Downgrade of the Effluent Treatment Facility (ETF) at the Savannah River Site from a Hazard Category Three to a Radiological Facility

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ABSTRACT

The Effluent Treatment Facility (ETF) at the Savannah River Site near Aiken, SC processes low-level radioactive and chemically contaminated wastewater from nuclear material processing and Tank Farm operations. During fiscal year 1999, ETF treated 18 million gallons of wastewater through a series of process steps involving filtration, organic removal, reverse osmosis, ion exchange and evaporation. Recently, efforts were undertaken to downgrade the ETF from a Hazard Category 3 Nuclear Facility to a Radiological Facility.

Since initiating operations in 1988, ETF has operated under the High Level Waste Tank Farm Authorization Basis as a Low Chemical Hazard/Category 3 facility. When the ETF operating management organization changed due to an M & O contractor reorganization in 1997 the facility was analyzed, as a stand-alone facility, for hazard classification purposes. Detailed studies concluded that ETF was more appropriately classified as a Radiological Facility requiring an Auditable Safety Analysis (ASA). The facility began implementation of the ASA in December 1999. This paper reviews the process that was taken to determine the hazard classification and the DOE's role in the development of the downgrade effort. Specific areas addressed include facility segmentation, analysis of expected waste streams, assumptions used to simplify inventory control, and radionuclide retention. It is hoped that this paper will assist others who are evaluating or in the process of downgrading facility hazard categorization consistent with actual or planned facility hazards.

BACKGROUND

The Effluent Treatment Facility (ETF) on the Savannah River Site collects and treats low level radioactive and chemically contaminated process wastewater and storm water. Facilities ETF supports include the F/H Canyon facilities, F/H High Level Waste Tank Farms, F/H High Level Waste Evaporators, the Consolidated Incineration Facility (CIF), and environmental restoration. During Fiscal Year 1999, ETF treated approximately 18 millions gallons of wastewater - 99% of which was released back into the environment. The remaining 1% was sent to the H-Area High Level Waste Tank Farm for eventual disposal in the Saltstone Facility.

ETF began operations in 1988 as part of the High Level Waste Tank Farm. ETF's operations were described and analyzed as part of the Tank Farm Design Basis Accident Analysis and Basis for Interim Operations (BIO). ETF was characterized as a Low Hazard/Category 3 facility. In 1997, the management organization changed due to M & O contractor reorganization (ETF went from the High Level Waste Division to the Solid Waste Division). This made it desirable to separate ETF from the HLW Tank Farms Authorization Basis and analyzed it as a stand-alone facility for the first time. This analysis supported the classification of ETF as a Radiological Facility requiring an Auditable Safety Analysis (DOE Standard 5502). A number of challenges were faced in supporting this classification and ensuring that ETF would remain a Radiological Facility.

FACILITY OPERATIONS

ETF is composed of two Cooling Water Basins (2 million gallons each), Two Retention Basins (6 million gallons each), and a processing facility. The facility spans approximately two miles from the F-Area Basins to the main processing facility. Incoming waste feed is collected in one of two 450,000 gallon Waste Water Collection Tanks where the pH is adjusted to maintain metals in suspension. By the use of pH adjustment tanks, the pH is again adjusted and a flocculent is added prior to processing through the filtration system to precipitate suspended solids. The filtrate continues to the Organic Removal (OR) system which is composed of Mercury Removal Columns and a set of Carbon Columns for the removal of organics and heavy metals. The filtrate continues to the Reverse Osmosis (RO) system. The RO system removes dissolved solids such as salts and radionuclides from the waste stream by use of semipermeable membranes that pass water and trap dissolved solids. After passing through three RO trains, the waste water passes on to the Ion Exchange (IE) system. The IE system removes any residual heavy metals, cesium, and strontium in the wastewater before release to the environment. This is accomplished through the use of Mercury Removal columns and two Cation columns. The treated water is then sent to one of three Treated Water Storage Tanks. Here the water is sampled to verify that it meets release criteria. If the water can not be released to the environment it is reprocessed. During two steps of the ETF process contaminate streams are separated from the wastewater. These are through Filtration and Reverse Osmosis. These streams are collected in the ETF Evaporator Feed Tank for eventual concentration. Additional smaller waste streams are fed directly to the Evaporator Feed Tank. These are incinerator blowdown and environmental restoration purge water. The ETF Evaporator overheads are fed back into the process system. Evaporator concentrate is collected and sent to a HLW tank for eventual disposal at the Saltstone facility. A block diagram of the ETF process is shown in Figure 1.

