Hanford K-Basin Sludge Characterization Overview

February 2005

1. Summary

The Hanford K-East and K-West Basins were used to store irradiated fuel prior to Spent Nuclear Fuel (SNF) processing. In 1980, irradiated N-Reactor fuel was placed, for what was intended to be short duration storage, under water in the pools previously used for temporary storage of irradiated fuel from the K-East/K-West Reactor production complex. Upon closure of the irradiated fuel reprocessing facility at Hanford (the PUREX facility) the N-Reactor irradiated fuel remained stored under water in the K-Basins.

Over the lifetime of these K-West and K-East Basins, debris, silt, sand, and material from operations resulted in the formation of sludge that accumulated in the bottom of these basins. In addition, the extended storage of the irradiated fuel resulted in corrosion of the fuel cladding and the storage canisters, especially in the K-East Basin, where the fuel was exposed directly to the storage water.

The sludge from the K-East and K-West Basins, about 50 cubic meters total, now consists largely of non-radioactive material (dirt, sand, and silt) contaminated with fission and activation products and uranium. This sludge must be removed and disposed as part of the basin decommissioning activities. The Department of Energy believes that this sludge does not meet the definition of high level waste (HLW) or SNF, and if properly processed, will meet the disposal requirements for transuranic waste, and thus be eligible for disposal at WIPP.

This paper describes the operation of the K-Basins, the N-Reactor irradiated fuel storage in the K-Basins, formation of the sludge, and the planned processing of the sludge. The paper summarizes information on the radiological, chemical, and physical properties of the sludge that provides the basis for our belief that this waste is Transuranic waste.

2. Statutory Definitions

In evaluating the waste contained in the K-Basins, the Department has applied the definition of Transuranic waste from the Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act of 1992, as amended (LWA) and the definition of High Level Waste (HLW) and Spent Nuclear Fuel (SNF) from the Nuclear Waste Policy Act of 1982, as amended (NWPA).

The WIPP Land Withdrawal Act of 1992 P. L. No. *102-579, as amended by the WIPP LWA Amendments of 1996, P. L. 104-210*, defines Transuranic wastes as:

> *The term "transuranic waste" means waste containing more than 100 nanocuries of alpha-emitting Transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for:*
> *(A) high-level radioactive waste;*
> *(B) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations; or*
> *(C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations.*

The Nuclear Waste Policy Act of 1982 (42 U.S. 10101(12)), as amended defines HLW as:

> *(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and*
> *(B) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.*

Reprocessing is a chemical process by which spent nuclear fuel is dissolved and the isotopes of interest such as plutonium and uranium are separated from other spent fuel constituents, i.e., waste products. None of the material in the K-Basins resulted from the reprocessing of spent nuclear fuel and hence, would not be considered as HLW. In addition, the second part of the HLW definition is not operative due to the lack of rulemaking by the Nuclear Regulatory Commission, and as a result, is not applicable to the K-Basin sludge.

The Nuclear Waste Policy Act of 1982 [42 U.S.C. 10101(23)] as amended defines SNF as:

"Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing".

A comparison of the origin and the radiological, chemical, and physical properties of this basin material with the origin and properties of SNF indicate that this sludge is not similar to SNF (refer to section 6.4). The inclusion of the foreign constituents, of which approximately 75% are not radioactive, results in the generation of a waste form more like that found from the clean-out of a hot cell, floor sweepings from a plutonium processing room, or clean-up of a contaminated fuel shipping cask.

3. Background

The Hanford K-East and K-West Reactors operated from 1955 until 1970 and 1971, respectively. The irradiated fuel from those reactors that was in the K-Basins was removed at the time of the reactor shutdowns. The K-Basins were then modified for use in receiving and storing Spent Nuclear Fuel (SNF) from the Hanford N-Reactor beginning in 1975 for the K-East Basin and 1981 for the K-West Basin. The K-West Basin was completely drained of water and its floor and walls coated with an epoxy paint as part of these modifications. The K-East Basin was neither drained nor epoxy coated prior to being placed into service for receiving N-Reactor fuel.

Each K-Basin is an open pool, approximately 67 feet wide, 125 feet long ,and about 21 feet deep filled with approximately 1,300,000 gallons of water to a depth of approximately 16 feet. Water used in the K- Basins during the reactor operation phase was treated to better than drinking water standards to provide a “friendly” environment for the short term storage of the irradiated aluminum clad fuel from the K-Reactors.

As shown in Figure 1, the basins were filled with water and designed with six side areas to support specialized activities. A brief description of the areas is discussed below.

- **The Discharge Chute** received the spent fuel elements (by free fall) when the elements were discharged from the reactor.

- **The North and South Loadout Pit** areas were used for loading the buckets, containing the irradiated elements, into railroad cask cars for shipment to the reprocessing facilities in the 200 Area. Loading and shipment of the irradiated fuel in the cask cars from the Loadout Pits was a routine operation, generally while the reactors were operating, and personnel were not focused on outage activities.

- The **Dummy Elevator Pit** was used for lifting buckets of aluminum spacers (dummies), used for positioning the fuel with the reactor process tubes, so that they could be decontaminated and recycled.

- The **Technical Viewing Pit** contained an underwater scope for examination of fuel and other items without undue exposure to the viewer. The 16 feet of water provided sufficient shielding from radiation. This area also included some specialized handling equipment to manipulate and position fuel pieces for viewing.

- The **Weasel Pit** was used to check radiation levels in objects (fuel and dummies primarily) through the use of an underwater detector. The activity of an irradiated fuel piece would cause an alarm to “squeal;” thus, the name weasel got attached to this activity and this location.

