3H Details and Evaluation Results of Seismic Category 1 Structures

The information in this appendix of the reference ABWR DCD, including all subsections, tables, and figures is incorporated by reference with the following departures and supplement.

STP DEP T1 5.0-1

STD DEP 3.8-1 (Tables and Figures)

STP DEP Admin

3H.1 Reactor Building

STP DEP T1 5.0-1

3H.1.4.2 Site Design Parameters

(3) *Maximum Flood Level*

— ~~*0.305*~~ 414.5 cm ~~*below*~~ above *grade*

(9) *Maximum Rainfall*

— *Design rainfall is* ~~*493*~~503 mm/h. *Roof parapets are furnished with scuppers to supplement roof drains, or are designed without parapets so that excessive ponding of water cannot occur. Such roof design meets the provision of ASCE 7-88 Section 8.*

3H.1.6 Site Specific Structural Evaluation

The following site specific supplement addresses the structural evaluation of the site specific design parameters for STP 3 & 4.

Sections 3.3 and 3A.12, the ABWR Standard Plant Reactor Building (RB) seismic loads, wind loads, and tornado loads bound these site parameters for STP 3 & 4. As documented in Subsection 2.5S.4, the STP 3 & 4 site has an average shear wave velocity greater than 305m/s.

As documented in Subsection 3.4, the STP 3 & 4 site has a flood elevation that is 414.5 cm above grade. This results in an increase in the flood level over what was used in the ABWR Standard Plant, however the load due to the revised flood level on the RB is less than the ABWR Standard Plant RB seismic load, hence it doesn't effect the Standard Plant RB structural design.

Therefore the STP 3 & 4 RB utilizing the Standard Plant design is structurally adequate.

3H.2 Control Building

STP DEP T1 5.0-1

3H.2.4.2.3 Design Flood Level

Design flood level is at ~~0.30~~ 414.5cm *~~below~~* above *grade level*.

3H.2.4.2.5 Maximum Rainfall

Design rainfall is ~~493~~ 503 *mm/h. Roof parapets are furnished with scuppers to supplement roof drains, or are designed without parapets so that excessive ponding of water cannot occur. Such roof design meets the provision of ASCE 7-88 Section 8.*

3H.2.6 Site Specific Structural Evaluation

The following site specific supplement addresses the structural evaluation of the site specific design parameters for STP 3 & 4.

As documented in Subsections 3.3 and 3A.12, the ABWR Standard Plant Control Building (CB) seismic loads, wind loads, and tornado loads bound these site specific parameters for STP 3 & 4. As documented in Subsection 2.5S.4, the STP 3 & 4 site has an average shear wave velocity greater than 305m/s.

As documented in Subsection 3.4, the STP 3 & 4 site has a flood elevation that is 414.5 cm above grade. This results in an increase in the flood level over what was used in the ABWR Standard Plant, however the load due to the revised flood level on the CB is less than the ABWR Standard Plant seismic load, hence it does not effect the Standard Plant CB structural design.

Therefore the STP 3 & 4 CB utilizing the Standard Plant design is structurally adequate.

3H.3 Radwaste Building

3H.3.1 Objective Scope

STD DEP Admin

The objective of this subsection is to document the structural design and analysis of the ABWR Radwaste Building substructure, which is a seismic Category I structure. *The scope includes the design and analysis of the basemat and exterior walls of the building for the normal, severe environmental, extreme environmental and construction loads.*

3H.3.2 Conclusions

STD DEP 3.8-1

The following are the major summary conclusions on the design and analysis of the STP 3 & 4 Radwaste Building substructures:

- *Based on the ~~design drawings identified~~* analysis presented *in Subsection 3H.3.5*.3.1, the reference ABWR DCD structural design of the seismic Category 1 portion of the Radwaste Building (exterior walls below grade and the basemat) is structurally adequate for STP 3 & 4. *~~stresses in concrete, reinforcement, and structural steel are less than the allowable stresses per the applicable codes listed in subsection 3H.3.4.1.~~*

- *~~The building has been evaluated for the design basis tornado. Welded studs are provided for the roof structural steel to provide required resistance for negative pressure.~~*

The structural design and analysis report for the Radwaste Building, including the non-seismic Category I portion of the superstructure, will be available for review prior to fuel load (COM 3H-1).

3H.3.3 Structural Description

STD DEP 3.8-1

The Radwaste Building is a ~~60.4~~ 66.2*m long ~~(0°-180° direction)~~ x ~~41.2~~* 38.8*m wide ~~(90°-270° direction)~~ structure that is ~~29.5~~* 27.4*m in height above the top of the 2.5m thick basemat. It consists of four floors, two of which are below grade. The total building embedment is ~~16~~*16.2*m. The Radwaste Building is a reinforced concrete structure consisting of walls and slabs and is supported by a mat foundation. Steel framing is used to support the slabs for construction loads. Steel deck is used as form work to support the slabs during construction.*

3H.3.4.2.1 Soil Parameters

STD DEP 3.8-1

Minimum shear wave velocity: *~~305~~* 226 *m/s*

Poisson's ratio: *~~0.3 to 0.38~~* 0.47

Minimum Static Soil Bearing Capacity Demand:≥~~718.2kPa~~ 191.5kPa

3H.3.4.2.5 Maximum Rainfall

STP DEP T1 5.0-1

*Design rainfall is ~~493~~*503 *mm/h. Roof parapets are furnished with scuppers to supplement roof drains, or are designed without parapets so that excessive ponding of water cannot occur. Such roof design meets the provision of ASCE 7-88 Section 8.*

3H.3.4.3.3.2 Safe Shutdown Earthquake Loads (E)

STD DEP 3.8-1

Seismic dynamic analysis of the Radwaste Building was performed to incorporate the Radwaste Building General Arrangement drawings, Figures 1.2-23a through 1.2.-23e, for STP 3 & 4 site-specific conditions. The time history analysis method was used and the computer program STARDYNE, was employed. The Radwaste Building natural frequencies for the fixed base condition are presented in Table 3H.3-17. Three statistically independent SSE accelerations, two horizontals and one vertical, were applied simultaneously.

~~The SSE Loads are applied in three directions, viz. the two horizontal directions and the vertical direction. The total structural response is predicted by combining the applicable maximum codirectional responses by "the square root of the sum of the squares (SRSS)" method~~

The SSE loads are based on a free field peak ground acceleration value of ~~0.30g~~ 0.15g *at plant grade elevation* for STP 3 & 4 site-specific soil conditions. This design response spectra was selected since it bounds the site-specific response spectra presented in Subsection 2.5S.2 in the frequency range of interest, namely frequencies greater than 1Hz. *The loads consist of story shears, torsional moments, and overturning moments. The loads are distributed to the resisting walls in proportion to their rigidities. The* STP 3 & 4 *SSE loads for the Radwaste Building are provided in Table 3H.3-1.* The STP 3 & 4 site-specific SSE loads are less than the reference ABWR DCD SSE loads.

