Offsite Contamination in Plum Brook, from Discovery and Characterization to Demonstration of Regulatory Compliance – 10045

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ABSTRACT

During the decommissioning of its Plum Brook Reactor Facility the National Aeronautics and Space Administration (NASA) discovered the presence of detectable levels of Cs-137 in Plum Brook. This small, offsite stream was used during operations (1963-1971) as part of the normal discharge path for process water that was below release limits. From the NASA fenceline it flows north for 5.8 km (3.5 miles) through a mixture of agricultural, residential, and recreational property before entering Sandusky Bay and Lake Erie. Environmental monitoring during operations and the shut down years had not detected the cesium, but a characterization survey with Final Status Survey instrumentation did. This paper discusses the actions taken by NASA starting with the discovery of the contamination, continuing through scoping and characterization activities, including public outreach efforts and some innovative sampling techniques. It finishes with a description of the use of dose analysis to demonstrate regulatory compliance sufficient to allow license termination.

INTRODUCTION

The National Aeronautics and Space Administration (NASA) Plum Brook Reactor Facility (PBRF) consists of two Nuclear Regulatory Commission (NRC) licensed reactors, a 60 MW test reactor and a 100 KW pool type mock-up reactor. The PBRF site is 10.9 hectares (27 acres) in size, and is located in the northern section of the 2630 hectares (6,500 acre) site known as the NASA Glenn Research Center Plum Brook Station (PBS). PBS is located in Sandusky, Ohio, approximately 83 km (50 miles) west of Cleveland.

NASA has been conducting decommissioning activities at the PBRF since 2002 under an NRC approved Decommissioning Plan. Much of the early work focused on building interiors and removal of activated fixed equipment. In 2005 that focus shifted to include characterizing potentially impacted open land areas. That summer NASA was working in an area known as Pentolite Ditch, a deep road cut ditch that was used as the discharge path for ‘clean’ process water during the operating life of the plant, 1963 to 1973. While low levels of Cs-137 were known to have been in the discharged water there was no record of a release of water above the allowed regulatory limits. Environmental monitoring over the years, both during operation and the shutdown years, had not detected much contamination further downstream. Some amount of Cs-137 was known to be present in the silt near the reactor outfall, but it was believed to be fairly localized.

Surveying was performed with a Ludlum Model 2350-1 with 44-10 sodium iodide detector, and a gamma-spectrum window set to focus on Cs-137 activity.   The effort covered Pentolite Ditch from the PBRF outfall to1 km (.6 miles) to the east, at which point the ditch empties into Plum Brook. The results showed that while the contamination levels dropped as sampling moved downstream (1,019 pCi/g peak near the western outfall down to intermittent spots in the 10 to 50 pCi/g range in the east end) there was still detectable contamination above background at the point where Pentolite Ditch emptied into Plum Brook. Background for Cs-137 in northern Ohio ranges from 0.3 to 0.8 pCi/g. Fig. 1 shows an aerial composite of the course from PBRF down Pentolite Ditch, and out into Plum Brook.