SEGMENTATION

When the downgrade plan was first presented to the Department of Energy (DOE), ETF was broken into sixteen segments. However, this breakdown was not in agreement with DOE Standard 1027 for independent segments. For example, the lift stations were considered separate from the forced main line that was separate from the Waste Water Collection Tanks. The main processing facility was also broken down into segments for the treatment process, control building, and laboratory. The segmentation was based on the original Hazards Assessment Document that pre-dated DOE Standard 1027. A great deal of effort was spent on both the DOE and contractor side reaching an agreement on the intent of the DOE Standard. A consolidation of the main process building and functions reduced the number of segments to nine (see Figure 2). Finally, a combination of the lift stations and Forced Main line with the Waste Water Collection Tanks reduced the segmentation to six (see Figure 3). Segment seven was added later to account for inventory associated with spent carbon columns and job control waste. Key to the determination of segment boundaries was the physical separation between process components since piping connects each of the segments. The lack of a hazardous interaction or energy source was also relied upon to justify segmentation.

The significance of reducing the number of facility segments is reflected in the inventory control program and procedures. The complexity of the inventory control program will be reduced and less tedious to perform. Even though the entire facility must be accounted for, regardless of segmentation, seven segments instead of sixteen are being individually tracked. Administrative costs associated with procedure development and revision are also expected to be reduced from sixteen segments.

RADIOLOGICAL FACILITY DETERMINATION

With the facility segments established, the next step was to determine the maximum possible radiological inventory in each segment. The inventory is then compared and verified to be below Hazard Category Three threshold quantities of DOE Standard 1027. While performing this analysis, the inventories in these segments were related to ETF's Waste Acceptance Criteria (WAC). The basins, process vessels, and piping were assumed to be full at the WAC limit. Multiplication factors were used for the inventory in process vessels where concentration occurs (e.g. evaporator feed tank, waste concentrate tank) or where the build-up of material is possible (e.g. the basins). Factional factors of the WAC were used for treated waste streams (e.g. Treated Water Tanks) to recognize the removal of contaminates. The evaluation concluded that ETF was a Radiological Facility. The calculation was simplified by using gross alpha and gross beta/gamma counts (excluding Cs-137 and Tritium that were tracked individually) and assuming the most limiting radionuclides. These were determined to be Am-241 for alpha and Ru-106 for beta/gamma.

