Calculation Cover Sheet
STPNOC - South Texas Project

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Calculation No.: 2008-09731 **Revision:** 1

Title: Cost Benefit Analysis for the Liquid and Gaseous Radwaste Systems

Unit No: 3 ☐ 4 ☐ 3 & 4 ☒	**Nuclear Safety Classification:**
System Code:	☐ **Safety-Related**
Equipment No:	☒ **Non-Safety Related**
Project No.: 12188-043	
Status: Draft	

Does this Calculation contain Unverified Inputs or Assumptions? **Yes** ☒ **No** ☐ **Action Tracking #** 4

This Calculation Supersedes:

Description of Revision (list affected pages for partials): Add Cost-Benefit analysis for the Gaseous Radwaste System (1, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21)

	Print Name	Sign Name	Date
Preparer:	Robert A. Nelson	[signature]	06/24/008
Preparer:			

Method of Review: **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer:	Anthony G. Klazura	[signature]	06/24/2008
Reviewer:			
Approver:	W. J. Johnson	[signature]	6/24/2008

STP Units 3 & 4
Project No(s): 12188-043

Sargent & Lundy LLC

Calculation No:2008-09731
Revision: 1

CERTIFICATION OF CALCULATION
FOR
STP UNITS 3 & 4

I hereby certify that this Calculation was prepared by me or under my supervision and that I am a registered professional engineer under the laws of the State of Texas.

Sargent & Lundy, LLC Texas Board of Professional Engineers registration number is F-2202.

Imprint PE SEAL(s) here
Signature & Date each seal

SEAL(s)

Revision:	Certified By:	Date

STP Units 3 & 4

Sargent & Lundy LLC

Calculation No: 2008-09731
Project No(s): 12188-043
Revision: 1

CALCULATION
ISSUE SUMMARY

Rev.	Purpose of Issue	Sections Affected
0	Initial Issue	All
1	Add Cost-Benefit Analysis for Gaseous Radwaste System	Title, 1.1, 1.2, 3.5, 3.11, 3.12, 3.13, 4.1, 4.2, 5.1, 5.1.1, 5.1.2, 5.2, 6.0, 7.0 and Attachment B

Rev.	Approved Date	Prepared By	Reviewed By	Approved By
0	05/21/2008	Barry C. Schwartz	Anthony G. Klazura	W. J. Johnson
1		Robert A. Nelson	Anthony G. Klazura	

Table of Contents

1.0 Purpose and Scope

1.1 Purpose

The purpose of this calculation is to provide a cost benefit analysis for providing (1) a number of augments to the Liquid Radwaste System and (2) one augment to the Gaseous Radwaste System currently described in the Construction and Operating License Application in order to meet the requirements of 10 CFR 50 Appendix I.

The objective of this calculation is to provide a basis for the cost benefit conclusion utilizing the process design diagram in Section 11.2 of the South Texas Project (STP) 3 & 4 FSAR [Reference 7.1], the Collective Total Body 50 Mile Population Doses in Section 5.4 of the STP 3 & 4 Environmental Report [Reference 7.2] and the methodology described in USNRC Regulatory Guide 1.110 [Reference 7.3].

1.2 Scope

This calculation is applicable to South Texas Project Units 3 and 4.

The Collective Total Body 50 Mile Population Doses are calculated on a per-station basis.

This analysis is limited to providing a cost benefit analysis for augments to the STP 3 & 4 Liquid and Gaseous Radwaste Systems. The block flow diagram of the STP 3 & 4 Liquid Radwaste System is provided in Attachment A. The block flow diagram of the STP 3 & 4 Gaseous Radwaste System is provided in Attachment B to this calculation. The process flow diagram for the STP 3 & 4 Liquid Radwaste System is provided in Figure 11.2-1 and the process flow diagram for the STP 3 & 4 Gaseous Radwaste System is provided in Figure 11.3-1 of the ABWR DCD [Reference 7.5]

2.0 Design Input

The specific input used for this calculation is summarized in this section.