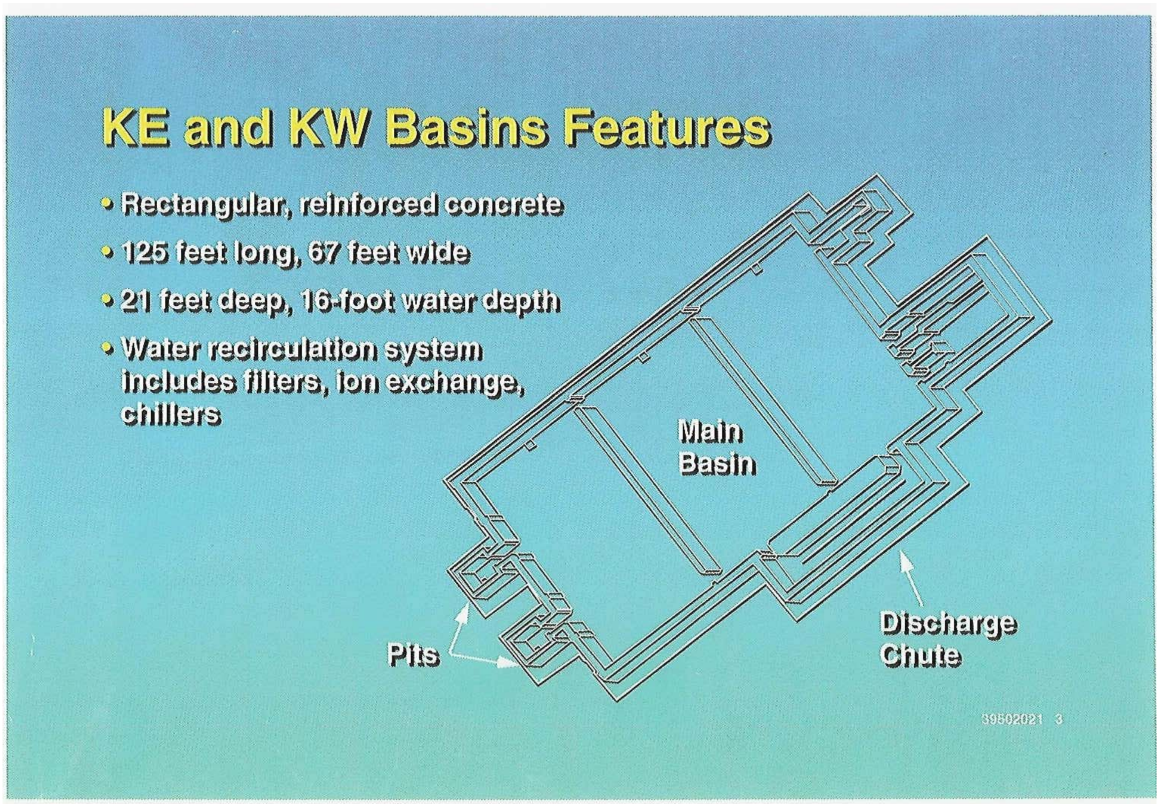

Figure 1. K-East and K-West Basin Layout

The K-Basins, with their 1.3 million gallons of treated water, were an active and integral part of the plutonium production mission of the K-East and K-West Reactors.

The K-Reactor basins, prior to storing N-Reactor fuel, were part of an active plant operation. Each of the K-Reactors contained 3,220 horizontal process tubes loaded with 38 to 56 aluminum clad fuel elements and 18 to 25 aluminum spacers (dummies). About 20% of the fuel in the K-Reactors was discharged (unloaded) into the K-Basin pool each month of operation. Thus, during the operating life of the K-Reactors, over 10,000,000 spent fuel elements were discharged into the K-Basins. Each of these irradiated fuel elements was placed remotely using hand operated tools into fuel transfer “buckets” for short term storage in the basins and then shipped to the reprocessing facilities in the 200 Area. Reactor maintenance activities, for example, the replacing of aluminum process tubes, contributed extraneous material and debris to the K-Basin water.

Each K-Reactor experienced “fuel failures” during operation. The aluminum cladding, for a variety of reasons, was occasionally breached and created a pathway for the process cooling water to contact the uranium metal. The rapid oxidation of the metallic uranium and the resulting volumetric expansion released particles of the uranium to the process water. As the reactors were "single-pass," each fuel failure resulted in a reactor shutdown to minimize the amount of fission products put into the process water. Discharge of the fuel column containing the failed element(s) put them (uncontained) into the basin water. Thus, the water in the irradiated fuel storage area was contaminated with fission products, as well as the other non-radioactive material.

The K-Basins had an operating deck of open-space grating allowing direct visual observation of the fuel covered by approximately 16 feet of water. This open-space grating permitted inadvertent entry into the basin water of wrenches, eyeglasses, nuts and bolts, and many other items associated with personnel engaged in active operation and maintenance activities. Dirt from shoes and equipment brought into the area contributed to the debris in the basin. In addition, the "rear face" of the reactors, where the irradiated fuel fell into the discharge pit, was directly open to the basin water and maintenance and operation activities in this area contributed, unintentionally, many items to the basin water.

4. Basin Sludge Formation

Prior to initiating modifications to the K-Basins for storage of the N-Reactor fuel, the following conditions existed:

- The K-East and K-West Basins were filled with water that had been in the basins as part of the K-East and K-West Reactor Plant operations. Both basins contained sludge, consisting primarily of non-radioactive sand, silt, and debris and radioactive corrosion products, activation products, and some fission products. Observations identified the sludge layer on the basin floors to be about three inches deep.

- The three-inch layer of sludge on the K-West Basin floor was removed as part of the planned decontamination activities in support of the anticipated storage of the N-Reactor spent fuel. The sludge was analyzed and determined to be low-level waste (contained less than 10 nanocuries per gram of transuranics) and was shipped to the 200 Area burial grounds for disposal. Similarly, sludge that was removed from the N-Reactor basin as part of a CERCLA removal action in the late 1990s was treated and shipped to the on-site CERCLA cell for disposal.

- Existing sludge in the K-East Basin was not removed before the N-Reactor spent fuel was placed into the basin for storage.

- The K-East Basin water was slightly contaminated with fission products; dose rates on the water surface were probably only slightly above background;

- The basin water, both K-East and K-West, had been slightly contaminated with oil and grease from routine and repair maintenance activities associated with fuel handling and transfer and from other operating activities;

- Some of the material and debris on the basin floor and in the various pits was radioactive from activation products.

The basins are filled with approximately 16 feet of water. The N-Reactor fuel was initially placed in the K-Basins for *short-term* storage. The disposition planned for the N-Reactor fuel at the time of storage was processing in the PUREX facility in the 200 area. Consequently, no long term considerations, preparations, or analyses were performed before the storage action was initiated. The PUREX facility was shut down in the early 1970s for what was intended at the time to be a short duration. Accordingly, N-Reactor continued to operate, thus allowing for increased inventories in the K-Basins. PUREX was permanently shut down in 1989 eliminating the planned disposition path for the N-Reactor spent fuel stored in the K-Basins. At this point, short-term storage became "indefinite" storage.

Approximately 105,000 N-Reactor spent nuclear fuel assemblies (an N-Reactor fuel assembly consists of an outer and an inner element) from the N-Reactor were placed into the K-Basins for storage. This irradiated (spent) fuel consisted primarily of metallic uranium, but also included plutonium, and radioactive fission and activation products. The N-Reactor fuel was encased in a Zircaloy-2 cladding; following discharge from the N-Reactor, the SNF was placed into open canisters and transported to the K-East Basin where it was placed into closed canisters and transported to the K-West Basin.