ETF Process

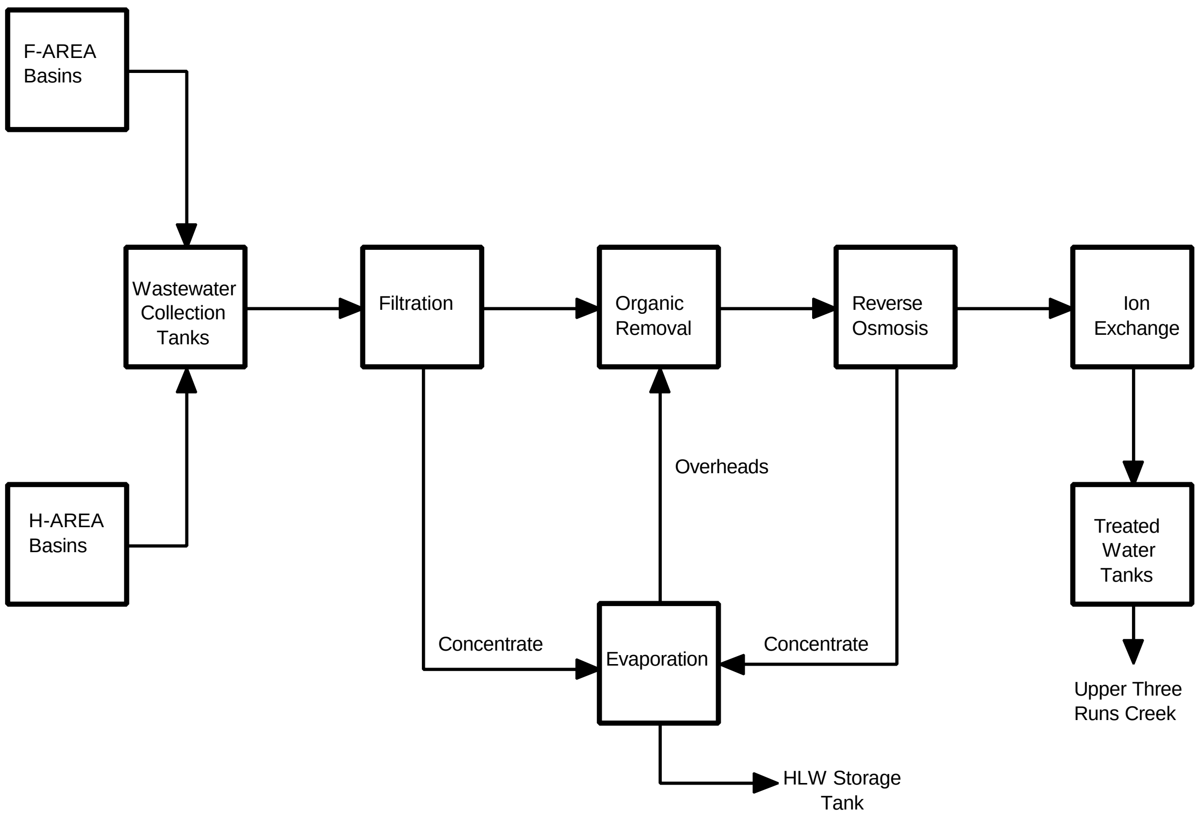

Figure 1

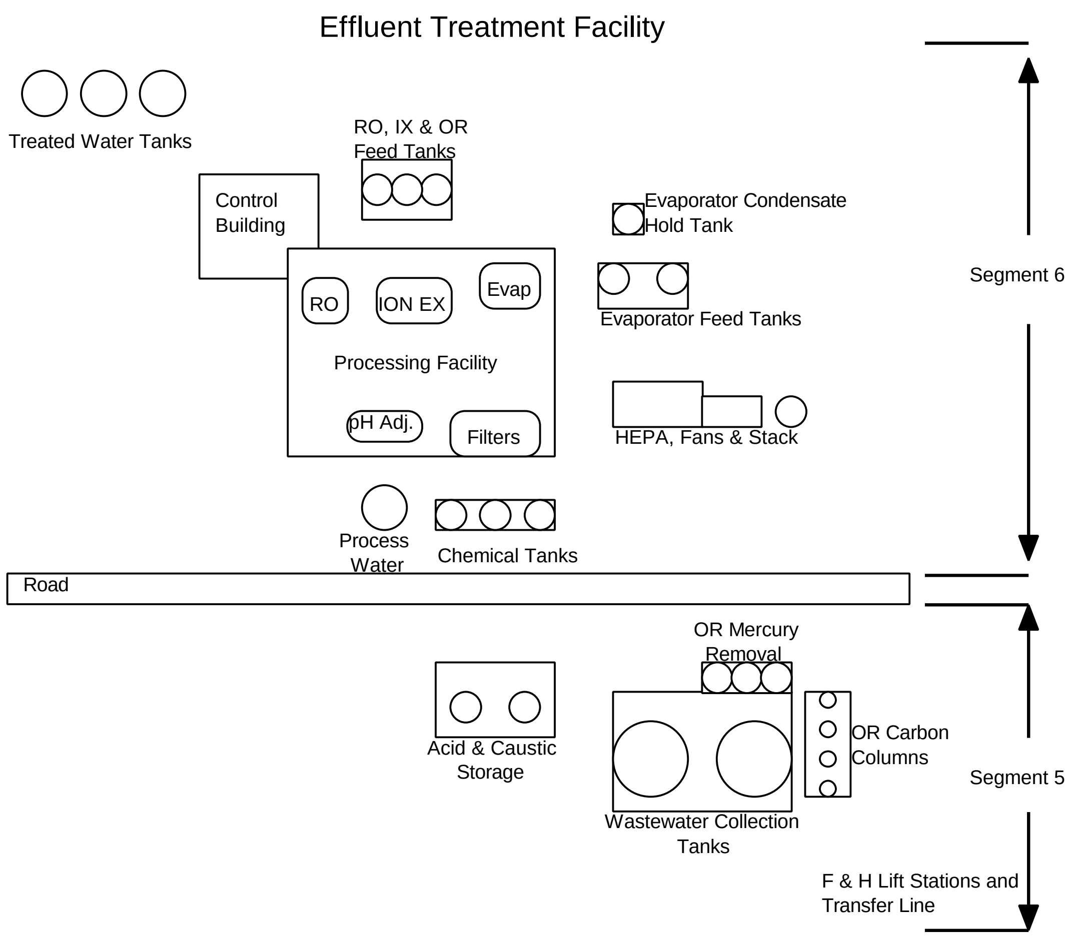
Effluent Treatment Facility
Treated Water Tanks
RO, IX & OR Feed Tanks
Control Building
Evaporator Condensate Hold Tank
RO
ION EX
Evap
Evaporator Feed Tanks
Segment 6
Processing Facility
pH Adj.
Filters
HEPA, Fans & Stack
Process Water
Chemical Tanks
Road
OR Mercury Removal
Acid & Caustic Storage
OR Carbon Columns
Segment 5
Wastewater Collection Tanks
F & H Lift Stations and Transfer Line

