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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002567

July 21, 2009

Subject: AP1000 Response to Request for Additional Information (TR 85)

Westinghouse is submitting responses to NRC requests for additional information (RAI) on Technical Report No. 85. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-TR85-SEB1-35 R2
RAI-TR85-SEB1-36 R2

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. A. Lindgren / FOR
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/Enclosure

1. Response to Request for Additional Information on Technical Report No. 85

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ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 85

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-35
Revision: 2

Question:

Section 2.9 indicates that the sliding resistance is based on the friction force developed between the basemat and the foundation using a coefficient of friction of 0.70. This is based on soil having a friction angle of 35 degrees. The Combined License will provide the site specific angle of internal friction for the soil below the foundation. Based on this information, address the following items:

a. Since DCD Section 3.8.5.5.3 indicates that the sliding factor of safety is based on the shearing or sliding resistance at the base of the basemat and the soil passive resistance, the reliance on both of these resisting forces need to be based on a consistent set of assumptions. Since the passive resistance of soil requires sufficient displacement to mobilize the full passive resisting forces at the foundation walls and side of the basemat, provide the technical basis for using a coefficient of friction of 0.70 for the sliding resistance beneath the basemat which is considered to be applicable to the static (not sliding or dynamic) friction resistance of soil.

b. What are the numerical contributions of the sliding frictional resistance and the soil passive pressure resistance for the NS and EW directions?

c. Has Westinghouse confirmed that using a minimum angle of internal friction of 35 degrees is achievable for most soil sites?

d. DCD Tier 1, Section 3.3, states that "Exterior walls and the basemat of the NI have a water barrier up to site grade level." Describe this water barrier and how does this affect the assumed coefficient of friction between the basemat and the soil? Is it high enough to ensure that soil friction would govern?

Additional Request (Revision 1):

Based on the review of the RAI response provided in Westinghouse letter dated 10/19/07, the following items need to be addressed:

a. The RAI response did not address the requested information in the RAI. In calculating the factor of safety for the basemat against sliding during earthquakes, Westinghouse combines the friction force at the bottom of the basemat and the maximum soil passive pressure resistance on the foundation walls and basemat vertical edge in order to obtain the total resistant force. Westinghouse is request to explain the basis for using the static coefficient of friction of 0.70 (which implies essentially no sliding of the basemat will occur) at the same time as the maximum soil passive resistance (which would require sufficient horizontal displacement of the foundation to mobilize the maximum passive resisting forces at the foundation walls and the side of the basemat). In other words, if the maximum soil passive pressure is relied upon to resist sliding, then the full static coefficient of friction cannot be utilized.

b. From the values given for the sliding resistance for the soil passive pressure, it appears that the soil passive resistance is an important contribution to the total sliding resistance of the foundation. Therefore, Westinghouse is requested to (1) describe how the maximum soil passive pressure resistance is calculated and the passive pressure distribution in the vertical direction and (2) describe whether saturated and/or unsaturated soil conditions were considered in your analysis and indicate which case governs.

c. The RAI response indicates that "soils can achieve a friction angle of 35 degrees which is addressed and answered in Question a of TR-85 RAI-35." However, the response to Question a of TR-85 RAI-35 did not demonstrate that a friction angle of 35 degrees can be achieved for a range of common soil profiles expected at various sites. The RAI response also indicates that "the basis being provided in Table RAI-TR85-1, which shows an internal friction angle of 35 degrees being included in the medium soil type (sand)." However the staff cannot identify what Table RAI-TR85-1 this statement is referring to. If the actual reference was intended to be Table RAI-TR85-37-1, then classifying soil as "medium soil type (sand)" by itself does not assure that a soil friction angle of 35 degrees can be achieved. Finally, the RAI response indicates that "Dense soil types and hard rock sites will also meet the minimum soil friction angle of 35 degrees, often proven to have a much higher friction angle." While this may be the case, the staff believes that demonstrating the required soil friction angle should be based on actual testing of the soil, and therefore, the staff is requesting that Westinghouse identify what type of testing will be required to be implemented by the COL applicants to demonstrate that the coefficient of friction for the soil material beneath the foundation at the site meets the required coefficient of friction used in the design. The response to the above items, should clearly demonstrate that the soil friction angle (and thereby the corresponding coefficient of friction) used in design can be achieved for a reasonable range of soil conditions expected to exist at plant sites.