3H.3.5 Structural Design and Analysis Summary

STD DEP 3.8-1

~~*3H.3.5.1 Analytical Model*~~ (Not Used)

~~A three dimensional finite element model, as shown in Figures3H.3-3 through 3H.3-8, was developed using the STARDYNE program. The Radwaste Building is idealized as a 3-D assemblage of linear elastic beams and rectangular plate elements. Interior structural steel columns are represented by beam elements and concrete base mat, exterior walls and floor slabs are represented by rectangular plate elements. The foundation soil is represented by soil spring elements. The model consists of 1715 nodes, 60 beam elements, 1728 plate elements and 741 nodal soil spring elements.~~

~~*3H.3.5.2 Analysis*~~ (Not Used)

~~*A three dimensional finite element model developed as described above for the structural evaluation of the Radwaste Building. The STARDYNE computer program was used for the analysis.*~~

~~*The foundation soil is represented by vertical and horizontal springs.*~~

~~*Reinforced concrete floor slab and its supporting structural steel framing beam and columns are used to resist vertical loads such as dead load, live load, and equipment loads. Floor slabs act as diaphragms to transmit lateral loads to the exterior walls. Exterior walls act as shear walls and are used to resist lateral loads, like soil earth pressure, seismic loads, wind loads and tornado loads. The roof slab and exterior walls above grade are non-seismic Category I structures and are designed for the wind loads given in Subsection 3H.3.4.3.2, however they are only checked for tornado loads given in Subsection 3H.3.4.3.3.1 such that they do not collapse and damage Category I portion of the structure.*~~

~~*All loads as described in Subsection 3H.3.4 are considered. The horizontal SSE seismic loads, as described in Subsection 3H.3.4.3.3.2, are the equivalent static loads as provided in Table 3H.3-1. The horizontal seismic loads applied at different elevations of the structural model are given as shear forces and moments. These forces are distributed to the nodal points at the appropriate elevations in proportion to the nodal point masses. The vertical SSE seismic loads are applied as pressure loads which are computed by multiplying the acceleration 'g' values by the total floor masses. The horizontal torsional moment has been considered in the analysis. Such torsions are provided in Table 3H.3-1.*~~

~~*Velocity pressure loading due to wind and tornado is determined by using the method and procedures contained in ASCE 7-88. Velocity pressure is assumed not to vary with height. All significant openings are considered sealed, i.e. the structure is non-vented.*~~

~~*For design, the CECAP computer program was used for the evaluation of stresses in rebar and concrete. CECAP is a Bechtel Computer Program, "Concrete Element Cracking Analysis." The input to CECAP consists of rebar ratios, material properties and element geometry of the section under consideration together with the forces and moments from the STARDYNE analysis for a critical load combination. The thermal loads are not critical and therefore not considered in the structural design.*~~

~~*Loads from Subsection 3H.3.4 are applied to the model as plate pressure and nodal loads and these loads are combined in accordance with the load combinations described in Subsection 3H.3.4.3.5.*~~

~~*3H.3.5.3 Structural Design*~~ (Not Used)

~~*3H.3.5.3.1 Reinforced Concrete and Structural Steel*~~ (Not Used)

The Radwaste Building design departs from the reference ABWR DCD due to the change in the building general arrangement. However, the seismic Category I portion of the Radwaste Building, the substructure including the exterior walls below grade and basemat are unchanged. The following table shows the comparison of critical dimensions of the substructure.

Citical Dimensions	Original RWB	New RWB
Depth below grade	16.0 m	16.2m
Thickness of exterior walls below grade	1.2 m	1.2 m
Thickness of basemat	2.5 m	2.5m

Based on the reference ABWR DCD Table 3H.3-13, the critical load combination for reinforced concrete design of exterior walls and the basemat is D+L+H'+E, which includes dead load, live load, dynamic soil pressure, and seismic loads. Per analysis results in Subsection 3H.3.4.3.3.3.2 for seismic loads and Subsection 3H.3.4.3.1.4 for lateral soil pressure, the STP 3 & 4 seismic loads and lateral soil pressures are smaller than or equal to those of the reference ABWR DCD. Therefore, the STP 3 & 4 Radwaste Building substructure utilizing the REFERENCE ABWR DCD design is structurally adequate.

~~*Forces and moments in critical elements of various components of the Radwaste Building such as base mat and exterior walls computed from the STARDYNE analysis are summarized in Tables through . Load combinations are summarized in Tables through with the section locations and the element coordinate system defined in Figure and , respectively. From these load combinations the base mat and exterior walls are designed and the resultant reinforcing steel and concrete stresses are computed and are shown on Tables through . The summary of reinforcing steel in the base mat and exterior walls below grade is provided in the Table . The summary of minimum and maximum reinforcement ratios is provided in Table . The summary of structural steel safety margins is provided in Table .*~~

~~*Figures 3H.3-11 to 3H.3-16 present the design drawings used for the evaluation of the Radwaste Building.*~~

3H.3.5.3.2 Stability Evaluation

The STP 3 & 4 *Radwaste Building foundation stability has been checked based on the shears and overturning moments provided in Table 3H.3-1* for site-specific seismic loads. The minimum safety factors for flood and tornado wind load combinations remain unchanged, since the flood (F') and tornado wind (Wt) at STP 3 & 4 are within the bounds of the REFERENCE ABWR DCD. *The foundation provides the following minimum factors of safety when subjected to SSE loads, tornado loads, lateral earth pressures, and buoyant forces.*

Load Combination	*Overturning*	*Sliding*	*Floatation*
D + F'	--	--	*1.3*
D + F + H + W_t	*1.97*	*2.63*	--
D + F + H' + E'	~~*112.0*~~ 630.0	~~*1.36*~~ 2.39	--

The factor of safety associated with overturning due to SSE loading (E) is computed using the energy approach. No live load is considered in *combination with SSE. The wind load is smaller than tornado load and the corresponding safety factors will be higher.*

3H.3.5.3.3 Maximum Soil Bearing Pressure

Maximum soil bearing pressures, as computed using conventional method, for ~~various~~ service and seismic *load combinations are summarized in Table 3H.3-16.*

