-6 16-18 cm	273.9	111.2	0.71	0.29	103

Table 5 continued. MFA mass of size fraction, size fraction, and <2 mm packed weight

Sample Name	**137Cs Activity Bq/kg**	**137Cs Error**	**210Pb Activity Bq/kg**	**210Pb Error**
MFA-1 0-2 cm	7.2	1.5%	29.1	2.6%
MFA-1 2-4 cm	11.7	2.2%	15.4	7.0%
MFA-1 4-6 cm	2.9	4.0%	6.2	13.0%
MFA-2 0-2 cm	5.2	2.2%	20.9	3.7%
MFA-2 2-4 cm	2.9	3.1%	12.2	5.1%
MFA-2 4-6 cm	2.1	3.1%	10.7	5.0%
MFA-2 6-8 cm	0.7	8.9%	7.3	8.2%
MFA-2 8-10 cm	0.4	8.5%	5.6	6.5%
MFA-3 0-2 cm	5.8	1.6%	12.4	4.9%
MFA-3 2-4 cm	3.6	2.2%	7.5	6.4%
MFA-3 4-6 cm	0.9	5.3%	4.1	13.0%
MFA-3 6-8 cm	0.5	9.4%	2.4	17.4%
MFA-3 8-10 cm	0.4	19.6%	3.1	25.8%
MFA-3 10-12 cm	0.5	14.8%	2.8	23.2%
MFA-3 12-14 cm	0.3	13.7%	2.0	26.6%
MFA-3 14-16 cm	0.5	11.1%	3.0	19.0%
MFA-3 16-18 cm	0.4	11.5%	4.3	11.4%
MFA-3 18-20 cm	0.3	15.7%	2.8	18.4%
MFA-4 0-2 cm	3.1	2.9%	10.4	6.7%
MFA-4 2-4 cm	2.8	2.6%	8.6	6.0%
MFA-4 4-6 cm	2.0	3.4%	6.3	8.5%
MFA-4 6-8 cm	1.5	4.1%	4.1	12.1%
MFA-4 8-10 cm	0.7	8.4%	2.8	19.9%
MFA-4 10-12 cm	0.3	20.9%	2.5	29.9%
MFA-4 12-14 cm	0.1	33.9%	2.5	16.5%
MFA-5 0-2 cm	2.5	2.2%	12.4	3.0%
MFA-5 2-4 cm	4.7	2.2%	8.5	7.0%
MFA-5 4-6 cm	4.4	2.2%	6.9	10.1%
MFA-5 6-8 cm	2.9	2.7%	5.5	8.9%
MFA-5 8-10 cm	2.7	2.9%	4.5	11.6%
MFA-5 10-12 cm	0.6	8.2%	2.2	23.4%
MFA-5 12-14 cm	0.1	34.5%	2.1	23.9%
MFA-5 14-16 cm	0.0	-	1.3	30.3%
MFA-5 16-18 cm	0.1	39.1%	0.6	69.0%

- Error not reported for 0 activity

Table 6. MFA - Activities. MFA ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	**137Cs Activity Bq/kg**	**137Cs Error**	**210Pb Activity Bq/kg**	**210Pb Error**
MFA-6 0-2 cm	3.2	2.2%	22.2	2.7%
MFA-6 2-4 cm	2.6	4.3%	8.3	8.6%
MFA-6 4-6 cm	1.3	5.0%	4.6	11.7%
MFA-6 6-8 cm	1.4	3.5%	3.2	13.4%
MFA-6 8-10 cm	1.5	4.0%	4.3	12.6%
MFA-6 10-12 cm	1.6	4.1%	4.1	13.7%
MFA-6 12-14 cm	1.3	4.9%	3.4	14.7%
MFA-6 14-16 cm	1.0	6.0%	3.7	13.9%
MFA-6 16-18 cm	0.3	16.9%	1.5	37.4%