d. The RAI response describes the types of waterproofing membranes that should be placed immediately beneath the upper mud mat, and on top of the lower mud mat or leveling concrete, which has been finished in accordance with ACI 301, Section 5.3.4.2.d. The staff requests that Westinghouse provide technical information which demonstrates that, for the types of waterproofing material proposed in the RAI response, the membranes can (1) achieve a coefficient of friction used in design (at this time specified as 0.70), (2) have the strength, with margin, to withstand the shear and compression loads from the NI, and (3) do not degrade over the design life of the plant under similar loading and environmental conditions in the mud mat concrete. In addition, since this waterproofing membrane is not soil, explain why the RAI response refers to a requirement for this material in terms of a minimum friction angle rather than a coefficient of friction. Describe the location in DCD Tier 1 and DCD Tier 2 for the requirements for the waterproofing membrane where the coefficient of friction and strength are specified.

Addition Request (Revision 2):

To address item b of the RAI response, Westinghouse selected Case number 15, which corresponds to dense sand, for the purpose of calculating the passive pressure. For design purposes of the foundation walls, this case can be considered appropriate. However, for calculating the appropriate value of passive resistance for use in the sliding stability evaluation, the use of the somewhat high value of passive resistance is considered to be unconservative. This becomes important since the response to RAI TR85-SEB1-37 implies that the soil friction angle of the backfill material could be as low as 32 degrees, based on a blow count as low as 10 blows per foot for the soil. Therefore, Westinghouse is requested to explain why, for sliding stability evaluation, a high value was used for the passive resistance of the backfill rather than a lower bound value such as Case 21. In addition, explain what specific passive pressure load(s) were used in the design of the foundation walls and how they compare to the Case number 15 value.

To address item d of the RAI response, Westinghouse indicated that they have reduced the requirement for the coefficient of friction of the waterproofing membrane to 0.55, which is the revised value utilized in the sliding evaluation. This requirement will be specified in DCD Section 3.4.1.1.1.1. However, the proposed mark-up of Section 3.4.1.1.1.1 in DCD Tier 2 does not identify this as a requirement to be satisfied by the COL applicant. Instead it indicates that "The specific static coefficient of friction between horizontal membrane and concrete is 0.55"." Westinghouse is requested to identify where in Section 2 of the DCD, a clear statement is made that this is a requirement to be demonstrated by the COL applicant by testing.

For waterproofing the foundations of the NI, several options are described in DCD Tier 2, Section 3.4.1.1.1.1. The options rely on either a textured waterproofing membrane or the use of crystalline material as an additive or sprayed-on membrane to the concrete. For the option which utilizes the textured waterproofing membrane discussed in DCD Section 3.4.1.1.1.1, more detailed information should be provided such as the type of waterproofing material, minimum thickness, and whether the provisions of an industry standard such as ACI 515.1R-79 (revised 1985) will be used.

For the option of the crystalline material for waterproofing the foundation, this appears to be a new approach to be used in the foundations of nuclear power plants with are deeply embedded, have large bearing pressures and shear forces, and high ground water levels. Therefore, Westinghouse should provide technical information that clearly demonstrates that the use of the crystalline material as an additive or sprayed-on membrane to the concrete is effective under similar loading conditions and groundwater pressure levels of the AP1000 design. Provide information that demonstrates the largest crack size in concrete (under this head of water) that the crystalline material is effective. Explain what provisions have been included in the design of the foundation to ensure that the expected cracks will not exceed these limit(s). Also, explain why sprayed-on crystalline material is presented as an option when it is clear that utilizing crystalline material as an additive within the concrete mix, and then supplemented by surface patching with crystalline wherever cracks may develop (subsequent to curing of the mudmat), would be much more effective.

