APPENDIX E

INTERNAL FLOODING

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E.1 INTERNAL FLOODING ANALYSIS INTRODUCTION

The objective of the IPE internal flooding analysis is to estimate the contribution of flooding, originating from station systems, to the core damage frequency at North Anna Power Station (NAPS) Units 1 and 2.

Internal flooding encompasses the effects from the accumulation, spraying or dripping of fluids arising from the rupture, cracking or incorrect operation of components within the station. In practice major internal floods have occurred in nuclear power plants, for example, from the rupture of pipes, valves and expansion joints as well as from operator errors during plant maintenance activities. All potential internal flood sources and causes are considered in this analysis, with the exception of those that result from the loss of primary or secondary reactor coolant outside the Containment (i.e., interfacing LOCAs or steam line breaks with failure to isolate). Such events are considered in the internal initiating events analysis of the IPE.

Internal flooding, like other so called "external events" merits consideration as a potentially significant risk contributor because of its potential for common cause equipment failures and/or human actions which may result in an accident initiating event (e.g., loss of Main Feedwater) and loss of one or more accident mitigating systems. The detailed analysis of such events is very plant specific, since their likelihood of progression and subsequent impact on plant systems is highly dependent on factors such as, layout, piping arrangements, drainage as well as the prevailing flood protection features and programs. Furthermore, in evaluating the frequency of flood induced accident sequences, the probability of coincident random equipment failures and operator errors must also be taken into account.

In theory, at least, the risk from all flood sources anywhere in the plant could be assessed in a detailed realistic manner. However, this is impractical due to the large number of potential flood sources, and unnecessary since floods in many areas can be shown to be insignificant contributors by simple bounding arguments and analyses. For the sake of efficiency the analysis is usually performed in several levels of detail, each one more refined than the previous. At the conclusion of each level of analysis some plant areas (or particular flood scenarios) are determined not to be significant while others are singled out for further analysis at the next level of detail.

Plant specific information required to evaluate the impact of flooding at North Anna was obtained mainly from the Appendix R safe shutdown submittal (Virginia Power, 1992c), UFSAR, (Virginia Power, 1992a), general arrangement and piping drawings and P&ID's. Previously performed deterministic evaluations of flood levels in Turbine Building (TB) and Auxiliary Building (AB) at North Anna

(SWEC, 1974, 1977) were also reviewed. In addition, information obtained during plant walk-downs and in discussions with North Anna plant staff proved invaluable.

The methodology involved in performing the flood analysis is summarized in Section E.2 and the analysis itself is discussed in Section E.3.

E.2 FLOOD ANALYSIS METHODOLOGY

E.2.1 Overall Approach

The analysis of internal floods consists of three basic phases:

1. a qualitative phase in which specific flood damage states are selected for quantification;
2. a quantitative phase in which the frequency of exceeding each damage state is determined; and
3. a final phase in which the systems and accident sequence analyses are performed.

The total contribution of flooding to core damage frequency (CDF) is subsequently determined by quantifying the following equation:

$$CDF = \Sigma_i FD_i (\Sigma_j P_{ij})$$

where P_{ij} is the probability of the core damage state j given flood state i with its initiating frequency FD_i. For this CDF calculation, all core damage accident sequences are included.

In the interests of efficiency, the analysis is conducted in four levels of detail, each one more refined than the previous one. At the conclusion of each level of analysis, some plant areas are determined not to be significant, while other areas are singled out for further analysis at the next level of detail.

At the first level of analysis, the plant is divided into broad areas, generally corresponding to the major plant buildings, that can be identified as having a significant degree of independence with respect to internal flooding. Flood propagation pathways for each area are identified at this stage. However, their analysis generally requires more detailed modeling and thus is deferred until the analysis of independent areas is complete. Flood frequencies are determined for each area from generic LWR flood data. The general manner in which the level of flood independence was established and the derivation of associated flood frequencies

are discussed in the following sections. The worst-case for a flooding event was determined by assuming that components located in the area where the flood originates fail with a probability of 1.0.

Event trees and fault trees constructed for the North Anna Internal Events PRA are then modified and requantified in order to evaluate the effects of flooding in each flood area in terms of the resulting accident sequence frequencies.

Evaluating the risk significance of a flood in a particular area, and deciding whether to proceed to a more refined analysis or categorize the area as nonsignificant, is done by comparing the worst-case flooding effect with a screening criterion that is based on the potential contribution to a core damage frequency. If the contribution was less than 1.0E-6/year, the flood scenario was not considered further.

At the second level of analysis, a more detailed examination of each broad flood location identified as potentially significant in the level-1 analysis is performed by considering the subdivisions of that broad location that can be regarded as physically independent flood areas. In doing so, it may be found that damage is much less severe for any given flood than was assumed in the level-1 analysis. The worst-case effects of flooding are again evaluated for each new independent flood area in exactly the same manner as before. Those plant areas that still remain potentially significant, according to the screening criterion, are considered in more detail in a level-3 analysis.

At the third level of analysis, it is not possible to redefine flood boundaries, since the smallest, physically independent areas have been considered at the second level. In order to be less conservative, the assumptions regarding "worst-case flooding effects" are refined and, if necessary, the probabilities and associated impacts of various intermediate stages leading up to those worst-case effects are determined. This is achieved by examining the location and size of potential flooding sources, the installed drainage systems, the location of equipment susceptible to flood damage, and the potential for operators to terminate the flood before significant damage occurs. The results of the level-3 analysis are final contributions to core damage frequency; that is, no further refinement of analysis is considered practicable.

In the fourth level of analysis, the inter-area flood propagation pathways that could not be ruled out on the basis of a qualitative analysis are evaluated quantitatively. The various factors included in this level are described in the following sections.

Finally, the various flood-induced accident sequence frequencies from each flood scenario are summed to obtain the overall contribution of flooding to the North Anna core damage frequency.

E.2.2 Plant Information Gathering

The plant is first divided into areas usually corresponding to the fire areas defined within the plants 10CFR50 Appendix R safe-shutdown analysis although non-safety related buildings such as the Turbine and Fuel buildings may be treated as single areas. Information concerning equipment and cable location, flood/fire mitigation features and flood sources is collected and documented.

E.2.3 Designation of Independent Flood Areas

In this sub-task various areas of the plant are designated independent with respect to internal flooding. An area is termed independent if flooding outside the area cannot intrude into the area without the failure of an enclosing flood barrier. Conversely, in the absence of a flood barrier failure, flooding in an independent area will not be the direct cause of failures outside the area. The concept is useful because it will allow the analyst to define the extent of common-cause failure attributed to a particular flood, and to assign frequencies to the flood.

The physical layout of the plant buildings together with the location and size of potential flood sources is considered in determining the independence of an area. It is useful to initially consider the plant as consisting of a few large independent areas, such as the Auxiliary Building, Turbine Building and Fuel Storage Building. These areas can be easily identified as independent with respect to internal flooding because they are distinct structures with only a few interconnecting pathways. These interconnections are generally in the form of personnel or equipment access ways or, in some cases, shared drainage systems. A review of the power station design was performed to identify design features (such as, watertight barriers, check valves in common drainage lines, and differences in floor elevations between buildings) that tend to inhibit any significant propagation of water from one building to the other. Other factors that may contribute to the independence of an area are physical separation, the presence of weir walls, and equilibrium flood heights compared with the lowest elevation of any opening in a flood barrier.

For plant structures containing safety related equipment (e.g., Auxiliary Building), the areas of independence were defined as smaller areas within a larger independent area. If possible, these areas were defined such that they contain components pertaining to a particular mitigating system. It should be noted that even non-watertight barriers may, under certain circumstances, be regarded as effectively providing independence; for example, a door in a stairwell will funnel virtually all water flowing down the stairwell to a lower elevation. Thus, the elevation to which the door provides access will not be susceptible to significant amounts

of water inflow from a higher elevation, even if the stairwell door is not watertight.

In considering the possibility of flood barrier failure, the failure modes will include: operational errors (e.g., watertight doors or hatchways left open); leakage through unsealed doors and hatchways; and mechanical failures (e.g., failure of check valves in common drain lines).

In general, the collapse of walls or leakage through construction joints were not considered to be important. (Although there have been instances of leakage through wall seams, the leakage rates have been minor and easily accommodated by installed drainage systems.)

A simplified station layout drawing showing major area boundaries at North Anna is shown as Figure E.2-1. Figure E.2-2 presents a cross sectional view of the plant site showing the SW reservoir and the buildings of interest in the flooding analysis.

E.2.4 Evaluation of Bounding Flood Frequencies

For the purpose of screening, flood frequencies are determined on the basis of United States nuclear power station experience from significant incidents reported in the following sources:

1) Oconee PRA

2) NUREG-1275

3) Electronic search of documentation found in the NRC Public document room

4) INPO Nuclear Network

The results of this search were originally used in the internal flooding analysis of Surry Power Station and a detailed description of the data search is available in the Appendix E of the Surry IPE (Virginia Power, 1991a).

E.2.5 Identification of Flood Induced Initiating Events and Mitigating System Damage

For each area in which a flood can occur, it is necessary to examine the flood susceptible equipment to determine which of the initiating events defined in the internal events study may occur and which accident mitigating systems may fail. A guide to the types of flood induced component failures is included as Table E.2-1. Generally all electrical equipment is assumed to be susceptible to damage. Cable raceways are not assumed to be

vulnerable. In the screening analysis, susceptible equipment is assumed to be damaged given that a flood occurs in an area or propagates to it unless damage can be easily ruled out on the basis of an inadequate maximum flood height and no possibility of spraying. Flood propagation is assumed to occur if a given pathway exists, unless it requires the failure of a physical barrier whose failure probability is independent of flood height. In this case propagation will be assumed to occur with a probability equal to the probability of the barrier failure.

In certain areas it will be possible for floods to cause more than one type of transient (floods are not usually capable of causing LOCAs). Since the objective of the screening analysis is to be conservative the most severe transient is assumed.

E.2.6 Determination of Realistic Frequency and Size (Flooding Rate) of Potentially Significant Flood Sources

For flood areas found to be potentially significant in the screening analysis it is necessary to obtain flood frequencies from each individual source of flooding in a given area (e.g., pipe, tank, valve, and expansion joint failures; major maintenance actions). The frequency of flooding from piping system failures is then determined on the basis of industry data on component leakage and rupture. Although this method to obtain flood frequencies is a time-consuming effort (and for this reason is applied only in the detailed analyses), it has the following advantages:

1. It permits a distribution of flood frequency versus flooding rate to be established, using hydraulic calculations when necessary.

2. It permits flood sources which result in inadequate equilibrium flood heights to cause damage to be dismissed (or at least their contribution to risk reduced).

3. It allows the prediction of flood frequency at a particular location within a flood area, which is important if the equipment failure mode being evaluated is attributable to spraying.

E.2.7 Definition of Flood Damage States

Following a flood incident, damage to some equipment in the local vicinity may occur immediately, due to spraying and/or dripping. However, for a flood area of reasonable size, much of the equipment will not sustain damage until the flood level rises to a critical level (e.g., for switchgear room MCCs this is generally 4 inches to 1 foot). Likewise flood propagation to an adjacent area may not occur until the flood level rises above a curb for example, and

then additional time will be required before the level reaches a critical height in that area. Therefore, there is usually a basis for defining a set of distinct flood damage states, each corresponding to a progressively increasing severity equipment loss. Each flood damage state is therefore defined in terms of the time at which it occurs after the initial flooding incident together with a set of accident mitigating systems which are damaged. Subsequent analysis then predicts the frequency of each flood damage state and the conditional core damage frequency given it does occur.

E.2.8 Probabilistic Evaluation of Flood Growth

The growth (or rate of rise) of flood level is then determined by taking into account the flooding rate, the free cross-sectional area of the flood area, and the capability of the drainage mechanisms (floor drains, and leakage pathways to adjacent areas). In some cases an equilibrium flood height is established when the outgoing flow through the drains or under doors equals the flood rate. Flood growth may be halted at any time either by automatic or operator action leading to isolation of the flood source, or by exhaustion of the flooding source itself. Factors considered in evaluating the probability of suppression include: the means of detecting occurrence of the flood (alarm, area occupancy, etc.); the means of detecting and isolating the specific source of the flood, the time available for the operator to isolate the flood source before equipment damage occurs and applicable flood procedures and operator training.

E.2.9 Probabilistic Evaluation of Flood Induced Accident Sequence Frequencies

The evaluation of the frequency associated with individual flood damage states is calculated using the event tree approach. The first event on the tree describes the discretized flood frequency distribution and subsequent events represent the failure of various automatic, manual and passive flood protection measures which may prevent progressive flood damage states being achieved by suppressing the flood source or isolating its pathway to other areas. When quantified, the end points of the event tree represent the frequency of each postulated flood damage state. Their contribution to core damage is then determined by transferring to a event tree corresponding to the flood induced initiating event and requantifying that tree with the failure probability of the flood damaged equipment set equal to 1.0.

E.3 ANALYSIS OF INTERNAL FLOODING EVENTS

E.3.1 Screening of North Anna Flood Areas

Using the approach discussed in Section E.2, twenty nine areas within the North Anna power block were identified as having a significant degree of independence with respect to internal flooding events. Some of the significant areas are identified in a simplified station drawing, shown as Figure E.2-1, and a brief discussion of the potential inter-area flood propagation pathways is given in Table E.3-1. A summary of the potential flood induced damage in each Unit 1 area is shown in Table E.3-2. The potential flood-induced damage for each Unit 2 area is considered to be the same as corresponding Unit 1 areas.

A preliminary study of the internal flooding hazard identified the following plant vulnerabilities:

1. Water accumulated in the Auxiliary Building could penetrate the charging pump cubicles via common drainage lines;

2. Flooding originating in the Quench Spray Pump House (QSPH) could propagate to the Auxiliary Building via the piping penetration between the two buildings by breaching the fire protection material that fills the piping penetration;

3. Flooding originating in the Main Control Room/Emergency Switchgear Room air conditioning Chiller Room (ACCR) could propagate to the Emergency Switchgear Room (ESGR) by leaking past the interconnecting door.

As a result of the preliminary study, the following modifications were identified to enhance the flood protection system:

1. Installation of backflow prevention devices in the common drain lines to prevent the propagation of the floods from the Auxiliary Building to the charging pump cubicles via the floor drain lines. This modification has increased the critical flood height in the Auxiliary Building from 24" to 44" which in turn has increased the critical flood volume and the time available for isolation of a flood source. The charging pump cubicles do have removable concrete blocks which are sealed to a height of 44" above the floor.

2. Reinforcement of the present fire barrier in the piping penetration the Auxiliary Building and the QSPH such that it limits the flooding flow rate reaching the Auxiliary Building to less than approximately 300 gpm. This modification will keep a majority of the flood water originating in the Safeguard Building or QSPH from damaging equipment in the Auxiliary Building. This modification will limit the flooding

flow rate between the QSPH basement and the Auxiliary Building.

3. Modifications to the Chiller Room/Fan Room door and the Chiller Room/Turbine Building door. The modification to the Chiller Room/Fan Room door is to add a 3'3" high dike. This will cause a flood originating in the Chiller Room to fill the room to 3' deep and overflow the existing 3' dike protecting the Chiller Room/Turbine Building door. The Chiller Room/Turbine Building door must be modified to allow a sufficient gap at the bottom to allow the worst case flood to leak under this door, around the missile shield protecting the door and into the Turbine Building. Due to the large area of the Turbine Building and relatively small flood rate, there will be no significant hazard to the Turbine Building.