Although not an operational mission at the time, the K-Basins provided two essential elements of storage for the N-Reactor fuel:

- Sufficient water depth for radiation shielding and
- Sufficient volume of water for adequate cooling of the spent fuel.

Storage of the N-Reactor fuel underwater extended from short-term to almost 30 years. During this storage time, there was an accumulation of non-radioactive material, such as sand, silt, dirt, insects, and rodents in the basins due to normal basin operations and monitoring and from the numerous dust storms experienced in the lower Columbia Basin. The basins are not, nor were they ever, intended to be environmentally controlled areas. Doors open directly to the outside; access to the storage area was without restriction of outer personal clothing, e.g. street shoes were allowed. Thus, the water in the basins was "contaminated" with dirt, dust, and other items associated with a relatively uncontrolled environment.

The primary sources of the sludge on the floor and the pit areas are degradation of the basin walls, storage racks, and the outside of the storage containers, as well as the introduction of sand and silt from the air. In the K-East North Loadout Pit, the sludge volume also includes particulate matter resulting from backwashing the sand filter for the basin water.

This accumulation of non-radioactive material, debris, dirt, sand, and silt contributed to the major portion of the sludge on the basin floors. This continued accumulation resulted in the K-East basin having more sludge than the K-West basin, since the K-East basin was not cleaned prior to storing the N-Reactor spent fuel..

Although the underwater corrosion of the canisters, the storage racks, and the fuel cladding itself was not rapid, the steady progression produced contaminants to the "naturally" occurring basin sludge. Underwater deposits of these corrosion products were evident by visual observation. No attempt was made to characterize the extent of this corrosion during the first two-thirds of the fuel storage period. Samples were taken from the K-East basin in the early-to-mid 1990s (HNF-SD-SNF-TI-009). Results of these analyses are reported in HNF-SD-SNF-TI-009, Volume 2, Rev. 4.

5. K Basin Sludge Radiological Assessment

As with just about all of the radioactive material and waste at Hanford, the radiation source in the K-Basin sludge is contamination from the metallic uranium fuel with plutonium and fission products generated in the Hanford reactors. As indicated earlier in this report, a very large quantity of fuel was irradiated in the nine Hanford reactors. Most of this irradiated fuel went from the reactor storage basins directly to the reprocessing facilities, with the following exceptions:

- Irradiated fuel elements sent to the C-Reactor Fuel Examination Facility for physical measurement and non-destructive visual examination

- Irradiated fuel elements, mainly failed elements and test fuel elements, sent to the Radiometallurgy Laboratory in the 300 Area for destructive examination

- The N-Reactor fuel sent to the K-Basins for short-term storage

The Zircaloy-2 cladding of the N-Reactor fuel in the reactor withstood the high temperature/high pressure environment in the horizontal process tubes while under irradiation. The long duration storage time in the relative passive environment of the K-Basins resulted in substantial amounts of external corrosion on the cladding. A large fraction of the N-Reactor fuel cladding in K-East Basin had deteriorated to the point of failing to perform its primary function: containment of the metallic uranium fuel with the loading of plutonium and fission products. Consequently, the K-East Basin water contamination included significant quantities of radioactive constituents that were not found in the other reactor basins.

The corrosion process can be described as self-perpetuating. Initial corrosion of the fuel cladding exposed the metallic uranium; the metallic uranium (containing plutonium) heated by latent fissions and radioactive decay of fission products oxidized upon contact with the basin water; this uranium oxidation resulted in a large volume expansion of the fuel; this, in turn, caused more of the cladding to open, exposing even more metallic uranium to the basin water. The volume expansion, in turn, forced the end caps of the fuel to "pop" off, opening up the entire end of the cylindrical fuel piece to the water environment. Thus, the N-Reactor fuel stored in the K-East Basin caused the existing sludge to become contaminated with fission products and with transuranic elements.

Figure 2 provides an illustration of the typical Hanford "Fuel Cycle."
The storage of N-Reactor fuel in the K-Basins was a departure from the normal irradiated fuel management plan at Hanford. Other than the approximately one tenth of one percent of the fuel that was given post-irradiation examination, the N-Reactor fuel represents the only departure from the "standard" practice of shipping the irradiated fuel directly from the reactor storage basins to the chemical separation facilities in the 200 Area. A few shipments in the 1940s were placed in short term storage in the 200 North area when it was thought that additional decay time was needed before the chemical processing operations. However, in all other cases, irradiated fuel from the reactors was chemically processed, and sludge from the storage basins was sent to LLW disposal.

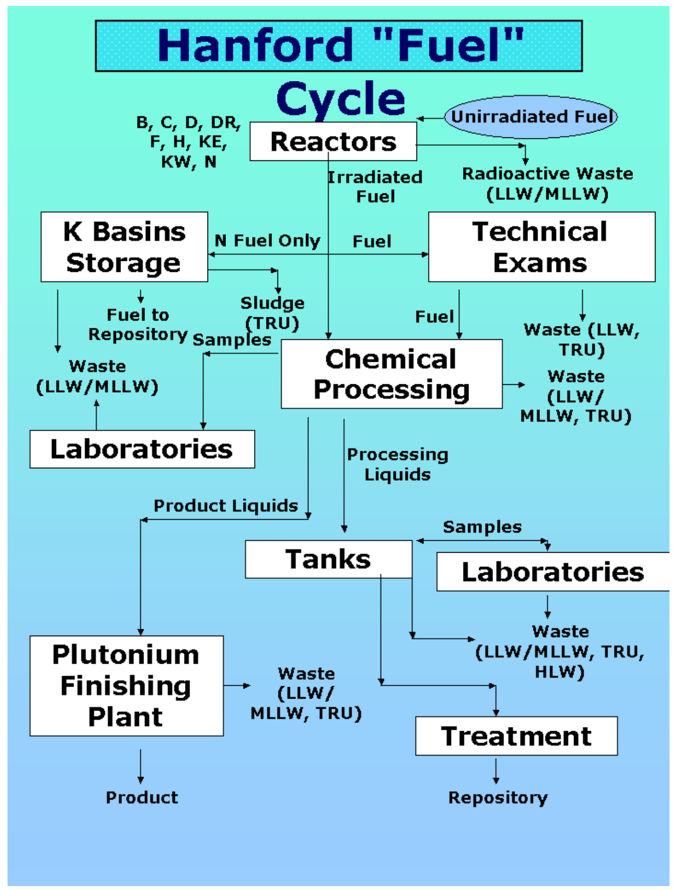

Figure 2. Hanford "Fuel Cycle"