Westinghouse Response:

a. Using the formula tan(δ) = φ (tan(35°) = 0.70), Terzaghi, Karl, and Ralph B. Peck, Soil Mechanics in Engineering Practice, the technical basis for using a coefficient of friction of 0.70 for the sliding resistance beneath the basemat is justified. Furthermore the coefficient of wall friction, the value of angle δ between concrete and soil, usually is taken as equal to the angle of internal friction φ of the soil medium, with the coefficient of friction being 0.70 for sound rock sites.

b. The sliding frictional resistance is 142,373 kips, with numerical contributions from the plant deadweight = 281,223 kips, buoyant force = 76,003 kips and vertical wind load = 1,830 kips. The soil passive pressure resistances for the NS and EW directions are 43,456 kips and 69,098 kips respectively.

c. The soils can achieve a friction angle of 35 degrees which is addressed and answered in Question A of TR-85 RAI35. The basis being provided in Table RAI-TR85-1, which shows an internal friction angle of 35 degrees being included in the medium soil type (sand). Dense soil types and hard rock sites will also meet the minimum soil friction angle of 35 degrees, often proven to have a much higher friction angle.

d. A Waterproofing Membrane should be placed immediately beneath the upper Mud Mat, and on top of the lower Mud Mat or leveling concrete, which has been finished in accordance with ACI 301, Section 5.3.4.2.d. This bottom (horizontally planar) geosynthetic membrane should be textured on both sides to maintain minimum sliding coefficient requirements. For plasticized polyvinyl chloride (PVC) membranes, a geocomposite should be formed by applying a geotextile to both sides of the PVC geomembrane, such as CARPI USA's "SIBELON 2CNT" liner. For high-density polyethylene (HDPE) membranes, the geosynthetic should be spiked or studded on both sides, such as AGRU-America's "Super Gripnet Liner." As the membrane transitions to the walls of the Nuclear Island (vertically planar), a smooth geosynthetic liner may be used since sliding is not a design concern along these vertical planes.

   A Waterproofing Membrane is to be selected such that for horizontal surfaces, the minimum friction angle achieved at any interface is at least 35 degrees, yielding a friction coefficient of at least 0.7, to be consistent with AP1000 DCD requirements. In order to provide the durability required for construction and implementation, as well as the flexibility for a manageable installation, it has been recommended from multiple vendors that the Waterproofing Membrane have a thickness of 80 mils, both for HDPE or PVC.

Westinghouse Response (Revision 1):

a. As noted in response to RAI-TR85-SEB1-10, Revision 1, the full passive pressure is not being used, only a portion. The static coefficient of friction has been lowered to 0.55. The maximum deflection of the nuclear island needed to develop the needed passive pressures are less than 0.15 inch for hard rock, less than or equal to 0.5 inch for upper bound soft to medium (UBSM) and soft to medium (SM) soil conditions. The other soil conditions have smaller deflection requirements than the UBSM and SM cases. Therefore, the maximum soil passive pressure is not relied upon to resist sliding.

b. (1) The method used to calculate the passive pressure is given below for the Nuclear Island walls below grade. There is no passive soil pressure resistance component in the vertical direction. Resistance in the vertical direction is supplied by the soil subgrade bearing capacity.

The coefficient of passive pressure (K_P) is determined from the following relationship:

$K_P = \mathrm{Tan}^2(45^\circ + \phi / 2)$ (Rankine Method with no wall friction and horizontal ground surface)

Where, ϕ = angle of internal friction of the granular backfill.

The passive earth pressure is calculated by the following formula:

$P_P = K_P \gamma h$

Where,
h = depth below grade (100' 0")
Above water table: $\gamma = \gamma_s$ = Saturated unit weight of granular back fill above water table.
Below water table: $\gamma = \gamma_s - \gamma_w$

Recognizing that the ground water table is at 98 feet plant elevation, the formula for the passive pressure at the base, 60' 6" can be written as follows:

$$P_P = [\mathrm{Tan}^2(45^\circ + \phi / 2)] \times [(100 - 98) \times \gamma_s + (98 - 60.5)(\gamma_s - \gamma_w)]$$

(2) The passive earth pressures are defined for 21 soil cases in Table RAI-TR85-SEB1-35-1 for soil types of rock, sand and gravel, and sand. As seen from this table, the highest loads are obtained for the rock cases. However, it is unrealistic to consider the properties for in-place rock to be similar to those of for the backfill material. A more representative soil is between dense and medium sand (case 15), which is the same as used for the AP600 plant.