Table 6 continued. MFA ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	Mass (g) < 2mm	Mass (g) > 2mm	Fraction < 2mm	Fraction > 2mm	Packed Weight (g) <2 mm
CG-1 0-2 cm	433.3	289.4	0.60	0.40	104.8
CG-1 2-4 cm	336.7	202	0.63	0.37	98.6
CG-1 4-6 cm	346.5	240.6	0.59	0.41	102.9
CG-1 6-8 cm	392.8	231	0.63	0.37	99.8
CG-1 8-10 cm	432.4	203.3	0.68	0.32	99.1
CG-1 10-12 cm	515.5	316.2	0.62	0.38	100.4
CG-1 12-14 cm	449.8	227.7	0.66	0.34	110.7
CG-1 14-16 cm	405.9	264.8	0.61	0.39	101.1
CG-1 16-18 cm	468.9	238.9	0.66	0.34	103.5
CG-1 18-20 cm	473.6	236.9	0.67	0.33	101.3
CG-1 20-22 cm	461.1	238.2	0.66	0.34	97.1
CG-1 22-24 cm	407.4	284.1	0.59	0.41	101.4
CG-2 0-2 cm	281.8	310.5	0.48	0.52	105
CG-2 2-4 cm	251.9	262.8	0.49	0.51	96.7
CG-2 4-6 cm	179	388.8	0.32	0.68	97.2
CG-3 0-2 cm	308.6	400.6	0.44	0.56	98.3
CG-3 2-4 cm	344	316.5	0.52	0.48	91.9
CG-3 4-6 cm	270	261.4	0.51	0.49	94.9
CG-3 6-8 cm	325.4	289	0.53	0.47	91.9
CG-3 8-10 cm	341.4	275.8	0.55	0.45	92
CG-3 10-12 cm	304.8	228.7	0.57	0.43	101
CG-3 12-14 cm	280.2	369.7	0.43	0.57	94.7
CG-3 14-16 cm	279.3	271.6	0.51	0.49	100.8
CG-3 16-18 cm	310.1	234	0.57	0.43	108.7
CG-4 0-2 cm	404.9	396.7	0.51	0.49	114.4
CG-4 2-4 cm	405.6	374.5	0.52	0.48	117.9
CG-4 4-6 cm	335.3	355.3	0.49	0.51	112.2
CG-4 6-8 cm	343	405	0.46	0.54	112.9
CG-4 8-10 cm	286.1	390.8	0.42	0.58	107.8
CG-4 10-12 cm	304.4	365.4	0.45	0.55	111.2
CG-4 12-14 cm	322.3	295.2	0.52	0.48	105.3
CG-4 14-16 cm	331.3	370.1	0.47	0.53	108.4
CG-4 16-30 cm	320.2	395.9	0.45	0.55	110.3
CG-5 0-2 cm	323.7	169.9	0.66	0.34	84.1

+ Data not recorded

Table 7. CG - Size Fraction and Packed Weight. CG mass of size fraction, size fraction, and <2 mm packed weight