Table 3H.3-1 Radwaste Building Design Seismic Loads

~~Beam/Node~~	Elevation ~~TMSL~~ (m)	Bending Moments (~~t-m~~ kN-m)	Web Shears (~~t~~ kN)	Torsion (~~t-m~~ kN-m)
		X Direction: Forces and Moments in Beam Elements		
~~1~~	~~–1.50~~ –1.70	~~2.45E+05~~ 1.28E + 06	~~1.18E+04~~ 7.87E + 04	~~2.36E+04~~ 8.45E + 04
~~2~~	~~4.80~~ 5.00	~~2.45E+05~~ 7.14E + 05	~~1.18E+04~~ 5.23E + 04	~~2.36E+04~~ 6.35E + 04
~~3~~	~~12.30~~ 12.00	~~1.45E+05~~ 3.04E + 05	~~9.50E+03~~ 2.53E + 04	~~1.90E+04~~ 7.97E + 04
~~4~~	~~21.00~~ 18.15	~~3.38E+05~~ 1.35E + 05	~~3.50E+03~~ 1.53E + 04	~~7.00E+03~~ 3.98E + 04
~~5~~	~~28.00~~ 25.25	~~1.36E+04~~ 6.74E + 04	~~3.50E+03~~ 1.53E + 04	~~7.00E+03~~ 3.98E + 04
		Y Direction: Forces and Moments in Beam Elements		
~~1~~	~~–1.50~~ –1.70	~~2.24E+05~~ 1.39E + 06	~~1.32E+04~~ 7.55E + 04	~~3.43E+04~~
~~2~~	~~4.80~~ 5.00	~~2.24E+05~~ 7.98E + 05	~~1.32E+04~~ 4.83E + 04	~~3.43E+04~~
~~3~~	~~12.30~~ 12.00	~~1.22E+05~~ 3.21E + 05	~~1.05E+04~~ 2.18E + 04	~~2.73E+04~~
~~4~~	~~21.00~~ 18.15	~~2.70E+04~~ 1.43E + 05	~~3.70E+03~~ 1.31E + 04	~~9.62E+03~~
~~5~~	~~28.00~~ 25.25	~~1.36E+04~~ 4.05E + 04	~~3.70E+03~~ 1.31E + 04	~~9.62E+03~~

Vertical Direction Maximum Accelerations

~~Node~~	Elevation ~~TMSL~~	Acceleration
	(m)	(g)
~~1~~	~~–1.50~~ **–1.70**	~~0.30~~ **0.25**
~~2~~	~~4.80~~ **5.00**	~~0.30~~ **0.26**
~~3~~	~~12.30~~ **12.00**	~~0.31~~ **0.26**
~~4~~	~~21.00~~ **18.15**	~~0.41~~ **0.26**
~~5~~	~~28.00~~ **25.25**	~~0.49~~ **0.27**
	Roof Truss	**0.43**

Table 3H.3-2 ~~*Forces and Moments in Critical Elements for Dead Load (D)*~~ Not Used

Table 3H.3-3 ~~*Forces and Moments in Critical Elements for Live Loads (L)*~~ Not Used

Table 3H.3-4 ~~*Forces and Moments in Critical Elements for Soil Pressure @ Rest (H)*~~ Not Used

Table 3H.3-5 ~~*Forces and Moments in Critical Elements for Seismic Soil Pressure (H')*~~ Not Used

Table 3H.3-6 ~~*Forces and Moments in Critical Elements for Seismic Load (E)*~~ Not Used

Table 3H.3-7 ~~*Forces and Moments in Critical Elements for Load Combination: 1.4D + 1.7L + 1.7H*~~ Not Used

Table 3H.3-8 ~~*Forces and Moments in Critical Elements for Load Combination (D + L + H′ ± E)*~~$_{\cancel{Max.\ Tension}}$ Not Used

Table 3H.3-9 ~~*Forces and Moments in Critical Elements for Load Combination (D + L + H′ ± E)*~~$_{\cancel{Max.\ Compression}}$ Not Used

Table 3H.3-10 ~~*Rebar and Concrete Stresses for Load Combination: 1.4D + 1.7L + 1.7H*~~ Not Used

Table 3H.3-11 ~~*Rebar and Concrete Stresses for Load Combination (D + L + H′ ± E)*~~$_{\cancel{Max.\ Tension}}$ Not Used

Table 3H.3-12 ~~*Rebar and Concrete Stresses for Load Combination (D + L + H′ ± E)*~~$_{\cancel{Max.\ Compression}}$ Not Used

Table 3H.3-13 ~~*Summary of Reinforced Steel*~~ Not Used

Table 3H.3-14 ~~*Summary of Reinforcing Steel Ratios*~~ Not Used

Table 3H.3-15 ~~*Summary of Structural Steel Safety Margins*~~ Not Used

Table 3H.3-16 Maximum Soil Bearing Pressures

Case Load Name	Load Combination	Max. Soil Bearing Pressure kPa
Service		
90°–270°	D + L + H	**108.0**~~73.75~~
0°–180°	D + L + H	**108.0**~~73.75~~
~~***Wind***~~		
~~*90° 270°*~~	~~$D + L + H + W_X$~~	~~*107.78*~~
~~*0° 180°*~~	~~$D + L + H + W_Y$~~	~~*123.07*~~
~~***Tornado (Wind Only)***~~		
~~*90° 270°*~~	~~$D + L + H + W_{WX}$~~	~~*116.11*~~
~~*0° 180°*~~	~~$D + L + H + W_{WY}$~~	~~*132.49*~~
~~***Tornado (Wind + 1/2PD)***~~		
~~*90° 270°*~~	~~$D + L + H + W_{WX} + 1/2\ W_{wp}$~~	~~*109.34*~~
~~*0° 180°*~~	~~$D + L + H + W_{WY} + 1/2\ W_{wp}$~~	~~*127.98*~~
~~***Tornado (Press. Drop)***~~		
~~*90° 270°*~~	~~$D + L + H + W_{WP}$~~	~~*92.57*~~
~~*0° 180°*~~	~~$D + L + H + W_{WP}$~~	~~*107.87*~~
Seismic		
90°–270°; E_Z (down)	$D + L + H' + E_X + E_Z$	~~*237.97*~~ **257.00**
0°–180°; E_Z (down)	$D + L + H' + E_y + E_Z$	~~*404.60*~~ **214.50**

Table 3H.3-17 Natural Frequencies of the Radwaste Building—Fixed Base Condition

Mode No.	Frequency (hz)	Direction
1	2.50	Z - Vert
2	12.24	X - Horiz
3	13.27	Y - Horiz
4	14.46	Y - Horiz
5	24.37	X - Horiz
6	25.51	Y - Horiz
7	30.99	Z - Vert
8	31.38	Z - Vert
9	32.96	Z - Vert

Figure 3H.3-3 ~~*Stardyne Modal of Radwaste Building (Front Wall Removed for Clarity)*~~ **Not Used**