   These door modifications will allow the redirection of the flood water away from the ESGR. This flood will cause the loss of all ESGR cooling for one unit. This is less severe than allowing the flood to propagate to the ESGR where it will cause the loss of AC and DC emergency electrical power and all instrumentation to both units.

Throughout the remainder of this report, credit is taken for the modifications described above.

E.3.2 Turbine Building Flood Analysis

E.3.2.1 Building Layout and Flood Sources

The Turbine Building is approximately 540' long and 135' wide. Other than the ground level (at 254' elevation) it is shared by Units 1 and 2. Primarily, the building houses components of the Power Conversion Systems. More specifically, certain key equipment is located on the following three floors:

1. Operating Level (303' 0" Elevation) - The turbine generator, moisture separators, and filter water storage tank.

2. Mezzanine Level (Approx. 282' 3" to 274' 0" Elevation) - The turbine oil reservoir, condensate polisher backwash recovery tanks, flash evaporator, blowdown tank, chilled water and reheater drain receivers.

3. Ground Level (254' 0" Elevation) - This is the lowest floor in the Turbine Building. The Condensate and Main Feedwater pumps are located here.

   The 96" diameter Circulating Water (CW) piping is located in the condenser inlet and outlet pits, which extend down to the

250' 0" elevation, and in the condenser tube cleaning pit approximately 11" below the Turbine Building basement.

A dividing wall separates the Unit 1 and 2 Turbine Buildings up to the 274' elevation. However, there are several non-watertight, interconnecting doorways, including three on lowest floor, as well as a common drain system.

All potential flooding sources within the Turbine Building are described in Table E.3-3. The major flooding sources are the Circulating Water system piping components which are tabulated in Table E.3-4.

E.3.2.2 Installed Flood Protection

Flood dikes are installed in the Turbine Building to reduce the effects of severe flooding from the Circulating Water and Fire Protection System. The major objective is to prevent flood water entering the Emergency Switchgear Room and Auxiliary Building which are connected with the Unit 1 Turbine Building at the 254' 0" elevation. In summary, the following flood protection measures are provided:

1. Level switch, 1-CW-LS-107A, installed in the condenser tube cleaning pit that is at a lower level than the Turbine Building floor (UFSAR, page 10.4-6). At 12" it actuates the "CONDENSER TUBE CLEANING PIT HIGH LEVEL" alarm in the control room.

2. Level switch 1-CW-LS-107B also senses condenser tube cleaning pit water level and at 24" actuates the "CONDENSER TUBE CLEANING PIT HIGH-HIGH LEVEL" alarm in the control room.

3. Six more level switches, arranged in three sets of two, where each set is distributed about the Turbine Building 254' elevation are used for automatic tripping of the circulating water system pumps and closing of the pump's discharge MOVs.

   1-CW-LS-106A-1, 2, and 3 provide signals so that when two out of three sense 12" of water on the Turbine Building floor, all CW pumps are stopped and the "TURBINE BUILDING FLOODING ALARM TROUBLE" is actuated in the control room.

   1-CW-LS-106B-1, 2, and 3 provide control signals such that, when two of three level switches sense 12" of water, all four CW pump discharge MOVs are shut and all four pumps stop when the valves reach the fully closed position.

4. In addition to automatic trip capability provided by the components described in item 3 above, on the receipt of flood alarm from the components described in items 1 and 2, the

control room operator (per 0-AP-39.1, "Turbine Building Flooding Procedure"), will check to see if the circulating water pumps are running, as indicated by the lights or ammeters on the intake structure control board, the operator will then place all CW pumps to pull-to-lock. If the pumps fail to stop, the operator would trip the main bus feeder breaker from the control room, securing power to the bus serving all four pumps.

5. 3' high flood dikes are provided at the entrance to the Emergency Switchgear Room and the Auxiliary Building tunnel.

6. An open grating is installed to allow flood water to enter the Amertap pit.

In addition, three floor drain sumps are provided, the No. 1 sump in the Unit 1 Turbine Building and the No. 2 and 3 sumps in Unit 2. Each sump is provided with three 1300 gpm pumps. Some of the Unit 1 floor drains share the No. 2 sump.

E.3.2.3 Level 1 Analysis of the Turbine Building Floods

Risk From Flooding Events Confined Within the Turbine Building

This section presents a conservative evaluation of the potential impact of flooding within the Turbine Building itself. Propagation to adjacent areas is considered later.

The worst case accident initiating event type resulting from flood damage in the Turbine Building is a loss of Main Feedwater transient (T2) on both Units 1 and 2.

With reference to Appendix C of the NAPS UFSAR, there are no safety related systems which can be damaged by flood water in the Turbine Building (if water does not flow over the 3' high flood dike). In addition, no equipment required for the safe shutdown of the plant is located in the Turbine Building other than the auxiliary SW lines which are located adjacent to the Auxiliary Building Tunnel behind a 3' high dike.

Based on US nuclear power plant CW system induced flooding experience, the frequency of all floods is 8.9E-3 per unit year of operation. Since the NAPS Turbine Building accommodates two units the frequency of flooding in this flood area is taken to be 1.8E-2 per year. In order to bound the risk from such an event the internal events T2 transient event tree was modified as follows:

- The initiating event frequency was changed to reflect the Turbine Building Flood frequency of 1.8E-2 per year.

Since no accident mitigating system would be damaged, the risk from the flooding event in the Turbine Building is calculated by:

T2 induced CDF = 8.86E-7 (Section 3.4 of this IPE)

T2 initiator = 5.0E-2 (Section 3.1 of this IPE)

Therefore:

Risk from flooding is (1.8E-2/5.0E-2) x 8.86E-7 = 3.2E-7

The resulting flood induced core damage frequency is 3.2E-7 per unit per year, which is below the screening criteria of 1E-6. Thus the risk from flooding damage which is solely confined to the Turbine Building is shown not to be significant and level 2 and level 3 analyses need not be applied.

Risk of the Turbine Building Flooding Propagating to Other Flood Areas

This analysis concerns the propagation of floods from the Turbine Building to other flood areas such as Emergency Switchgear Room (ESGR).

Flood Propagation Pathways

All the potential flood propagation pathways have been evaluated qualitatively using calculations to determine maximum propagation flow rates. It was concluded that only two pathways from the Unit 1 and Unit 2 Turbine Building merit further, probabilistic, investigation as follows:

1. Overflow of the 3' high dike protecting Emergency Switchgear room and flow into the room (also at 254' elevation) via gaps at the sides and bottom of the doors or by forcing the doors to open. (For the purpose of analysis, the door is assumed to be open). Water would initially enter the Unit 2 Emergency Switchgear room and subsequently overflow to the Unit 1 Emergency Switchgear room.

2. Overflow of the 3' high dike protecting the Auxiliary Building Tunnel and flow into the Auxiliary Building basement (244' 6" elevation).

3. Flow to the Air Conditioning and Chiller Room Area (ACCR), via gaps in the door or by forcing the door open and then overflowing the 3' high dike protecting the rest of the ACCR.

Critical Flood Volumes and Significant Flood Sources

From a review of the possible flood sources, shown in Table E.3-3, the only source in the Unit 1 and 2 Turbine Building with a capacity which is in excess of the minimum needed for causing damage outside the Turbine Building, is the CW system. The probability of failure to automatically isolate the CW system is determined to be 4E-4 and the frequency of floods which can only be automatically isolated is determined to be 2E-3 per unit and 4E-3 for both units. Given the following conservative assumptions:

1) ESGR is lost when water level reaches the 257' elevation in the Turbine Building,

2) Loss of ESGR has a one to one ratio with Core Damage Frequency;

the contribution of Turbine Building flood to the core damage frequency is given:

4E-4 x 4E-3 = 1.6E-6 per unit

Given the conservative assumptions used for calculation of significant flooding frequency, probability of isolation (manual isolation not considered) and contribution to CDF, a frequency of 1.6E-6 is considered small enough to be screened out.

Confidence in Ability to Trip the CW Pumps and Valves

The screening-out of Turbine Building floods relies heavily on the capability of the flood mitigating systems to warn the operators of potential flooding problems and thus, allowing for the trip the CW pumps and valves per their design basis. The confidence in the proper functioning of the flood mitigating components is based on the following (with reference to NAPS UFSAR 10.4-7 and document reviews):

1. All breakers associated with the circulating water pump motor circuits and bus feeder are identical to seismically qualified, safety-grade breakers.

2. All relays associated with Turbine Building level alarms and circulating pump trip circuits are seismically qualified and safety-grade, and are mounted in the emergency switchgear room.

3. Trip control relay and alarm relay power is from the vital bus and is redundant.

4. Normal pump controls are identical to seismically qualified and safety-grade controls.

5. Water box inlet and outlet valve controls are mounted on the main control board and are identical to seismically qualified and safety-grade equipment.

6. Regular (every 18 months) Preventive Maintenance (PM) and testing of the auto trip probes are carried out (Procedures 1-EPM-0801-01 and 2-EPM-0801-01).

E.3.3 Auxiliary Building Flood Analysis

E.3.3.1 Building Layout and Flood Sources

The Auxiliary Building is shared between both units. It is a four level building consisting of the 244' 6", 259' 6", 274' 0", and 290' 10" elevations. The basement of this area is located at 244' 6" elevation. The building houses both normal operating and emergency system components, in particular those associated with the Chemical Volume and Control System, the Component Cooling Water System, and the Safety Injection System. The building has an open structure which is divided into four main floors. Major equipment is located as follows:

Elevation 291' 10": Heating and ventilation equipment, steam generator blowdown tanks (1-BD-TK-1, 2-BD-TK-1), and CC Surge Tank (1-CC-TK-1).

Elevation 274' 0": Boric acid tanks (1-CH-TK-1A, B, and C); Volume control tanks (1-CH-TK-2, 2-CH-TK-2).

Elevation 259' 6": No significant flood source or safety significant equipment is located at this elevation.

Elevation 244' 6": Liquid waste tanks (drain tanks), 1-LW-TK-3A/B, boron evaporator test tanks 1-LW-TK-5A/B, 1-LW-TK-2A/B, and contaminated drains collecting tanks 1-LW-TK-7A/B), boron injection tanks 1-SI-TK-1, 1-SI-TK-2 and 2-SI-TK-2, boron recovery tank 1-BR-TK-5.

Other components at this elevation include, SW piping components for CCW heat exchangers, CCW pumps, Charging Pumps, Boric acid Recirculation pumps and Auxiliary Building sump.

The majority of the equipment within the Auxiliary Building which is utilized for safe plant shutdown is located on the 244' 6" elevation. Furthermore, based on the size of openings in the floor, no safety significant flooding could occur at higher elevation and flood induced damage is assumed to be limited to those components that are on the basement level (i.e., 244' 6" elevation).

The charging pumps for both units are located in this area (on the 244' 6" elevation) and are protected by missile/radiological walls. The cubicle walls around each pump extend up to the floor of the next elevation (259' 6"). Each cubicle is 9.5' wide, 26' long and has a floor to ceiling height of approximately 14'. The power cables for the pumps exit the cubicles on the 259' 6" elevation.

Each cubicle has a 3" diameter floor drain. All floor drains are connected to a common drain header and this header is connected to the sump pit in the Auxiliary Building. Backflow prevention devices are installed in the common drainage to prevent flow of water from the Auxiliary Building to the charging pump cubicles. The Auxiliary Building sump pit has a flood alarm (window 1E-F6) which actuates when water level is at 48"-50" in the sump. There are two sump pumps in the Auxiliary Building sump (1-DA-P-3A/B) each with a dewatering capacity of 50 gpm.

All potential flood sources within the Auxiliary Building are described in Table E.3-5. The major sources are:

1) Chemical Volume Control System

2) SW to the Charging Pumps and Component Cooling Heat Exchangers

3) Component Cooling System Water

4) Fire Protection

5) RWST supply to the Charging Pumps

6) Primary Grade Water

E.3.3.2 Installed Flood Protection

With reference to the North Anna IPE flooding analysis plant walkdown and the 11715-FAR-205 series drawings, the following protection is provided:

Each cubicle is protected against water ingress from 259' 6" elevation by a 4" high flood dike.

The opening in the south wall of the charging pump cubicles for valve stems (with valve handles located in the corridor outside the cubicles), have metal plates covering the openings which provide a barrier against flood ingress into the cubicles based on the configuration and small size of these valve stem openings.

Interconnection of the charging pump cubicles and the Auxiliary Building are sealed up 44". The charging pump cubicles have removable concrete blocks which are sealed to be watertight at

least to 44" above the floor. These blocks are removed when major maintenance is performed on the charging pumps. The length of time these blocks are not in place is considered to be insignificant. If the blocks are out of place for extended periods then the penetrations between the charging pump cubicle in maintenance to adjoining operable charging pumps below 44" should be made watertight until the removable block is reinstalled.

Flood detection switch (1-DA-LSH-114), which alarm in the Control Room, is installed in the SW valve pit. This SW valve pit is located next to the tunnel which extend from the Turbine Building to the Auxiliary Building basement level and the elevation of the valve pit is lower than the pipe tunnel. This alarm would indicate flooding from the rupture of one or more pipes in the Turbine Building which would flow to the Auxiliary Building tunnel.

High water level alarm switches (1-DA-LS-105, 111A/B), indicating the Auxiliary Building flooding problem in the control room, are installed in the Auxiliary Building sump pit. The sump is located to the east of the charging pump cubicles and contains two sump pumps each with 50 gpm dewatering capacity.

E.3.3.3 Level 1 and 2 Analyses of the Auxiliary Building

A level 1 and 2 analysis of this area is not useful because the Auxiliary Building has a generally open structure with significant sources of flood and the postulated damage is significant.

E.3.3.4 Level 3 Analysis of the Auxiliary Building Floods

Critical Flood Volumes and Significant Water Sources

As previously mentioned in Section E.3.3.1, the majority of safety required systems are located at the basement level of the Auxiliary Building. Furthermore, based on the size of openings in the floor, no safety significant flooding could occur at higher elevations and flood induced damage is assumed to be limited to those components that are on the basement level (i.e., 244' 6" elevation). An existing flood evaluation (SWEC 1974), has established the following:

1) 5850 gallons of water are required to flood the drains and sumps in the Auxiliary Building.

2) After drains and sumps are full, water will collect at the basement level, with a rate of 11,500 gallons per inch.

The evaluation of the flood susceptible equipment in the Auxiliary Building has established the following critical components and their associated critical heights and flood volumes:

1. The critical height of CC pumps is 24" above the Auxiliary Building basement floor elevation and the critical flood volume is determined to be 281,000 gallons.

2. The critical height for the charging pumps is considered to be 44" above the Auxiliary Building basement floor elevation. This translates to the critical volume of 511,000 gallons.

Analyses of the consequences of flood damage to the equipment addressed above indicate that the major contribution to CDF would result if both the charging and CC pumps are damaged. Thus, 511,000 gallons is considered to be the critical flood volume for the Auxiliary Building and flood sources with potential for causing damage must have source capacity equal or greater 511,000 gallons.