The general geotechnical model for the site contains a static ground water level 2 feet below the horizontal ground surface. The horizontal ground surface is assumed at elevation 100 feet and the static ground water level is at elevation 98 feet. A saturated unit weight density of the soil above and below the ground water level has been assigned a value of 150 pounds per cubic foot (pcf) for the Case 15 granular (dense sand) soil model.

Table RAI-TR85-SEB1-035-1 – Passive Pressure, El. 60' 6"

Type of Soil		Case	γ_{sub} #/ft^3	γ_{sat} #/ft^3	ϕ deg	P_P psf
Rock	Hard Rock	1	115	175	46	28563
	Rock	2	100	160	46	24933
	Soft Rock	3	100	160	52	34328
	Soft Rock	4	100	160	43	21527
	Soft Rock	5	85	145	52	29331
	Soft Rock	6	85	145	43	18393
Sand & Gravel		7	80	140	36	12634
		8	80	140	32	10675
Sands	Very Dense	9	100	160	46	24933
		10	100	160	41	19597
		11	70	130	46	17674
		12	70	130	41	13891
	Dense	13	88	150	41	17334
		14	88	150	36	13867
		15	87.6	150	35	13229
		16	65	110	36	10236
		17	65	110	36	10236
	Medium	18	68	130	36	10824
		19	68	130	32	9145
		20	60	95	36	9398
		21	60	95	32	7941

c. In Chapter 2 of the AP1000 Design Control Document, Revision 17, Table 2-1site characteristics for which the AP1000 is designed are provided. It is stated:

> "The site is acceptable if the site characteristics fall within the AP1000 plant site design parameters in Table 2-1. Should specific site parameters or characteristics be outside the envelope of assumptions established by Table 2-1, the Combined License applicant referencing the AP1000 will demonstrate that the design satisfies the requirements imposed by the specific site parameters

and conforms to the design commitments and acceptance criteria described in the AP1000 Design Control Document."

In Table 2-1 the Minimum Soil Angle of Internal Friction is defined to be Greater than or equal to 35 degrees below footprint of nuclear island at its excavation depth. It should not be Westinghouse's responsibility to identify what type of testing will be required to be implemented by the COL applicants to demonstrate that the coefficient of friction for the soil material beneath the foundation at the site meets the required coefficient of friction used in the design. This is the responsibility of the COL applicants. Therefore, the Combined License applicant must demonstrate that they have a friction angle of 35 degrees using the testing procedures defined by them.

d. Reference to the angle of friction should not have been given in the initial response, only the coefficient of friction for the membrane. In Section 3.4.1.1.1.1, Revision 17 Tier 2, the requirement related to coefficient of friction and the horizontal membrane is given:

"... the membrane between the mudmats must transfer horizontal shear forces due to seismic (SSE) loading. This function is seismic Category I. The specific static coefficient of friction between horizontal membrane and concrete is ≥0.7."

The requirement for the coefficient of friction will be changed to 0.55. Tests will be performed that demonstrate that this coefficient of friction is achieved.

For strength and durability requirements of the membrane it has been recommended from multiple vendors that the Waterproofing Membrane have a thickness of 80 mils, both for HDPE or PVC. However, it is noted that if the membrane looses strength or degrades over its life, this will not result in a lower coefficient of friction than 0.55 since the surface will be concrete on concrete. In accordance with Reference 2, Section 11.7.4.3, the coefficient of friction shall be taken as a) 1.0 for normal weight concrete placed against hardened surface intentionally roughened as in Section 11.7.9 or b) 0.6 for normal weight concrete placed against hardened surface not intentionally roughed. Case b) could result if the waterproofing membrane looses strength of degrades over time. However, the alkaline (concrete) environment in which the HDPE membrane will be placed is not detrimental to this material.