During the K-Basin storage time, much of the irradiated fuel stored in the K-East Basin experienced deterioration of the cladding due to corrosion in the static water environment as explained above. It was estimated that approximately 1% of the original mass of the fuel corroded because of cracks and breaks in the cladding that were stored in open containers. This contributed directly to the sludge already existing in the K-East basin. Conversely, the spent fuel stored in the K-West Basin was placed in closed containers before storage. Corrosion products were not released to the K-West basin until it was washed and packaged during recent fuel handling operations. All processing and re-packing of the spent nuclear fuel for storage was performed underwater in the west bay of the K-West basin using a special cleaning machine for the canisters and fuel, tables for remote handling and re-packing of the fuel and a water clean-up system to capture sludge. This process line handled all intact fuel as well as associated sludge remaining in fuel storage canisters as well as all damaged fuel. The bulk of the sludge ended up in the integrated water clean-up system; however, some of this sludge was lost to the surrounding water and basin floor, especially when severely damaged fuel was handled.

The K-Basins, during storage of the N-Reactor fuel, were used exclusively for that purpose. No material or equipment was placed into the water in the basins, other than that needed to monitor, characterize, sample, or prepare for fuel removal operations.

The sludge, including the transuranic elements, fission and activation products from the spent fuel, resides in the bottom of the basin due to its higher density than water. Fission products, especially cesium, strontium, and their daughter products are significant contributors to the radioactivity of the sludge. The transuranic elements, especially Am-241, also make a major contribution to the radiological makeup of the sludge. Uranium and activation products are present in smaller quantities (refer to Section 6 for additional radiological composition).

Analyses of the sludge taken during the 1990s clearly show the variation in the characteristics of samples taken in different locations of the basin floors and pits. Details of these analyses are provided in Attachment A.

6. Current K-Basin Sludge Characterization

Composition of the in-place K-Basin sludge is complex and varies depending upon location and the specific basin, and includes in varying amounts, a combination of:

- Sand, silt and dirt
- Concrete grit from basin walls
- Metal oxides (corrosion of basin equipment and racks)
- Miscellaneous items: paint chips, plastic and paper, dosimeters, metal identification plates, wire and metal scrap, lost tools, etc.

- Metallic uranium, uranium hydrides and oxides
- Aluminum and Zirconium compounds (from fuel cladding corrosion)
- Ion exchange media from the water treatment plant
- Fission and activation products
- Plutonium and other transuranic isotopes

The sludge components are not uniformly distributed throughout the basin sludge. Additional sludge characterization data are shown in Attachment A. The data shown are those reported from samples taken in the K-East and K-West Basins from 1993 through 1999 and are for sludge in-place in the basins.

In reviewing the in-place sludge data (refer to Attachment A for details), it becomes evident that the sludge is largely "residual solids" (sand, dirt, silt) contaminated by uranium. The highest source of radiological contamination in the sludge is almost entirely from fission products, mostly cesium, strontium, their daughter products and transuranic elements that resulted from neutron capture during irradiation. The original uranium, the activated fuel cladding, corrosion products from the activated fuel cladding, storage canisters, and other debris items contribute a small amount to the radiation source.

6.1 Debris:

The basins currently contain a large amount of debris, separate from sludge or the recently removed spent fuel. Debris is comprised of a wide spectrum of materials, including approximately 7,500 fuel canisters, old basin equipment and piping, hand tools, fuel canister storage racks, construction materials, equipment used for basin clean out, components of the basin water pretreatment system, and waste generated during deactivation of the basins such as contaminated equipment and structural materials. Most of this debris is expected to be characterized as mixed low-level waste or mixed TRU waste, depending on the radiological composition of the debris itself and the residual sludge attached to the debris.

6.2 Organic Ion Exchange Resin (Beads) and Zeolite Resins (Beads):

Two water treatment systems were employed in the K-Basins that used resin beads. The ion exchange columns (IXC) were used during the K-Reactor operation through 1991. Ion exchange modules (IXM) were placed into service in 1984. Both systems used an organic ion exchange resin. Spherical resin beads have been observed on the K-East Basin floor, in the Weasel Pit, and the North Loadout Pit.

One pathway for the resin beads to enter the K-Basin sludge is via the in-place IXC, as the IXC discharge water drains into the basin through a 6-inch diameter pipe. Because the pipe outlet is located above the level of the canisters, it is possible that the beads dropped into the canisters, as well as onto the floor of the basins, when the sump overflow was drained into the basin.

A second potential pathway for the resin beads to enter the basin is via the IXM system. When the IXMs were first put into service, the vent system did not have screens installed. During change out, resin beads were observed coming through the vent system. The IXMs were operated from 1984 through 1993 without screens. As the vent system discharges in the South Loadout Pit, this could be a possible path for the resin beads to enter the basin.

A third potential pathway for the resin beads to have gotten into the basin is through a pipe that was routed from the sand filter backwash to the discharge chute (see Figure 1 for the position of the discharge chute and pits). The contents of the discharge chute were pumped into the Weasel Pit in 1994.

6.3 PCBs:

The two analysis campaigns, the Initial Analysis and Reanalysis, detected low levels of PCBs in the K-East Basin sludge. It is most likely that the source of the PCBs in the basins is from maintenance activities conducted prior to storage of the N-Reactor fuel in the basins. No PCB containing equipment or material has been knowingly added to the basins during the N-Reactor fuel storage. No PCB contamination was identified in the K-West Basin

6.4 K-Basin Sludge Waste Stream Characterization:

The sludges from the various locations in the K-East and K-West Basins will be collected for processing, as listed below, before being transferred out of the basins. These collections are planned in a prescribed manner, with the generation of the following six sludge waste streams anticipated:

1. K-East/K-West Floor and Pit sludge: Sludge retrieved from the various K-Basin pit and floor areas as well as some of the small diameter particles from the fuel handling and shipment preparation activities.

2. K-East/K-West North Load Out Pit Sludge: Sludge retrieved from the transfer pits where the N-Reactor fuel was removed from the basins and where the backwash of the K-Basin water treatment systems discharged.

3. Settler Tank Sludge: In the K-West Basin the fuel cleaning system transferred sludge

into two "staging" areas, the Knock-Out Pots and the Settler Tanks. This fuel cleaning system contained an array of horizontal tubes (settler tanks), downstream of the Knock-Out Pots, that allowed small particles, less than 500 microns, in the water to settle out and not be re-circulated.