As determined above a minimum of 511,000 gallons of water could be allowed on the Auxiliary Building lowest floor before any damage to equipment is sustained assuming that the level equalizes across the whole floor. In fact the minimum flood volume would be substantially less if the flood source were located in one of the Charging Pump cubicles. Under such circumstances possibly two or three cubicles could be flooded via interconnecting drainage system and possibly via the gap in the interconnecting I Beams. However, this scenario is not considered to be risk significant since the remaining Charging Pumps would remain unaffected until the general flood level rose to 44". Thus, the critical flood volume in the Auxiliary Building is assumed to be 511,000 gallons at which point all Charging and Component Cooling water pumps are assumed to fail.

Therefore, those flood sources with less than 511,000 gallon capacity are not considered in this analysis and only the following systems merit further consideration:

1) SW to the Charging Pumps and Component Cooling Heat Exchangers

2) Fire Protection System

The discussion of flooding risk from each of these flood sources is discussed below.

Service Water Sources

The SW piping components located in the Auxiliary Building include the SW piping to the CC heat exchangers and Charging Pump component coolers (e.g., Charging Pump Lube Oil Coolers).

SW supply headers to the Charging Pump component coolers are of 2" diameter piping or smaller with estimated maximum flow rate of 150 gpm. This limited flow rate will provide sufficient time for isolation; therefore, the SW supply headers to the Charging Pump component coolers are not considered as risk contributors.

SW piping supply to CC components consists of two lines. Each line has a 24" diameter piping, one 24" diameter expansion joint, and two 24" diameter MOVs. Each line reduces into an 18" diameter pipe which has four 18" diameter manual valves. Two 18" diameter pipes, one from each line, feed into a 20" diameter pipe that leads to a CC heat exchanger. This 20" diameter pipe has an expansion joint before each of the CC heat exchangers (see 11715-FM-78C). Two 10" diameter SW piping sections feeding the CC fuel oil pit coolers are also in this area.

The SW piping from the CC heat exchangers has a configuration that is very similar to the inlet piping configuration described above.

1AB2 is designated to represent the SW induced Flood Damage State (FDS) in the Auxiliary Building. Postulated damage in the Auxiliary Building includes:

- Loss of all charging pumps
- Loss of all CC pumps
- Loss of a SW header

Flooding Event Types

A review of SW supply headers to the CC heat exchangers indicate that SW induced flooding events in the Auxiliary Building can be divided into two types. Manually Isolable Floods and Remotely Isolable Floods depending on the location of the rupture. The Manually and remotely isolable flooding events are defined as follows:

> Manual Isolable Floods are those which occur due to breaks in the isolation valves (i.e., 1-SW-MOV-108A/208A) or the SW piping prior to the first isolation valves. Tripping of the SW pumps is not considered to be effective in terminating this type of the flooding events because of siphoning effects. MIF floods can only be isolated by closing the SW pump's discharge valves which are located in the SW pump house by the SW reservoir. This room is not manned. Thus, this analysis assumes that it would take at least 30 minutes for an operator to be dispatched and valve closure to be completed.

> Remotely Isolable Floods are those which occur due to breaks in the SW piping upstream of the isolation valves (1-SW-MOV-108A/B and 2-SW-MOV-208A/B) of the SW supply header to the CC heat exchangers. Tripping of the SW pumps in combination with

closure of the isolation MOVs will isolate the SW reservoir. However, the water in the SW return header would siphon into the Auxiliary Building.

Individual flood sources and maximum flow rates are shown in Table E.3-6. The evaluation of the frequency of flood categories is shown in Tables E.3-7 and E.3-8. Tables E.3-9 and E.3-10 show the evaluation of the frequency of FDS 1AB2 due to manually isolable and remotely isolable Service Water flooding scenarios, respectively. The contribution of this flood damage state to core damage frequency is evaluated in Section E.4.

Fire Protection System

The fire protection system piping sections in the Auxiliary Building which could contribute to the internal flooding hazard, consist of 4" diameter piping located at the 244' 6" elevation and 6" diameter piping located at the 291' 10" elevation. The system is normally maintained at a pressure of 100 - 110 psig by a small jockey pump. When the pressure drops, due to a system demand, one electric motor driven and one diesel driven pump, each rated for 2500 gpm at 325' to 330' head, start automatically. In the event of a break in the fire protection system flood water would flow via the stairways, open gratings and floor drains to the 244' 6" elevation. Operators in the Control Room would be made aware of the abnormal situation by both a high sump level alarm and a warning that the fire suppression system pumps were running. Flood isolation can be achieved by stopping the fire suppression pumps and closing the appropriate manual isolation valves.

1AB4 is designated to represent the Fire Protection System induced FDS. Postulated damage in the Auxiliary Building includes:

- Loss of all charging pumps
- Loss of all CC pumps

Individual flood sources and maximum flow rates are shown in Table E.3-11. The evaluation of the frequency of flood categories is shown in Table E.3-12. Table E.3-13 shows the evaluation of the 1AB4 FDS frequency. The contribution of this flood damage state to core damage frequency is evaluated in Section E.4.

E.3.3.5 Level 4 Analysis of the Auxiliary Building

The Auxiliary Building adjoins the Containments for both units, the cable vault and tunnel areas for both units and the fuel and decontamination building. It also connects with the Turbine Building and the Quench Spray Pump Houses associated with each unit via pipe tunnels. In an analysis of flood propagation it was determined that only flood propagation into the Auxiliary Building

from the Turbine Building is a potentially important contributor to risk. Such a scenario is considered in the analysis of the Turbine Building flood area.

E.3.4 Analysis of the Unit 1 Quench Spray Pump House

E.3.4.1 Building Layout and Flood Sources

In this analysis, the Quench Spray Pump House and the Safeguards Building, where the Low Head Safety Injection Pumps are located, are treated as one flood area due to the nature of the flooding sources in these areas. This area has two levels adjacent to the containment building. The highest elevation for this area is at 272' 0" where the 1-QS-P-1A/B and their associated piping are located on a platform (El. 286' 6"). Other components at this elevation include 1-QS-P-2A/B and their associated piping (the refueling water recirculation pumps).

The basement elevation is at the 254' elevation and consists of two rooms. One room is located below the Quench Spray Pump compartment and the other room is located below the Main Steam Valve House. The Unit 2 Quench Spray Pump House basement level has three rooms, one room is located below the Main Steam Valve House, one below the Quench Spray Pump House, and the third room is located below a portion of the service water valve housing.

At elevation 256' 0" a pipe tunnel connects this room to the Turbine Building, the Auxiliary Feedwater Pump Houses, and the Auxiliary Building. Pipe penetrations are sealed from the QSPH side. A description of these tunnels is provided below:

1. Tunnel between Unit 1 Quench Spray Pump House and Unit 1 Turbine Building:

   This pipe tunnel starts at the south wall of the Unit 1 Turbine Building Basement. The tunnel runs a distance of 80' under the Service Building and alleyway. The tunnel then runs west for approximately 20' to the northeast corner of the basement elevation of the QSPH, approximately 8' above the floor.

   The tunnel has a 5' x 3.5' opening at the Turbine Building wall, about 6' above the Turbine Building floor (station drawing 11715-FC-5D). The tunnel is sealed by a 2' thick concrete wall at the QSPH and except for an 18" diameter hole which has a seal plate bolted over it.

2. Tunnel Between Unit 1 Quench Spray Pump House and Unit 1 Auxiliary Feedwater Pump Houses:

This pipe tunnel starts at the east wall of the basement elevation of the Unit 1 QSPH, approximately 8' above the floor. The tunnel runs southeast through the yard area to the Unit 1 Auxiliary Feedwater Pump House. The tunnel has a opening into the Motor Driven Auxiliary Feedwater (MDAFW) Pump room and the Turbine-Driven Auxiliary Feedwater (TDAFW) Pump room. The openings into the MDAFW and TDAFW pump rooms are located approximately 8' below floor level (station drawing 11715-FP-7A).

This tunnel is sealed by a 2' thick concrete wall at the QSPH except for four penetrations. Three of these penetrations are pipe sleeves which have been sealed with Dow Corning Silicon foam, 12" deep. The other is an 18" diameter hole which has a steel plate bolted over it. The tunnel has an opening approximately 15"x 2'4" into the MDAFW pump room which has not been sealed. The tunnel also has an opening approximately 15"x15" into the TDAFW pump room, but this opening has also been sealed with a steel plate bolted over the opening.

3. Pipe Penetration Between the Unit 1 Quench Spray Pump House and the Auxiliary Building:

   This piping penetration is on the west wall of the basement elevation of the Unit 1 QSPH, approximately 3' above the floor and is sealed by a damming board at the QSPH side. This damming board is reinforced such that it can act as a flood barrier.

All potential flooding sources in the QSPH and Safeguards Building are listed in Table E.3-14.

E.3.4.2 Installed Flood Protection

No flood detection sensors were identified in the QSPH but the Safeguards area contains several flood detection sensors (1-DA-LS-101-1, 1-DA-LS-101-2) which annunciate in the control room (window 1A-C1).

E.3.4.3 Level 1 Analysis of Quench Spray Pump House

Flooding in this area will result in:

1. Loss of Quench Spray Pumps.

2. Loss of Unit 1 Low Pressure Injection pumps.

3. Loss of Unit 1 Outside Recirculation Spray pumps.

Additionally, depending on the source of the flood, the following plant operational conditions will be affected,

either:

a. Degradation of the Service Water System;

b. Degradation of Service Water Supply to the Recirculation Spray Heat exchangers;

or:

c. Loss of Unit 1 RWST supply.

Since none of the damage conditions outlined above will result in an initiating event (automatic plant trip) and significant accident mitigating systems such as the Auxiliary Feedwater System will not be affected, the risk from flooding within this area is considered insignificant. In addition, no significant flood propagation pathways exist, therefore risk from floods which could propagate from this area is also considered insignificant.

E.3.5 Analysis of Unit 2 Quench Spray Pump House

This area is identical to the Unit 1 Quench Spray Pump House, with the exception of the Safeguards area piping penetration to the Quench Spray Pump House. This piping penetration is sealed and no flood propagation is considered to be possible. Therefore, damage to accident mitigating systems would be less severe and there are fewer possible flood sources. Thus the risk from flooding in this area is even less significant and an analysis need not be repeated.

E.3.6 Analysis of Unit 1 Air Conditioning Chiller Room

E.3.6.1 Flood Area Layout and Flood Sources

This is a relatively small area, approximately 31' by 30', located to the east of the Emergency Switchgear Room on the 254' elevation. The area contains pumps, valves and chillers associated with the Main Control Room/Emergency Switchgear Room HVAC system.

The only significant flood source is the Service Water supply to the chillers.

E.3.6.2 Installed Flood Protection

A 3'0" dike is installed at the entrance between the Air Conditioning and Chiller Room and the Turbine Building. A flood alarm which annunciates in the Control Room has been provided in the Chiller Room sump.

E.3.6.3 Level 1 and 2 Analyses

A worst case flood in this area could potentially cause complete loss of the Main Control Room/Emergency Switchgear Room HVAC leaving only the opposite unit's HVAC system to prevent core damage. The area cannot be subdivided into smaller independent flood areas. Therefore, Level 1 or 2 analyses were not useful in this case.

E.3.6.4 Level 3 and 4 Analyses

Flood Propagation Pathways

The potential flood propagation pathways from this area are:

1. Via gaps in the interconnecting door flowing into the Fan Room then into the Instrument Rack Room and on to the Emergency Switchgear Room (both units will be affected).

2. Overflowing the existing 3'0" dike protecting the Chiller Room/Turbine Building door then under the door, past the missile shield, flowing into the Turbine Building.

3. Water being pumped into the Turbine Building via sump pumps located in the Chiller Room.

As previously described, the first flood propagation pathway has been sealed up to 3'3" above the Chiller Room floor elevation by adding a new dike protecting the Chiller Room/Fan Room door and trimming the bottom of the Chiller Room/Turbine Building door to ensure adequate flow rate under the door.

Removing part of the Chiller Room/Turbine Building door has a potential effect on Chiller Room air pressure. A review of this issue shows that this modification has no detrimental effect on station operation.

Previous control room pressure boundary tests identified a design deficiency in the Chiller Room and the Fan Rooms. This design deficiency was that the flow rate of the MCR/ESGR ventilation fans was so high that the Fan Room operated at a slightly lower pressure than the remaining control room pressure boundary envelope. Also, the Chiller Room operated at a slightly higher pressure than the Turbine Building. The overall effect was an air leakage into the control room pressure boundary. Technical Specifications 3/4.7.7, Control Room Emergency Habitability Systems, requires the control room to be able to maintain a positive pressure. This design deficiency has been corrected and is not affected by modification of the Chiller Room/Turbine Building door.

The low pressure in the Fan Room was caused by the Bernoulli effect on the air flowing through the relatively small opening between the instrument rack room and the Fan Room. This low pressure condition was corrected by removing the block wall between the instrument rack room and the Fan Room so that the return air flow passes through a much larger area. The air pressure in the Fan Room is now closer to the rest of the control room pressure envelope.

The high pressure in the Chiller Room was caused by the Chiller Room ventilation system. There are two louvered sections between the Chiller Room and the Turbine Building. Previously a supply fan forced air through one louvered section. This arrangement caused the Chiller Room air pressure to be slightly greater than the Turbine Building air pressure. The Chiller Room pressure was also greater than the Fan Room pressure which allowed air inleakage from into the control room pressure boundary. This design deficiency was corrected by modifying the Chiller Room ventilation fan so that it is now an exhaust fan. Air flows from the Chiller Room into the Turbine Building causing the Chiller Room to be at the same or less pressure than the Turbine Building pressure.

The Chiller Room/Turbine Building door needs to have its bottom trimmed so that the worse case Chiller Room flood, 1500 gpm, will flow under the door. Increasing this gap will provide an increased flow area which may cause the Chiller Room air pressure to be closer to the Turbine Building air pressure. The modification will not cause the Chiller Room pressure to exceed the Turbine Building air pressure. Because the Fan Room air pressure is above the Turbine Building air pressure, the control room pressure boundary envelope will remain at a positive pressure relative to the surrounding areas.

Critical Flood Volumes and Significant Flood Source

One flood damage state (FDS 1AC1) is considered possible. FDS 1AC1 occurs when the damage is sustained in the Chiller Room itself. This occurs when the flood depth reaches 28" and requires 11,000 gallons of water (excluding drainage losses) and results in loss of the MCR/ESGR HVAC.

The only flood source with a capacity in excess of the minimum required to cause damage in the Chiller Room is the Service Water supply.

Service Water Flood Scenarios

Service Water is supplied to the three HVAC chiller units (1-HV-E-4A/4B/4C) via two 4" diameter headers which enter the Air Conditioning and Chiller Room and is fed from the 24" diameter supply lines to the Recirculation Spray Heat exchangers. In the

event of a break in the SW pipe in the Air Conditioning and Chiller Room, the flood source may be isolated by closing manual valves in the Quench Spray Pump House (For Unit 2, the isolation valve is in the Auxiliary Building). Individual SW flood sources and their maximum discharge rates are listed in Table E.3-15. The derivation of the SW flood category frequencies is shown in Table E.3-16. Table E.3-17 shows the evaluation of the frequency of 1AC1 FDS. The contribution of these flood damage states to core damage frequency is evaluated in Section E.4.