Sample Name	Mass (g) < 2mm	Mass (g) > 2mm	Fraction < 2mm	Fraction > 2mm	Packed Weight (g) <2 mm
CG-5 2-4 cm	394.6	144.7	0.73	0.27	106.7
CG-5 4-6 cm	315.3	113.3	0.74	0.26	106.3
CG-5 6-8 cm	448.9	183.6	0.71	0.29	100.7
CG-6 0-2 cm	300.5	266.8	0.53	0.47	107.1
CG-6 2-4 cm	315.3	262.7	0.55	0.45	109.7
CG-6 4-6 cm	356.1	248.6	0.59	0.41	110.8
CG-6 6-8 cm	345.5	206.9	0.63	0.37	107.1
CG-6 8-10 cm	392.7	202.2	0.66	0.34	109.1
CG-6 10-12 cm	387.5	181.4	0.68	0.32	111.7
CG-6 12-14 cm	379.2	187	0.67	0.33	+
CG-6 14-16 cm	346.8	189	0.65	0.35	+
CG-6 16-18 cm	330.6	167.5	0.66	0.34	+
CG-6 18-20 cm	296.5	144.9	0.67	0.33	+
CG-6 20-22 cm	286.9	148.3	0.66	0.34	+
CG-6 22-24 cm	300.5	144.1	0.68	0.32	+
CG-6 24-26 cm	236.3	135.3	0.64	0.36	+
CG-6 26-28 cm	307.1	160.8	0.66	0.34	+
CG-6 28-30 cm	275.8	175	0.61	0.39	+
CG-7 0-2 cm	396	227.2	0.64	0.36	105.1
CG-7 2-4 cm	358.6	149.2	0.71	0.29	106
CG-7 4-6 cm	401.1	145.7	0.73	0.27	102.5
CG-7 6-8 cm	344.4	208.5	0.62	0.38	103.7
CG-7 8-10 cm	264.8	264.7	0.50	0.50	105.5
CG-7 10-12 cm	227.5	340.4	0.40	0.60	102.8
CG-7 12-14 cm	234.8	367.6	0.39	0.61	109.4
CG-8 0-2 cm	319	282.6	0.53	0.47	103.9
CG-8 2-4 cm	323	294.5	0.52	0.48	104.2
CG-8 4-6 cm	342.3	274.5	0.55	0.45	102.7
CG-8 6-8 cm	365.7	287.2	0.56	0.44	105.1
CG-8 8-10 cm	348.5	210.9	0.62	0.38	103.7
CG-8 10-12 cm	284	201.2	0.59	0.41	106.7
CG-8 12-14 cm	368.7	309.2	0.54	0.46	109.9

Table 7 continued. CG mass of size fraction, size fraction, and <2 mm packed weight

Sample Name	137Cs Activity Bq/kg	137Cs Error	210Pb Activity Bq/kg	210Pb Error
CG-1 0-2 cm	4.7	5.1%	27.2	9.7%
CG-1 2-4 cm	7.7	5.6%	29.8	8.5%
CG-1 4-6 cm	3.8	3.7%	24.2	8.5%
CG-1 6-8 cm	3.9	3.0%	24.8	7.8%
CG-1 8-10 cm	3.9	3.5%	22.7	10.4%
CG-1 10-12 cm	1.9	2.9%	18.8	11.5%
CG-1 12-14 cm	0.9	1.8%	18.2	7.4%
CG-1 14-16 cm	0.6	0.8%	19.0	6.5%
CG-1 16-18 cm	0.0	0.0%	20.1	8.2%
CG-1 18-20 cm	0.0	0.0%	20.4	7.1%
CG-1 20-22 cm	0.0	0.0%	20.2	7.0%
CG-1 22-24 cm	0.0	0.0%	15.0	7.1%
CG-2 0-2 cm	8.2	3.1%	37.6	4.2%
CG-2 2-4 cm	2.1	6.7%	23.8	6.4%
CG-2 4-6 cm	0.3	24.8%	14.7	5.8%
CG-3 0-2 cm	4.8	4.9%	28.2	6.8%
CG-3 2-4 cm	4.9	4.1%	29.8	7.0%
CG-3 4-6 cm	3.2	3.1%	21.7	7.7%
CG-3 6-8 cm	2.8	2.7%	23.9	6.7%
CG-3 8-10 cm	3.1	3.9%	26.6	9.0%
CG-3 10-12 cm	2.0	3.0%	24.2	8.5%
CG-3 12-14 cm	0.9	2.7%	15.6	9.9%
CG-3 14-16 cm	1.0	2.7%	18.3	8.7%
CG-3 16-18 cm	0.0	0.0%	18.7	6.4%
CG-4 0-2 cm	4.7	3.5%	31.8	4.5%
CG-4 2-4 cm	3.5	4.4%	28.5	6.9%
CG-4 4-6 cm	1.9	3.4%	19.3	8.1%
CG-4 6-8 cm	0.9	2.8%	17.8	8.0%
CG-4 8-10 cm	1.2	2.4%	15.3	7.9%
CG-4 10-12 cm	1.1	1.1%	12.4	7.4%
CG-4 12-14 cm	1.1	1.1%	18.9	5.7%
CG-4 14-16 cm	0.7	2.0%	14.5	8.3%
CG-4 16-30 cm	0.0	-	13.7	7.2%
CG-5 0-2 cm	8.5	4.6%	49.0	5.2%