4. K-East Canister Sludge: The K-East fuel was stored in open canisters and the fuel cladding and a small portion of the metallic uranium corroded and was deposited in the storage canisters.

5. Knock-Out Pot Sludge: In the K-West Basin the fuel cleaning system transferred sludge into two "staging" areas, the Knock-Out Pots and the Settler Tanks. The Knock-Out Pots collected particles greater than 500 microns in size. There were two configurations of Knock-Out Pots, one employing an internal 500 micron screen and the second utilizing a downstream strainer. The Knock-Out Pot sludge includes the sludge captured in the associated strainers.

6. Containerized Sludge. Several of the sludge retrieval operations will take sludge from various locations and place the sludge into large underwater containers. This clean-up activity will result in a separate and distinct sludge stream.

Data for these streams are summarized in Attachment A; for the various K-Basin sludge waste streams, the table shows the characterization information, including data on the N-Reactor spent fuel, for comparison.

The following table illustrates a comparison of the origin, as well as physical, chemical and radiological characteristics of the K Basin sludge compared to N-Reactor Fuel. Clearly this sludge, either in a small locally taken sample or as the whole volume, is not spent nuclear fuel as defined in the Nuclear Waste Policy Act (see also 40 CFR 191.02). First and foremost, the K-Basin sludge is NOT the result of irradiation of fuel elements in a nuclear reactor at the Hanford site. Approximately 75% of the sludge consists of non-radioactive materials such as sand, silt, debris, etc. that accumulated over the course of K Basin operations, resulting in the generation of a waste stream more like that found from the clean-out of a hot cell, or floor sweepings from a plutonium processing room, or clean-up of a contaminated fuel shipping cask.

In addition, the physical, chemical, and radiological characteristics of the sludge are significantly different than spent nuclear fuel. The sludge is an accumulation of non-uniform, small particles that are over 60% oxides (iron and aluminum oxides) and are comprised of approximately 65% fission products and 30% transuranic isotopes.

In contrast, the N-Reactor fuel consists of irradiated fuel elements housed in a Zircaloy-2 cladding. The fuel is predominantly metallic uranium (approximately 93% by weight) and fission products (approximately 95% of the radioactivity).

Table 1 – Comparison of the Characteristics of the K-Basin Sludge and the N-Reactor Spent Nuclear Fuel

Characteristic	K-Basin Sludge	N-Reactor Fuel
Origin	K-East and K-West Basins – Continued accumulation of sand, silt, and debris during storage; corrosion and deterioration of metal canisters and metal storage racks. K-East Basin – sand, silt, dirt, and debris accumulated during the 15 years of K-East Reactor Plant operations; corrosion and deterioration of fuel elements. K-West Basin – scale and debris from handling and packing the spent fuel for removal from the basins.	Irradiated in and discharged from the Hanford N-Reactor
Physical Form	Non-uniform, small particles less than ¼ inch.	Two concentric tubes made of uranium metal co-extruded into Zircaloy-2 cladding.
Chemical Composition (weight percent)	Iron Oxide – 43% Solids (sand, silt, etc.) – 23% Aluminum Oxide – 19% Uranium (total) – 14% All Others – 1%	Metallic uranium – 93% Zircaloy-2 – 7%
Radiological (percentage of curies)	Fission products – 65% Transuranic isotopes – 30% All Others – 5%	Fission products – 95% Transuranic isotopes – 4.4% All others – less than 1%

7. K-Basin Sludge Processing and Packaging Information

Removal of the sludge from the K-Basins requires a relatively sophisticated series of closely coordinated operations. See Figure 3 for a schematic for K-Basin sludge processing. The sludge consists only of material that will pass through a ¼ inch screen. The process of recovering the sludge from the various locations in the basin involves a "vacuuming" operation, the strainer employed in the recovery/retrieval process limits the size of particle retrieved to less than ¼ inch in cross-section. All of the material collected and/or isolated by the strainers will be managed as debris or scrap as part of the spent fuel recovery process. Thus, no piece of uranium or cladding greater than ¼ inch is allowed in the sludge.

The sludge that is recovered from the K-East North Loadout Pit (NLOP) will be pumped into a "Large Diameter Container (LDC)", after passing through the strainer basket. The LDC is a container about 5 feet in diameter and 10 feet tall. It has a volumetric capacity of approximately 2 cubic meters of sludge. Once the LDC is loaded, it will be transferred to the T-Plant in the 200 Area by truck, using a specially designed "Sludge Transportation Trailer."

NLOP sludge is expected to be contact-handled TRU waste. The planned approach for preparing the NLOP sludge is to unload the sludge from the LDC and stabilize the waste in grout.

Other operations performed on the K-Basin NLOP sludge waste, include:

- Dewatering
- Assaying sludge containers
- Packaging stabilized sludge in drums with grout

It is expected that a majority of the K-Basin sludge waste will be RH in the final waste form. For those streams, all of the preparation and packaging activities will be conducted under an authorized and certified Remote-Handled TRU Waste Certification Program. Criteria required for such certification will be employed throughout the process of preparation and stabilization.

The basic process to be employed for preparing the balance of remote-handled (RH) sludge for WIPP includes partial dewatering, in the Cold Vacuum Drying Facility in the K-Basin complex, of the retrieved sludge. The sludge will be stabilized in 55-gallon drums with a grout suitable for immediate or delayed transportation as RH Transuranic waste to WIPP.

All of the activities associated with K-Basin sludge preparation for final disposition will be accomplished under the Hanford WIPP Certification program. All WIPP Waste Acceptance Criteria (WAC) and transportation protocols will be adhered to throughout the treatment and packaging operations. Waste will be packaged in NRC-certified waste containers. Waste will be visually examined to confirm the acceptability of the wastes while providing independent validation that wastes are compliant with the waste stream profile and meet the WIPP requirements.

WIPP compliant waste characterization will be performed by trained professional staff performing to WIPP approved procedures, on certified equipment, and in compliance with the WIPP WAC. All of the equipment, procedures, examinations, and certifications will meet the requirements set forth by the EPA at 40 CFR 194.8, 194.22 and 194.24, and implemented by the Department before these waste streams are shipped for disposal at WIPP.