Figure 2

Facility Segments

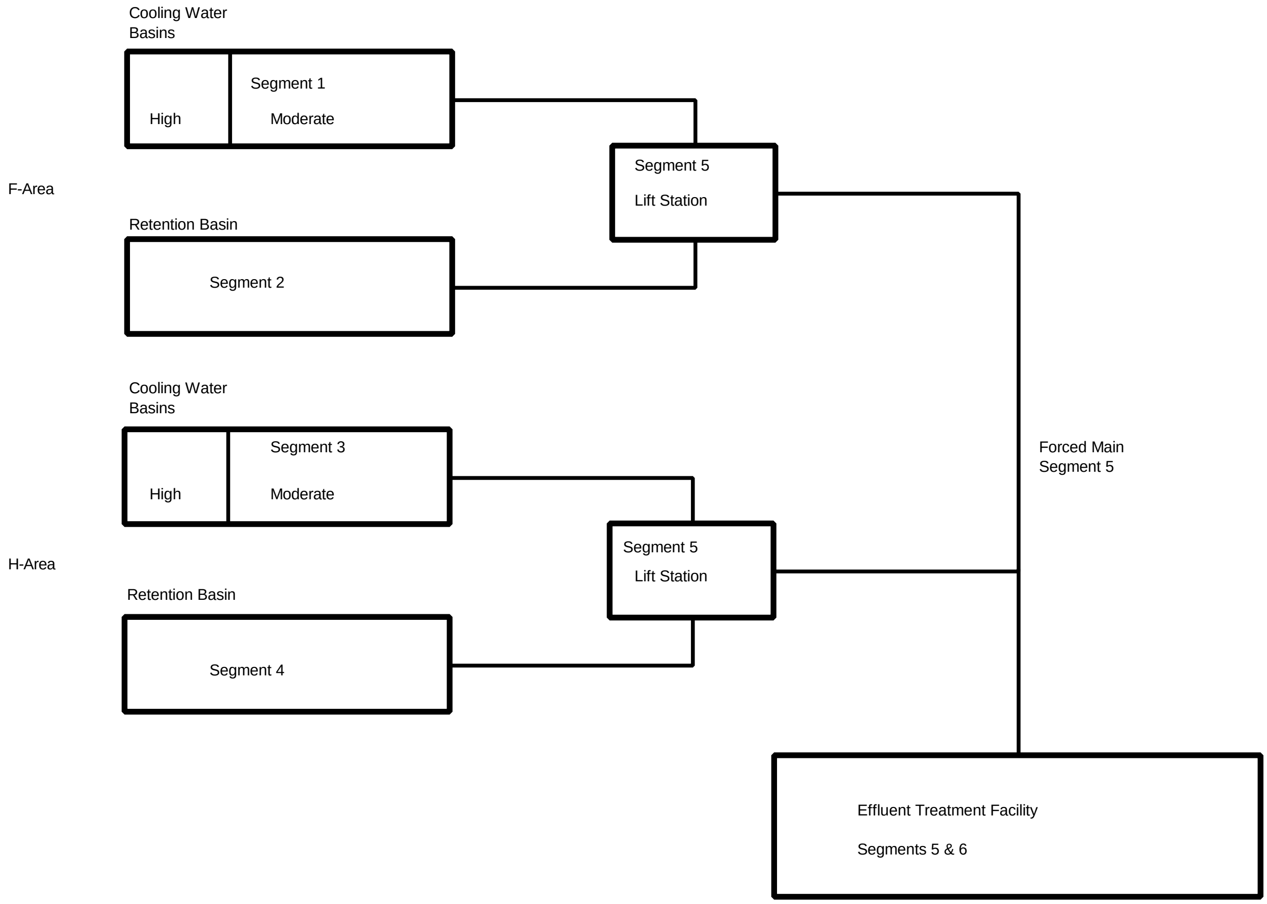

Figure 3

DOE pursued several issues relative to this evaluation. 1) Was there a defendable bases for the selected limiting radionuclides, 2) How would segment inventory be tracked and maintained below category three limits, 3) How is the initial or baseline inventory for inventory tracking determined.

Upon probing into the basis for the selected limiting isotopes (Am-241, Ru-106) it was determined that these results were based on historical OR carbon column data. These columns are sampled for characterization purposes prior to disposal. It was thought that since this is one of the first places radionuclides would be captured, it would bound the facility. DOE challenged this assumption and investigated waste characterization of incoming waste streams, historical sample data from the basins, and characterization of other ETF hold-up locations. These studies determined that Sr-90 would be a more realistic and defendable beta-gamma limiting radionuclide. DOE's evaluation of the data supported the selection of Am-241 to bound the alpha activity.

Due to the low inventory allowed for Sr-90, (16 curies) it was necessary to examine further the beta-gamma activity. The Sr-90 was shown to be at a ratio slightly higher than 25% of the Cs-137. It was further determined that Cs-137 is bounded at 50% of the gross beta-gamma activity. For simplification purposes, a composite beta-gamma radionuclide was created composed of 50% Cs-137 and 50% Sr-90. Utilizing the category three limits from 1027, gross beta gamma activity in each segment at ETF will be limited to:

0.5 Beta-Gamma/60 + 0.5Beta-Gamma/16** = 1* [Equation 1]
Beta-Gamma = 38 curies

* - DOE Standard 1027 limit for Cs-137 in curies
** - DOE Standard 1027 limit for Sr-90 in curies

By selecting bounding radionuclides, gross (alpha and beta-gamma) counts may be used when performing the sum of fractions, simplifying the analyses and inventory control calculation. Tritium, which is analyzed separately, was found to pass through the facility without hold-up. The amount of Tritium in the facility will be a constant based on process vessels and piping full at 25% of the ETF WAC limit. The resulting sum of fractions equation for inventory control purposes becomes:

Total Sum of Fraction = Tritium/16000Ci + Alpha/0.52Ci +Beta-Gamma/38Ci [Equation 2]

Each ETF segment will be maintained below a sum of fractions of 1.0 to ensure that the inventory does not exceed category three thresholds.