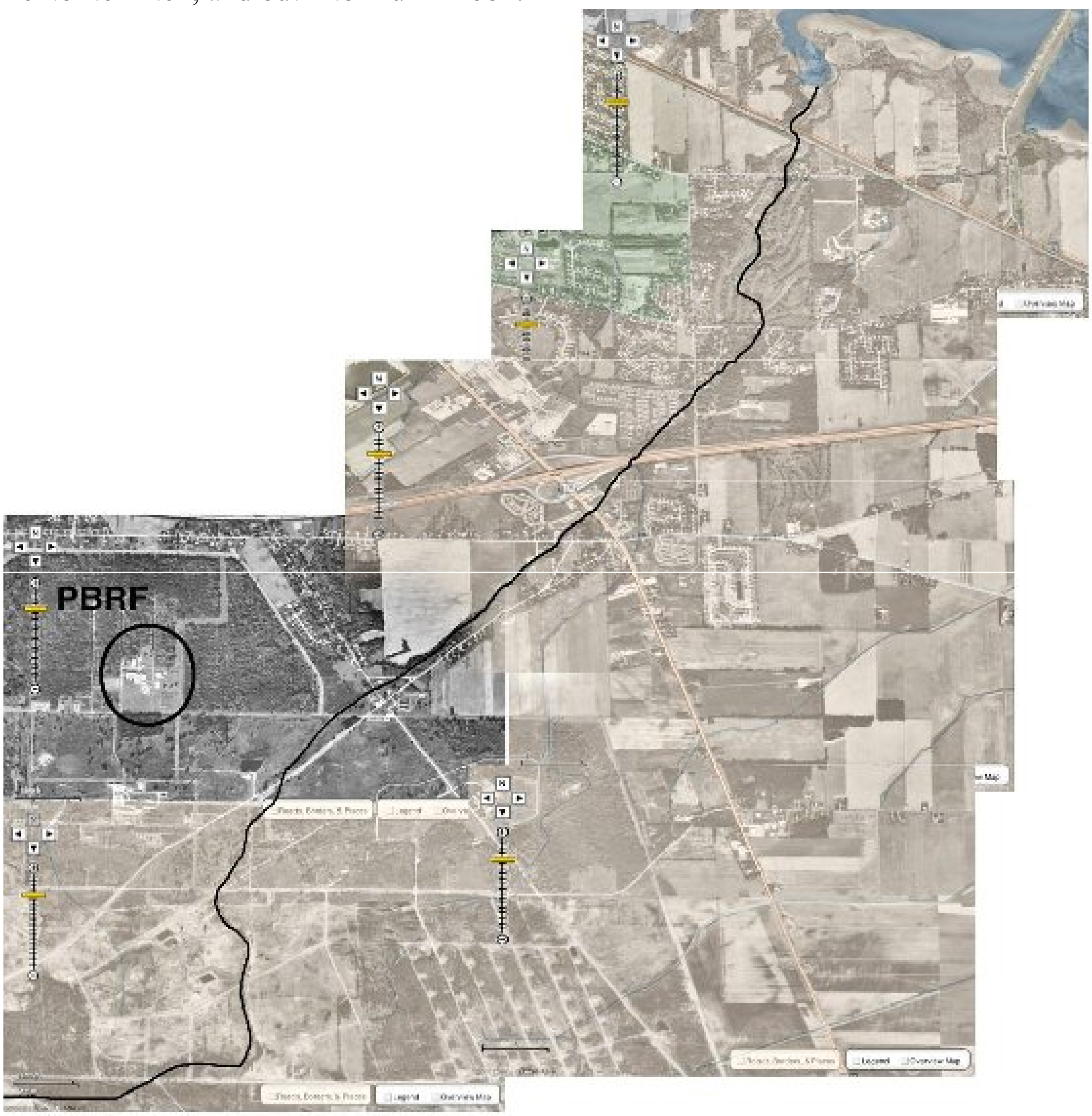

Fig. 1. Aerial view of the path of Plum Brook

Plum Brook is a small perennial stream whose flow varies greatly with the season. For much of the year it is less than a 0.3 m (1') deep with an average flow rate at the NASA fenceline of 64 l/m (2.3 cfm). In the springtime, however, especially with heavy rains and snowmelt it can overrun its 1.5 – 2.5 m (5' to 8') banks, with a flow rate of thousands of liters per minute (hundreds of cfm). It originates in farmland just south of the NASA Plum Brook Station (PBS). It runs north through the station for about 8.3 km (5 miles). Just before exiting NASA property it is joined by Pentolite Ditch. It then continues north for another 5.8 km (3.5 miles), passing through mixed agricultural and residential property, then a golf course, and finally a 1 km (.6 mile) marshy section that is a State of Ohio nature preserve. It then enters Sandusky Bay, the primary water supply for the city of Sandusky. The bay in turn empties into Lake Erie.