A list of acronyms used in this calculation follows.

Acronyms

AFC - Annual Fixed Cost
ALC - Adjusted Labor Cost
AMC - Annual Maintenance Cost
AOC - Annual Operating Cost
CRF - Capital Recovery Factor
DCEM- Direct Cost of Equipment and Maintenance
DLC- Direct Labor Cost
GWMS - Gaseous Waste Management System
HCW – High Conductivity Waste
HSD – Hot Shower Drains
ICF- Indirect Cost Factor
LCCF- Labor Cost Correction Factor
LCW – Low Conductivity Waste
LWMS - Liquid Waste Management System
STP – South Texas Project
TAC- Total Annual Cost
TCC- Total Capital Cost
TDC- Total Direct Cost

2.1 The Collective Total Body Doses within a 50 Miles radius are taken from Table 5.4-9 of the STP 3 & 4 Environmental Report [Reference 7.2] **(UNVERIFIED)**

Table 2-1 The Collective Total Body Doses within 50 Miles (person-rem per year)

	STP 3 & 4		STP 1 & 2	
	Liquid	Gaseous	Liquid	Gaseous
Noble gases	0	0.11	0	0.0018
Iodines and particulates	0.0030	0.14	0.00076	0.00043
Tritium and C-14	0.0000056	0.32	0.00068	0.017
Total	0.0030	0.58	0.0014	0.019
Natural background (1)	1.85E5		1.85E5	

Notes:
(1) The natural background dose is based on a dose rate of 360 mrem/person/yr and an estimated 2060 population of 514,003.

2.2 Codes and Standards for Design of Radwaste System Components

USNRC Regulatory Guide 1.110, “Cost Benefit Analysis For Radwaste Systems For Light-Water-Cooled Nuclear Power Reactors”, March 1976 (For Comment)

USNRC NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants”

3.0 Assumptions

3.1 Differences between total values reported in tables of this analysis and total values obtained by summing the values presented in the table are due to round off.

3.2 It is assumed that the Liquid Radwaste System (i.e., the Liquid Radwaste System components) described in Section 11.2 of the STP FSAR [Reference 7.1] and the process block diagram shown in Attachment A and the process flow diagram shown in FSAR Figure 11.2-1 are representative of the Liquid Radwaste System that will be installed at STP 3 and 4.

A description of the assumed Liquid Radwaste System follows.

Liquid radwaste at STP 3 & 4 will be processed using a low conductivity waste (LCW) and a high conductivity waste (HCW) mobile processing system, and a strainer for hot shower and detergent waste (HSD) that consists of the following units:

Table 3-1
LCW Mobile System for LCW Processing
• LCW Filter A
• LCW Filter B
• LCW Reverse Osmosis Unit
• LCW Demineralizer
HCW Mobile System for HCW Processing
• HCW Filter A (Charcoal)
• HCW Filter B
• HCW Reverse Osmosis Unit
• HCW Demineralizer
Strainers
• HSD strainer

3.3 The cost benefit analysis only utilizes the HCW and LCW process streams. Based on industry experience, the HSD process stream is usually released through a filtered pathway to the environment without additional processing. This indicates radioactivity in the HSD release stream is substantially below that of the HCW and LCW process streams.

3.4 It is assumed that any proposed modifications to the "already established" radwaste system will eliminate all radioactivity in the process stream, reducing the 50 mile collective population dose from STP 3 & 4 radwaste sources to zero.

3.5 The costs for the liquid and gaseous radwaste augments are provided in Regulatory Guide 1.110 [Reference 7.3]. These include the Annual Operating Costs (AOC), Annual Maintenance Cost (AMC), Direct Cost of Equipment and Materials (DCEM) and Direct Labor Cost (DLC)

3.6 A plant life of 60 years is assumed for this analysis.

3.7 The Capital Recovery Factor (CRF) is taken from Table A-6 of Regulatory Guide 1.110 and reflects the cost of money for capital expenditures. A cost-of-money value of 7% per year is assumed in this calculation, consistent with this table [Reference 7.3].