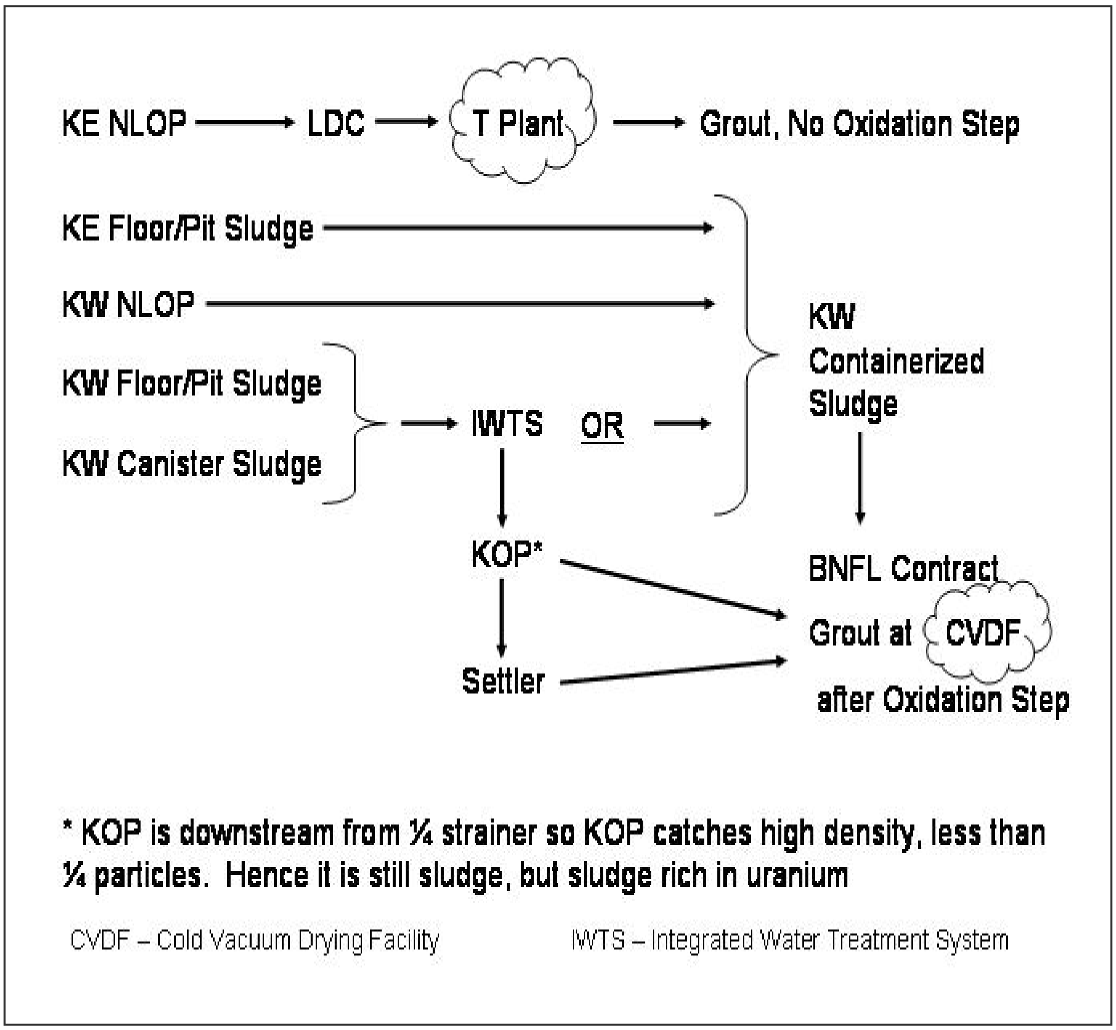

Figure 3. Schematic of K-Basin Sludge Processing

Conclusion

Clearly, the K-Basin sludge is not spent nuclear fuel. The sludge is predominantly nonradioactive material (sand, silt, debris, etc.), fission products and transuranic isotopes that accumulated over the course of decades of storage in the basins. About 30% of the radioactivity in curies in the sludge is derived from Pu-241, the parent for Am-241, a transuranic isotope. As a result, the K Basin sludge has been contaminated with radionuclides to a level that makes them transuranic waste.

In contrast, spent nuclear fuel is the product of irradiation from nuclear reactors. In the case of the N-Reactor fuel at Hanford, the SNF consists of fuel elements encased by Zircaloy-2 cladding. Over 95% of the radioactivity in curies in the N-Reactor fuel are fission products, with a small percentage of transuranic isotopes (approximately 4%).

Based on a comparison of the origin, and physical, chemical and radiological characteristics, the K-Basin sludge is not spent nuclear fuel and meets the definition of Transuranic waste as defined in the WIPP Land Withdrawal Act. The LWA states that, "The term Transuranic waste means waste containing more than 100 nanocuries of alpha-emitting Transuranic isotopes per gram of waste, with half-lives greater than 20 years…" (P.L. 102-579).

References:

1. 105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities, Volume 2, HNF-SD-SNF-TI-009, Rev. 4.
2. Spent Nuclear Fuel Project Databook, Volume 2, Sludge, HNF-SD-SNF-TI-015, Sludge Data Book, Rev 12, 2004.
3. SNF Sludge Stabilization and Packaging, Volume 1, BNFL.
4. K Basin Closure Project, "Sludge and Waste System Overview, North Load Out Pit Sludge Retrieval, 213061, Revision 0A.
5. U.S. Congress 1996. Public Law 102-579, Waste Isolation Pilot Plant Land Withdrawal Act, as amended by Public Law 104-201, 1996.

ATTACHMENT A

K-BASIN CHARACTERIZATION

The following tables present a summary of the measured characteristics of the K-Basin sludge. Three measurement campaigns provided data: September 1993; August and September 1995; and in FY 1999.

Samples used for the measurements were taken from the "as-settled" sludge (i.e., as the sludge sits in the basin). Details of the analyses of the measured properties are reported in HNF-SD-SNF-TI-009, Volume 2, Rev. 4.

The final table is a comparison of the characteristics of the K-Basin sludge with the N-Reactor fuel.