WASTE TRACKING – PROCESSING FACILITY

For Segments 5 and 6, the radionuclide inventory will be tracked to maintain a running sum of fractions. By tracking radionuclide inventory entering and leaving the segments, the radionuclide inventory retained and therefore, the sum of fractions, can be determined. Before a new batch of wastewater is processed, samples are drawn from the Wastewater Collection Tanks (Segment 5) and analyzed to determine the radiological inventory of the incoming waste stream. This inventory is then added to Segment 5 as well as Segment 6 since there is no hold-up mechanism between the two segments. Additional inventory is added to Segment 6 for waste streams added directly to the Evaporator Feed Tank. This inventory, added downstream of the WWCT, will not be introduced to Segment 5 and will not be counted in the Segment 5 inventory (inventory from evaporator overheads was determined to be insignificant). Prior to transfer to H Tank Farm tank 50, samples are taken at the Waste Concentrate Tanks (Segment 6) to determine the radiological inventory of the waste leaving the facility. This inventory is debited from Segment 6 only since there is no means to determine what fraction came from Segment 5. Similarly, the radiological characteristics of the carbon columns or ion exchange resin are determined and debited from the appropriate segment when they are replaced. The total inventory is compared to and maintained below the category 3 quantities of DOE Standard 1027 by determining the sum of fractions. The sum of fractions calculation is performed once a month for Segment 5 & 6 by use of facility procedures. Over time, the amount of retained inventory may build to the point that a facility clean out may be required to continue processing (inventory approaching 0.90). The clean out removes held-up radionuclides from various process vessels and piping. It is expected that normal plant change out of various process column material will help reduce segment inventory and eliminate or prolong the time between clean outs. Analysis by the contractor projected that facility clean outs would be needed every 10 – 12 years using some assumptions that were not necessarily conservative. DOE performed an independent calculation that only included the effects of influent streams without credit for debiting effluent streams. The calculation showed there was greater than 9 years until a clean out would be required. This will not be an operational limitation since normal facility operations requires more frequent clean outs to maintain filtration efficiency and limit sludge build up in process vessels. (Note: The projection of time between clean outs was based on waste feeds before the processing of incinerator blowdown which has higher alpha activity than that initially analyzed and could lead to more frequent clean outs.)

WASTE TRACKING – BASINS

Where Segments 5 & 6 inventories are tracked on a monthly basis, Segments 1-4 are tracked on an annual basis. Sampling data and waste characterization has shown that that the category three threshold limits for the basin segments (1-4) will not be challenged. Calculations were performed at multiples of the WAC limits for alpha, beta, and gamma activity to show that the threshold limits would not be exceeded for these segments. Multiples were used to account for sludge buildup and possible radionuclide concentration in the basins while allowing for increases in the WAC limits. To verify that the sludge was bounded by these multiplication factors, DOE requested that historical sample data be reviewed. Sludge samples from basin clean-outs and routine liquid samples were collected and analyzed to show that the basin segments remained below the hazard category three threshold. Historical sludge accumulation rates were such that up to fifty years would be required to approach the category three threshold for any basin filled to the WAC limit. The basins' inventory control procedure assumes that the basins are full at their environmental discharge limit (3 d/m/ml alpha, 10 d/m/ml beta-gamma, and 2500 d/m/ml Tritium). Annually, samples will be drawn of the sludge and the volume of sludge estimated. These samples will be analyzed and along with the estimated volume, a sum of fractions inventory will be recorded. During the course of the year, if a routine sample shows higher activity than the discharge limit, an engineering evaluation would be performed to ensure that the category three thresholds had not been exceeded.