Figure 3H.3-4 ~~*Basemat Element Reinforcing Regions*~~ **Not Used**

Figure 3H.3-5 ~~*Wall Elements — 0° Wall*~~ **Not Used**

Figure 3H.3-6 ~~*Wall Elements — 90° Wall*~~ **Not Used**

Figure 3H.3-7 ~~*Wall Elements — 180° Wall*~~ **Not Used**

Figure 3H.3- 8 ~~*Wall Elements — 270° Wall*~~ **Not Used**

Figure 3H.3-9 ~~*Section Locations*~~ **Not Used**

Figure 3H.3-10 ~~*Element Coordinate System*~~ **Not Used**

Figure 3H.3-11 ~~*Radwaste Building Reinforced Concrete Basemat*~~ **Not Used**

Figure 3H.3-12 ~~*Radwaste Building Structural Steel Framing Plan—Typical Floor*~~ **Not Used**

Figure 3H.3-13 ~~*Radwaste Building Structural Steel Framing Plan Roof El. 28000 mm*~~ **Not Used**

Figure 3H.3-14 ~~*Radwaste Building Cross Section A-A*~~ **Not Used**

Figure 3H.3-15 ~~*Radwaste Building Exterior Walls Sections*~~ **Not Used**

Figure 3H.3-16 ~~*Radwaste Building Sections and Details*~~ **Not Used**

3H.6 Site-Specific Seismic Category I Structures

The following site-specific supplement addresses site specific Seismic Category I structures.

3H.6.1 Objective and Scope

The objective of this appendix is to document the structural analysis and design of the STP 3 & 4 site-specific seismic Category I structures that are identified below and shown in Figures 1.2-32 through 1.2-37.

(1) Ultimate Heat Sink (UHS) including a cooling tower enclosure for each unit and a storage basin that is shared by STP 3 & 4. The basin and cooling tower enclosures will share a common foundation with the two Reactor Service Water (RSW) pump houses (one for each unit), which are also addressed in this appendix.

(2) RSW piping tunnel for each unit.

3H.6.2 Summary

Seismic analyses of the site-specific seismic Category I structures have been performed using simplified models, SSE damping values, and RG 1.60 spectra normalized to 0.15g. Results from these analyses have been combined with results from other applicable loads that are defined in this appendix to develop conceptual designs of the structures. These designs will be used to define the structural models that will be considered in the final seismic analysis that is described in Subsection 3H.6.5.2. The responses from the final seismic analysis will be combined with responses from other applicable loads and the FSAR will be updated in accordance with 10 CFR 50.71(e) by the third quarter of 2008 to address the final results identified below. (COM 3H-2)

- Natural frequencies.
- Seismic accelerations.
- Seismic forces, moments, and torques.
- Seismic displacements.
- Floor response spectra
- Factors of safety against sliding, overturning, and flotation.
- Combined forces and moments at critical locations in the structures along with corresponding calculated and allowable stresses, and required and provided rebar.

The final combined responses are used to evaluate the designs against the following criteria:

- Stresses in concrete and reinforcement are less than the allowable stresses in accordance with the applicable codes listed in Subsection 3H.6.4.1.

- The factors of safety against flotation, sliding, and overturning of the structures under various loading combinations are higher than the required minimum values identified in Subsection 3H.6.4.5.
- The calculated static and dynamic soil bearing pressures/displacements are less than the allowable values.
- The thickness of the roof slabs and exterior walls are more than the minimum required to preclude penetration, perforation, or spalling resulting from impact of design basis tornado missiles. In addition, the passage of tornado missiles through openings in the roof slabs and exterior walls is prevented by the use of missile-proof covers and doors, or the trajectory of missiles through ventilation openings is limited by labyrinth walls configured to prevent safety-related substructures and components from being impacted.

3H.6.3 Structural Descriptions

3H.6.3.1 Ultimate Heat Sink Basin

The UHS basin is a vertical right cylinder with an inside diameter of 106.7 meters. It is constructed of reinforced concrete and serves as the reservoir for the RSW system. The walls of this basin are 1.52 meters thick, and extend from an elevation of 16.8 meters mean sea level (MSL) down to elevation -0.305 meter MSL at the pump houses. The base of the walls then follow the contour of the basin floor rising to an elevation of 1.83 meters MSL away from the pump houses. The walls are supported on a 115.8 meters diameter by 2.44 meters thick mat foundation, which supports the cooling tower enclosures and extends to form the base slab for each pump house. The basin is surrounded by a berm that incorporates a 7.62 meters-wide access road whose elevation ranges from 11.9 meters MSL to 14.9 meters MSL.

In order to provide+ a dedicated water supply for each unit, the basin is divided in half by a 1.22 meter thick reinforced concrete wall, that is braced by buttresses spaced 14 meters apart.

As noted in Subsection 9.2.5.5.2, the seepage loss estimated during the 30 days of operation following a design basis accident, with no makeup available, is within the acceptance criteria for standard hydrostatic test HST-025, as defined in ACI 350.1.

3H.6.3.2 Ultimate Heat Sink Cooling Tower Enclosures

The two UHS cooling tower enclosures are reinforced concrete structures that house the equipment used to cool the water for the RSW system. The enclosures are located within the UHS basin and are supported by the basin mat foundation. Each enclosure is 84.1 meters long by 14.0 meters wide and extends from the UHS basin mat foundation, to which it is anchored, to elevation 32.6 meters MSL. Each enclosure is divided into six compartments or cells, with each compartment housing a fan and associated equipment. Openings are provided at the base of each compartment to allow for the flow of water. Each compartment includes a basin at the base of the structure, air intake, and substructures and components used to cool the water (fill, drift eliminators, spray system piping and nozzles, and the associated concrete support beams). The air intakes, which are located on only one side of the enclosures, are configured to limit the trajectory of tornado missiles into the enclosures, thereby preventing damage to safety-related substructures and components. In addition, each compartment includes a reinforced concrete fan deck that supports the fan and the associated motor. Finally, heavy steel grating, which is supported by structural steel beams, is installed at the top of each compartment. This grating allows for the passage of air out of the compartment and prevents the intrusion of tornado wind-borne missiles.

3H.6.3.3 Reactor Service Water Pump Houses

The two RSW pump houses are reinforced concrete structures that are located on opposite sides of the UHS basin and house the RSW pumps (six pumps per pump house, with three RSW divisions, and two pumps per division) and their associated auxiliaries. Each set of pumps extracts water for the RSW system from the basin. The pump bay of each pump house is located within the basin. The remainder of each pump house straddles the basin wall, with a portion of the pump house operating floor serving as the ceiling of the pump bay.

The pump bay of each pump house is divided into six separate areas from which each RSW pump takes suction. The operating floor of each pump house is divided into three separate rooms (one per RSW division), each containing two pump drivers and associated equipment, including self-cleaning strainers. There is also an access tunnel through which the RSW system piping is routed to and from the corresponding control building.