3.8 Indirect Cost Factor (ICF) – This factor takes into account whether the radwaste system is unitized or shared (in the case of a multi-unit site). It is assumed that the radwaste system in this analysis for STP 3 & 4 is a unitized system at a 2-unit site although the current design is independent for each unit.

3.9 Labor Cost Correction Factor (LCCF) – This factor takes into account the differences in relative labor costs between geographical regions. A factor of 1 (the lowest value) is assumed in this analysis.

3.10 As directed in Regulatory Guide 1.110, the value of one person-rem is $1000 in 1975 dollars.

3.11 For the purposes of this evaluation, the collective total body doses of 0.003 person-rem per year for radioactivity releases in liquid effluent and 0.58 person-rem per year for radioactivity releases in gaseous effluents (Table 2-1 of this calculation) within a 50 mile radius of STP 3 & 4, due to radioactivity releases in liquid effluents, is are assumed to be attributed to a single reactor unit. This assumption is conservative when determining the cost-benefit relationship of Liquid Radwaste System augments because it maximizes the effective benefit.

3.12 It is assumed that the Gaseous Radwaste System (i.e., the Gaseous Radwaste System components) described in Section 11.3 of the ABWR DCD [Reference 7.5] and the process block diagram shown in Attachment B to this calculation and the process flow diagram shown in ABWR DCD Figure 11.3-1 are representative of the Gaseous Radwaste System that will be installed at STP 3 and 4.

A description of the assumed Gaseous Radwaste System follows.

Gaseous radwaste at STP 3 & 4 will be processed using a system that consists of the following units:

Table 3-2
Gaseous Radwaste System
• Steam Jet Air Ejectors
• Interstage Condenser
• Offgas Preheater
• Hydrogen Recombiner
• Offgas Condenser
• Cooler Condenser
• Guard Bed
• Activated Charcoal Delay Beds
• HEPA Filter
• Offgas Vacuum Pump

3.13 The gaseous radwaste cost benefit analysis only utilizes the Main Condenser off-gas process streams. Based on industry experience, the Main Condenser off-gas process stream is usually released through a hydrogen recombiner, activated charcoal delay, and HEPA filter pathway to the environment without additional processing.

4.0 Methodology and Acceptance Criteria

4.1 Methodology

The methodology utilized for calculating the cost benefit for modifying an "already established" liquid radwaste design with augments is described in the USNRC Regulatory Guide 1.110 [Reference 7.3]. In accordance with Regulatory Position C.3 of Regulatory Guide 1.110, all costs are given in 1975 dollars (as is the $1000 per person-rem cost) and there is no allowance for inflation after 1975.

For this analysis, the proposed modifications are (1) the addition of one new demineralizer, or one new evaporator, or the addition of one 10,000 gallon hold-up tank to the Liquid Radwaste System effluent stream prior to entry into the discharge canal and (2) a 3-ton Charcoal Adsorber to the Gaseous Radwaste System.

The following methodology was extracted from Regulatory Guide 1.110 and appropriately edited:

The total annual cost of each augment considered is determined as follows:

a. The Total Direct Cost (TDC):

(1) The direct cost of equipment and materials is obtained from Table A-1 of Regulatory Guide 1.110.

(2) The direct labor cost obtained from Table A-1 of Regulatory Guide 1.110 is multiplied by the appropriate labor cost correction factor from Table A-4 of Regulatory Guide 1.110 to obtain the corrected labor cost for the geographical area from Figure A-1 of Regulatory Guide1.110, in which the plant is to be built.