E.3.7 Summary of North Anna Power Station Flood Damage States

In previous sections, most significant independent flooding areas were discussed. For ease of reference, a summary of all the significant postulated flood damage states is presented in Table E.3-18.

E.4 ANALYSIS OF FLOOD INDUCED CORE DAMAGE SEQUENCES

The purpose of this section is to combine the results of the North Anna flood damage state evaluation, discussed in Section E.3, with the North Anna internal event model to determine the flood induced core damage sequence frequencies.

The process is simply performed by selecting an internal events initiator and set of accident mitigating failures which combined, most accurately reflect each flood damage state. In some cases more than one internal initiating event may be induced during a flooding event and in such a case the most severe is usually selected. These internal event models are then requantified setting the initiating frequency to the frequency of the flood damage state being evaluated and the failure probability of the systems damaged by the flooding event to unity.

A summary of the flood damage states, their associated frequencies, and corresponding internal initiating event models selected is shown in Table E.3-18.

The requantified internal events models are shown in Figures E-FAB2, E-FAB4 and E-FAC1. The function equations used in the flooding event trees are the same as those used in the level 1 analysis with the exception of the functions which were modified to account for equipment damaged by the flood initiator. In the case of North Anna only the containment heat removal function is affected for floods in the Auxiliary Building. So, the unavailability for this function is set to one. The function is named CHFLD. The other functions, which are shown on the event trees, are defined in Appendix B.

E.5 KEY ASSUMPTIONS AND RESULTS OF NORTH ANNA POWER STATION INTERNAL FLOODING ANALYSIS

Screening analysis eliminated most types of flooding at North Anna. Quantitative analysis was required for the following three types of flooding.

FAB2, flooding in the Auxiliary Building due to Service Water pipe or component failure, core damage frequency of 2.6E-6 (see Figure E-FAB2).

FAB4, flooding in the Auxiliary Building due to fire protection pipe or component failure, core damage frequency of 1.60E-8 (see Figure E-FAB4).

FAC1, flooding in the ESGR/MCR air conditioning chiller room due to Service Water pipe or component failure, core damage frequency of 9.7E-7 (see Figure E-FAC1).

The sum of the risk from all three results in a total core damage frequency due to internal flooding at North Anna of 3.63E-6/year. The key assumptions which were made during the quantification of the CDF from internal flooding included hardware modifications and that certain existing equipment was operable due to administrative controls or testing. The key flooding mitigation equipment is included in Table E.5-1. The following modifications were identified due to significant reductions in risk identified during the IPE process and assumed to be implemented in the IPE model:

1. Installation of backflow prevention devices in the common drain lines to prevent the propagation of the floods from the Auxiliary Building to the charging pump cubicles via the floor drain system. This modification increases the critical flood height in the Auxiliary Building from 24" to 44" which in turn increases the critical flood volume and the time available for isolation of a flood source. Without the backflow devices or the charging pump cubicles sealed to 44", the total flooding core damage frequency increases to 9.0E-5/year.

2. Reinforcement of the present fire barrier in the piping penetration between the Auxiliary Building and the QSPH such that it limits the flooding flow rate reaching the Auxiliary Building to less than approximately 300 gpm. This modification will keep a majority of the flood water originating in the Safeguards Building or QSPH from damaging equipment in the Auxiliary Building. Without the improvement to limit flooding from the QSPH reaching the Auxiliary Building, the total flooding core damage frequency increases to 7.0E-5/year.

3. Modifications to the Chiller Room/Fan Room door and the Chiller Room/Turbine Building door. The modification to the Chiller Room/Fan Room door is to add a 3'3" high dike. This will cause a flood originating in the Chiller Room to fill the room to 3' deep and overflow the existing 3' dike protecting the Chiller Room/Turbine Building door. The Chiller Room/Turbine Building door must be modified to allow a sufficient gap at the bottom to allow the worst case flood to leak under the door, around the missile shield protecting the door and into the Turbine Building. Due to the large area of the Turbine Building and relatively small flood flow rate, there will be no significant hazard to the Turbine Building. These door modifications will allow the redirection of the flood water away from the ESGR. This flood will cause a loss of all ESGR cooling for one unit. This is less severe than allowing the flood to propagate to the ESGR where it will cause a loss of AC and DC emergency electrical power and all instrumentation to both units. Without the modifications which direct flooding from the Chiller Room to the Turbine Building and away from the ESGR, the total flooding core damage frequency increases to 6.4E-5/year.

E.6 BASIS FOR THE FLOODING ANALYSIS SUPPORTING CALCULATIONS

This section discusses the basis used for some of the calculations performed to support the flooding analysis described in Section E.3.

A complete internal flood hazard analysis should take into account all possible locations where flooding can be initiated, flood initiating sources, and identify all locations where the effects of flooding on the plant safety related systems posses significant threat to the plant. The analysis should contain complementary qualitative and quantitative phases for discussion and evaluation of the above mentioned sources. However, undertaking such a task would be an unjustifiable burden to the analyst and to the power plant in terms of time and money spent. However, by implementing a well documented and reasoned screening process, it is possible to reduce the scope and contents of the analysis without introducing an unacceptable level of inaccuracy.

For this purpose, the internal flood hazard analysis (FHA) is subdivided into the following phases:

i) Plant Area Based Flood Frequencies for Level 1 and 2 Screening Analyses;

ii) Component Based Rupture Frequencies for Level 3 and 4 Detailed Analysis.

For the purpose of level 1 and 2 screening, flood frequencies are generally determined on the basis of US power plant experience from incidents reported in various references. However, because of incomplete event descriptions and differences in plant layout and flood sources, such data must be used carefully and often in a conservative fashion.

For determining component based flood rate/frequency distributions, two approaches are used. The first approach, which is identical to the approach adopted in the Oconee study (NSAC, 1984), is used for all piping components other than the 24 inch to 10 inch diameter SW system piping sections. For these piping sections, the methodology developed for the Surry internal flooding analysis (i.e., Log-Linear approach) is used. The Oconee and Log-Linear approaches are discussed in detail in Section E.6.1.2 and E.6.1.4 of the Surry IPE (Virginia Power, 1991a). Tables from the Surry report which provide historical information on industry floods are presented in Tables E.6-1 through E.6-7 for completeness.

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11715-ESK-5BF,	Elem. Diagram 4160 V Circuits Circulating Water Pump, Revision 4.
11715-ESK-5K,	Elem. Diagram 4160 V Circulating Water Pump, Revision 24.
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11715-FC-5D,	Circulating Water Discharge Tunnel, Revision 2.
11715-FM-7A,	Arrangement Aux. Bldg. Plan Elev. 244'-6" Safety Related Equipment, Revision 4.
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0-AP-39.1 Turbine Building Flooding Procedure, Revision 0, December 14, 1990.

TABLE E.2-1
GUIDE TO FLOOD INDUCED COMPONENT FAILURES

Component Type	Submerged	Sprayed	Steam
Valves:			
Motor	Fail as is	Fail as is	Fail as is(1)
Air	Fail	OK	OK
Hydraulic	Fail	OK	OK
Solenoid	Fail	Fail	Fail(1)
Manual	OK	OK	OK
Check	OK	OK	OK
Pumps (motor or turbine)	Fail	Fail	Fail(1)
Compressors	Fail	Fail	Fail(1)
Fans	Fail	Fail	Fail(1)
Diesels	Fail	Fail	(2)
Electrical	Fail	Fail	Fail(1)
Cables	OK	OK	OK (3)
Instrumentation	Fail	Fail	Fail(1)
Strainers/Filters	OK	OK	OK
Heat Exchangers	OK	OK	OK
Tanks/Accumulators	OK	OK	OK
Piping	OK	OK	OK
Duct Work	OK	OK	OK
Room Air Unit Coolers (excluding fan)	Fail	OK	OK
Vaporizers/Heaters	Fail	Fail	Fail

1) Consideration of EQ testing/analysis as basis for OK.

2) Probably not applicable but if it is exposed failure will be assumed for screening purposes.

3) In this study no examination of the potential for flood damage to junction boxes or cable splices was performed.

TABLE E.3-1
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
FLA1-1	1-1	Unit 1 Containment.
FLA1-2	1-2	Unit 2 Containment.
FLA2	2	Unit 1 and 2 Control Room. This area is located on the 276'9" elevation in the Service Building. Control and instrumentation cabinets for all Unit 1 and 2 systems are located in this area. The flood sources in the area are domestic water and HVAC chilled water. The only possible method of flood ingress would be from the Turbine Building walkway at the 276'9" elevation via a door. However, this is unlikely and would be readily detected and isolated. Flood egress is not important due to the limited water sources in the area.
FLA3-1	3-1	Unit 1 Cable Vault and Tunnel. This area is located on the 259'6" and 280'0" elevations in the Service Building. The major safety related equipment items are the 480 V MCC's 1J1-2N and 1H1-2N. The only flood source within the area is the fire protection system. There are three mechanisms for flood ingress into this area. (1) From the ESGR room by over flowing dikes at the interconnecting doorways. (2) From the Auxiliary Building via interconnecting doorways. (3) Via back flow through the drain system from the Turbine Building.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
		Flood egress is not important due to the limited water sources in this area.
FLA3-2	3-2	Unit 2 Cable Vault and Tunnel. Similar to FLA 1.
FLA5-1	5-1	Unit 1 Air Conditioning and Chiller Room. See Section E.3.6.
FLA5-2	5-2	Unit 2 Air Conditioning and Chiller Room. Similar to FLA 5-1.
FLA6-1	6-1	Unit 1 and 2 Emergency Switchgear Rooms. This area is located on the 252'0"/254'0" elevation in the Service Building. The reason for treating both of these fire areas as a single flood area is due to the interconnecting, normally open fire door. The area contains all Unit 1 and Unit 2 4kv switchgear, DC switchboards and batteries. No flood source is present in this area. There are four mechanisms for flood ingress. (1) From the Unit 1 and Unit 2 cable vaults and tunnels by over flowing the dikes. (2) From the Unit 1 Turbine Building via over flowing the 36" dikes. (3) Via the stairway from the Control Room, cable spreading room and normal switchgear rooms. Flood egress is not important due to the limited water sources in this area.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
		(4) From Chiller Room via interconnecting doorway.
FLA7A-1	7A-1	Battery Room 1-I. This area is located at 294'0" elevation of the Service Building and it contains control storage battery (2-BY-B-01-04). No source of flood was identified in this area and flooding ingress to the area is considered unlikely.
FLA7A-2	7A-2	Battery Room 2-I. Similar to FLA 7A-1.
FLA7C-1	7C-1	Battery Room 1-III. Similar to FLA 7A-1.
FLA7C-2	7C-2	Battery Room 2-III. Similar to FLA 7A-1.
FLA8A	8A	Unit 1 and 2 Turbine Building. See Section E.3.2.
FLA8B	8B	Unit 1 and 2 Normal Switchgear Room. This area is located at the 307'3" elevation in the service building. The area contains switchgear serving all balance of plant equipment. There are no significant flood sources in this area. The only method of flood ingress is from the Turbine Building operating floor via the interconnecting door. However, this is unlikely since accumulation of flood water at this elevation would not occur due to the numerous drainage pathways to lower Turbine Building elevations. Flood egress is not important due to lack of flood sources.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
FLA8C	8-C	Unit 1 and Unit 2 Cable Spreading Rooms. This area is located on the 294' elevation in the service building. There are no flood susceptible equipment located in this area and no flood sources. The only possible flood ingress pathways are as follows: (1) From the Unit 1 and Unit 2 Mechanical Equipment Rooms via interconnecting doors. However, the main floor of these areas are located at least 3 feet below the cable spreading room floor. (2) From the Turbine Building via an interconnecting door. However, the entrance is located such that there is no possibility of water accumulation outside the door.
FLA9A-1	9A-1	Emergency Diesel Generator 1H Room. This area is located on the 271'6" elevation in the Service Building and contains the 1H diesel generator. There are no significant water sources in the area and water cannot accumulate in the area due to ventilation louvers to the yard. The only method of flood ingress is from the Turbine Building walkway at the 271'6" elevation.
FLA9A-2	9A-2	Emergency Diesel Generator 2H Room. Similar to FLA 9A-1.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
FLA9B-1	9B-1	<u>Emergency Diesel Generator 1J Room</u>. Similar to FLA 9A-1.
FLA9B-2	9B-2	<u>Emergency Diesel Generator 2J Room</u>. Similar to FLA 9A-1.
FLA11A	11	<u>Auxiliary Building</u>. See Section E.3.3.
FLA11B	11	<u>Fuel and Decontamination Building</u>. This area is located to the north of the Auxiliary Building and contains no safety related equipment. The only potential flood source is the fire protection system, however this is normally isolated. Flood ingress is not important due to the lack of safety related equipment in the building. Flood egress is possible to the Auxiliary Building via a connecting tunnel, but is not important due to lack of flood sources.
FLA14A-1	14A-1	<u>Unit 1 Turbine Driven Auxiliary Feedwater Pump Room</u>. This area is located at 272'0" elevation adjacent to the Containment Building and contains the turbine driven Auxiliary Feedwater Pump. The only potential flood source is the Emergency Condensate Tank Supply to the AFW pump. Flood ingress and egress is not considered possible due to adequate sealing of all piping penetration and the elevation of the building.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
FLA14B-1	14B-1	Unit 2 Motor Driven Auxiliary Feedwater Pump Room. This area is located at 272'0" elevation adjacent to the Containment Building and contains the two motor driven Auxiliary Feedwater Pumps. The Emergency Condensate Storage Tank is located in this section of the building and is the only significant flood source. Flood ingress and egress from this area is not considered likely due to adequate sealing of all piping penetrations.
FLA14A-2	14A-2	Unit 2 Turbine Driven Auxiliary Feedwater Pump Room. This area is located at 272'0" elevation adjacent to the Containment Building and contains the turbine driven Auxiliary Feedwater Pump. The only potential flood source is the Emergency Condensate Tank Supply to the AFW pump. Flood ingress and egress is not considered possible due to adequate sealing of all piping penetration and the elevation of the building.
FLA14B-2	14B-2	Unit 2 Motor Driven Auxiliary Feedwater Pump Room. This area is located at 272'0" elevation adjacent to the Containment Building and contains the two motor driven Auxiliary Feedwater Pumps. The Emergency Condensate Storage Tank is located in this section of the building and is the only significant flood source.

TABLE E.3-1 (Continued)
DESCRIPTION OF NORTH ANNA FLOOD AREAS

Flood Area Designator	Fire Area Designator	Description of Area Boundary
		Flood ingress and egress from this area is not considered likely due to adequate sealing of all piping penetrations.
FLA15-1	15-1	Unit 1 Quench Spray Pump House. See Section E.3.4.
FLA15-2	15-2	Unit 2 Quench Spray Pump House. See Section E.3.4.
FLA17-1	17-1	Unit 1 Main Steam Valve House. This area is located adjacent to the Unit 1 Containment and contains various safety related equipment (main steam line isolation and relief valves) associated with Main Steam System. The major flood source in this area is the Main Steam System. Flood ingress is not considered possible due to the lack of flood propagation pathways. Flood egress is not considered risk significant due to the existence of ventilation louvers (at the lowest elevation) to the yard.
FLA17-2	17-2	Unit 2 Main Steam Valve House. Similar to FLA 17-1.