As a result of the findings in Pentolite Ditch NASA determined a scoping survey of Plum Brook should be performed. Several locations within the first 1 km (.6 miles) downstream of the NASA fenceline were scanned with the sodium iodide detectors, and biased samples were taken based on these scans. The results of this scoping survey showed that while areas of contamination were isolated and relatively limited in number Cs-137 could be found along the bank and in the silt of Plum Brook at levels up to 38 pCi/g. With these results NASA was now faced with the fact that Plum Brook had been impacted by reactor operations in an area outside the PBS fenceline, but there was insufficient information on the extent or level of the contamination.

SCOPING SURVEYS

NASA informed the NRC of the results and put together a plan for a more through scoping survey, to try and bound the level and location of the contamination. Much of Plum Brook is on private property. This meant the first step was to identify locations down the length of the brook that could be reached from publicly accessible area, such as bridge overpasses and right-of-ways. A total of sixteen locations were identified, from 3 km (1.8 miles) upstream of the junction of Pentolite Ditch and Plum Brook all the way down to the bay.

The samples were taken from the bank immediately next to the stream, biased toward locations where the sodium iodide detectors indicated there was activity. Downstream results showed more than half the locations had no contamination above background. Unfortunately they also found several isolated spots with readings as high as 38 pCi/g. Most interesting was the result from nearest the mouth of the stream, which showed 3 pCi/g. Low, but definitely above background, meaning the PBRF footprint went all the way down the length of the brook to the lake. Again, see Fig. 1.

The scoping survey also proved that historic PBRF operational discharges were the source of the 'above background' readings in Plum Brook. As was stated previously several of the scoping samples were taken upstream of the confluence of Plum Brook and Pentolite Ditch – all were at or below background. More importantly, laboratory analysis of the elevated samples showed trace amounts of Co-60 and Sr-90 in a ratio that matched that found in PBRF process water piping systems (approximately 1% of the level of Cs-137 present in the sample).

NASA shared the scoping survey results with the NRC, the Ohio Department of Health, Ohio Environmental Protection Agency, county officials, and Community Workgroup members. The information was also shared with the broader public through a normally scheduled annual Media Day, Community Information Session, and Project Newsletter as well as the Project website and Telephone Information Line. An important part of the communication effort was to note that while the levels found to that point did not represent a health risk to the public NASA needed to more completely characterize Plum Brook, and would take whatever appropriate actions were needed.

TRANSPORT MECHANISM

To develop a credible and efficient Characterization Plan NASA recognized the need to understand the transport mechanism for the Cs-137. Haag Environmental Company, a local environmental contractor with hydrogeologic expertise, was brought in to help. They were tasked with figuring out how the Cs-137 moved downstream and deposited, and therefore where NASA should expect to find contamination. They were also asked to identify any areas besides the channel of the brook where characterization was warranted. This information was then to be used in putting together the Characterization Plan.

Results of the transport and fate assessment indicated that the sediment in the bottom of Pentolite Ditch is fine clay, known as ‘illite’. It has a great affinity for cesium, and once it bonds onto it, it doesn’t let go. It was determined that the Cs-137 contained in the normal discharges from the operating plant had bound tightly with the silt and had concentrated there over time. With normal flow conditions little or no motion would be expected of the cesium bearing silt. During 35 to 40 years of storm events, however, the silt was swept downstream, deposited, eroded, and redeposited all the way from the reactor outfall in the ditch down to the mouth of Plum Brook. As Haag stated, “90% of your movement occurs during 10% of the time, when the water is high”. What could be expected then was that contamination would be found wherever the silt had settled out: in low flow regions such as eddies or before culverts, with minimal deposits in the straight running sections of the brook. The question was also raised as to whether or not there was a final, large deposit or ‘delta’ somewhere downstream, either in Sandusky Bay, Lake Erie, or Plum Brook itself.

Haag identified seven different areas where cesium bearing silt might have deposited out, including groundwater, upper and lower meander sections, flood plain wetlands, adjacent ponds (which were subject to deposits during times when the brook was flooded), the stream mouth, and Sandusky Bay. A Characterization Plan was written to address each of the areas. Federal and state regulators as well as Community Work Group members were given the opportunity to review and comment on the plans.