K-Basin Characterization
Radiological*

KE Basin
Table 1 of 2

Radionuclide	Floor Sludge µCi/g	Weasel Pit µCi/g	North Loadout Pit µCi/g	Tech View Pit µCi/g	Dummy Elevator µCi/g
Am-241	2.15E+01	8.65E+00	6.85E+00	1.12E+01	1.84E+00
Np-237	6.43E-03	1.83E-03	-	-	-
Pu-238	3.59E+00	1.77E+00	1.37E+00	2.12E+00	3.90E-01
Pu-239	1.45+01	7.12E+00	5.57E+00	8.96E+00	1.47E+00
Pu-240	7.96E+00	3.91E+00	3.06E+00	4.92E+00	8.06E+01
Pu-241	4.27E+02	2.10E+02	1.64E+02	2.64E+02	4.33E+01
Co-60	1.75E+00	1.33E+00	1.03E+00	9.35E-01	1.67E+00
Cs-137	4.42E+02	2.58E+02	3.53E+01	1.00E+02	3.96E+01
Cs-138	1.06E-01	1.47E-01	2.78E-02	-	-
Eu-152	1.92E-01	1.38E-01	-	-	-
Eu-154	3.36E+00	1.21E+00	1.42E+00	9.41E-01	1.46E-01
Eu-156	1.66E+00	5.57E-01	8.28E-01	3.89E-01	-
Sr-90	3.30E+02	2.05E+02	6.28E+00	8.66E+00	5.19E+00
Tc-99	-	-	-	-	

*Activity levels are as of 2000, so it can be expected that some isotopes will have decayed to other radionuclides, for example Pu-241 decays to Am-241.

K-Basin Characterization
Radiological*

KE Basin
Table 2 of 2

Radionuclide	Canisters µCi/g	Fuel Wash Coating µCi/g	Fuel Wash Internal µCi/g	Fuel Wash Slurry µCi/g	KE Basin Totals, Ci
Am-241	1.12E+02	5.77E+01	4.78E+02	1.69E+03	1.21E+03
Np-237	1.54E-02	-	-	2.48E-01	1.90E-01
Pu-238	2.31E+01	1.02E+01	6.80E+01	4.97E+02	2.47E+02
Pu-239	8.91+01	3.81E+01	2.87E+02	9.54E+02	8.27E+02
Pu-240	4.89E+01	2.24E+01	1.73E+02	5.24E+02	4.62E+02
Pu-241	2.63E+03	7.35E+02	5.92E+03	2.81E+04	2.31E+04
Co-60	9.44E-01	5.80E-01	7.76E-01	1.53E+01	4.50E+01
Cs-137	1.02E+03	8.71E+02	7.81E+03	5.38E+04	2.35E+04
Cs-138	2.48E-01	-	-	5.71E+01	1.25E+01
Eu-152	-	-	-	3.84E+00	4.29E+00
Eu-154	1.40E+01	5.54E+00	3.37E+01	4.36E+02	1.84E+02
Eu-156	7.91E+00	-	1.18E+01	9.21E+01	7.21E+01
Sr-90	1.82E+03	1.09E+03	8.74E+03	4.08E+04	2.23E+04
Tc-99	1.54E-01	-	-	1.19E+01	5.27E+01

*Activity levels are as of 2000, so it can be expected that some isotopes will have decayed to other radionuclides.

K-Basin Characterization
Radiological*

KW Basin
Table 1 of 2

Radionuclide	Floor Sludge µCi/g	Weasel Pit µCi/g	North Loadout Pit µCi/g	Tech View Pit µCi/g	Dummy Elevator µCi/g	Discharge Chute µCi/g
Am-241	1.22E+01	8.33E+00	2.72E+00	6.06E+00	1.39E+00	8.33+00
Np-237	3.67E-03	1.76E-03	-	-	-	1.76E-03
Pu-238	2.05E+00	1.70E+00	5.45E-01	1.15E+00	2.93E-01	1.70E+00
Pu-239	8.26E+00	6.85E+00	2.21E+00	4.85E+00	1.10E+00	6.85E+00
Pu-240	4.54E+00	3.76E+00	1.21E+00	2.66.E+00	6.06E-01	3.76E+00
Pu-241	2.44+02	2.02E+02	6.52E+01	1.43E+02	3.25E+01	2.02E+02
Co-60	9.98E-01	1.28E+00	4.09E-01	5.06E-01	1.26E+00	1.28E+00
Cs-137	2.52E+02	2.48E+02	1.40E+01	5.43E+01	2.98E+01	2.48E+02
Cs-138	6.03E-02	1.41E-01	1.11E-02	-	-	1.41E-01
Eu-152	1.09E-01	1.33E-01	-	-	-	1.33E-01
Eu-154	1.92E+00	1.18E+00	5.64E-01	5.09E-01	1.10E-01	1.16E+00
Eu-156	9.44E-01	5.36E-01	3.29E-01	2.11E-01	-	5.36E-01
Sr-90	1.88E+02	1.98E+02	2.49E+00	4.69E+00	3.90E+00	1.98E+02

*Activity levels are as of 2000, so it can be expected that some isotopes will have decayed to other radionuclides

K-Basin Characterization
Radiological*

KW Basin
Table 2 of 2

Radionuclide	Canisters µCi/g	Fuel Wash Coating µCi/g	Fuel Wash Internal µCi/g	Fuel Wash Slurry µCi/g	KW Basin Totals Ci
Am-241	2.62E+02	2.71E+00	3.36E+-2	1.67E+03	5.21E+02
Np-237	2.86E-02	-	-	2.67E-01	5.28E-02
Pu-238	5.52E+01	4.35E-01	4.69E+01	5.04E+02	1.14E+02
Pu-239	1.90E+02	1.57E+00	2.43E+02	9.97E+02	3.61E+02
Pu-240	1.04E+02	8.53E-01	1.28E+02	5.46E+02	1.96E+02
Pu-241	6.12E+03	3.56E+01	3.95E+03	3.22E+04	1.04E+04
Co-60	2.01E+01	1.39E+01	4.56E-01	2.07E+01	3.31E+01
Cs-137	3.78E+03	3.57E+01	5.01E+03	6.56E+04	1.08E+04
Cs-138	2.85E+00	-	6.80E-01	8.85E+01	1.01E+01
Eu-152	-	-	-	4.71E+00	4.67E-01
Eu-154	4.97E+01	4.53E-01	2.74E+01	5.37E+02	1.04E+02
Eu-156	2.23E+01	2.45E-01	8.19E+00	1.07E+02	3.55E+01
Sr-90	6.17E+03	5.74E+01	4.80E+03	5.11E+04	1.19E+04
Tc-99	2.11E+00	-	-	1.41E+01	3.22E+00

Units: Micro-curies per cubic centimeter sludge, except for Totals, which is in Curies
*Activity levels are as of 2000, so it can be expected that some isotopes will have decayed to other radionuclides