+ Data not recorded

- Error not reported for 0 activity

Table 8. CG - Activities. CG ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	137Cs Activity Bq/kg	137Cs Error	210Pb Activity Bq/kg	210Pb Error
CG-5 2-4 cm	11.8	3.9%	40.7	7.7%
CG-5 4-6 cm	6.1	5.0%	30.1	6.0%
CG-5 6-8 cm	3.0	7.0%	34.0	7.3%
CG-6 0-2 cm	6.0	3.1%	38.8	4.1%
CG-6 2-4 cm	7.5	3.1%	38.3	4.5%
CG-6 4-6 cm	3.7	5.8%	33.7	6.5%
CG-6 6-8 cm	2.7	4.9%	31.1	6.9%
CG-6 8-10 cm	0.0	-	38.1	8.4%
CG-6 10-12 cm	0.0	-	32.0	8.3%
CG-6 12-14 cm	+	+	+	+
CG-6 14-16 cm	+	+	+	+
CG-6 16-18 cm	+	+	+	+
CG-6 18-20 cm	+	+	+	+
CG-6 20-22 cm	+	+	+	+
CG-6 22-24 cm	+	+	+	+
CG-6 24-26 cm	+	+	+	+
CG-6 26-28 cm	+	+	+	+
CG-6 28-30 cm	+	+	+	+
CG-7 0-2 cm	11.7	2.9%	47.6	5.6%
CG-7 2-4 cm	14.7	3.3%	43.0	5.6%
CG-7 4-6 cm	15.6	3.6%	44.9	5.1%
CG-7 6-8 cm	9.3	3.7%	36.8	6.2%
CG-7 8-10 cm	6.1	4.0%	27.3	5.2%
CG-7 10-12 cm	3.6	4.5%	16.9	12.3%
CG-7 12-14 cm	1.4	4.1%	20.5	4.4%
CG-8 0-2 cm	5.5	4.8%	34.2	5.1%
CG-8 2-4 cm	7.2	4.3%	38.2	5.2%
CG-8 4-6 cm	6.1	3.1%	35.6	4.2%
CG-8 6-8 cm	3.4	3.3%	26.8	4.9%
CG-8 8-10 cm	4.1	6.0%	36.4	4.9%
CG-8 10-12 cm	1.6	1.3%	30.9	6.4%
CG-8 12-14 cm	2.3	1.8%	28.0	4.4%

- Error not reported for 0 activity

Table 8 continued. CG ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample **Name**	**Packed Weight (g)**
CG-6 0-2 cm >250um <2mm	100.5
CG-6 2-4 cm >250um <2mm	103.7
CG-6 0-2 cm <250um	64.9
CG-6 2-4 cm <250um	59.5

Table 9. CG packed weight for <250um size fraction and size fraction between 250um and 2 mm.

Sample Name	**137Cs Activity Bq/kg**	**137Cs Error**	**210Pb Activity Bq/kg**	**210Pb Error**
CG-6 0-2 cm >250um <2mm	6.6	3.9%	43.5	4.8%
CG-6 2-4 cm >250um <2mm	6.2	3.4%	34.4	5.6%
CG-6 0-2 cm <250um	23.4	5.3%	161.8	5.4%
CG-6 2-4 cm <250um	28.4	4.3%	153.9	6.5%