CHARACTERIZATION SURVEYS

Characterization sample collection and analysis was conducted over the next 18 months. A combination of biased and random sampling collection was used. The dry areas along the sides of the brook were covered with biased samples, meaning a 100% survey of the areas was performed using a sodium iodide detector. Samples were collected anywhere there was an elevated reading (greater than 300 cpm, based on empirical tests at PBRF that showed this reading corresponded to 12 pCi/g of Cs-137). The entire stream bed, including the stream bed and the banks, was covered by use of random samples. The location for these samples was determined using a MARRSSIM based triangular grid technique. Samples were typically collected in three 15 cm (6 inch) sections, for a total sample depth of 45 cm (18 inches). A photo showing sampling taking place is shown in Fig. 2. When the work was finished a total of 3,000 samples from 1,200 locations had been collected. The samples were processed and analyzed in an onsite laboratory.

Fig. 2. Sample collection along Plum Brook

The results confirmed the earlier scoping survey results of a scenario of isolated deposits of slightly elevated amounts of Cs-137 surrounded by large areas of little or no detectable activity above background. Concentrations ranged from the majority of samples that were “less than detectable” (less than 0.02 pCi/g) to as high as one reading at 90 pCi/g. Most importantly, however, the highest average concentration in any single section of the brook was only 1.16 pCi/g.

Higher readings, such as they were, were typically found in the upper 15 cm (6 “) of the sediment in areas of low flow. This matched Haag Environmental Company’s prediction that the material would be found in smallish flat cells, often on the surface, but sometimes under several inches of clean sediment. In these cases the contamination would only be detectable if there was an exposed edge along the stream side wall. There was no indication of contamination in the ground water, neighboring ponds, the wetland flood plain, or Sandusky Bay. The detailed results for the areas Haag Environmental was involved in sampling are given in the reports for each area shown as References # 1-6.

The sampling effort did manage to identify the location of the final resting area, or 'delta', for cesium bearing silt that washed downstream over the years. It was not in the Sandusky Bay or Lake Erie, but was determined to be still in the mouth of Plum Brook, in the Putnam Marsh Nature Preserve. At this point the stream comes down a short elevation from the golf course, and the grade goes to essentially zero. The stream widens out into a wetland, and the flow rate drops way off. The same pattern was seen here as it was upstream of small, isolated spots of activity. The contamination level peaked out at 15 pCi/g, but the overall average level was between 1.0 and 1.5 pCi/g. This area is typically under .3 m (1') or more of water, and is covered with very difficult to penetrate wetland vegetation. As a side note, this same location was where something else from upstream dropped out – several thousand golf balls from the upstream golf course were found here.

INNOVATIVE SAMPLING METHODS

There were two instances during the sampling campaign that presented unusual physical challenges for collecting the samples. In each case a rather innovative approach to collecting the sample was developed by Haag Environmental Company.

The first area was in Sandusky Bay. This was one of the first areas done based on the concern that the bay is a primary source of drinking water for the city of Sandusky, and local officials and the public wanted to be assures of the safety of the supply. The water level in the bay rises and falls with the water level in Lake Erie. Currently the east end of the bay where Plum Brook discharges averages .5 to 1.0 m (1.5' to 3'0) deep. Aerial photos show that as recently as the 1930's, when Lake Erie's level was 1 m (3.5') lower than it is today, this area was dry, with channels cutting through it. The channels are still there underwater, meaning a worker could be walking in knee deep water 100 m (110 yards) from shore, and suddenly step into an area twice that deep. The ground under the water consisted of a thin layer of silt over several feet of compressed organic material (basically a layer of peat). Under this was another layer of clay. It was determined that to assess the potential contamination in this area it was necessary to collect samples that penetrated to the lower clay layer, a depth of 2.5 - 3 m (8' to 10') in some cases. While initial collection of samples close to shore was accomplished by manual means, standing in shin deep water, a different method was needed further out.

To accomplish this Haag developed a floating geoprobe arrangement. They purchased a used pontoon boat for $600, cut a hole in the middle of the deck, and mounted a small geoprobe rig over the hole. The boat easily handled the water conditions within the bay, and provided a stable work platform for the sample work. Fig 3 is a picture of the arrangement. Note the workers standing at opposite corners of the boat, helping to counteract the torque of the geoprobe unit. This proved to be easier and faster than using anchors. The canoe was used to ferry tools, supplies, and samples back and forth from shore.