K-Basin Sludge Characterization
Chemical Composition*

KE Basin

Measured Compound	Floor Sludge g/cm^3	Weasel Pit g/cm^3	North Loadout g/cm^3	Tech View Pit g/cm^3	Dummy Elevator g/cm^3
Ag_2O	1.65E-05	-	-	-	-
Al_2O_3	8.51E-02	6.35E-02	1.42E-02	3.54E-02	6.37E-02
B_2O3	4.05E-04	4.49E-04	-	-	-
BaO	1.65E-04	3.56E-04	9.68E-05	-	9.56E-05
BeO	8.44-05	4.49E-05	1.62E-05	3.70E-05	1.05E-05
CaO	5.05E-03	1.73E-02	4.04E-03	1.80E-03	3.67E-03
CdO	9.47E-05	4.83E-05	5.31E-05	7.09E-05	6.06E-05
Cr_2O_3	5.14E-04	1.44E-03	1.53E-04	8.50E-04	6.432-04
CuO	4.48E-04	7.93E-04	2.56E-04	5.49E-04	4.19E-04
FeO (OH)	2.29E-01	4.52E-01	3.96E-02	3.14E-01	2.79E-01
K_2O	1.83E-03	1.74E-03	-	-	-
MgO	1.83E-03	2.93E-03	6.47E-04	1.32E-03	5.45E-03
Mn0	4.28E-04	6.02E-04	3.30E-04	5.25E-04	1.12E-03
Na_2O	2.77E-03	1.07E-03	-	-	-
NiO	7.15E-05	1.68E-04	-	1.28E-04	2.31E-04
PbO	2.79E-04	5.50E-04	1.05E-04	6.29E-04	8.48E-04
Ti_2O_3	-	-	1.13E-04	-	-
U (total)	6.28E-02	6.63E-02	1.57E-02	3.92E-02	2.18E-02
ZnO	6.96E-04	1.87E-03	2.71E-04	1.62E-03	2.30E-03
ZrO_2	2.89E-04	5.59E-04	2.27E-05	1.47E-04	3.85E-05
Residual Solids	1.05E-01	2.61E-01	8.36E-02	-	-

*Units are grams per cubic centimeter of as-settled sludge.

K-Basin Sludge Characterization

Chemical Composition*

KW Basin**

Measured Compound	Floor Sludge g/cm^3	Weasel Pit g/cm^3	North Loadout g/cm^3	Tech View Pit g/cm^3	Dummy Elevator g/cm^3	Discharge Chute g/cm^3
Ag_2O	1.66E-05	-	-	-	-	-
Al_2O_3	8.51E-02	6.35E-02	1.42E-02	3.54E-02	8.37E+02	6.35E-02
BaO	1.65E-04	3.56-E-04	9.68E-05	-	9.56E-05	3.56E-04
CaO	5.05E-03	1.73E-02	4.04E-03	1.80E-03	3.67E-03	1.73E-02
CdO	9.47E-05	4.83E-05	5.31E-05	7.09E-05	8.06E-05	4.83E-05
Cr_2O_3	5.14E-04	1.44E-03	1.53E-04	8.50E-04	6.42E-04	1.44E-03
FeO(OH)	2.29E-01	4.52E-01	3.98E-02	3.14E-01	2.79E-01	4.52E-01
PbO	2.79E-04	5.50E-04	1.05E-04	6.29E-04	8.48E-04	5.50E-04
U (total)	6.28E-02	6.63E-02	1.57E-02	3.92E-02	2.20E-02	6.63E-02
Residual Solids	1.05E-01	2.61E-01	8.36E-02	-	-	2.61E-01

*Units are grams per cubic centimeter of as-settled sludge.
** Consistent with recommendations in 1*05-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities*, Volume 2, Sludge (HNF-SD-SNF-TI-009, Volume 2, Rev. 4), the values for KW Floor and Pit sludges are based on KE Floor and Pit sludge analyses.

K-Basin Sludge Characterization
Physical Properties

(Values are for as-settled sludge)

KE Basin

Parameter	Unit	Basin Floor	Weasel Pit	North Loadout	Tech View Pit	Dummy Elevator
Volume	(m^3)	21.5	10.1	6.3	0.4	1.4
Mass	(Mg)	27.3	15.6	7.98	0.5	1.86
Density	(g/m^3)	1.27	1.54	1.27	1.25	1.33
Water Fraction	(Vol %)	70	58	87	71	58

KW Basin*

Parameter	Unit	Basin Floor	Weasel Pit	North Loadout	Tech View	Dummy Elevator
Volume	(m3)	0.8	0.3	3.8	0.07	0.04
Mass	(Mg)	1.04	0.04	4.6	0.08	0.05
Density	(g/m^3)	1.27	1.54	1.27	1.25	1.33
Water Fraction	(Vol %)	70	58	87	71	58

* Consistent with recommendations in 105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities, Volume 2, Sludge (HNF-SD-SNF-TI-009, Volume 2, Rev. 4), the values for KW Floor and Pit sludges are based on KE Floor and Pit sludge analyses.

Table 2
Comparison of N-Reactor Fuel to K-Basin Sludge Stream Characteristics*

Parameter/Property	N-Reactor Fuel	KE/KW Floor-Pit Sludge	KE/KW NLOP Sludge	Settler Tank Sludge	KE Canister Sludge	Knock-Out Pot Sludge	Containerized Sludge
Physical Properties							
Volume, m^3	134	34.8	9.9	2.8	2.5	0.4	37.3
Wet Density, g/m^3	16.5	1.4	1.4	3	1.9	10.5	1.4
Chemical Properties							
Uranium Total, g/cm^3	15.6	0.06	0.0084	1.9	0.77	9.4	0.11
Uranium Metal, g/cm^3	15.6	0.004	0.00008	0.083	0.04	9.4	0.0064
Radiochemistry							
Decay Power, W/m^3	1140	3.12	0.26	87.2	21.7	690	4.37
TRU Content, nCi/g	3.67E+05	1.93E+04	4.04E+03	2.04E+05	1.44E+05	3.54E+05	2.77E+04
FGE/liter	148	0.53	0.086	14	6.4	89	0.923
Specific Isotopes							
Am-241**	2.77E+03	1.22E+01	2.42E+00	2.62E+02	1.12E+02	1.67E+03	1.89E+01
Pu-238**	8.36E+02	2.05E+00	3.84E-01	5.52E+01	2.31E-01	5.04E+02	3.46E+00
Cs-137**	1.09E+05	2.52E+02	9.75E+00	3.78E+03	1.02E+03	6.56E+04	3.03E+02

* This data is from 2000 (HNF-SD-SNF-TI-015, Rev. 12, Volume 2) and has not been corrected for decay.
**Units of isotopes are micro-curies per ml.