NOTE:

Other self contained buildings, outside the main power block were not considered explicitly due to the inability of floods in those areas to directly cause plant trips or significant accident mitigating system damage.

TABLE E.3-2
SUMMARY OF POTENTIAL FLOOD DAMAGE IN EACH FLOOD AREA

Flood Area	Worst Case Mitigating System Damage	Worst Case Initiating Event
FLA1-1: Unit 1 Containment	Loss of inside Recirculation Spray pumps and primary PORVs	T2 Unit 1 Loss of Feedwater
FLA2: Unit 1 and 2 Control Room	Loss of control to all safety and non safety systems (Unit 1 and 2)	Not Defined
FLA3-1: Unit 1 Cable Vault and Tunnel	1-EP-MC-19 (1H1-2N MCC) 1-EP-MC-20 (1H1-2S MCC) 1-EP-MC-21 (1J1-2H MCC) 1-EP-MC-22 (1J1-2S MCC) (Consequence of damage to this equipment has not been analyzed due to the elevation difference between the flood source and the equipment.)	No initiating event is postulated since flooding in this area is unlikely.
FLA5-1: Unit 1 Air Conditioning Chiller Room	Loss of Unit 1 Air Conditioning Chillers	T8, Unit 1 & 2 ESGR HVAC
FLA8A: Unit 1 Turbine Building	Loss of Unit 1 & 2 Systems: - Feedwater System	T2 Unit 1 & 2 Loss of Feedwater
FLA8B: Unit 1 Switchgear Rooms	Not analyzed due to the improbability of flooding in this area	
FLA8C: Unit 1 Cable Spreading Room	None	None
FLA9A-1: 1H Diesel Generator Room	Loss of DG 1H (Unit 1)	None
FLA9B-1: 1J Diesel Generator	Loss of DG 1J (Unit 1)	None

TABLE E.3-2 (Continued)
SUMMARY OF POTENTIAL FLOOD DAMAGE IN EACH FLOOD AREA

Flood Area	Worst Case Mitigating System Damage	Worst Case Initiating Event
FLA11A: Auxiliary Building	Loss of the following Unit 1 and 2 systems: - HHSI Suction - HHSI Pumps - HHSI Discharge - HHSI Recirculation - Component Cooling Water	T4, Unit 1 & 2 Loss of RCP Seal Cooling
FLA11B: Fuel and Decontamination	None	None
FLA14A-1: Unit 1 Turbine Driven Auxiliary Feedwater Pump Room	Loss of Unit 1 Systems: - TDAFW Pump	None
FLA14B-1: Unit 1 Motor Driven Auxiliary Feedwater Pump Room	Loss of Unit 1 Systems: - MDAFW Pumps	None
FLA15-1: Unit 1 Quench Spray Pump House	Loss of Unit 1 Systems: - QS Pumps - QS Discharge - LHSI Pumps - LHSI Recirculation - Outside RS Pumps	None

TABLE E.3-3
TURBINE BUILDING FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
Main Feedwater (1 & 2)	20,000 gpm	50,000 gallons	Volume is estimated and does not include CN or CN makeup.
Main Condensate (1 & 2)	18,000 gpm	100,000 gallons	Each CN pump = 9,000 gpm. Volume is estimated and does not include condenser or makeup.
Main Steam (1 & 2)	20,000 gpm	100,000 gallons	Volume is estimated and does not include total S/G volume.
Condenser		71,000 gallons	
Condensate Storage Tank (condenser makeup)	1,000 gpm	600,000 gallons	
Bearing Cooling	12,500 gpm	260,000 gallons (When in Tower-to-Tower mode of operation)	This is an engineering estimate of the BC Tower. Makeup from the CW inlet Tunnel is available. However, due to low capacity of makeup pump (850 gpm), sufficient time will be available to isolate all flooding scenarios.

TABLE E.3-3 (Continued)
TURBINE BUILDING FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
Component Cooling Surge Tank	8,000 gpm	6,000 gallons	Volume is Engineering estimate. CC Head Tank = 2810 gallons.
Fire Protection 6" Fire Main on Mezzanine Level also wet pipe sprinklers	5,000 gpm	SW reservoir or the North Anna Lake	~ 44 minutes of operator response time to reach 12".
CW for Condenser Cooling Pipes (1 & 2)	772,000 gpm	North Anna Lake	Four 96" diameter inlet and outlet pipes are provided per unit.

TABLE E.3-4
CIRCULATING WATER SYSTEM FLOOD SOURCES

Component	Nominal Size	Quantity	Estimated Max. Discharge Rate (gpm)
Condenser Piping	96" diameter		199,000
Condenser MOVs (106,A,B,C,D)	96" diameter	8	199,000
Condenser Inlet Expansion Joints	96" diameter	12	190,000
Condenser Water Box		1	80,000

TABLE E.3-5
AUXILIARY BUILDING FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
Charging Pump SW System	90 gpm	SW Reservoir	Maximum pipe size 2" diameter.
PG System/Tanks 1-PG-TK-1A/B	325 gpm	185,000 gallons each	Tanks are located in the South Yard (South of the Fuel Building). Piping and pumps only 3" & 4" pipes (3" feeds 4").
Domestic Water		25,000 gallons	Small bore piping.
Low Level Waste Tanks 1-LW-TK-3A/B	N/A	2,874 gallons each	
Primary Drain Tank 1-BR-TK-3	N/A	5,000 gallons	
Boron Test Tanks 1-BR-TK-2A/B	N/A	20,000 gallons each (UFSAR Table 1.3)	
High Level Waste Drain Tanks 1-LW-TK-2A/B	N/A	2,390 gallons each	
Steam Generator Blowdown Tanks 1/2-FW-TK-3	N/A	Small Capacity	

TABLE E.3-5 (Continued)
AUXILIARY BUILDING FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
Boron Recovery Tanks	325 gpm	120,000 gallons each - 3 tanks	Tanks not in the Auxiliary Building piping only 4".
Distillate Accumulator	N/A	550 gallons each	
Component Cooling Surge Tank	N/A	3,120 gallons (max)	
Safety Injection		RWST, 487,000 gallons (each) - 2 tanks	Tanks not located in this area.
Boric Acid Storage Tanks	N/A	8,000 gallons (each) - 3 tanks	
Volume Control Tanks	N/A	2,244 gallons (each) - 2 tanks	
Fire Protection	5,000 gpm (2 pumps x 2,500 gpm)	SW Reservoir or Lake Anna	Pump starts at 90 psig and 80 psig
Decon Tank	N/A	~ 11,400 gallons	
Waste Disposal Evap Test Tank	N/A	400 gallons	

TABLE E.3-5 (Continued)
AUXILIARY BUILDING FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
Contaminated Drains Collecting Tanks	N/A	1,230 gallons	
Waste Disposal Distillate Accumulator	N/A	290 gallons	
SW System Supply to CC heat exchangers	53,000 gpm	SW Reservoir	Four 24" diameter pipes are the main inlet and outlet lines for the SW Supply to the CC heat exchangers.

TABLE E.3-6
MAXIMUM FLOW RATES FROM MAJOR SW FLOOD SOURCES

Manually Isolable Sources

Component	Nominal Size	Quantity	Estimated Maximum Flow Rate from Rupture (in gpm)
Component cooling SW MOV's (1-SW-108A, 1-SW-208A)	24"	2	37,000
SW Piping Upstream of the First SW MOVs (upstream of 108A and 208A)	24"		53,000
Component Cooling Fuel Pit Coolers SW Supply MOVs	10"	2	6,500
SW Piping Upstream of Component Cooling Fuel Pit Coolers SW MOVs	10"		6,500

TABLE E.3-6 (Continued)
MAXIMUM FLOW RATES FROM MAJOR SW FLOOD SOURCES

Remotely Isolable Sources

Component	Nominal Size	Quantity	Estimated Maximum Flow Rate from Rupture (in gpm)
Component Cooling SW Supply MOVs	24"	2	37,000
Component Cooling SW Supply expansion joints	24"	2	53,000
Component Cooling SW Supply Piping (downstream of isolation valves)	24", 20", 18"		53,000/37,000/ 30,000
Component Cooling SW Supply manual valves	18"	8	21,000
Component Cooling SW Supply expansion joints	20"	4	37,000
Component Cooling SW discharge manual valves	24",18"	2, 4	10,000/6,000
Component Cooling SW discharge expansion joints	24", 20"	2, 4	15,000/11,000
Component Cooling SW discharge piping	24", 20" 18"		15,000/11,000/ 8,500

TABLE E.3-7
FREQUENCY OF MANUALLY ISOLABLE SW FLOODING EVENTS IN THE AUXILIARY BUILDING

CAT. 1 (25000 gpm < FLOW RATE< 53000 gpm)	Frequency/ Year
1 - Two 24" Diameter MOV on the SW Supply Headers	5.9E-6
2 - 24" Diameter Piping SEC. on the SW Headers	7.3E-6
CAT. 1 TOTAL CONTRIBUTION =	1.3E-5

CAT. 2 (8000 gpm < FLOW RATE< 25000 gpm)	Frequency/ Year
1 - Two 24" Diameter MOV on the SW Supply Headers	1.7E-5
2 - 24" Diameter Piping SEC. on the SW Headers	1.1E-5
CAT. 2 TOTAL CONTRIBUTION =	2.8E-5

CAT. 3 (3800 gpm < FLOW RATE< 8000 gpm)	Frequency/ Year
1 - Two 24" Diameter MOV on the SW Supply Headers	1.1E-5
2 - 24" Diameter Piping SEC. on the SW Headers	7.2E-6
3 - 10" Diameter MOV on the SW Supply Header to the CCW Pit Coolers	1.4E-6
4 - 10" Diameter Piping on the SW Supply Header to the CCW Pit Cooler	1.7E-5
CAT. 3 TOTAL CONTRIBUTION =	3.7E-5

TABLE E.3-8
FREQUENCY OF REMOTELY ISOLABLE SW FLOODING EVENTS IN THE AUXILIARY BUILDING

CAT. 1 (25000 gpm < FLOW RATE< 53000 gpm)	Frequency/ Year
1 - Two 24" Diameter EJ on the SW Supply Headers	3.1E-5
2 - Four 20" Diameter EJ on the SW Supply Headers	3.4E-5
3 - Two 24" Diameter MOV on the SW Supply Headers	5.9E-6
4 - Two 24" Diameter Piping SEC. on the SW Supply Headers	1.6E-5
5 - One 20" Diameter Piping Sec. on the SW Supply Headers	4.0E-6
6 - Two 18" Diameter Piping Sec. on the SW Supply Headers	2.6E-6
CAT. 1 TOTAL CONTRIBUTION =	9.3E-5

TABLE E.3-8 (Continued)
FREQUENCY OF REMOTELY ISOLABLE SW FLOODING EVENTS IN THE AUXILIARY BUILDING

CAT. 2 (8000 gpm < FLOW RATE< 25000 gpm)	Frequency/ Year
1 - Two 24" Diameter EJ on the SW Supply Headers	4.7E-5
2 - Two 24" Diameter EJ on the SW Return Headers	7.7E-5
3 - Four 20" Diameter EJ on the SW Supply Headers	9.9E-5
4 - Four 20" Diameter EJ on the SW Return Headers	1.3E-4
5 - Two 24" Diameter MOV on the SW Supply Headers	1.7E-5
6 - Two 24" Diameter MAN. VLVs on the SW Return Headers	2.3E-5
7 - Eight 18" Diameter MAN. VLVs on the SW Supply Headers	5.8E-5
8 - 24" Diameter Piping SEC. on the SW Supply Headers	2.4E-5
9 - 24" Diameter Piping SEC. on the SW Return Headers	3.9E-5
10- 20" Diameter Piping SEC. on the SW Supply Headers	1.2E-5
11- 20" Diameter Piping SEC. on the SW Return Headers	1.6E-5
12- 18" Diameter Piping SEC. on the SW Supply Headers	1.6E-5
13- 18" Diameter Piping SEC. on the SW Supply Headers	1.9E-5
CAT. 2 TOTAL CONTRIBUTION =	5.8E-4

TABLE E.3-8 (Continued)
FREQUENCY OF REMOTELY ISOLABLE SW FLOODING EVENTS IN THE AUXILIARY BUILDING

CAT. 3 (3800 gpm < FLOW RATE< 8000 gpm)	Frequency/ Year
1 - Two 24" Diameter EJ on the SW Supply Headers	3.0E-5
2 - Two 24" Diameter EJ on the SW Return Headers	3.0E-5
3 - Four 20" Diameter EJ on the SW Supply Headers	6.5E-5
4 - Four 20" Diameter EJ on the SW Return Headers	6.5E-4
5 - Two 24" Diameter MOV on the SW Supply Headers	1.1E-5
6 - Two 24" Diameter MAN. VLVs on the SW Return Headers	4.6E-5
7 - Eight 18" Diameter MAN. VLVs on the SW Supply Headers	4.5E-5
8 - Eight 18" Diameter MAN. VLVs on the SW Return Headers	7.2E-6
9 - 24" Diameter Piping SEC. on the SW Supply Headers	1.6E-5
10- 24" Diameter Piping SEC. on the SW Return Headers	1.6E-5
11- 20" Diameter Piping SEC. on the SW Return Headers	7.7E-6
12- 20" Diameter Piping SEC. on the SW Return Headers	7.7E-6
13- 18" Diameter Piping SEC. on the SW Supply Headers	1.1E-5
14- 18" Diameter Piping SEC. on the SW Return Headers	1.1E-5
CAT. 3 TOTAL CONTRIBUTION =	3.7E-4

TABLE E.3-9
CONTRIBUTION OF MANUALLY ISOLABLE FLOODING TO THE FREQUENCY OF FAB2 FDS

Contributor	Frequency	Probability of Failure to Isolate	Contribution to the Frequency of of FAB2 FDS
1 - CAT. 1	1.3E-5	1.0E+0	1.3E-5
2 - CAT. 2	2.8E-5	1.0E+0	2.8E-5
3 - CAT. 3	3.7E-5	5.0E-2	1.9E-6
TOTAL CONTRIBUTION	=		4.3E-5

TABLE E.3-10
CONTRIBUTION OF REMOTELY ISOLABLE FLOODING TO THE FREQUENCY OF FAB2 FDS

Contributor	Frequency	Probability of Failure to Isolate	Contribution to the Frequency of of FAB2 FDS
1 - CAT. 1	9.3E-5	1.0E-1	9.3E-6
2 - CAT. 2	5.8E-4	8.0E-2	4.6E-5
3 - CAT. 3	3.7E-4	5.0E-3	1.9E-6
TOTAL CONTRIBUTION =			5.7E-5

TABLE E.3-11
MAXIMUM FLOW RATES FROM AUXILIARY BUILDING
FIRE PROTECTION SYSTEM FLOOD SOURCES

Component	**Nominal Size**	**Quantity**	**Estimated Max. Flow**
Piping	6" diameter	147'0"	8000 gpm
	4" diameter	266'6"	3600 gpm
Manual Valves	4" diameter	4	3600 gpm

TABLE E.3-12
FREQUENCY OF FIRE PROTECTION SYSTEM FLOODING EVENTS IN THE AUXILIARY BUILDING

CAT. 1 (2700 < FLOW RATE< 8000)	FREQUENCY
1 - Most severe rupture of 4" pipe	7.0E-6
2 - Most severe rupture of 6" pipe	1.7E-6
3 - Most severe rupture of any one of four manual valves	2.5E-6
TOTAL FREQUENCY FOR CAT. 1 =	1.1E-5

CAT. 2 (900 < FLOW RATE< 2700)	FREQUENCY
1 - Severe rupture of 4" pipe	2.1E-5
2 - Severe rupture of 6" pipe	5.1E-6
3 - Severe rupture of any one of four manual valves	7.5E-6
TOTAL FREQUENCY FOR CAT. 2 =	3.4E-5

CAT. 3 (FLOW RATE< 900)	FREQUENCY
1 - Least severe rupture of 4" pipe	4.2E-5
2 - Least severe rupture of 6" pipe	1.0E-5
3 - Least severe rupture of any one of four manual valves	1.5E-5
TOTAL FREQUENCY FOR CAT. 3 =	6.7E-5

TABLE E.3-13
CONTRIBUTION OF FIRE PROTECTION SYSTEM FLOODING
TO THE FREQUENCY OF FAB4 FDS

Contributor	Frequency	Probability of Failure to Isolate	Contribution to the Frequency of of FAB4 FDS
1 - CAT. 1	1.1E-5	3.6E-2	4.0E-7
2 - CAT. 2	3.4E-5	4.7E-3	1.6E-7
3 - CAT. 3	6.7E-5	8.8E-4	5.9E-8
TOTAL CONTRIBUTION =			6.2E-7

TABLE E.3-14
SAFEGUARDS AREA - UNIT 1 FLOOD SOURCES

Source	System Flow Rate	Source Capacity	Comment
LHSI	3000 gpm	RWST >450,000 gallons	Tank located outside area but piping in area is normally pressurized.
Quench Spray (FLA19A)		RWST >450,000 gallons	
Service Water Piping Associated with Recirculation Spray Heat Exchangers (FLA19A)		Service Water Reservoir	24" dia. SW piping to RS Heat Exchangers. The SW Isolation valves are located in this area. 8" dia. SW piping to the recirculation air cooling coils are also located in this area.