(3) The costs obtained from steps (1) and (2) are added to obtain the Total Direct Cost.

b. The appropriate Indirect Cost Factor (ICF) is obtained from Table A-5 of Regulatory Guide 1.110 or the associated formula provided.

c. Total Capital Cost (TCC) is determined by using the equation:

$$TCC = TDC \times ICF$$

d. The appropriate Capital Recovery Factor (CRF) is obtained using the formula in Table A-6 of Regulatory Guide 1.110.

e. The Annual Fixed Cost (AFC) is determined by using the equation:

$$AFC = TCC \times CRF$$

f. The Annual Operating Cost (AOC) and the Annual Maintenance Cost (AMC) are determined from Tables A-2 and A-3 of Regulatory Guide 1.110. For multi-unit sites using shared radwaste systems the AOC is multiplied by the number of reactors sharing the augment.

g. The Total Annual Cost (TAC) is determined by using the equation:

$$TAC = AFC + AOC + AMC$$

4.1.1. The "benefit" of each augment is determined by multiplying the calculated dose reduction by $1000 per man-rem and/or $1000 per man-thyroid-rem, as appropriate.

4.1.2. The system should be augmented with any items for which the TAC from Item 4.1.g above is less than the value calculated in item 4.1.1, in the order of diminishing cost-benefit.

4.2 Acceptance Criteria

The following was extracted from the USNRC NUREG-0800 Chapter 11.2 SRP Acceptance Criteria 1B:

"The LWMS should include all items of reasonable demonstrated technology that, when added to the system sequentially and in order of diminishing cost-benefit return for a favorable cost-benefit ratio, can effect reductions in doses to the population reasonably expected to be within 80 kilometers (km) (50 miles (mi)) of the reactor. Regulatory Guide 1.110 provides an acceptable method for performing this analysis."

The following was extracted from the USNRC NUREG-0800 Chapter 11.3 SRP Acceptance Criteria 1.D:

"In addition to 1.A. 1.B, and 1.C, above, the GWMS should include all items of reasonably demonstrated technology that, when added to the system sequentially and in order of diminishing cost-benefit return, for a favorable cost-benefit ratio, can effect reductions in dose to the population reasonably expected to be within 80 km (50 mi) of the reactor."

The methodology as described in Regulatory Guide 1.110 is used in this cost benefit analysis.

The following was extracted from NUREG-0800 Chapter 11.2 Evaluation Findings Item 2:

"The applicant has met the requirements of Section II.D of Appendix I to 10 CFR Part 50 with respect to meeting the ALARA criterion. The staff has considered the potential effectiveness of augmenting the proposed LWMS using items of reasonably demonstrated technology and has determined that further effluent treatment will not effect reductions in cumulative population doses reasonably expected within an 80-km (50-mi) radius of the reactor at a cost of less than $1000 per man-rem or man-thyroid-rem."

The following was extracted from NUREG-0800 Chapter 11.3 Evaluation Findings Item 2.C:

"Regarding Section II.D of Appendix I we have considered the potential effectiveness of augmenting the proposed GWMS using reasonably demonstrated technology and determined that further gaseous effluent treatment will not effect reductions in the cumulative population doses within an 80 km (50-mi) radius of the reactor at a cost of less than $1,000 per man-rem or $1,000 per man-thyroid-rem."

5.0 Calculations

5.1 Postulated Liquid Radwaste System Augmentations

5.1.1 Postulated Liquid Radwaste System Augmentations

As previously stated, this cost benefit analysis postulates the following Liquid Radwaste System augments:

- The addition of one low capacity evaporator to the liquid discharge stream, or
- The addition of the lowest capacity demineralizer to the liquid discharge stream, or
- The addition of one 10,000 gallon Holdup Tank to the liquid discharge stream.