Westinghouse Response (Revision 2)

b. A lower bound soil case similar to Case 21 was considered. This evaluation is described in RAI-TR85-SEB1-10, Revision 2. Full passive pressure is used in the design of the Nuclear Island walls below grade. The value of the passive pressure is defined using the Case 15 soil properties. This is discussed in RAI-TR85-SEB1-02, Revision 2.

d. Proposed changes to the DCD in this revision are offered with the intent of defining the performance requirements for waterproofing and eliminating the current restrictions on the systems acceptable for use. Changes incorporate COL applicant's requirement to provide waterproofing membrane capabilities and material properties.

Reference:

1. Terzaghi, Karl, and Ralph B. Peck, Soil Mechanics in Engineering Practice, John Wiley & Sons, Inc., New York, 1948.
2. Building Code Requirements for Structural Concrete (ACI 318-05), American Concrete Institute, 2005

Design Control Document (DCD) Revision:

3.4.1.1.1.1 Waterproofing

A waterproof membrane or waterproofing system for the seismic Category I structures below grade will be installed as an architectural aide to limit the infiltration of subsurface water. The seismic Category I structures below grade are protected against flooding by this water barrier. COL applicant will utilize a waterproofing system for the below grade, exterior walls exposed to flood and groundwater that will maintain a friction coefficient ≥0.55 with all unbonded concrete surfaces for the life expectancy of the plant and will not introduce a slip plane increasing the potential for movement during an earthquake. (See Section 3.8.5.5.3) Typical waterproofing approaches are described as follows:

- HDPE Double-Sided Textured Waterpoof Membrane

  Figures 3.4-1 and 3.4-2 show the typical application of this waterproofing approach for a mechanically stabilized earth (MSE) wall and for a step-back configuration.

- Sprayed-on Waterproofing Membrane

  This method may be used either for soil sites, in conjunction with an MSE wall, or for rock sites, where an open excavation may be used. Figure 3.4-3 shows the typical installation using MSE walls with the sprayed-on waterproofing membrane placed on the MSE wall panels and between the two layers of the mudmat. Where the vertical face of excavation is used as a form for the exterior walls, the waterproof membrane is installed on the vertical face of the excavation prior to placement of concrete in the exterior walls.

The waterproof function of the membrane is not safety-related; however, the membrane between the mudmats must provide adequate shear strength to transfer horizontal shear forces due to seismic (SSE) loading. This function is seismic Category I. The waterproof membrane will have physical properties, including surface and texture, to achieve the required static coefficient of friction. Primer, geotextile, or aggregate scatter may be added as required.

DCD Figures Removed:
3.3.3

DCD Figures Modified to include the phase, "Typical Details of...":
3.3.1, 3.3.2, 3.3.4

Modify Section 2.5.4.1.3, Tier 2 to read as follows:

The waterproofing system is described in subsection 2.5.4.6.12.

Include Section 2.5.4.6.12, Tier 2 to read as follows:

2.5.4.6.12 Waterproofing System – The Combined License applicant will provide a waterproofing system used for the below grade, exterior walls exposed to flood and groundwater under seismic Category I structures. Waterproofing membrane should be placed immediately beneath the upper Mud Mat, and on top of the lower Mud Mat. The performance requirements to be met by the COL applicant for the waterproofing system are described in subsection 3.4.1.1.1.1.

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-36
Revision: 2

Question:

Section 5.1 presents the proposed revisions to DCD Tier 2, Table 2-1, which contains the Site Parameters including those for the soil media. Section 5.2 presents the proposed revisions to DCD Tier 1, Table 5.0-1, which also contains the Site Parameters for the soil. Considering that now the foundation of the AP1000 design has been extended to soil sites, both tables should include the additional items listed below or justification provided for not including the items.

a) Minimum required soil friction angle for soils below and adjacent to the NI. A minimum value of 35 degrees was used in the foundation stability calculations.

b) Settlement Criteria - maximum settlement at key locations (e.g., the corners of the basemat and west side of the shield building), maximum average settlement considering these key locations, maximum differential displacement (e.g., between key locations), and maximum differential displacement between any adjacent structures. Considering the relatively thin 6'-0" basemat for the NI, this criteria is considered important to ensure that there will not be significant settlement which might compromise the structural integrity of the NI basemat and foundation. Also, meeting differential settlement criteria would maintain adequate gap with adjacent structures under seismic loadings to preclude impact. The approach or basis for the selected settlement values should be described.