TABLE E.3-15
MAXIMUM FLOWRATES FROM SERVICE WATER FLOOD SOURCES IN THE UNIT 1 AIR CONDITIONING CHILLER ROOM

Component	Nominal Size	Quantity	Estimated Max. Flow (gpm)
MOV	4" diameter	3	1500
Manual Valves	4" diameter	6	1500
Check Valves	4" diameter	3	1500
	3" diameter	3	850
Air Operated Valves	3" diameter	6	850
Piping	4" diameter	200' (Approx.)	1500
	3" diameter	100' (Approx.)	850

TABLE E.3-16
FREQUENCY OF SW FLOOD CATEGORIES
IN THE AIR CONDITIONING CHILLER ROOM

	Frequency/ Year
CAT. 1 (1000 gpm < FLOW RATE< 1500 gpm)	
1 - Most Severe Rupture Of 4" Diameter Piping	9.1E-6
2 - Most Severe Rupture of Any One of 3 MOVs	8.3E-6
3 - Most Severe Rupture of Any One of 6, 4" MVs	3.8E-6
4 - Most Severe Rupture of Any One of 9, 4" EJ	2.3E-4
5 - Most Severe Rupture of Any 1 of 3, 4" CK Valves	7.6E-6
CAT. 1 TOTAL CONTRIBUTION =	2.6E-4
CAT. 2 (500 gpm < FLOW RATE< 1000 gpm)	
1 - Severe Rupture Of 4" Diameter Piping	2.7E-5
2 - Severe Rupture of Any One of 3 MOVs	2.5E-5
3 - Severe Rupture of Any One of 6, 4" MVs	1.1E-5
4 - Severe Rupture of Any One of 9, 4" EJ	6.8E-4
5 - Severe Rupture of Any 1 of 3, 4" CK Valves	2.3E-5
6 - Most Severe Rupture of Any One of 6 AOVs (3"DIA)	5.8E-6
7 - Most Severe Rupture of 3" Piping Section	1.9E-6
8 - Most Severe Rupture of Any 1 of 3, 3" CK Valves	7.6E-6
CAT. 2 TOTAL CONTRIBUTION =	7.8E-4

TABLE E.3-16 (Continued)
FREQUENCY OF SW FLOOD CATEGORIES
IN THE AIR CONDITIONING CHILLER ROOM

CAT. 3 (200 gpm < FLOW RATE< 500 gpm)	Frequency/ Year
1 - Severe Rupture of Any One of 6 AOVs (3"DIA)	5.7E-6
2 - Severe Rupture of 3" Piping Section	1.7E-5
3 - Severe Rupture of Any 1 of 3, 3" CK Valves	2.3E-5
CAT. 3 TOTAL CONTRIBUTION =	4.6E-5

TABLE E.3-17
CONTRIBUTION OF SW FLOODING
TO THE FREQUENCY OF FAC1 FDS

Contributor	Frequency	Probability of Failure to Isolate	Contribution to the Frequency of of FAC1 FDS
1 - CAT. 1	2.6E-4	1.0E+0	2.6E-4
2 - CAT. 2	7.8E-4	3.9E-1	3.0E-4
3 - CAT. 3	4.6E-5	2.8E-2	1.3E-6
TOTAL CONTRIBUTION =			5.6E-4

TABLE E.3-18
SUMMARY OF NORTH ANNA INTERNAL FLOOD DAMAGE STATES

Flood Source	Flood Damage State	Frequency	Internal Events Model
	AUXILIARY BUILDING		
SW (Unit 1)	1AB2 - Loss of All Charging Pumps - Loss of All CC Pumps - Loss of SW To RS Heat Exchangers	1.0E-4 Table E.3-9/10	Loss of Seal Cooling (T4)
Fire Protection System (Unit 1)	1AB4 - Loss of All Charging Pumps - Loss of All CC Pumps	6.2E-7 Table E.3-13	Loss of Seal Cooling (T4) Conservatively Quantified=1AB2
	AIR CONDITIONING AND CHILLER ROOM		
SW Supply to HVAC	1AC1 - Loss of Control/Relay Room HVAC Chillers	5.6E-4 Table E.3-19	Loss of HVAC (Units 1 & 2)

TABLE E.5-1
FLOODING MITIGATION EQUIPMENT

Item	Area	Hardware	Procedure
1	Turbine Building	1-CW-LS-107A and B level switches installed in the condenser tube cleaning pit.	Test operability and proper calibration every 18 months (included in the EPM-0801-01).
2	Turbine Building	1-CW-LS-106A-1, 2, 3 and 1-CW-LS-106B-1, 2, 3 level switches distributed about the turbine building 254' elevation.	Test operability and proper calibration every 18 months (included in the EPM-0801-01).
3	Turbine Building		O-AP-39.1, Turbine Building Flooding Procedure.
4	Turbine Building		Per NAPS UFSAR (page 10.4-7), if CW Pumps fail to auto trip, the Control Room Operator will close the condenser inlet or outlet water box MOVs, which will shut down all four CW Pumps when valve is ≤17% closed (ESK-6CC). (This flooding counter measure is not covered in O-AP-39.1, Step 3b.)
5	Turbine Building	Flood dikes in front of the ESGR and the Auxiliary Building Tunnel.	Administrative control over removal of the flood dikes. Periodic inspection to ensure dikes in place.
6	Turbine Building	Valve Pits	Ensure the floor openings of all pits are sufficiently exposed for ingress of flood water.

TABLE E.5-1 (Continued)
FLOODING MITIGATION EQUIPMENT

Item	Area	Hardware	Procedure
7	Auxiliary Building	Back flow prevention devices in the equipment and floor drains of the charging pump cubicles	Replace devices based on the service life. Flush every 18 month to ensure the proper functioning of the devices.
8	Auxiliary Building	Seals on the Charging Pump cubicles	Inspection every 18 months to ensure the integrity of the seals (up to 44")
9	Auxiliary Building	4" high flood dike around each charging pump cubicles at 259' 6" elevation of the Auxiliary Building	Administrative control over removal of flood dikes periodic to ensure the integrity of these flood dikes.
10	Auxiliary Building	1-DA-LSH-114 flood detection switch in the SW Valve Pit	Periodic testing to ensure operability and correct calibration.
11	Auxiliary Building	1-DA-LS-105, 111A&B high water level switches installed in the Auxiliary Building sump pit	Periodic testing to ensure operability and correct calibration.
12	Auxiliary Building	All the piping penetrations between the charging pump cubicles and the Auxiliary Building are sealed to at least 44" above the floor elevation.	Periodic testing of the piping penetrations to ensure the integrity of the seals.

TABLE E.5-1 (Continued)
FLOODING MITIGATION EQUIPMENT

Item	Area	Hardware	Procedure
13	Quench Spray Pump House	The damming board sealing the piping penetration between the Quench Spray Pump House and the Auxiliary Building is supported such that it can act as a flood barrier	Periodic inspection to ensure the integrity of the damming board and the support mechanisms.
14	Quench Spray Pump House	The piping tunnel between the Quench Spray Pump house and the Auxiliary Feedwater Pump Houses	Periodic inspection to ensure the integrity of the seals at the pertinent end of the tunnel.
15	Quench Spray Pump House	The piping tunnel between the Quench Spray Pump House and the Turbine Building	Periodic inspection to ensure the integrity of the seals at the pertinent end of the tunnel.
16	Quench Spray Pump House	Flood detection sensors in the safeguards area (1-DA-LS-101-1 and 2)	Periodic inspection to ensure operability and correct calibration.
17	Chiller Room	3' flood dike in front of the Chiller Room/Turbine Building door	Administrative control over removal of the flood dikes. Periodic inspection to ensure dikes are in place.

TABLE E.5-1 (Continued)
FLOODING MITIGATION EQUIPMENT

Item	Area	Hardware	Procedure
18	Chiller Room	Gap under the Chiller Room/ Turbine Building door is large enough to allow SW induced flooding in the Chiller Room to propagate to the Turbine Building.	Regular inspection to ensure the door gap is clear of any obstruction.
19	Chiller Room	The 3'3" dike protecting the Chiller Room/Fan Room door	Regular inspection to ensure the seal(s) integrity
20	Chiller Room	Two sump pump (1-DB-P-10A-B) each with dewatering capacity of 100 GPM	Regular cycling to ensure the operability of the pumps.
21	Emergency Switch Gear Room	9" flood dikes in front of the door between the ESGR and the cable vault tunnel	Administrative control
22	Emergency Switch Gear Room	Pipe in pipe arrangement of the SW lines in the air conditioning section of the ESGR.	Periodic inspection to ensure the integrity of the outer pipe.
23	Emergency Switch Gear Room	Isolation of the fire protection lines	Periodic inspection to ensure the fire protection isolation valve which is located in the Turbine Building is closed.

TABLE E.6-1
TURBINE BUILDING FLOOD EVENTS, THROUGH JULY 1985

Plant	System	Event Description	Severity	Remarks
Duane Arnold (July 74)	Cond. CW	Total of 123000 gal accumulated in Turbine Building due to tank overflow caused by valve malfunction.	Unknown (123000 gal total spill)	NPE, Oconee PRA
Quad Cities (June 72)	CW	Valve closed inadvertently and water hammer rupture expansion joint.	Very large spill (150000 gal)	NPE, Oconee PRA
Oconee 3 (Oct 76)	CW	During maintenance solenoid failure caused condenser outlet valve to open while water box manways were removed.	Large spill (60000 gpm)	NPE, Oconee PRA, SOER 85—5
Crystal River (Jan 79)	CW	Seawater inlet block valve was opened due to solenoid failure causing seawater to accumulate in Turbine Building.	Large spill (65000 gpm)	NPE, Oconee PRA, SOER 85—5
Peach Bottom (Jan 84)	CW	Vent valve on condenser waterbox inadvertently left open following maintenance. Operators ignored high sump alarm. 6-8 feet of water in pump room.	Large spill	SOER 85—5
Surry 2 (Jan 75)	SW	Pump developed seal leak.	Small	Oconee PRA

TABLE E.6-1 (Continued)
TURBINE BUILDING FLOOD EVENTS, THROUGH JULY 1985

Plant	System	Event Description	Severity	Remarks
Surry 2 (Oct 77)	SW	Personnel forgot to close valves opened for maintenance.	Small	Oconee PRA
E. Hatch (Oct 78)	SW	Valve body blowout during repair.	Small	Oconee PRA
Surry 2 (Oct 78)	SW	SW valve malfunctioned during maintenance	Small	NPE, Oconee PRA
Surry 2 (July 82)	SW	Valve pit flooded	Small	NPE
Dresden (Sept 74)	Conden-sate System	Condensate booster pump vent line was ruptured causing 20" of water to accumulate in pump room.	Unknown (assume severe)	NPE

TABLE E.6-2
FREQUENCY OF TURBINE BUILDING FLOODING EVENTS

Flood Area	No. Of Significant Events Reported	Years Of Experience Through July 1985	Frequency Per Year
Turbine Building	6	829	7.2E-3

TABLE E.6-3
AUXILIARY BUILDING FLOODING EVENTS IN US LIGHT-WATER REACTORS THROUGH JULY 1985

No.	Plant	Event Description	Severity	Remarks
1	Browns Ferry 3 (Apr 78)	Supply line to condensate ring header failed at welded joint, resulting in spillage of 80,000 gal on condensate onto core spray pump room floor. Probable cause was weld fatigue caused by line movement during repeated pump starts.	Severe flood from ECCS	NPE
2	Brunswick 1 (July 77)	Rupture of flange gasket on RHR SW heat exchanger outlet valve resulted in water accumulation which damaged pump and valves.	Severe flood from SW system	NPE
3	Brunswick 1 (Nov 77)	Water accumulated in HPCI pump room, producing backflow through sump drain system, and HPCI turbine tripped due to shorted oil pump.	Small	NPE
4	Dresden 2 (Nov 77)	River water spilled from disassembled RHR heat exchanger outlet valve during test. About 3.5 feet of water accumulated in room.	Severe flood from SW system	NPE
5	Trojan (May 77)	Head gasket on spent fuel pool demineralizer failed, causing large volume of water to spill into passage way.	Small	NPE

TABLE E.6-3 (Continued)
AUXILIARY BUILDING FLOODING EVENTS IN US LIGHT-WATER REACTORS THROUGH JULY 1985

No.	Plant	Event Description	Severity	Remarks
6	Oconee (Oct 74)	Operator failed to isolate LPCI header, and 3 feet of water accumulated in LPCI pump room. Both pumps were submerged.	Severe flood from ECCS	NPE
7	Indian Point 2	Leakage between essential and nonessential headers of CCW pump room during ISI hydro test led to accumulation of about 4 feet of water in room.	Severe flood from SW system	NPE

TABLE E.6-4
FREQUENCY OF FLOODING IN AUXILIARY BUILDINGS

Plant Type	Flood Area	No. Of Events	Table E.6-3 Incident No.	Years Of Experience Through July 85	Frequency
BWR	HPPR	2	1,3	690	2.9E-3
BWR	LPPR	2	2,4	690	2.9E-3
BWR	General	0	NA	345	0
PWR	HPPR	0	NA	968	0
PWR	LPPR	2	6,7	968	2.1E-3
PWR	General	1	5	484	2.1E-3
PWR/ BWR	HPPR	2	NA	1658	1.2E-3
PWR/ BWR	LPPR	4	NA	1658	2.4E-3
PWR/ BWR	General	1	NA	829	1.2E-3