The north and south exterior walls of each pump house and the piers dividing the pump bay are integral with the UHS basin walls, while the foundation slab of the pump house is an extension of the basin mat foundation. The pump bay for each pump house measures approximately 12.5 meters by 33.5 meters in plan with the top of the bay slab being located at elevation –0.305 meters. Each of the six pump bay areas is fitted with stop logs as well as coarse and fine screens. The operating floor is at elevation 15.2 meters and measures 30.5 meters by 33.5 meters in plan. Openings are provided in the roof of each pump house, which is located at elevation 24.4 meters, to allow access to the six pumps.

3H.6.3.4 Reactor Service Water Piping Tunnels

The RSW piping tunnels are reinforced concrete structures 11.9 meters wide and 4.42 meters high. They extend from each pump house to the corresponding control building. Each tunnel is divided into three sections (one section for each RSW division) by reinforced concrete walls, which serve to isolate the supply and return lines and associated equipment for each of the three divisions. Access to the tunnels from the surface, for inspections and maintenance activities, is provided by reinforced concrete manholes. The interfaces between the tunnels and the pump houses and control buildings are configured to allow relative movement between the tunnels and structures.

3H.6.4 Structural Design Criteria

3H.6.4.1 Design Codes and Standards

- Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349), as supplemented by RG 1.142
- Code Requirements for Environmental Engineering Concrete Structures (ACI 350)

- Tightness Testing of Environmental Engineering Concrete Structures (ACI 350.1)
- Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7)
- Seismic Analysis of Safety-Related Nuclear Structures and Commentary (ASCE 4)

3H.6.4.2 Site Design Parameters

3H.6.4.2.1 Soil Parameters

- Poisson's ratio (above groundwater): 0.42
- Poisson's ratio (below groundwater): 0.47
- Unit weight (moist): .... 1.92 t/m^3
- Unit weight (saturated): .... 2.24 t/m^3
- Liquefaction potential: .... None
- Soil Bearing Capacity: .... See FSAR Subsection 2.5S.4.10

3H.6.4.2.2 Design Groundwater Level

Design groundwater level is at elevation 8.53 meters MSL. This elevation bounds the groundwater elevation defined in FSAR Subsection 2.4S.12.

3H.6.4.2.3 Design Flood Level

Design flood level is at 14.5 meters MSL. This elevation is defined in Subsection 2.4S.2.2.

3H.6.4.2.4 Maximum Snow Load

Design snow load is 0 kPa in accordance with Subsection 2.3S.1.3.4.

3H.6.4.2.5 Maximum Rainfall

Design rainfall is 503 mm/hour in accordance with Subsection 2.3S.1.3.4. The roof of each pump house is designed without parapets so that excessive ponding of water cannot occur. Such roof design meets the provisions of RG 1.102.

3H.6.4.3 Design Loads and Load Combinations

3H.6.4.3.1 Normal Loads

Normal loads are those that are encountered during normal plant startup, operation, and shutdown.

3H.6.4.3.1.1 Dead Loads (D)

Dead loads include the weight of the structure, permanent equipment, and other permanent static loads. An additional 2.39 kPa uniform load is considered to account for dead loads due to piping, raceways, grating, and HVAC duct work.

3H.6.4.3.1.2 Live Loads (L and L_o)

Live loads include floor and roof area loads, movable loads, and laydown loads. The only areas of the site-specific Category I structures requiring consideration of a live load are the operating floor and roof of the pump houses. While a live load of 9.58 kPa is defined for the operating floor, a live load of 2.39 kPa is defined for the roof.

For the computation of global seismic loads and the definition of load combinations that include seismic loads, the live load is limited to the expected live load present during normal plant operation, Lo. This load has been defined as 25% of the operating floor and roof live loads.

3H.6.4.3.1.3 Snow Loads

No snow load is considered in the evaluation of the site-specific seismic Category I structures.

3H.6.4.3.1.4 Lateral Soil Pressures (H and H')

Lateral soil pressures are calculated using the following soil properties.

- Unit weight (moist): .... 1.92 t/m^3
- Unit weight (saturated): .... 2.24 t/m^3
- Internal friction angle: .... 30°
- Poisson's ratio (above groundwater) 0.42
- Poisson's ratio (below groundwater) 0.47

3H.6.4.3.2 Severe Environmental Load

The severe environmental load considered in the design is that generated by wind. The following parameters are used in the computation of the wind loads:

- Basic wind speed (100 year recurrence interval, 3-second gust): .... 215 km/h
- Exposure: C
- Importance factor: 1.15
- Velocity pressure exposure coefficient as per ASCE 7 Table 6-3, but ≥ 0.87
- Topographic factor 1.0

- Wind directionality factor 1.0

Wind loads will be calculated in accordance with the provisions of Chapter 6 of ASCE 7.

3H.6.4.3.3 Extreme Environmental Load

Extreme environmental loads consist of loads generated by the tornado and safe shutdown earthquake (SSE).

3H.6.4.3.3.1 Tornado Loads (Wt)

The following tornado load effects are considered in the design:

- Wind speed .... (W_w)
- Differential pressure .... (W_p)
- Missile impact .... (W_m)

Parameters used in computation of tornado loads are as follows (see Tables 1 and 2 of RG 1.76, for Region II):

- Maximum wind speed: .... 320 km/h
- Maximum rotational speed: .... 259 km/h
- Maximum translational speed: .... 65 km/h
- Radius of maximum rotational speed: 45.7m
- Differential pressure: .... 06.3 kPa
- Pressure differential rate: .... 2.5 kPa/s
- Missile spectrum: .... (See Table 2 of RG 1.76)

(1) Tornado Wind Pressure (W_w)

With the exception of the RSW piping tunnel, which does not require the consideration of a tornado wind pressure, tornado wind pressures are computed using the procedure described in Chapter 6 of ASCE 7, in conjunction with the maximum wind speed defined above and the following parameters:

- Importance factor 1.15
- Velocity pressure exposure coefficient 0.87
- Topographic factor 1.0
- Wind directionality factor 1.0

(2) Tornado Differential Pressure (W_p)

The designs of the UHS basin and the RSW piping tunnel do not require the consideration of a tornado differential pressure. Although the UHS cooling tower enclosures and the RSW pump houses are partially vented, they are evaluated for the specified differential pressure.

(3) Tornado Missile Impact (W_m)

Tornado missile impact effects on the UHS basin and cooling tower enclosures, and the RSW pump houses are evaluated for the following two conditions:

(a) Local damage in terms of penetration, perforation, and spalling, which is evaluated using the TM 5-855-1 formula (Reference 3H.6-1).