Additional Request (Revision 1):

The proposed revision to the DCD does not clearly state what is required regarding the evaluation for settlement. As an example, Sections 2.5.4.3 and 2.5.4.6.11 state that "Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values in Table 2.5-1." Therefore, Westinghouse is requested to explain whether the intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements before construction activities begin. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. These predicted displacements would then be compared to the proposed acceptable settlement values (considered in design), which are presented in Table 2.5-1 of the RAI response. If the predicted displacements exceed the limits of acceptable settlement, then a detailed evaluation and plan needs to be developed before proceeding with the construction. As construction begins, actual measured settlements would then be compared to the predicted settlement values and if exceeded, then a detailed evaluation and plan needs to be developed before proceeding with the construction. If this is the intent of the DCD settlement criteria, then revise DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information, and DCD Tier 1, Section 5 - Site Parameters to clearly describe the settlement criteria requirements in terms of the items discussed above. Otherwise, provide the technical basis for not doing so.

Additional Request (Revision 2):

Based on the information provided in Revision 1 to this RAI response, Westinghouse is requested to provide the staff with the following information:

(a) If acceptable soil sites are already known to cause potential settlements of as much as one foot as previous studies have indicated, it can be expected that construction settlements will in fact exceed the listed limitations of 3 inches for most soil sites. Buildings of the size and dead load of the NI can be routinely expected to settle well in excess of 3 inches, even at relatively stiff soil sites. Therefore, explain why Table TR85-SEB1-36-1 and the corresponding mark-up of DCD Table 2.5-1 do not present the larger, more realistic and expected settlement value for the NI. Also, explain what should be the components of the detailed plan that the COL applicant needs to implement when the predicted settlements in fact exceed 3 inches.

(b) As is well known in geotechnical engineering, the ability to predict settlements at deep soil sites is difficult at best, with much uncertainty in predictions, even when making conservative assumptions of soil properties. If any of the predicted settlements are indicated to be less than three inches for the total settlement as well as less than the other values presented in Table 2.5-1, and measured settlements during construction are found to seriously exceed these values before completion of construction, what should be the impact on the follow-on construction process and what is the requirement for the COL applicant?

Westinghouse Response:

a) The minimum required soil friction angle has been added to both Tables 2-1 and 5.0-1 in accordance with Westinghouse's response to RAI-TR-SEB1-37.

b) DCD subsection 2.5.4.6.11 requires the Combined License applicant to evaluate settlement at soil sites. These evaluations may be performed assuming rigid basemat behavior of the nuclear island and the adjacent buildings.

The effect of settlement on the nuclear island basemat during construction has been considered in the design of the nuclear island as described in Section 2.5 of the report and in DCD subsection 3.8.5.4.2. These analyses consider the flexibility of the basemat during construction. They consider a soft soil site with properties selected to maximize the settlement during construction. These analyses show total settlements of about one foot. The analyses demonstrate that even this significant settlement does not compromise the structural integrity of the NI basemat and foundation.

Westinghouse has established guidance on settlement for the Combined License applicant shown in Table TR85-SEB1-36-1. If site specific settlement analyses predict settlement below the values in this table, the site is acceptable without additional evaluation. If the analyses predict greater settlement, additional evaluation will be performed. This may include specification of the initial building elevations, specification of the stage of construction and settlement for making connections of systems between buildings, etc. It would also include review of the effect of the rotation of buildings and its effect on the gap between adjacent structures. These analyses would provide the basis for review of settlement measurements during construction and subsequent operation.

Acceptable differential settlement between buildings without additional evaluation is identified as 3 inches between the Nuclear Island and the Turbine Building, the Annex Building, and the Radwaste Building. The 3 inches is measured from the center of the Containment Building to the center of the Turbine Building, center of the Annex Building, or the center of the Radwaste Building. Each building, including the Nuclear Island, also has a settlement criterion of no more than ½ inch in 50 feet in any direction. The Nuclear Island has a maximum absolute settlement value of 3 inches.