Table 10. CG ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample	**Mass (g)**	**Mass (g)**	**Fraction**	**Fraction**	**Packed Weight (g)**
Name	**< 2mm**	**> 2mm**	**< 2mm**	**> 2mm**	**<2 mm**
BRC-0A	434.2	313.9	0.58	0.42	102.6
BRC-0B	385.9	317.1	0.55	0.45	94.3
BRC-1A 0-2 cm	423.8	179	0.70	0.30	105.3
BRC-1A 2-4 cm	391.2	202.7	0.66	0.34	97.5
BRC-1A 4-6 cm	301.4	140.7	0.68	0.32	105.9
BRC-1A 6-8 cm	338.9	134.7	0.72	0.28	102.5
BRC-2A 0-2 cm	307.6	116.8	0.72	0.28	83.3
BRC-2A 2-4 cm	252.1	134.9	0.65	0.35	88.2
BRC-2A 4-6 cm	237	195.5	0.55	0.45	90.2
BRC-2A 6-8 cm	243.3	205.6	0.54	0.46	98.7
BRC-2A 8-10 cm	154.7	142.9	0.52	0.48	94.6
BRC-3A 0-2 cm	254.5	82.4	0.76	0.24	97.6
BRC-3A 2-4 cm	286.7	103.2	0.74	0.26	90.2
BRC-3A 4-6 cm	287.1	94.6	0.75	0.25	93.9
BRC-3A 6-8 cm	271.5	89.1	0.75	0.25	94.9
BRC-3A 8-10 cm	269.9	101.7	0.73	0.27	92.6
BRC-3A 10-12 cn	318.3	133.5	0.70	0.30	97.4
BRC-3A 12-14 cn	290.3	142.5	0.67	0.33	94.9
BRC-3A 14-16 cn	240.4	128.7	0.65	0.35	95.4
BRC-3A 16-18 cn	257.2	194.3	0.57	0.43	96
BRC-3A 18-20 cn	192.5	189.4	0.50	0.50	+
BRC-3A 20-22 cn	148.3	160.1	0.48	0.52	+
BRC-4A 0-2 cm	333.3	206.7	0.62	0.38	104.5
BRC-4A 2-4 cm	307.1	200.9	0.60	0.40	101
BRC-4A 4-6 cm	268.3	155.5	0.63	0.37	90.8
BRC-4A 6-8 cm	264.9	209.6	0.56	0.44	92.7
BRC-4A 8-10 cm	258.3	157.8	0.62	0.38	91.1
BRC-4A 10-12 cn	197.3	207	0.49	0.51	92
BRC-4A 12-14 cn	267	136.7	0.66	0.34	98
BRC-4A 14-16 cn	189	129.2	0.59	0.41	98.8
BRC-4A 16-18 cn	254.5	178.2	0.59	0.41	95.6
BRC-4A 18-20 cn	187.8	121.4	0.61	0.39	86.2
BRC-4A 20-22 cn	195.4	184	0.52	0.48	97.7
BRC-4A 22-24 cn	185.9	174.5	0.52	0.48	94.5

+ Data not recorded

Table 11. BRC - Size Fraction and Packed Weight. BRC mass of size fraction, size fraction, and <2 mm packed weight.

Sample Name	Mass (g) < 2mm	Mass (g) > 2mm	Fraction < 2mm	Fraction > 2mm	Packed Weight (g) <2 mm
BRC-4A 24-26 cm	190.8	136.8	0.58	0.42	96.8
BRC-4A 26-28 cm	162.1	163.8	0.50	0.50	101.9
BRC-4A 28-30 cm	144.8	136.9	0.51	0.49	100.3
BRC-5A 0-2 cm	253.8	154.4	0.62	0.38	87.8
BRC-5A 2-4 cm	319.2	191.4	0.63	0.37	93.7
BRC-5A 4-6 cm	294.9	229.2	0.56	0.44	98.8
BRC-5A 6-8 cm	263.4	185.6	0.59	0.41	101.9
BRC-5A 8-10 cm	218.9	217.6	0.50	0.50	97.6
BRC-5A 10-12 cm	212.3	218.7	0.49	0.51	99.1
BRC-5A 12-14 cm	218	201.6	0.52	0.48	101.5
BRC-5A 14-16 cm	242.6	221.4	0.52	0.48	105.1
BRC-5A 16-18 cm	256.1	168.4	0.60	0.40	101.3
BRC-5A 18-20 cm	225	224.8	0.50	0.50	98.8
BRC-5A 20-22 cm	229.3	182.6	0.56	0.44	98.9
BRC-5A 22-24 cm	169	165.1	0.51	0.49	100.8
BRC-5A 24-26 cm	189.3	153.3	0.55	0.45	100.6
BRC-5A 26-28 cm	171.6	108.9	0.61	0.39	+
BRC-5A 28-30 cm	204.8	152.1	0.57	0.43	+
BRC-6A 0-2 cm	33.1	0	1.00	0.00	33.1
BRC-6A 2-4 cm	20	0	1.00	0.00	20
BRC-6A 4-6 cm	20.2	0	1.00	0.00	20.2
BRC-6A 6-8 cm	20.4	0	1.00	0.00	20.4
BRC-6A 8-10 cm	41.4	107.5	0.28	0.72	40.1
BRC-6A 10-12 cm	90.5	97.6	0.48	0.52	67.9
BRC-6A 12-14 cm	79.4	135.1	0.37	0.63	72.3
BRC-6A 14-16 cm	87.4	119	0.42	0.58	85.2
BRC-6A 16-18 cm	115.5	104.4	0.53	0.47	87.8
BRC-6A 18-20 cm	233.6	151.6	0.61	0.39	96.2
BRC-6A 20-22 cm	206.9	162.6	0.56	0.44	97.3
BRC-6A 22-24 cm	179.6	110.4	0.62	0.38	93.3
BRC-6A 24-26 cm	+	+	+	+	+
BRC-6A 26-28 cm	+	+	+	+	+
BRC-6A 28-30 cm	+	+	+	+	+
BRC-1B 0-2 cm	330.6	133.5	0.71	0.29	96.9