HPPR = High Pressure Pump Room
LPPR = Low Pressure Pump Room

TABLE E.6-5
SUMMARY OF HISTORICAL FLOODING FROM SERVICE WATER SYSTEMS

DATE	PLANT	LEAKING COMPONENT	DESCRIPTION	LINE SIZE	FLOW RATE	TOTAL DISCHARGE	ISOLABLE?	APPLICABLE TO SURRY?	REF.
06/75	Surry 2	Pump Seal	Pump developed seal leak.		"Small"			Yes	Oconee PRA
04/19/89	River Bend	Freeze Seal	Loss of cooling to freeze seal on unit cooler (during maintenance).		1250 gpm	15000 gallons	Yes 12 min.	Yes	OE 3322
10/87	Oconee 1	Freeze Seal			?	?	10 hrs.	Yes	IS 912
07/28/82	Surry 2	N/A	Condenser waterboxes were drained for cleaning. The water drained into the Service Water valve pit and there was a failure to inform the next shift of the need to pump the pit. The unit was at full power before this was detected. Valve motor submerged.	N/A	(500 gpm?)	(5000 gallons?)	Yes Limited Source	No Dikes were built	LER 281/ 82 39
05/08/90	Clinton 1	Expansion Joint	Missing tie-rods across expansion bellows, bellows developed leak, piping/supports damaged.	6"	"Leak" (1 gpm?)	V. Small		Yes	LER 461/ 90 010
06/16/86	Surry	Metal Expansion Joint	Corrosion of dissimilar metal weld in a stagnant environment.		1 gpm	Small	Yes	Yes	OE 1763
07/28/88	Susquehanna 2	Pipe Cap	Corrosion of 120 psi ESW piping caused ejection of cap on 1/2" drain.	1/2"	(20 gpm?)	Small	Yes Iso Valve	Yes	OE 284/
06/17/85	Quad Cities 1	Broken Vent Line	RHR Service Water pump vault partially filled with water. Spray also affected the Diesel Generator cooling water pump.		(50 gpm?)	Small	Yes	Yes	LER 254/ 85 08
07/22/75	Millstone 2	Hx Nozzle	Cast iron SW inlet nozzle to air cooler Hx severed due to improper design. Flooding of diesel generator room.		?	?	Yes	No	Deficiency Report No. 21
02/91	Palisades	Pipe	Flow through valve caused erosion and pinhole leak.		"Leak" (1 gpm?)	Small		Yes	OE 4381
Several	Pilgrim	Pipe	Erosional removal, perforation and/or delamination of rubber pipe lining leading to corrosion and pinhole leaks of carbon steel pipe in sea water.		Nil-6 gpm	Small	Yes	Yes	OE 2157

TABLE E.6-5 (Continued)
SUMMARY OF HISTORICAL FLOODING FROM SERVICE WATER SYSTEMS

DATE	PLANT	LEAKING COMPONENT	DESCRIPTION	LINE SIZE	FLOW RATE	TOTAL DISCHARGE	ISOLABLE?	APPLICABLE TO SURRY?	REF.
09/08/87	Susquehanna 1	Flex Pipe	Fifteen out of 80 flex pipes to room coolers were leaking/spraying due to corrosion.		"Leak" "Spray" (1 gpm?)	Small		Yes	OE 2509
05/26/82	Salem 2	Seam Weld	Failed motor cooler seam weld.		100 gpm	(5000 gallons)	Yes	Yes	LER 311 82 39
06/23/81	Salem 2	Threaded Pipe Cap	A 1/2" threaded pipe cap on a motor cooler vent line had backed off.	1/2"	(25 gpm)	12000 gallons	Yes Upon detection	Yes	LER 311/ 81 38
10/17/80	Indian Point 2	Cooling Coil	Multiple leaks from the coils of the Containment fan cooling units. These coolers have a history of such leakage. The problem was exacerbated by inoperative sump pumps. The lower end of the RPV head was submerged.	Small	Small (10 gpm?)	100000 gallons		Yes	NUREG 1275 Vol. 3
02/27/90	Arkansas Nuclear One	Cooling Coil	Leak from 1 of 8 reactor building cooling coils.	Small	0.1 gpm	Small		Yes	OE 3835
11/19/87	Robinson 2	Cooling Coil	Leak in SW supply to coil.	Small	"Leak" (5 gpm?)	Small		Yes	PS 1430
12/06/87	Salem 1	Cooling Coil	Leak from fan cooling unit in Containment.	Small	< 1 gpm	5 gallons		Yes	PS 1439
05/14/87	Salem 1	Cooling Coil	Leak from fan cooling unit in Containment.	Small	7.5 gpm	Small	Yes 25 min.	Yes	PS 1295

Note: ( ) indicates value was estimated from event description.

TABLE E.6-6
SUMMARY OF HISTORICAL FLOODING FROM CIRCULATING WATER SYSTEMS

DATE	PLANT	LEAKING COMPONENT	DESCRIPTION	LINE SIZE	FLOW RATE	TOTAL DISCHARGE	ISOLABLE?	APPLICABLE TO SURRY?	REF.
06/72	Quad Cities 1	Expansion Joint	The failure of a high pressure hydraulic system caused a loss of supply to a valve operator, permitting the valve to slam shut. This created a water hammer and ruptured an expansion joint.		150000 gpm	1000000 gallons	Yes Top Pumps 6 min.	No. Valve operators are not hydraulic	Oconee PRA
05/31/ 5	LaSalle 1	Rubber Expansion Joint	Water hammer due to sudden closure of 108" Henry Pratt butterfly valve with undersized Limitorque operator. The operator mounting bolts were not sufficiently torqued, became loose and failed in fatigue, permitting the disk to swing freely and slam shut. Filled pump pit to 15'. Flooding terminated when level reached that of the cooling pond.	108"	2000 gp	600000 gallons	With great difficulty Stop logs used at intake	Possibly	IS 531 LER 3737 85 45
3/17/87	South Texas 1	Pump Casing & Discharge Elbow	Water hammer with peak pressure of ~400 psi due to sudden closure of Allis-Chalmers butterfly valve. Failure resulted from fatigue of cap screws to EIM valve operator permitting disk to swing freely. Pump casing failed at weld repair causing breach approx. 3' or 4' by 7'. Rapid flooding of pump bay to 7'. Dropped to 4' - 5' by time operations personnel arrived.	96"	(200000 gpm)	(300000 gallons)	Yes	Possibly	PNO V 87 10 IS 712 PS 1252
06/28/87	Palo Verde 1	Piping/Water Box	Water hammer due to sudden closure of 120" Henry Pratt butterfly valve at condenser outlet. Failure due to backing out of one cap screw to EIM valve operator and shear failure of remaining screws, permitting disk to swing freely. Several 1' to 1-1/2' long splits occurred in the piping and waterbox. Flooded stair-well to 3', Turbine Building to 3 to 8 inches.	120"	(40000 gpm)	(500000 gallons)	Yes	Possibly	PNO V 87 49 IS 712
04/77	Three Mile Island 1	Pump Body	During circulating water pump start, the 8' diameter pump casing split and separated 1 to 5 inches. The event was caused by a water hammer originating by starting the pump when it was rotating backwards.	96"	37500 gpm	(600000 gallons)	No Stopped when flood at source level	No No pump start transient	Oconee PRA

TABLE E.6-6 (Continued)
SUMMARY OF HISTORICAL FLOODING FROM CIRCULATING WATER SYSTEMS

DATE	PLANT	LEAKING COMPONENT	DESCRIPTION	LINE SIZE	FLOW RATE	TOTAL DISCHARGE	ISOLABLE?	APPLICABLE TO SURRY?	REF.
08/05/79	Doel 2 (Belgium)	Valve Body	Leakage from the lower portion of a butterfly valve. The flood level continued to increase until unit was shut down and the system inventory was drained.		(25000 gpm)	(2500000 gallons)	With great difficulty 6 hrs.	Possibly But valves are ductile iron	IS 399
10/19/89	Vandellos 1 (Spain)	Expansion Joint	Fire causes failure of an expansion joint and subsequent sea water leak. Fire water and sea water flood Turbine Building and Reactor Building.		(?)	(?)	No (?)	Yes	OE 3618
04/07/88	Fort St. Vrain	Rubber Expansion Joint	24" long tear in expansion joint (age degradation suspected) which flooded circulating water pump pit in minutes. Two prior flooding events in same pit due to other causes. An inspection of other joints showed deterioration.	54"	15000 gpm	300000 gallons	No Must de-energiz to gain access to ISO valve	Possibly If not maintained	1 LH 88 006 MI 5758 OE 2764 PS 1521
10/10/76	Oconee 3	Open Manway	With the waterbox manways open, the failure of the invertor supplying power to the condenser cooling water outlet valve solenoids, compounded by the failure of a "hold closed" jackscrew, allowed the valve to open. This allowed the Turbine Building to flood by gravity until the solenoid was re-energized. Water reached a depth of 24 inches in common Turbine Building.	N/A	63000 gpm	2000000 gallons	Yes With difficulty 32 min.	No Air operator not used	IS 399 Oconee PRA
01/14/84	Peach Bottom 3	Valve	Improper valve line up during maintenance.	6"	3000 gpm	200000 gallons	Yes Upon detection	Yes	IS 399
09/17/86	Brunswick 1	Sight Glass	The rupture of an amertap sight glass in the condenser pit resulted in flooding of the pit and tripping of all four circulating water pumps.	N/A	(5000 gpm)	(150000 gallons)	Yes Top pumps	Yes	PS 1128

TABLE E.6-6 (Continued)
SUMMARY OF HISTORICAL FLOODING FROM CIRCULATING WATER SYSTEMS

DATE	PLANT	LEAKING COMPONENT	DESCRIPTION	LINE SIZE	FLOW RATE	TOTAL DISCHARGE	ISOLABLE?	APPLICABLE TO SURRY?	REF.
12/23/87	Susquehanna	Manway Gasket	Improperly installed manway gasket on waterbox exhibits significant leak on startup. Condenser bay flooded to 3'4".	N/A	(5000 gpm)	~60000 gallons	No ISO valves	Yes	OE 2329
01/16/88	Catawba 1	Pipe Weld	Failure in yard, thought to result from thermal stress (lower third of pipe encased in concrete), leakage less than make-up.	120"	?	?		No Different concrete enclosure	OE 2395
06/74	Duane Arnold	Valve	A backwash valve malfunctioned during condensate demineralizer backwash.	N/A	(10000 gpm?)	120000 gallons	Yes	Yes	Oconee PRA
10/78	Surry 2	Valve	Valve malfunction during maintenance.		(1000 gpm?)		Yes	Yes	Oconee PRA

NOTE: ( ) indicates value was estimated from event description.

TABLE E.6-7
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
J. M. Farley Unit 1	Alabama Power		Jun - 77	13.8						
J. M. Farley Unit 2	Alabama Power		Oct - 80	10.5						
Palo Verde - 1	Arizona Public Service		Dec - 84	6.3						
Palo Verde - 2	Arizona Public Service		Dec - 84	6.3						
Palo Verde - 3	Arizona Public Service		Mar - 87	4.1						
ANO Unit 1	Arkansas Power & Light	PWR	May - 74	16.9	Bechtel	12	4	0	8	Stainless SW EJ's
ANO Unit 2	Arkansas Power & Light	PWR	Jul - 78	12.7	Bechtel	12	4	0	8	Stainless SW EJ's
Calvert Cliff 1	Baltimore Gas & Electric		Jun - 74	16.8						
Calvert Cliff 2	Baltimore Gas & Electric		Aug - 76	14.6						
Pilgrim Unit 1	Boston Edison	BWR	Jun - 72	18.8	Bechtel	17	8	5	8	
Brunswick Unit 1	Carolina Power & Light		Nov - 76	14.4						
Brunswick Unit 2	Carolina Power & Light		Dec - 74	16.3						
Robinson - 2	Carolina Power & Light		Sep - 70	20.6						
Harris - 1	Carolina Power & Light		Jan - 87	4.2						
Perry - 1	Cleveland Elec. Illum. Co.		Mar - 86	5.1						
Dresden Unit 2	Commonwealth Edison		Dec - 69	21.3						
Dresden Unit 3	Commonwealth Edison		Jan - 71	20.2						
Zion Unit 1	Commonwealth Edison	PWR	Apr - 73	18.0	S & L	12	6	0	0	
Zion Unit 2	Commonwealth Edison	PWR	Nov - 73	17.4	S & L	12	6	0	0	

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
Quad City Unit 1	Commonwealth Edison	BWR	Oct - 71	19.5	S & L	42	13	0	7	
Quad City Unit 1	Commonwealth Edison	BWR	Apr - 72	19.0	S & L	42	13	0	7	
LaSalle County - 1	Commonwealth Edison		Apr - 82	9.0						
LaSalle County - 2	Commonwealth Edison		Dec - 83	7.3						
Byron - 1	Commonwealth Edison		Feb - 85	6.1						
Byron - 2	Commonwealth Edison		Jan - 87	4.2						
Braidwood - 1	Commonwealth Edison		May - 87	3.9						
Braidwood - 2	Commonwealth Edison									
Haddam Neck	Connecticut Yankee		Jun - 67	23.8						
Indian Pt. Unit 2	Consolidated Edison/NY	PWR	Sep - 73	17.6	UE & C		12		20	No SW information
Big Rock Point	Consumers Power Co.		Aug - 62	28.7						
Palisades	Consumers Power Co.		Oct - 72	18.5						
Permi - 2	Detroit Edison Co.		Mar - 85	6.1						
Oconee Unit 1	Duke Power		Feb - 73	18.1						
Oconee Unit 2	Duke Power		Oct - 73	17.5						
Oconee Unit 3	Duke Power		Jul - 74	16.7						
McGuire - 1	Duke Power		Jun - 81	9.8						
McGuire - 2	Duke Power		Mar - 83	8.1						

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
Catawba - 1	Duke Power		Jun - 85	5.8						
Catawba - 2	Duke Power		May - 86	4.9						
Beaver Valley 1	Duquesne Light		Jan - 76	15.2						
Beaver Valley 2	Duquesne Light		Aug - 87							
Crystal River 3	Florida Power Corp.		Dec - 76	14.3						
Turkey Point 3	Florida Power & Light		Jul - 72	18.7						
Turkey Point 4	Florida Power & Light		Apr - 73	18.0						
St. Lucie 1	Florida Power & Light		Mar - 76	15.1						
St. Lucie 2	Florida Power & Light		Apr - 83	8.0						
Edwin I. Hatch 1	Georgia Power		Aug - 74	16.6						
Edwin I. Hatch 2	Georgia Power		Jun - 78	12.8						
Vogtle - 1	Georgia Power		Jan - 87	4.2						
Vogtle - 2	Georgia Power		Mar - 89							
River Bend - 1	Gulf States Utilities		Aug - 85	5.6						
Clinton - 1	Illinois Power Co.	BWR	Apr - 87	4.0	S & L	25	4	0	6	
Donald C. Cook 1	Indiana & Mich. Pwr. Co.		Oct - 74	16.5						
Donald C. Cook 2	Indiana & Mich. Pwr. Co.		Dec - 77	13.3						