INITIAL INVENTORY

The next step in the process was to determine the initial inventory held in the facility as a baseline starting point. All basins (segments 1-4) were assumed to be full at the environmental discharge limit of 3 d/m/ml alpha, 10 d/m/ml beta-gamma, and 2500 d/m/ml Tritium. DOE additionally requested that basin sediment be accounted for in the initial inventory. A number of the basins had been cleaned over the years with sediment sampled for characterization purposes. Historical sample results, with the highest activities, were used to characterize the sediment for each retention basin and cooling water basin. Based on the time between cleanings, a monthly sediment accumulation rate was determined. Analysis showed that several decades would be required before the sum of fractions in any basin would approach 1.0. As a requirement of the downgrade, basin sediment will be sampled once a year in validate assumed characterization.

Similarly, for Segment 5 the liquid activity is assumed to be full at 100% of the WAC limit (100 d/m/ml alpha and 2500 d/m/ml beta-gamma) for the lift stations and forced main and 25% of the WAC limits for the Waste Water Collection Tanks (WWCT). Tritium is assumed to be at 250,000 d/m/ml for all of Segment 5. Initially, all of Segment 5 was full at the WAC limit; however, after considering the clean out frequency, the WWCT was reduced to 25% to be more in line with historical sample results. Should a routine sample result in activity higher than that assumed, an engineering evaluation would need to be performed before processing could continue.

Finally, Segment 6, which receives waste from Segment 5 must assume the same 25% WAC limit inventory with the following exceptions. The evaporator feed tanks and associated piping and Reverse Osmosis housings are concentrated at 10 times the 25% WAC limits. The evaporator, waste concentrate and associated piping are at 175 times the 25% WAC limits. The Ion Exchange Columns, Treated Water Tanks and associated piping are at 0.01 times the 25% WAC limits due to decontamination. Tritium is assumed to pass straight through the facility at 250,000 d/m/ml. Radionuclide retention on process columns was estimated based on historical sample results and accumulation rates.

Using the sum of fractions, Equation (2), the initial inventory fractions for ETF are as follows:

ETF Segment	Sum of Fraction
Segment 1 (F-Cooling Water Basin)	5.28E-02
Segment 2 (F-Retention Basin)	1.17E-01
Segment 3 (H-Cooling Water Basin)	2.86E-02
Segment 4 (H-Retention Basin)	8.44E-02
Segment 5 (WWCT and OR Columns)	3.05E-01
Segment 6 (Main Processing Building)	2.36E-01

Table 1

IMPLEMENTATION

Operations under the requirements of the inventory control program began in June of 1999 after DOE Site Manager concurrence of the downgrade concept. ETF was still governed by the Authorization Basis documentation (Basis for Interim Operations and Design Basis Accident Analysis) at this time. However, to demonstrate the facility's ability to operate under the ASA, dual safety documentation was implemented. The authorization basis would be replaced by the ASA, after the successful completion of a DOE validation assessment. Over the next several months, ETF worked out issues with ASA implementation. Mismatches were identified between the ASA, implementing procedures, and supporting calculations. After the performance of a self-assessment and a complete review of all ASA requirements by the facility, the ASA was declared implemented in December 1999. DOE completed a validation assessment in January 2000 with several comments. Most significant among these was the need to complete process vessel inspections for material build-up. These comments were resolved and the ASA was fully implemented on March 1, 2000.

IMPACT to the FACILITY

As a result of the downgrade effort, one time cost savings of $650,000 was estimated for development of an ASA over the cost of a Safety Analysis Report (SAR). An additional $60,000 per year savings was estimated for ASA maintenance over the cost of SAR maintenance. This is due to the less complex nature of the ASA documentation. Facility engineering training requirements will also be reduced over that required for a SAR. Unreviewed safety question evaluation training and certification will not be required under an ASA.