Fig 3. Pontoon Boat mounted geoprobe for sampling in Sandusky Bay

The second challenge was the collection of samples in Putnam Marsh. Samples of several meters were desired in this area. Here the ‘soil' was often a mat of organic material loaded with roots. This made it very tough to get a push core sample by hand, which was the only method available. The pontoon boat could not be brought in without disturbing protected vegetation. In cases where a sample was collected the force of pushing the core down into the material caused a compaction of the sample of up to 70%, making it harder to analyze the results.

Haag's solution was to construct a device they named the ‘Vibracore', shown if Fig. 4. The key component of the Vibracore was a commercially available wand-like device normally used for settling concrete poured inside a wall. It was powered by a 2-cycle gasoline engine which was mounted in a backpack. The vibrating element was attached to the top a 3.1 m (10') length of thin walled, 7.5 cm (3") diameter aluminum fence post stock. The ‘cutting' end of the post was ground to a bevel. Once the device was turned on the vibration in the post allowed it to cut through the organic material without problem. Sampling went to the desired depth, or first refusal (this is an area of shallow bedrock). Once it was at full depth the wand was detached and a rubber worm-clamped cap was placed on top of the tube to create sufficient suction to keep the sample material in the tube. In dryer areas the tube was extracted using a tripod and winch or a truck jack and chain. In water covered areas extraction was achieved using 2 to 3 people with pipe wrenches. After the tube was removed the bottom was capped, the empty portion of tube at the top was cut off, the top was capped, and the tube was marked with an indelible pen for sample location and orientation.

There was very little compaction of the sample collected. This device worked very well for cutting through clay as well as the organic mat. It did prove less effective in rocky soils, which refused its passage, and in sandy soils where the vibration shook the sample to the point where it fell apart when attempting to withdraw it from the ground.

Fig. 4. The ‘Vibracore’ in use in the field

PUBLIC OUTREACH

From the very beginning of the project NASA had worked hard to be open with the public in its approach to decommissioning. Quarterly Community Work Group meetings as well as the previously mentioned annual Media Day and Community Information Session had been used since 1999 to provide the public with decommissioning plans and updates, and to receive feedback from them on their concerns and questions. This sustained effort at two-way communication had served to build up a level of credibility with the local residents. In addition to these tools NASA also had a number of other vehicles such as the Project website; Telephone Information Line where callers would receive recorded project updates and could also leave their questions or concerns with a commitment by NASA to respond to them in 24 hours; and the Project Quarterly Newsletter. These ongoing outreach efforts and the resulting high level of trust of NASA were invaluable through the rest of the sampling, analysis, and release of results. The public accepted NASA's word when assurances were made that what had been found to date posed no risk to those living, working, or playing along Plum Brook, but that NASA had plans to continue sampling to prove this. In addition, NASA senior management made a commitment to take any action required to protect the public.

Unlike earlier scoping efforts which were accomplished on publicly accessible land, the detailed characterization effort required access to private property. Prior to beginning characterization sampling NASA held a public meeting specifically for property owners along Plum Brook. The sampling process was explained, and individual concerns were addressed. NASA sent out a request for written permission to each owner to access their property for sampling. As a result of the meeting a section was included on the permission form for the owner to include any special provision or concern they might have. The responses included everything from expected "please don't sample when my children are out playing" to the surprising "while you are sampling the brook, can you sample my garden, since I built it up using soil from Plum Brook?". All requests were honored, and following analysis of the results all property owners eventually received a report showing the results from their own property as well as all of the other surrounding results. Contact information with project personnel was also provided in case of questions, but none were received.

EVALUATING THE RISK TO THE PUBLIC FROM PLUM BROOK

With the characterization data in hand the question remained as to how to demonstrate to the NRC that the levels involved did not represent a risk to the public. The NRC had stated in a public meeting that while Plum Brook was outside of the PBRF licensed area, and therefore not technically part of the licenses, that they would not terminate the licenses until NASA had shown that all necessary remediation of Plum Brook had been completed. So what was the appropriate clean up level?