(b) Structural response in terms of deformation limits, strain energy capacity, structural integrity, and structural stability, which is evaluated in accordance with BC-TOP-9A (Reference 3H.6-2).

(4) Tornado Load Combinations

Tornado load effects are combined as follows:

$$W_t = W_p$$

$$W_t = W_w + 0.5W_p + W_m$$

3H.6.4.3.3.2 Safe Shutdown Earthquake Loads (E')

The SSE loads are applied in three orthogonal directions— two horizontal directions and the vertical direction. The total structural response is predicted by combining the applicable maximum co-directional responses in accordance with RG 1.92.

The SSE loads are based on free-field peak ground motions consistent with the ground motion response spectra defined in Subsection 3H.6.5.1.1. The loads consist of vertical forces, horizontal forces, torsional moments, and overturning moments.

3H.6.4.3.4 Load Combinations

The load combinations and structural acceptance criteria used to evaluate the site-specific Category I concrete structures are consistent with the provisions of ACI 349, as supplemented by RG 1.142 as well as ACI 350. Loads T_o, R_o, T_a, R_a, P_a, and E_o, as defined in ACI 349, are not applicable to the evaluation of the site-specific seismic Category I structures and are not included in the load combinations defined below.

3H.6.4.3.4.1 Notation

S = Allowable stress for allowable stress design method

U = Required strength for strength design method

D = Dead load

F = Hydrostatic load

L = Live load

Lo = Live load concurrent with SSE

H = Lateral soil pressure and groundwater effects

H' = Lateral soil pressure and groundwater effects, including dynamic effects

W = Wind load

Wt = Tornado load

E' = SSE load, including associated hydrodynamic loads

3H.6.4.3.4.2 Structural Steel Load Combinations

$S = D + L$

$S = D + L + W$

$1.6S = D + L + Wt$

$1.6S = D + L_o + E'$

3H.6.4.3.4.3 Reinforced Concrete Load Combinations

$U = 1.4D + 1.7F + 1.7L + 1.7H$

$U = 1.4D + 1.7F + 1.7L + 1.7H + 1.7W$

$U = D + F + L + H + W_t$

$U = D + F + L_o + H' + E'$

$U = 1.05D + 1.05F + 1.3L + 1.3H$

$U = 1.05D + 1.05F + 1.3L + 1.3H + 1.3W$

For the UHS basin, the required strength defined by the above load combinations are multiplied by the following Environmental Durability Factors (S) defined in ACI 350:

- Flexural strength .... S = 1.3
- Axial tension (including hoop tension) .... S = 1.65

- Excess shear strength carried by shear reinforcement..S = 1.3

3H.6.4.4 Materials

Structural materials used in the design of the site-specific Category I structures are as follows:

3H.6.4.4.1 Reinforced Concrete

Concrete conforms to the requirements of ACI 349. Its design properties are:

- Compressive strength ....27.6 MPa
- Modulus of elasticity .... 24.8 GPa
- Shear modulus .... 10.6 GPa
- Poisson's ratio 0.17

3H.6.4.4.2 Reinforcement

Deformed billet steel reinforcing bars are considered in the design. Reinforcement conforms to the requirements of ASTM A615. Its design properties are:

- Yield strength ....414 MPa
- Tensile strength ....621 MPa

3H.6.4.4.3 Structural Steel

High strength, low-alloy structural steel conforming to ASTM A572, Grade 50 is considered in the design. The steel design properties are:

- Yield strength ....345 MPa
- Tensile strength ....448 MPa

3H.6.4.4.4 Steel Grating

Grating conforming to ASTM A36 is considered in the design. The design properties are:

- Yield strength ....248 MPa
- Tensile strength ....400 MPa

3H.6.4.4.5 Anchor Bolts

Material for anchor bolts conforms to the requirements of ASTM F1554, Grade 36. Its design properties are:

- Yield strength ....248 MPa

- Tensile strength ....400 MPa

3H.6.4.5 Stability Requirements

The following minimum factors of safety are required against overturning, sliding, and flotation:

Load Combination	Overturning	Sliding	Flotation
D + F' [1]	–	–	1.1
D + H + W	1.5	1.5	–
D + H + W_t [1]	1.1	1.1	–
D + H' + E' [1]	1.1	1.1	–

[1] Based on the section of the basin for one unit being empty, while the section for the other unit is filled to a level 1.52 meters (5'-0") below the normal low-water level.

Loads D, H, H', W, W_t, and E' are defined in Subsection 3H.6.4.3.4.1. F' is the buoyant force corresponding to the flood water level.

3H.6.5 Seismic Analysis

3H.6.5.1 Seismic Design Parameters

3H.6.5.1.1 Design Ground Motion

3H.6.5.1.1.1 Design Response Spectra

Site-specific horizontal and vertical ground motion response spectra (GMRS) for the SSE are developed for the STP 3 & 4 site. The development of these spectra is documented in Subsection 2.5S.2.

3H.6.5.1.1.2 Design Time Histories

Acceleration time histories consistent with the GMRS defined in Subsection 2.5S.2 are developed for use as input to the seismic analysis. The time histories (two horizontal and one vertical) comply with the response spectra and power spectral density enveloping criteria as well as the cross-correlation criteria specified in RG 1.206.

3H.6.5.1.2 Percentage of Critical Damping Values

The percentages of critical damping values considered in the seismic analysis for site-specific seismic Category I structures and associated systems and components are in accordance with the criteria defined in RG 1.61. This includes consideration of the calculated stress levels when establishing the appropriate damping values to be used.

The strain-compatible, soil-damping values considered in the seismic analysis are defined in Subsection 2.5S.4.

3H.6.5.1.3 Supporting Media for Seismic Category I Structures

Soil conditions at the STP 3 & 4 site are described in Subsection 2.5S.4. The soil at the site extends down several thousand feet and consists of alternating layers of clay, silt, and sand.

The characteristic dimensions of the above grade site-specific seismic Category I structures are summarized below:

Structure	Embedment Depth to Bottom of Foundation	Maximum Height[1]	Base Dimensions
UHS Basin	9.75 meters [2]	17.4 meters	115.8 meter diameter x 2.44 meter thick foundation
UHS Cooling Towers	[3]	33.2 meters	84.1 meters x 14.0 meters [3]
RSW Pump Houses Pump Bays	[3]	27.1 meters	12.5 meter x 33.5 meter [3]
RSW Pump Houses Operating Floors	17.7 meters [4]	27.1 meters	18.0 meter x 34.1 meter [4]

[1] As measured from the bottom of the foundation.

[2] Does not include the berm that surrounds the basin and varies in depth from 2.74 meters to 5.79 meters.

[3] Located within the basin and supported on the 2.44 meter thick basin foundation.