5.1.2 Postulated Gaseous Radwaste System Augmentations

As previously stated, this cost benefit analysis postulates the Gaseous Radwaste System augment to be the addition of a 3-ton Charcoal Adsorber:

5.2 In Plant Specific Factors

The Indirect Cost Factor takes into account whether the radwaste system is shared by the two units or whether each unit has its own stand alone radwaste system. In the case of STP 3 & 4, it is assumed that the radwaste system is unique to each unit, i.e. n = 2 (Assumption 3.8). Using the formula provided in Table A-5 of Regulatory Guide 1.110 [Reference 7.3]

$$ICF = \frac{(1.75 + (n-1)\times 1.5)}{n} = \frac{(1.75 + ((2-1)\times 1.5))}{2} = 1.625$$

The Capital Recovery Factor is determined using the equation from Table A-6 in Regulatory Guide 1.110 [Reference 7.3] and reflects the cost of money for capital expenditures. A cost-of-money value, i, of 7% per year is assumed for this calculation (Assumption 3.7) with an assumed plant life of 60 years (Assumption 3.6).

$$CRF = \frac{i(1+i)^{60}}{(1+i)^{60}-1} = \frac{0.07(1+0.07)^{60}}{(1+0.07)^{60}-1} = 0.0712 = 7.12\%$$

Using the methodology described in Section 4.0, the Total Annual Cost of the proposed three (3) Liquid Radwaste System augments and one (1) Gaseous Radwaste System augment were calculated and are provided in Table 5-2.

Table 5-1 REGULATORY GUIDE 1.110 DATA								
COST BENEFIT PARAMETER	**15 gpm Radwaste Evaporator**	**Regulatory Guide 1.110 Value (1000s of 1975 dollars)**	**50 gpm Demineralizer BWR 2nd Waste Demineralizer in Series**	**Regulatory Guide 1.110 Value (1000s of 1975 dollars)**	**10,000 gal Tank**	**Regulatory Guide 1.110 Value (1000s of 1975 dollars)**	**3-Ton Charcoal Adsorber**	**Regulatory Guide 1.110 Value (1000s of 1975 dollars)**
Equipment/ Material Cost	Table A-1	386	Table A-1	43	Table A-1	55	Table A-1	53
Direct Labor Cost (DLC)	Table A-1	201	Table A-1	29	Table A-1	43	Table A-1	14
Labor Cost Correction Factor (LCCF)	Table A-4	1 (1)	Table A-4	1 (1)	Table A-4	1 (1)	Table A-41 (1)	1 (1)
Annual Operating Cost (AOC) Per Unit	Table A-2	20	Table A-2	15	Table A-2	1	Table A-2	Neg.
Annual Maintenance Cost (AMC)	Table A-3	30	Table A-3	5	Table A-3	2	Table A-3	Neg.

Notes:
(1) The lowest Labor Cost Correction Factor was used (Assumption 3.9).

TABLE 5-2 TOTAL ANNUAL COST OF LIQUID AND GASEOUS RADWASTE SYSTEM AUGMENTS (1)											
Augments	Equipment/ Material Direct Cost (DCEM) (2)	Direct Labor Cost (DLC)(2)	LC Correction Factor (LCCF) (2)	Adjusted Labor Cost (ALC)(3)	Total Direct Cost (TDC)(4)	Indirect Cost Factor (ICF) (5)	Total Capital Cost (TCC) (6)	Annual Fixed Cost (AFC) (7)	Annual Operating Cost (AOC) Per Unit (8)	Annual Maintenance Cost (AMC) (9)	Total Annual Cost per Unit (TAC) (10)
15 gpm Radwaste Evaporator	386	201	1	201	587	1.625	953.9	67.94	20	30	117.94
50 gpm Demineralizer BWR 2nd Waste Demineralizer in Series	43	29	1	29	72	1.625	117.0	8.33	15	5	28.33
10,000 gal Tank	55	43	1	43	98	1.625	159.3	11.34	1	2	14.34
3-Ton Charcoal Adsorber	53	14	1	14	67	1.625	108.9	7.75	Neg.	Neg.	7.75

Notes:

(1) All dollar values are in terms thousands of 1975 dollars.
(2) Values are from Table 5-1 of this calculation.
(3) Adjusted Labor Costs are obtained by multiplying the Direct Labor Costs in column 3 by the LC Correction Factor in column 4.
(4) Total Direct Cost (TDC) is the sum of the DCEM in column 2 and the Adjusted Labor Cost in column 5. For the 10,000 gal Tank, TDC = 55 + 43 = 98.
(5) The Indirect Cost Factor is calculated in Section 5.2 of this calculation.
(6) The Total Capital Cost (TCC) is the product of the TDC in column 6 and the ICF in column 7. For the 10,000 gal Tank, TCC = 98 x 1.625 = 159.3.
(7) The Annual Fixed Cost (AFC) is the product of the TCC in column 8 and the Capital Recovery Factor (CRF) of 0.0712 that is calculated in Section 5.2 of this calculation. For the 10,000 gal Tank, AFC = 159.3 x 0.0712 = 11.34.
(8) The Annual Operating Costs (AOC) per unit are from Table 5-1.
(9) The Annual Maintenance Costs (AMC) are from Table 5-1.
(10) The Total Annual Cost (TAC) is the sum of the Annual Fixed Cost (AFC) from column 9, the Annual Operating Cost (AOC) from column 10, and the Annual Maintenance Cost (AMC) from column 11. For the 10,000 gal Tank, TAC = 11.34 + 1 + 2 = 14.34.

TABLE 5-3 RESULTANT BENEFIT OF PROPOSED RADWASTE AUGMENTS

Radwaste System Augment Equipment	Total Annual Cost (TAC) of Radwaste System Augment (1000s of 1975 Dollars) (1)	Collective 50 Mile Total Body Dose Saved per Year (Person-Rem) (2)	Benefit in 1975 Dollars (3)
15 gpm Radwaste Evaporator	117.94	0.003	3.00
50 gpm Demineralizer BWR 2nd Waste Demineralizer in Series	28.33	0.003	3.00
10,000 gal Tank	14.34	0.003	3.00
3-Ton Charcoal Adsorber	7.75	0.58	580

Notes:

(1) TAC dollar values are from column 12 of Table 5-2.

(2) The collective 50 mile total body dose saved per year (i.e., 0.003 rem for the liquid radwaste releases and 0.58 rem for the gaseous radwaste releases) is from Table 2-1 of this calculation. It is assumed the dose of 0.003 rem is attributed to liquid radwaste releases from a single reactor unit and the dose of 0.58 rem is attributed to gaseous radwaste releases from a single reactor unit (Assumption 3.11) and that the proposed augments to the Liquid Radwaste System eliminates all Liquid Radwaste System radioactivity releases and proposed augments to the Gaseous Radwaste System eliminates all Gaseous Radwaste System radioactivity releases (Assumption 3.4).

(3) The benefit in 1975 dollars is obtained by multiplying the collective dose saved per year from column 3 by the value of one person-rem (i.e., $1000 per Assumption 3.10).

TABLE 5-4 PROPOSED RADWASTE AUGMENTS BENEFIT COST RATIO

Radwaste System Augment Equipment	Benefit Cost Ratio (1)
15 gpm Radwaste Evaporator	2.54E-05
50 gpm Demineralizer BWR 2nd Waste Demineralizer in Series	1.06E-04
10,000 gal Tank	2.09E-04
3-Ton Charcoal Adsorber	7.48E-02

Notes:

(1) The Benefit Cost Ratio is the ratio of the Benefit in 1975 Dollars value from column 4 of Table 5-3 divided by 1000 times the Radwaste System Augment TAC Dollars from column 2 of Table 5-3. A factor of 1000 is applied to the values in column 2 of Table 5-3 since the units of column 2 are in thousands of dollars.

6.0 Results and Conclusions

Comparing the Total Annual Costs of the three (3) proposed Liquid Radwaste System augments and the proposed Gaseous Radwaste System augment presented in Table 5-2 with the Benefits presented in Table 5-3, both in 1975 dollars, shows that the annual costs of the augments exceeds the cost associated with the benefits (i.e., the benefit cost ratio is substantially less than one (1) as shown in Table 5-4). Therefore, the Total Annual Cost of the augments is substantially more than the value derived. The proposed Liquid Radwaste System and Gaseous Radwaste System for STP 3 & 4 meet the numerical guides for dose design and objectives. Augments to the proposed Liquid Radwaste System and Gaseous Radwaste System would not be cost effective.