NASA's original intended approach was to develop isotope specific Derived Concentration Guide Lines (DCGLs) for Cs-137, Co-60, and Sr-90. The application of the existing on-site soil DCGLs was problematic, not because levels found exceed the limit, but because those limits were based on the Resident Farmer Scenario. This scenario was not reflective of the physical arrangement of the area or of the actual land use scenarios along Plum Brook.

The first step was to perform an analysis of the dose pathways that did exist along the brook. Given the length and variety of uses the public made of Plum Brook it was decided to break it into sections, and to look at the uses for each one. Table I shows the results of this analysis. The idea was to analyze these scenarios, develop the various DCGLs, and then to apply the most conservative one to the entire length. Two problems were found with this approach. First, using a MARSSIM based DCGL and FSS type approach might lead to the need to do more sampling in Plum Brook, merely to satisfy the requirements of MARSSIM. NASA believed that given the sampling already performed and the low levels of contamination found that this was unnecessary. Secondly, due to the steep nature of the banks over much of Plum Brook's length it would have been physically difficult to prepare for (i.e. removal of shielding vegetation) and to perform a proper scan in accordance with MARSSIM.

Table I. Land Use for Each Stream Section

Section	**Stream Course (mi)**	**Land use (zoning)**	**Public Access**
1 – Upper Stream (meander)	1.6	30% Residential 30% Agricultural 30% Commercial 10% Government	Private Property, or access by permission only
2- Lower Stream (meander)	1	60% Residential 20 % Government 20% Commercial - recreational (golf course)	Private Property, or access by permission only
3 – Upper Flood Plain	0.85	60% Commercial – recreational (golf course) 40% Agricultural	Private Property, or access by permission only
4 – Lower Flood Plain and Mouth	0.55	100% Erie Metro Park	Controlled public access

NASA worked internally on an alternate approach, and discussed the situation with the NRC. The approach eventually chosen was to demonstrate compliance with NRC regulations to protect the public by means of dose analysis. The analysis would be used in combination with the existing characterization sampling results to demonstrate compliance with the dose criteria of 10CFR20.1402. This method is consistent with the

methodology described in Section 2.5 of NUREG -1757, Volume 2. The end result of this approach is the same as the end result of a DCGL/FSS approach – insuring a dose to the average member of the public of less than 25 mrem per year.
Further discussions with the NRC took place on the question of how to document this approach from a license point of view. Specifically, while the material in Plum Brook was from a licensed reactor it was outside the physical footprint covered by the license. The NRC determined that best approach was for NASA to submit a request for a license amendment that made the cleanup of Plum Brook part of the license. In this way, the decommissioning is not complete unless all associated contamination, on or off site, is remediated to a level that protects public health. The amendment states that dose analysis will be the method used to demonstrate off site cleanup.

DOSE ANALYSIS

To perform dose analysis it is necessary to understand what dose pathways exist. NASA looked at the previously identified stream sections, and determined the dose pathways associated with each one. The scenarios that were developed were the Suburban Gardner, the Streamside Resident, the Golf Course Maintenance Worker, and the Recreationist. The dose analysis considered an "average member" of each target population for each stream section.

The Suburban Gardner was modeled on someone living along the upper stream meander section. This person was assumed to have excavated sediment from Plum Brook to use in building up their garden. Note that this was a real situation, and sampling of the garden had shown nothing above background. For analysis purpose, though, it was assumed that there was activity in the soil, and that the resident was exposed directly while working in the garden, and from consuming home-grown vegetables.

The Brook Side Resident was based on someone living in the lower meander stream section. In this scenario the source was assumed to be sediments deposited in the yard during periods of high water. A home was then assumed to be built, with contaminated soil around the foundation. The result would be direct dose while in the house as well as when out in the yard.