TABLE TR85-SEB1-36-1
Limits of Acceptable Settlement Without Additional Evaluation

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential between Nuclear Island and Turbine Building.	Differential between Nuclear Island and Other Buildings
½ inch 50 ft	3 inches	½ inch	½ inch

Westinghouse Response to Revision 1:

The intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements and provide them in the Combined License application. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. The predicted settlements will be based on conservative assumptions of soil properties. The predicted settlements would be compared to the settlement values in Table 2.5-1 of the DCD that are considered acceptable without further evaluation. If the predicted settlements exceed the limits of acceptable settlement, a detailed evaluation and plan will be described by the Combined License applicant before proceeding with the construction. As construction begins at a soil site, actual measured settlements would then be compared to the predicted settlement values and any exceedances would require additional investigation before proceeding with the construction.

A revision is shown below to DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information to clearly describe the settlement criteria requirements in terms of the items discussed above. This is Tier 2 information and does not require a revision to the DCD Tier 1, Section 5 - Site Parameters

Westinghouse Response to Revision 2:

(a) Table TR85-SEB1-36-1 contains triggers values that require the COL applicant to further investigate the site for the effects of long-term, rotational settlement. The limit values have been updated in this revision of the RAI to account for discussions of the May 4-8, 2009 Audit meeting, and are listed as follows and provided in Table TR85-SEB1-36-2, updated from Revision 1:

- Total for Nuclear Island Foundation Mat – 6 inches
- Differential between NI and adjacent buildings – 3 inches

TABLE TR85-SEB1-36-2
Limits of Acceptable Settlement Without Additional Evaluation

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential between Nuclear Island and Turbine Building.	Differential between Nuclear Island and Other Buildings
½ inch 50 ft	6 inches	3 inch	3 inch

In the case that the COL applicant's site specific predicted settlement analysis yields results exceeding these limit values, the following alternatives are presented:

1. Evaluate the impact of the elevated estimated settlement values on the critical components of the AP1000 including, but not limited to, piping spanning between the Nuclear Island and the adjacent structures, the equipment support pads, the construction gap between the NI and adjacent buildings, and the stresses on the basemat (along with influences to the underlying soil).

2. Submit a construction sequence to control the predicted settlement behavior. A revised sequence should follow the specific schedule to distribute construction loads as necessary in order to obtain acceptable values. Depending on soil conditions, a significant amount of the settlement could occur during construction, and can be controlled through the construction sequence.

3. Provide a uniform excavation and engineered backfill to manage static building rotation and differential settlement between the Nuclear Island and adjacent structures.

4. Implement an active settlement monitoring system throughout the entire construction sequence as well as a long-term (plant operation) plan. By monitoring the settlement throughout construction, the COL applicant will be able to modify the construction sequences of adjacent buildings to conform to the site's settlement characteristics and minimize differential settlement. For soil sites, the potential heave or rebound of the excavation bottom, the effect of dewatering and the effect of foundation loading during construction should be monitored by the COL applicant. The monitoring system shall consist of three primary elements as follows:

   - Piezometers to measure pore pressures in a soil layer prone to consolidation type settlement. Vibrating wire piezometers are preferred for this purpose as they are adequately sensitive and responsive and easily record positive and negative changes on a real time basis.

   - Settlement monuments placed directly on concrete, preferably on the Mud Mat for early construction monitoring and on the corners of the structures at grade once the Mud Mat monuments have been covered by backfill to be used for long term monitoring. Monuments at grade are to be accessible with conventional surveying equipment

   - Settlement telltales if monuments are not practical or if fills are used over consolidation type soils and it is necessary to monitor settlement of the consolidation type in-situ soils independent of the consolidation of the engineered fill soil. Most soil sites will not need this particular form of monitoring.

   Develop graphs and plots of the field measurements to:

   - Show Movement (settlement or heave) versus Time
   - Estimate Construction Loads versus Time
   - Measure Ground water levels from the dewatering activities versus Time

   This data should be maintained during construction and post-construction as needed depending on the field measurement results.

(b) If the actual settlement values obtained at any given stage of construction are significantly higher than the predicted values or those in Table TR85-SEB1-36 (Revision 1), whichever is higher, the COL applicant shall execute any applicable option(s) provided in section (b) of this RAI response to minimize differential settlement and assure adequate seismic gaps and proper installation of safety related systems and components.