7.0 References

7.1 STP 3 & 4 Final Safety Analysis Report Revision 01, January 15 2008.

7.2 STP 3 & 4 Environmental Report, Revision 01, January 15 2008

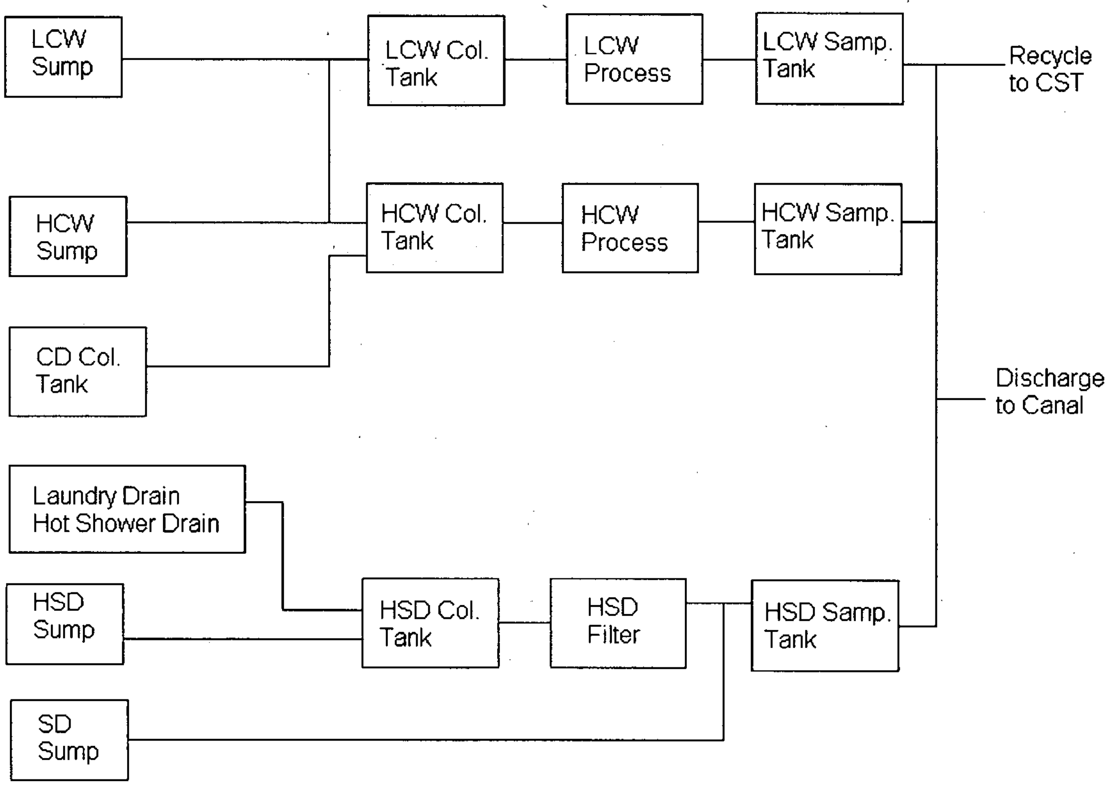
7.3 USNRC Regulatory Guide 1.110, "Cost-Benefit Analysis For Radwaste Systems For Light-Water-Cooled Nuclear Power Reactors," March 1976 (For Comment)

7.4 USNRC NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants"

7.5 USNRC Issued Design Certification, ABWR, Design Control Document/Tier 2, Chapter 11, Rev. 0 http://www.nrc.gov/reactors/new-licensing/design-cert/abwr/dcd/tier-2/ch-11.pdf

Attachment A

STP 3 & 4 Liquid Radwaste System Block Flow Diagram



Attachment B

STP 3 & 4 Gaseous Radwaste System Block Flow Diagram