+ Data not recorded

Table 11 continued. BRC mass of size fraction, size fraction, and <2 mm packed weight.

Sample Name	Mass (g) < 2mm	Mass (g) > 2mm	Fraction < 2mm	Fraction > 2mm	Packed Weight (g) <2 mm
BRC-1B 2-4 cm	297	82.7	0.78	0.22	94.1
BRC-1B 4-6 cm	336.3	119	0.74	0.26	99.1
BRC-1B 6-8 cm	242.7	242.5	0.50	0.50	101.9
BRC-2B 0-2 cm	339.6	129.4	0.72	0.28	88.2
BRC-2B 2-4 cm	276	145.4	0.65	0.35	90.5
BRC-2B 4-6 cm	305.4	145.3	0.68	0.32	91.3
BRC-2B 6-8 cm	330.1	143.7	0.70	0.30	87.5
BRC-2B 8-10 cm	264.4	137.8	0.66	0.34	90.2
BRC-3B 0-2 cm	113	80.6	0.58	0.42	61
BRC-3B 2-4 cm	248.1	133.1	0.65	0.35	80.9
BRC-3B 4-6 cm	213.4	121.4	0.64	0.36	87.5
BRC-3B 6-8 cm	212	150.8	0.58	0.42	89
BRC-3B 8-10 cm	186.8	123.9	0.60	0.40	85.5
BRC-3B 10-12 cm	205.7	126.7	0.62	0.38	85.2
BRC-3B 12-14 cm	207.9	132.8	0.61	0.39	89
BRC-3B 14-16 cm	241.8	118.4	0.67	0.33	92.3
BRC-3B 16-18 cm	283.5	193.2	0.59	0.41	88.6
BRC-3B 18-20 cm	219.2	93	0.70	0.30	92.8
BRC-3B 20-22 cm	226.2	95.6	0.70	0.30	+
BRC-3B 22-24 cm	205.9	113.2	0.65	0.35	+
BRC-3B 24-26 cm	201.9	128.7	0.61	0.39	+
BRC-3B 26-28 cm	239.2	208.5	0.53	0.47	+
BRC-3B 28-30 cm	219.3	145.9	0.60	0.40	+

+ Data not recorded

Table 11 continued. BRC mass of size fraction, size fraction, and <2 mm packed weight.