[4] Supported on 2.44 meter thick extensions of the basin foundation.

3H.6.5.2 Seismic System Analysis

3H.6.5.2.1 Seismic Analysis Methods

The site-specific seismic Category I structures at STP 3 & 4 consist of the UHS basin, two UHS cooling tower enclosures, two RSW pump houses, and two RSW piping tunnels. While the basin, cooling towers, and pump houses share a common foundation, the tunnels extend from the two pump houses to the corresponding control buildings. Seismic analyses of these structures were performed using simplified models, SSE damping values, and RG 1.60 spectra normalized to 0.15g. Results from these analyses were used in combination with other applicable loads to develop conceptual designs of the structures that were then used to define the structural models considered in the final seismic analysis that is described in Subsection 3H.6.5.2.3.

The final seismic analysis of the site-specific seismic Category I structures is a frequency-domain time history analysis. Analyses are performed for three orthogonal (two horizontal and one vertical) directions and account for the translational, rocking, and torsional responses of the structures and foundations.

3H.6.5.2.2 Natural Frequencies and Responses

As discussed in Section 3H.6.2, the natural frequencies and the seismic responses of the UHS cooling tower enclosures and RSW pump houses will be provided upon completion of the final seismic analysis.

3H.6.5.2.3 Procedures Used for Analytical Modeling

The seismic analysis of the UHS basin and two cooling tower enclosures as well as the two RSW pump houses is performed using the three-dimensional finite element model shown in Figure 3H.6-1. The model consists primarily of plate elements that represent the reinforced concrete basin walls and foundation as well as the walls and slabs of the cooling towers and pump houses. Beam elements are used to represent concrete columns and concrete and steel beams in the cooling towers. Finally, brick elements are used to represent a soil berm surrounding the basin and pump houses as well as concrete piers located in the pump bays.

Because of the symmetry of the combined structures, only half of the structures are represented in the model, with appropriate boundary conditions being defined along the plane corresponding to the axis of symmetry.

The mass of the structures is represented primarily by the density of the plate, beam, and brick elements comprising the model. These densities have been appropriately modified to account for applicable live loads. Concentrated masses have been used to represent the weight of the pumps and strainers in the pump houses, and the impulsive water mass that has been calculated using the procedure defined in Commentary Subsection C3.5.4 of ASCE 4.

The seismic analysis of the RSW piping tunnels will address the effects of seismic waves on the tunnels as well as lateral earth pressures and groundwater effects.

3H.6.5.2.4 Soil-Structure Interaction

Soil-structure interaction (SSI) effects are accounted for by the use of the SASSI computer program in conjunction with time histories described in Subsection 3H.6.5.1.1.2 and the structural model described in Subsection 3H.6.5.2.3. The SASSI analysis addresses the embedment of the structure, groundwater effects, the layering of the soil, and variations of the strain-dependent soil properties.

3H.6.5.2.5 Development of In-Structure Response Spectra

In-structure response spectra are developed as part of the SSI analysis in accordance with RG 1.122. This includes combining the seismic response spectra in all three orthogonal directions by the square-root-of-the-sum-of-the-squares (SRSS) method to define the response spectra in a given direction and the smoothing and broadening of the resulting spectra.

3H.6.5.2.6 Three Components of Earthquake Motion

Separate analyses are performed in three orthogonal (two horizontal and one vertical) directions. Total structural responses (accelerations, displacements, and forces) are calculated by combining the co-directional responses in accordance with RG 1.92.

3H.6.5.2.7 Combination of Modal Responses

Since a frequency-domain seismic analysis is performed, there will be no modal responses to be combined.

3H.6.5.2.8 Interaction of Non-Category I Structures with Category I SSCs

There are no non-Category I structures near the site-specific seismic Category I structures. Consequently, there is no interaction between non-Category I and the site-specific seismic Category I structures.

3H.6.5.2.9 Effects of Parameter Variations on Floor Responses

The soil property variation referred to in Subsection 3H.6.5.2.4 is accounted for in the generation of the floor response spectra (FRS). In addition, the impact of variations in the input parameters to the seismic analysis is accounted for by broadening the FRS in accordance with RG 1.122.

3H.6.5.2.10 Use of Equivalent Vertical Static Factors

Since a separate seismic analysis is performed for the vertical direction, equivalent static factors are not used to define the vertical seismic responses.

3H.6.5.2.11 Methods Used to Account for Torsional Effects

The effect of torsion on the seismic responses is accounted for by the use of a three-dimensional model of the structures in the seismic analysis.

The detailed structural analyses are performed using the results from the seismic analysis account for eccentricities of plus and minus 5% in both horizontal directions.

3H.6.5.2.12 Comparison of Responses

Since only a frequency-domain analysis is performed, there will be no comparison of responses.

3H.6.5.2.13 Analysis Procedure for Damping

The SSI analysis accounts for the structural and soil-damping described in Subsection 3H.6.5.1.2.

3H.6.5.2.14 Determination of Seismic Overturning Moments and Sliding Forces for Seismic Category I Structures

The evaluation of seismic overturning moments and sliding accounts for the simultaneous application of forces in three directions.

3H.6.6 Structural Analysis and Design Summary

3H.6.6.1 Analytical Models

The structural analysis of the UHS basin, UHS cooling tower enclosures, and RSW pump houses is performed using the three-dimensional finite element model shown in Figure 3H.6-1, with the brick elements representing the berm deleted. A separate model will be developed for use in the evaluation of the RSW piping tunnels and will be described in the FSAR update discussed in Subsection 3H.6.2.

3H.6.6.2 Analytical Approach

3H.6.6.2.1 UHS Basin, UHS Cooling Tower Enclosures, and RSW Pump Houses

A static analysis is performed on the finite element model shown in Figure 3H.6-1. This analysis considers the following loads, combined in accordance with Subsection 3H.6.4.3.4:

- Dead and live loads on the UHS basin, UHS cooling tower enclosures, and RSW pump houses as specified in Subsection 3H.6.4.3.1, plus the weight of the UHS cooling tower fill, the RSW pumps, and the RSW strainers.
- Hydrostatic and hydrodynamic (impulsive and convective) loads corresponding to the water in the basin, on the walls of the UHS basin and cooling tower enclosures, and the piers of the RSW pump houses. These loads are calculated in accordance with Subsection C3.5.4 of ASCE 4.
- At-rest lateral soil pressure on the walls of the UHS basin and RSW pump houses.
- Hydrostatic pressures on the walls of the UHS basin and RSW pump houses due to groundwater.
- Dynamic lateral soil pressures on the walls of the UHS basin and RSW pump houses due to an SSE, calculated using the methodology defined in Subsection 3.5.3.2.2 of ASCE 4.
- Surcharge pressure of 300 psf (14.4 kPa) applied to the access road surrounding the UHS basin and RSW pump houses.
- SSE forces corresponding to the weight of the structures being acted on by the accelerations established by the SSI analysis.