A fair portion of Plum Brook passes through a country club's golf course. There are several man made irrigation ponds located on flat land adjacent to the brook. For the Country Club Maintenance Worker scenario it is assumed that sediments in the pond were contaminated during periods of high water in the brook. Subsequently this sediment was removed from the pond when maintenance workers used the material to fill in low spots along the golf cart paths around the course. Again, this is a situation which was based on actual events. The maintenance worker then is assumed to be exposed by doing the repair, traveling on the cart path, and maintaining the adjacent landscaping.

The stream mouth of Plum Brook is in a flat stretch of land. The brook widens out into a swampy area approximately 1 km (.6 miles) in length. In fact, this is the State of Ohio Putnam Marsh Nature Preserve. There is a nesting pair of bald eagles in the marsh. The dose recipient in this case was based on the Recreationist, someone assumed to be using the nature preserve for hiking and fishing. Dose in this case is from direct exposure to the stream bottom and bank, and from consumption of fish caught in the stream.

The dose analysis was performed by taking the RESRAD Resident Farmer scenario and turning off the appropriate paths so that only those that could actually impact the user in each case were in effect. The results are shown in Table II, including a comparison to the PBRF Resident Farmer Scenario.

Table II. Dose Modeling Results

Scenario	Dose (mrem/y per pCi/g)	Dose Fraction by Pathway (%)	
		Direct	Food Consumption
Suburban Gardner	0.04	64	36 (vegetables)
Brook Side Resident	0.17	99.9	NA
Country Club Worker	0.10	99.9	NA
Recreationist	0.11	33	67 (fish)
PBRF Resident Farmer	1.7	82	18 (Plants, meat, milk)

Not shown on the table, but also included for analysis was the scenario of a child playing in the brook. This was based on concerns raised by parents living along Plum Brook. This dose was calculated using the ICRP-72 dose factors that were recently added to the RESRAD libraries. The scenario developed in this case was based on the playground scenario. Given the weather in Ohio and the small chance of significant exposure during the cold winter months 450 hours per year of occupancy were used. Based on this the highest dose was to a young child, 1-5 years old. The dose was 0.13 mrem/y per pCi/g.

The most limiting scenario is the Brook Side Resident, which results in a dose of 0.17 mrem/y per pCi/g. Since the characterization data demonstrates that the highest average level of contamination along Plum Brook is 1.16 pCi/g that means the expected dose to the average member of the affected public is 0.19 mrem/year, well below the limit of 25 mrem/year. As a side note NASA did place Thermo Luminescent Devices (TLDs) close to Plum Brook in the analyzed areas for a period of 3 1/2 months. The dose received in that period by all the TLDs was less than detectable. MicroRem measurements at the same locations further validated these results.

Even though the analyzed dose is sufficient to demonstrate the safety of the public there is still the issue of As Low As Reasonably Achievable (ALARA) to consider. As a final step, following the remediation of all upstream sources, NASA is planning to perform a walk down of both banks of Plum Brook during a low water condition. During the walk down isolated spots of elevated contamination will be identified and removed, most likely with a bucket and shovel. That activity is currently planned for the summer of 2010.

SUMMARY

The level of effort expended by NASA in Plum Brook was not in the original plan, but dealing with the unexpected is a big part of any decommissioning project. While it was a sizable impact on the decommissioning budget it could have been worse. Several things helped to contain the cost growth:

1. A preexisting 2-way communication effort with the public and local media gave NASA the credibility to be trusted when the bad news (contamination at unknown levels is on public property) became known. This minimized the immediate negative public response and allowed NASA to avoid a potentially expensive and inappropriate knee jerk reaction in dealing with the contamination.
2. Continued sharing with the public, media, and regulators of results and future plans was key in maintaining this credibility.
3. Bringing in an outside expert helped point NASA in the right direction, and the fact that they were local and known in the community to be independent thinkers helped maintain credibility. Their expertise made sure all possibly impacted areas were identified and sampled, and their innovative techniques made sampling easier.
4. Dose analysis in this case proved to be a better solution than a MARSSIM/FSS approaches, using the results of a reasonable characterization effort to ensure public safety.

NASA's commitment throughout this process has been to insure the safety of the public, the environment, and the workers. Through the efforts to identify and address the offsite contamination in Plum Brook NASA has met that promise.

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