Sample Name	**137Cs Activity Bq/kg**	**137Cs Error**	**210Pb Activity Bq/kg**	**210Pb Error**
BRC-0A	3.8	3.8%	20.4	5.7%
BRC-0B	2.0	4.4%	13.1	6.7%
BRC-1A 0-2 cm	7.9	3.5%	26.8	5.4%
BRC-1A 2-4 cm	3.7	4.1%	17.2	5.2%
BRC-1A 4-6 cm	3.8	3.9%	11.6	7.9%
BRC-1A 6-8 cm	2.2	5.9%	13.9	8.2%
BRC-2A 0-2 cm	14.2	3.1%	42.5	4.4%
BRC-2A 2-4 cm	5.9	3.8%	18.8	5.4%
BRC-2A 4-6 cm	1.1	8.6%	10.2	6.4%
BRC-2A 6-8 cm	0.2	28.3%	7.9	7.1%
BRC-2A 8-10 cm	0.3	21.5%	8.0	8.2%
BRC-3A 0-2 cm	8.6	3.9%	29.0	7.9%
BRC-3A 2-4 cm	5.6	3.9%	23.5	6.6%
BRC-3A 4-6 cm	3.6	5.1%	15.6	9.1%
BRC-3A 6-8 cm	2.0	5.8%	11.6	8.2%
BRC-3A 8-10 cm	1.5	7.5%	14.1	8.8%
BRC-3A 10-12 cm	0.0	-	9.5	11.8%
BRC-3A 12-14 cm	0.3	25.1%	10.7	6.8%
BRC-3A 14-16 cm	0.0	-	9.6	9.0%
BRC-3A 16-18 cm	0.0	-	9.4	8.0%
BRC-3A 18-20 cm	+	+	+	+
BRC-3A 20-22 cm	+	+	+	+
BRC-4A 0-2 cm	4.8	5.9%	21.0	10.5%
BRC-4A 2-4 cm	2.9	7.7%	14.8	12.5%
BRC-4A 4-6 cm	1.9	5.4%	16.3	6.6%
BRC-4A 6-8 cm	0.7	9.2%	9.5	8.0%
BRC-4A 8-10 cm	0.0	-	10.8	14.1%
BRC-4A 10-12 cm	0.4	23.3%	9.6	11.3%
BRC-4A 12-14 cm	0.0	-	12.8	15.6%
BRC-4A 14-16 cm	0.0	-	9.0	17.3%
BRC-4A 16-18 cm	+	-	+	+
BRC-4A 18-20 cm	+	-	+	+
BRC-4A 20-22 cm	+	-	+	+
BRC-4A 22-24 cm	+	-	+	+

+ Data not recorded

- Error not reported for 0 activity

Table 12. BRC - Activities. BRC ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	137Cs Activity Bq/kg	137Cs Error	210Pb Activity Bq/kg	210Pb Error
BRC-4A 24-26 cm	+	+	+	+
BRC-4A 26-28 cm	+	+	+	+
BRC-4A 28-30 cm	+	+	+	+
BRC-5A 0-2 cm	10.0	3.6%	35.9	5.6%
BRC-5A 2-4 cm rec	2.1	7.2%	16.4	9.7%
BRC-5A 4-6 cm	0.0	-	9.7	16.5%
BRC-5A 6-8 cm	0.0	-	10.4	14.7%
BRC-5A 8-10 cm	0.0	-	9.0	11.1%
BRC-5A 10-12 cm	0.0	-	8.4	5.6%
BRC-5A 12-14 cm	0.0	-	8.7	7.9%
BRC-5A 14-16 cm	+	+	+	+
BRC-5A 16-18 cm	+	+	+	+
BRC-5A 18-20 cm	+	+	+	+
BRC-5A 20-22 cm	+	+	+	+
BRC-5A 22-24 cm	+	+	+	+
BRC-5A 24-26 cm	+	+	+	+
BRC-5A 26-28 cm	+	+	+	+
BRC-5A 28-30 cm	+	+	+	+
BRC-6A 0-2 cm	27.4	4.3%	176.7	5.3%
BRC-6A 2-4 cm	34.7	4.3%	273.5	5.1%
BRC-6A 4-6 cm	30.8	3.6%	261.9	4.3%
BRC-6A 6-8 cm	47.7	3.2%	305.9	4.0%
BRC-6A 8-10 cm	25.2	3.2%	40.6	5.8%
BRC-6A 10-12 cm	18.0	3.3%	25.1	7.3%
BRC-6A 12-14 cm	6.8	3.6%	15.2	5.6%
BRC-6A 14-16 cm	2.1	5.3%	11.7	8.2%
BRC-6A 16-18 cm	1.3	12.5%	12.0	14.2%
BRC-6A 18-20 cm	0.0	-	10.8	15.2%
BRC-6A 20-22 cm	0.0	-	8.5	9.7%
BRC-6A 22-24 cm	0.0	-	8.8	9.1%
BRC-6A 24-26 cm	+	+	+	+
BRC-6A 26-28 cm	+	+	+	+
BRC-6A 28-30 cm	+	+	+	+
BRC-1B 0-2 cm	11.6	3.1%	38.3	4.5%