- Wind loads on the UHS basin, UHS cooling tower enclosures, and RSW pump houses calculated as indicated in Subsection 3H.6.4.3.2.
- Tornado wind and pressure loads on the UHS basin, UHS cooling tower enclosures, and RSW pump houses calculated as specified in Subsection 3H.6.4.3.3.1.

3H.6.6.2.2 RSW Piping Tunnels

A static analysis is performed on the finite element model of the RSW piping tunnels. This analysis considers the loads identified below, combined in accordance with Subsection 3H.6.4.3.4. In addition, SSE forces created in the tunnel walls due to the passage of seismic waves through the soil are considered.

- Dead load of the tunnel walls and the soil above the tunnel.
- Live load of 9.6 kPa applied to the floor of the tunnels.
- At-rest lateral soil pressure on the tunnel walls.
- Hydrostatic pressures on the tunnel walls due to groundwater.
- Dynamic lateral soil pressures on the tunnel walls due to an SSE calculated using the methodology defined in Subsection 3.5.3.2.2 of ASCE 4.
- Surcharge pressure of 23.9 kPa applied to the ground above the tunnels.
- SSE forces corresponding to the weight of the tunnels being acted on by the accelerations established by the SSI analysis.

3H.6.6.3 Structural Design

The strength design criteria defined in ACI 349 as supplemented by RG 1.142 as well as ACI 350, is used to design the reinforced concrete elements making up the UHS basin and cooling tower enclosures as well as the RSW pump houses and piping tunnels. Concrete with a compressive strength of 27.6 MPa and reinforcing steel with a yield strength of 414 MPa are considered in the design.

3H.6.6.4 Foundations

The UHS basin, UHS cooling tower enclosures, and RSW pump houses share a common foundation. This foundation consists of a reinforced concrete mat supported on undisturbed soil or engineered structural backfill material. The RSW piping tunnels, which extend from each pump house to the corresponding control building, are provided with flexible connections at the building interfaces that prevent any potential movement of the buildings from creating forces or moments in the tunnels.

The loads and load combinations considered in the design of the common foundation mat are as defined in Subsection 3H.6.4.3. The design is in accordance with the strength design criteria defined in ACI 349 as supplemented by RG 1.142 as well as ACI 350, and will consider concrete with a compressive strength of 27.6 MPa and reinforcing steel with a yield strength of 420 MPa.

To prevent seepage of water through the common foundation or through the walls of the basin and pump houses, a chemical waterproofing agent is applied to the exposed concrete surface of the mudmat. In addition, a waterproof membrane installed on the walls up to one foot below grade, with a water proof coating being applied from that level up to the flood level. While, as indicated in FSAR Subsection 3.8.6.1, the waterproofing of the mudmat will not reduce the ability of the foundation to transfer horizontal shear forces to the underlying soil, the waterproof membrane will protect the walls from any possible deleterious effects from aggressive groundwater. To prevent seepage of groundwater into the tunnels, a waterproof membrane is used.

3H.6.6.5 Stability Evaluations

As discussed in Subsection 3H.6.2, the factors of safety of the combined UHS basin, UHS cooling tower enclosures, RSW pump houses, and RSW Piping tunnel against sliding, overturning, and flotation will be provided in a FSAR update upon completion of the final seismic analysis.

3H.6.6 References

3H.6-1 3H.6-1US Department of Army, Fundamentals of Protective Design for Conventional Weapons, TM 5-855-1, November 1986.

3H.6-2 3H.6-2“Design of Structures for Missile Impact,” Bechtel Topical Report BC-TOP-9A, Rev. 2, September 1974.

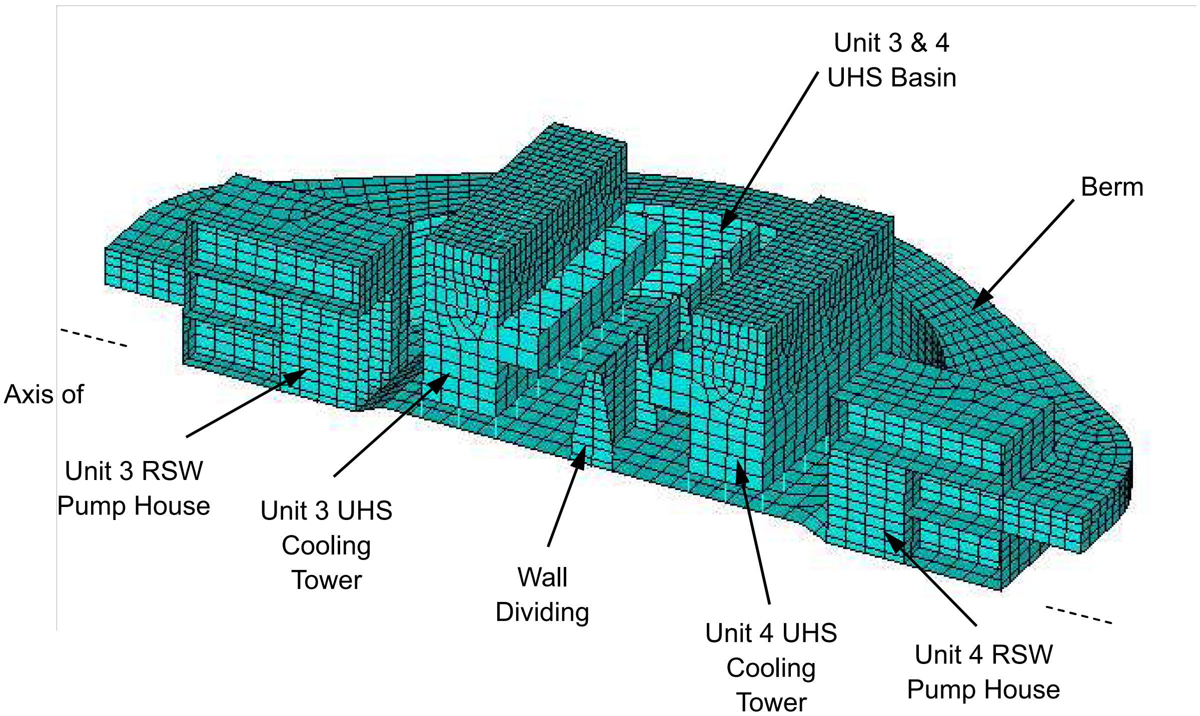

Figure 3H.6-1 Finite Element Model of UHS Basin, UHS Cooling Tower Enclosures, and RSW Pump Houses