Costs associated with the inventory control program are minimal. The inventory control program would have been in place regardless of the hazard category. Even though the limits for a radiological facility will require closer tracking, no significant cost over what would be in place for a SAR are expected. No additional sampling costs are expected. Before ASA implementation, normal facility operations already required the samples and analysis that will be needed to put an inventory control program in place. Some additional costs may be realized in the area of process vessel inspection (required every ten years to confirm no material build-up); however, the benefits gained from these inspections outweigh the cost. From earlier analysis, it is evident that the downgrade will not impact the facility's WAC and therefore will not impact currently supported waste generators.

The resulting safety basis documentation provides ETF with better defined and improved operating philosophy over that previously existing in the Tank Farm authorization basis. The facility is more appropriately classified as a Radiological Facility through the analysis of facility radiological inventory. The facility now has an inventory control program established to track facility inventory where none existed before. Instead of being the small part of a large facility (HLW Tank Farms), ETF now has its own safety documentation with more operational detail.

The following table and diagram shows the Segment 5 and 6 inventory for ETF since initiating inventory control on June 1, 1999.

ETF Inventory

	Segment 5				Segment 6			
Thru	Alpha	Beta-Gamma	I-129	Sum of Fractions	Alpha	Beta-Gamma	I-129	Sum of Fractions
	Curies				Curies			
6/1/99	7.89E-02	1.76	4.60E-03	0.305	8.63E-02	2.1	1.20E-05	0.236
7/1/99	8.11E-02	1.87	4.95E-03	0.318	1.42E-01	2.22	1.22E-05	0.347
8/1/99	8.43E-02	2.02	5.30E-03	0.334	1.64E-01	2.34	1.24E-05	0.391
9/1/99	9.06E-02	2.23	5.65E-03	0.358	2.25E-01	2.54	1.26E-05	0.515
10/1/99	9.29E-02	2.33	6.00E-03	0.37	0.00E+00	2.5	1.28E-05	0.081
11/1/99	9.53E-02	2.45	6.35E-03	0.384	0.00E+00	2.49	1.30E-05	0.081
12/1/99	9.64E-02	2.46	6.70E-03	0.392	9.34E-02	2.55	1.19E-06	0.262
1/1/00	9.79E-02	2.47	7.05E-03	0.401	7.35E-02	2.51	1.38E-06	0.222
2/1/00	1.00E-01	2.48	7.40E-03	0.411	0	2.51	1.57E-06	0.0809
3/1/00	1.02E-01	2.54	8.44E-03	0.435	0	2.55	1.76E-06	0.082
4/1/00								
5/1/00								
6/1/00								
7/1/00								
8/1/00								
9/1/00								
10/1/00								

Table 2

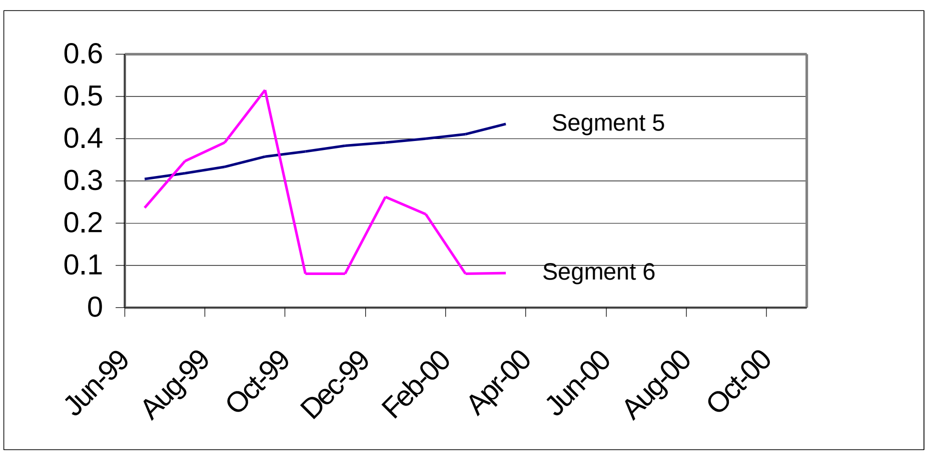

Figure 4