+ Data not recorded

- Error not reported for 0 activity

Table 12 continued. BRC ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	137Cs Activity Bq/kg	137Cs Error	210Pb Activity Bq/kg	210Pb Error
BRC-1B 2-4 cm	7.7	3.3%	17.0	6.8%
BRC-1B 4-6 cm	3.2	4.2%	10.4	9.0%
BRC-1B 6-8 cm	0.4	15.7%	7.6	11.6%
BRC-2B 0-2 cm	12.8	3.3%	39.1	6.6%
BRC-2B 2-4 cm	5.5	4.0%	20.5	7.0%
BRC-2B 4-6 cm	2.9	5.6%	16.7	8.1%
BRC-2B 6-8 cm	2.4	5.8%	19.0	7.3%
BRC-2B 8-10 cm	0.8	17.9%	12.4	8.4%
BRC-3B 0-2 cm	16.4	3.1%	36.9	4.3%
BRC-3B 2-4 cm	9.7	3.6%	24.8	6.7%
BRC-3B 4-6 cm	2.8	5.2%	11.8	10.2%
BRC-3B 6-8 cm	0.6	13.6%	10.0	9.2%
BRC-3B 8-10 cm	0.0	-	9.5	62.8%
BRC-3B 10-12 cm	0.0	-	10.1	8.4%
BRC-3B 12-14 cm	0.0	-	9.1	13.2%
BRC-3B 14-16 cm	0.0	-	11.5	10.1%
BRC-3B 16-18 cm	0.0	-	8.6	12.1%
BRC-3B 18-20 cm	+	+	+	+
BRC-3B 20-22 cm	+	+	+	+
BRC-3B 22-24 cm	+	+	+	+
BRC-3B 24-26 cm	+	+	+	+
BRC-3B 26-28 cm	+	+	+	+
BRC-3B 28-30 cm	+	+	+	+

+ Data not recorded

- Error not reported for 0 activity

Table 12 continued. BRC ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %

Sample Name	Packed Weight (g)
BT-1 (Light)	101.8
BT-2A (Light)	90.5
BT-2B (Dark)	91.6
BT-3 (Dark)	80.6
BT-4 (Light)	89.3
BT-5 (Dark)	85.7
BT-6 (Drk-Intmd)	91.7
BT-7 (Dark)	80.6
BT-8 (Dark)	76

Table 13. BT packed weight, unseived.

Sample Name	**137Cs Activity Bq/kg**	**137Cs Error**	**210Pb Activity Bq/kg**	**210Pb Error**
BT-1 (Light)	6.2	5.6%	34.4	6.5%
BT-2A (Light)	4.1	3.7%	25.2	6.8%
BT-2B (Dark)	6.2	3.6%	47.2	5.1%
BT-3 (Dark)	9.3	3.6%	86.7	4.6%
BT-4 (Light)	4.3	4.7%	41.1	5.1%
BT-5 (Dark)	10.2	3.2%	77.7	4.3%
BT-6 (Drk-Intmd)	1.4	26.5%	28.0	19.4%
BT-7 (Dark)	9.4	3.7%	75.3	4.9%
BT-8 (Dark)	11.4	3.2%	171.1	3.9%

Table 14. BT - Activities. BT ^{137}Cs Activity (Bq/kg), ^{137}Cs Activity Error %, ^{210}Pb Activity (Bq/kg), ^{210}Pb Activity Error %