References: None

Design Control Document (DCD) Revision:

The revisions to the DCD identified in Revision 0 of this response have been incorporated in DCD Revision 17. The following revisions are to DCD Rev 17 and include the changes made in Revision 1.

Revise subsections 2.5.4.3 and 2.5.4.6.11 as follows:

2.5.4.3 Settlement

The Combined License applicant will address short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure.

The AP1000 does not rely on structures, systems, or components located outside the nuclear island to provide safety-related functions. Differential settlement between the nuclear island foundation and the foundations of adjacent buildings does not have an adverse effect on the safety-related functions of structures, systems, and components. Differential settlement under the nuclear island foundation could cause the basemat and buildings to tilt. Much of this settlement occurs during civil construction prior to final installation of the equipment. Differential settlement of a few inches across the width of the nuclear island would not have an adverse effect on the safety-related functions of structures, systems, and components. Table 2.5-1 provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period or otherwise justified. The predicted settlements will be based on conservative assumptions of soil properties. If the predicted settlements exceed the limits of Table 2.5-1, a detailed evaluation and construction plan will be described by the Combined License applicant. During construction and plant operation at a soil site, settlements would be measured and compared to the predicted settlement values and any exceedances would require additional investigation.

Suggested alternatives for the additional evaluations are provided as follows:

1. Evaluate the impact of the elevated estimated settlement values on the critical components of the AP1000 including, but not limited to, piping spanning between the

Nuclear Island and the adjacent structures, the equipment support pads, the construction gap between the NI and adjacent buildings, and the stresses on the basemat (along with influences to the underlying soil).

2. Submit a construction sequence to control the predicted settlement behavior. A revised sequence should follow the specific schedule to distribute construction loads as necessary in order to obtain acceptable values. Depending on soil conditions, a significant amount of the settlement could occur during construction, and can be controlled through the construction sequence.

3. Provide a uniform excavation and engineered backfill to manage static building rotation and differential settlement between the Nuclear Island and adjacent structures.

4. Implement an active settlement monitoring system throughout the entire construction sequence as well as a long-term (plant operation) plan. By monitoring the settlement throughout construction, the COL applicant will be able to modify the construction sequences of adjacent buildings to conform to the site's settlement characteristics and minimize differential settlement. For soil sites, the potential heave or rebound of the excavation bottom, the effect of dewatering and the effect of foundation loading during construction should be monitored by the COL applicant. The monitoring system shall consist of three primary elements as follows:

   - Piezometers to measure pore pressures in a soil layer prone to consolidation type settlement. Vibrating wire piezometers are preferred for this purpose as they are adequately sensitive and responsive and easily record positive and negative changes on a real time basis.

   - Settlement monuments placed directly on concrete, preferably on the Mud Mat for early construction monitoring and on the corners of the structures at grade once the Mud Mat monuments have been covered by backfill to be used for long term monitoring. Monuments at grade are to be accessible with conventional surveying equipment

   - Settlement telltales if monuments are not practical or if fills are used over consolidation type soils and it is necessary to monitor settlement of the consolidation type in-situ soils independent of the consolidation of the engineered fill soil. Most soil sites will not need this particular form of monitoring.

   Develop graphs and plots of the field measurements to:

   - Show Movement (settlement or heave) versus Time
   - Estimate Construction Loads versus Time
   - Measure Ground water levels from the dewatering activities versus Time

This data should be maintained during construction and post-construction as needed depending on the field measurement results.

2.5.4.6.11 Settlement of Nuclear Island – Data will be provided on short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure. Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1.

Table 2.5-1

LIMITS OF ACCEPTABLE SETTLEMENT WITHOUT ADDITIONAL EVALUATION

Differential Across Nuclear Island Foundation Mat	**Total for Nuclear Island Foundation Mat**	**Differential Between Nuclear Island and Turbine Building***	**Differential Between Nuclear Island and Other Buildings***
1/2 inch 50ft	6 inches	3 inch	3 inch

* Differential settlement is measured at center of Nuclear Island and center of adjacent structures.

PRA Revision:

None

Technical Report (TR) Revision:

None