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
Duane Arnold 1	Iowa Electric & Power		Feb - 74	17.1						
Oyster Creek 1	Jersey Central Pwr.& Light		Apr - 69	22.0						
Wolf Creek	Kansas Gas & Electric Co.		Mar - 85	6.1						
Waterford - 3	Louisiana Pwr. & Light		Dec - 84	6.3						
Maine Yankee	Maine Yankee		Jun - 73	17.8						
Three Mile Island 1	Metropolitan Edison		Apr - 74	17.0						
Three Mile Island 2	Metropolitan Edison		Feb - 78	13.1						
Grand Gulf 1	Mississippi Pwr. & Light		Jul - 82	8.7						
Cooper	Nebraska Power		Jan - 74	17.2						
Indian Pt. 3	NY Power Authority		Dec - 75	15.3						
J. A. FitzPatrick	NY Power Authority		Oct - 74	16.5						
Nine Mile 1	Niagara Mohawk		Aug - 69	21.6						
Nine Mile 2	Niagara Mohawk		Oct - 86	4.5						
Monticello	North States Power		Sep - 70	20.6						
Prairie Island 1	North States Power		Aug - 73	17.6						
Prairie Island 2	North States Power		Oct - 74	16.5						
Millstone 1	Northeast Utilities	BWR	Oct - 70	20.5	Ebasco	12	9	0	17	
Millstone 2	Northeast Utilities		Aug - 75	15.6						

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
Millstone 3	Northeast utilities		Jan - 86	5.2						
Ft. Calhoun 1	Omaha Pub. Pwr. District		May - 73	17.9						
Humboldt Bay	Pacific Gas & Electric		Aug - 62	28.7						
Diablo Canyon 1	Pacific Gas & Electric		Sep - 81	9.6						
Diablo Canyon 2	Pacific Gas & Electric		Aug - 85	5.6						
Susquehanna 1	Pennsylvania Pwr. & Light	BWR	Jul - 82	8.7	Bechtel	18		0		No CW information.
Susquehanna 2	Pennsylvania Pwr. & Light	BWR	Mar - 84	7.1	Bechtel	18		0		No CW information.
Peach Bottom 2	Philadelphia Electric	BWR	Aug - 73	17.6	Bechtel		6		12	No SW information.
Peach Bottom 3	Philadelphia Electric	BWR	Jul - 74	16.7	Bechtel		6		12	No SW information.
Limerick - 1	Philadelphia Electric		Oct - 84	6.5						
Limerick - 2	Philadelphia Electric		Aut - 89							
Trojan 1	Portland General Electric		Nov - 75	15.4						
Salem 1	Public Serv. Elec. & Gas	PWR	Aug - 76	14.6	Utility	26		0		No CW information.
Salem 2	Public Serv. Elec. & Gas	PWR	Apr - 80	11.0	Utility	26		0		No CW information.
Hope Creek 1	Public Serv. Elec. & Gas		Apr - 86	5.0						
Seabrook - 1	Public Service of NH	PWR	Jun - 89	1.8	UE & C	35	6	10	6	
R. E. Ginna 1	Rochester Gas & Electric		Sep - 69	21.6						
Rancho Seco 1	Sacramento Munic. (SMUD)		Aug - 74	16.6						

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
Summer 1	So. Carolina Elec. & Gas		Aug - 82	8.6						
San Onofre 1	So. California Edison		Mar - 67	24.1						
San Onofre 2	So. California Edison		Feb - 82	9.1						
San Onofre 3	So. California Edison		Nov - 82	8.4						
So. Texas Proj. 1	So. Texas Proj. El Gen Sta		Mar - 88							
So. Texas Proj. 2	So. Texas Proj. El Gen Sta		Mar - 89							
Sequoyah 1	Tennessee Valley Author.		Sep - 80	10.6						
Sequoyah 2	Tennessee Valley Author.		Sep - 81	9.6						
Browns Ferry 1	Tennessee Valley Author.		Dec - 73	17.3						
Browns Ferry 2	Tennessee Valley Author.		Aug - 74	16.6						
Browns Ferry 3	Tennessee Valley Author.		Aug - 76	14.6						
Comanche Peak 1	Texas Utilities	PWR	Apr - 90	1.0	G & H	10	27	2	18	
Davis Besse 1	Toledo Edison		Apr - 77	14.0						
Callaway 1	Union Electric Co.		Jun - 84	6.8						
Vermont Yankee	Vermont Yankee		Feb - 73	18.1						
Surry 1	Virginia Power	PWR	May - 72	18.9	SWEC	14	8	37	12	
Surry 2	Virginia Power	PWR	Jan - 73	18.2	SWEC	14	8	37	12	
North Anna 1	Virginia Power	PWR	Nov - 77	13.4	SWEC		8		12	

TABLE E.6-7 (Continued)
NUCLEAR COMPONENT YEARS OF EXPERIENCE: BUTTERFLY VALVE AND EXPANSION JOINTS IN SW & CW SYSTEMS

PLANT	UTILITY	REACTOR TYPE	OP. DATE	YRS/ OP.	A/E	SW VALVES	CW VALVES	SW E - J's	CW E - J's	COMMENTS
North Anna 2	Virginia Power	PWR	Aug - 80	10.6	SWEC		8		12	
WNP 2	Washington Pub. Pwr.Supply		Dec - 83	7.3						
Pt. Beach 1	Wisconsin Elec. Pwr. Co.		Oct - 70	20.5						
Pt. Beach 2	Wisconsin Elec. Pwr. Co.		May - 72	18.9						
Kewanee	Wisconsin Public Service		Dec - 73	17.3						
Yankee Rowe	Yankee Atomic		Jul - 60	30.7						
(1) Total reactor years of operation				1463.						
(2a) Total components for plants with available information						347	156	91	177	
(2b) No. of plants with available information						17	18	17	18	
(2c) Average components per plant						20.41	8.67	5.35	9.83	
(3) Component years of experience						29869	12682	7833	14389	

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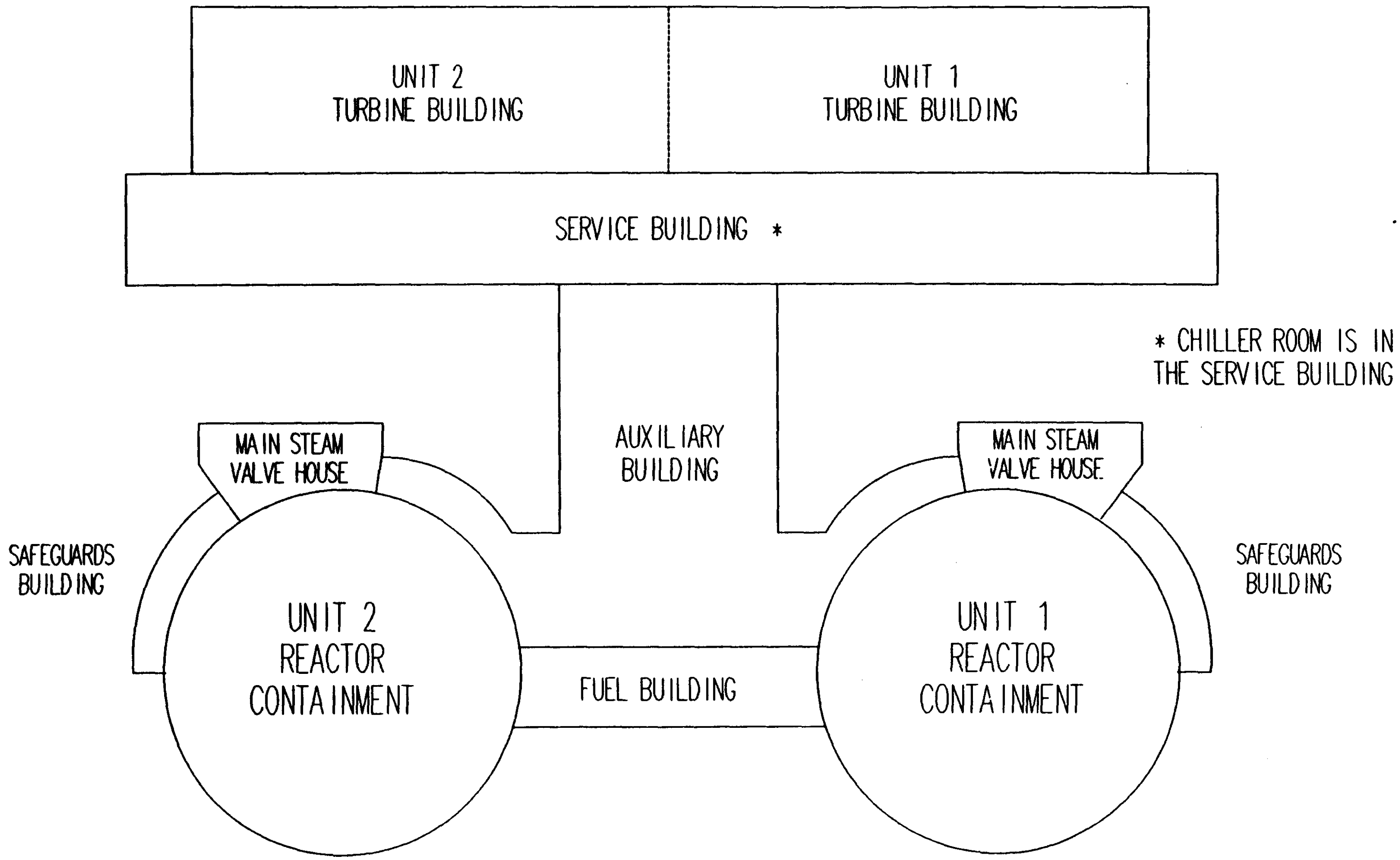


FIGURE E.2-1
STATION LAYOUT

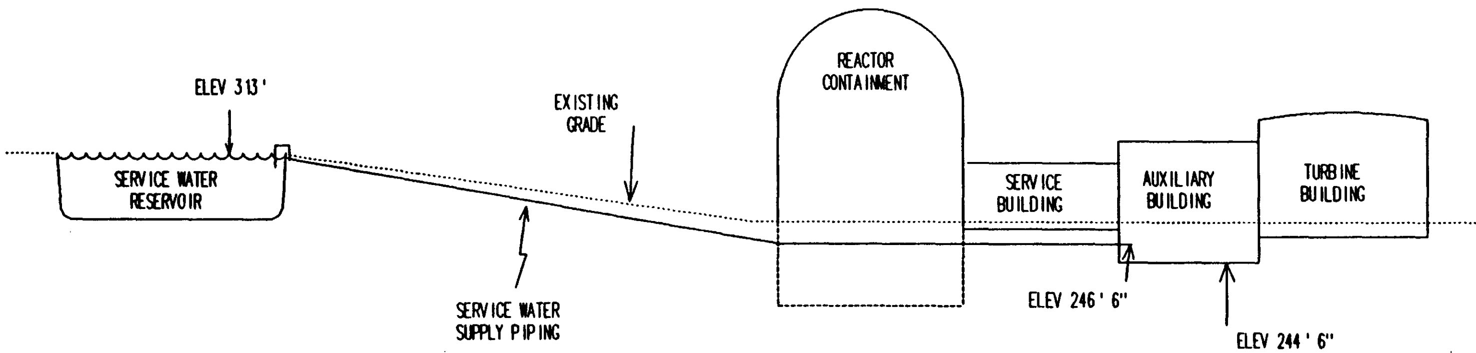
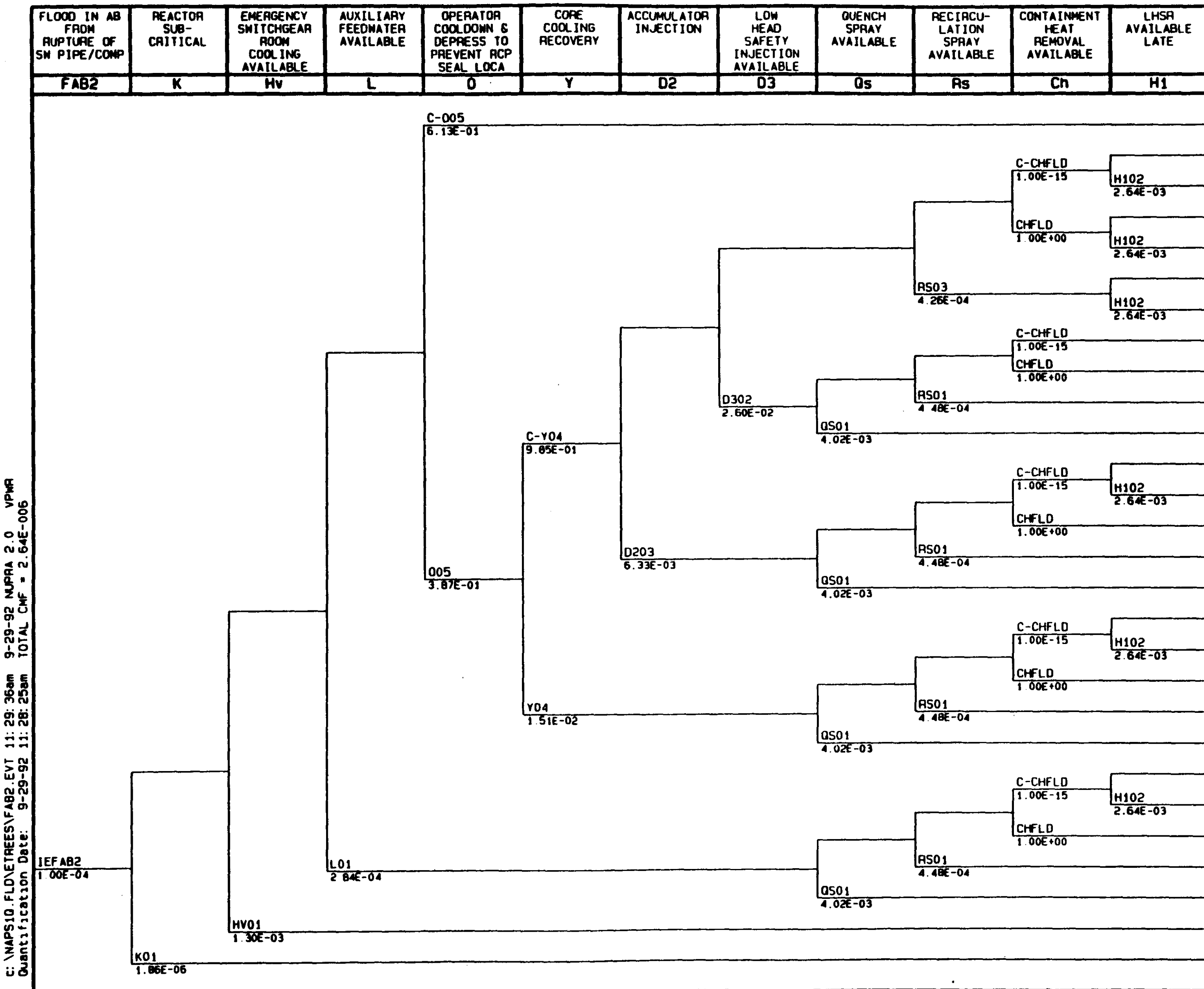


FIGURE E.2-2
CROSS SECTIONAL VIEW - SERVICE WATER SUPPLY

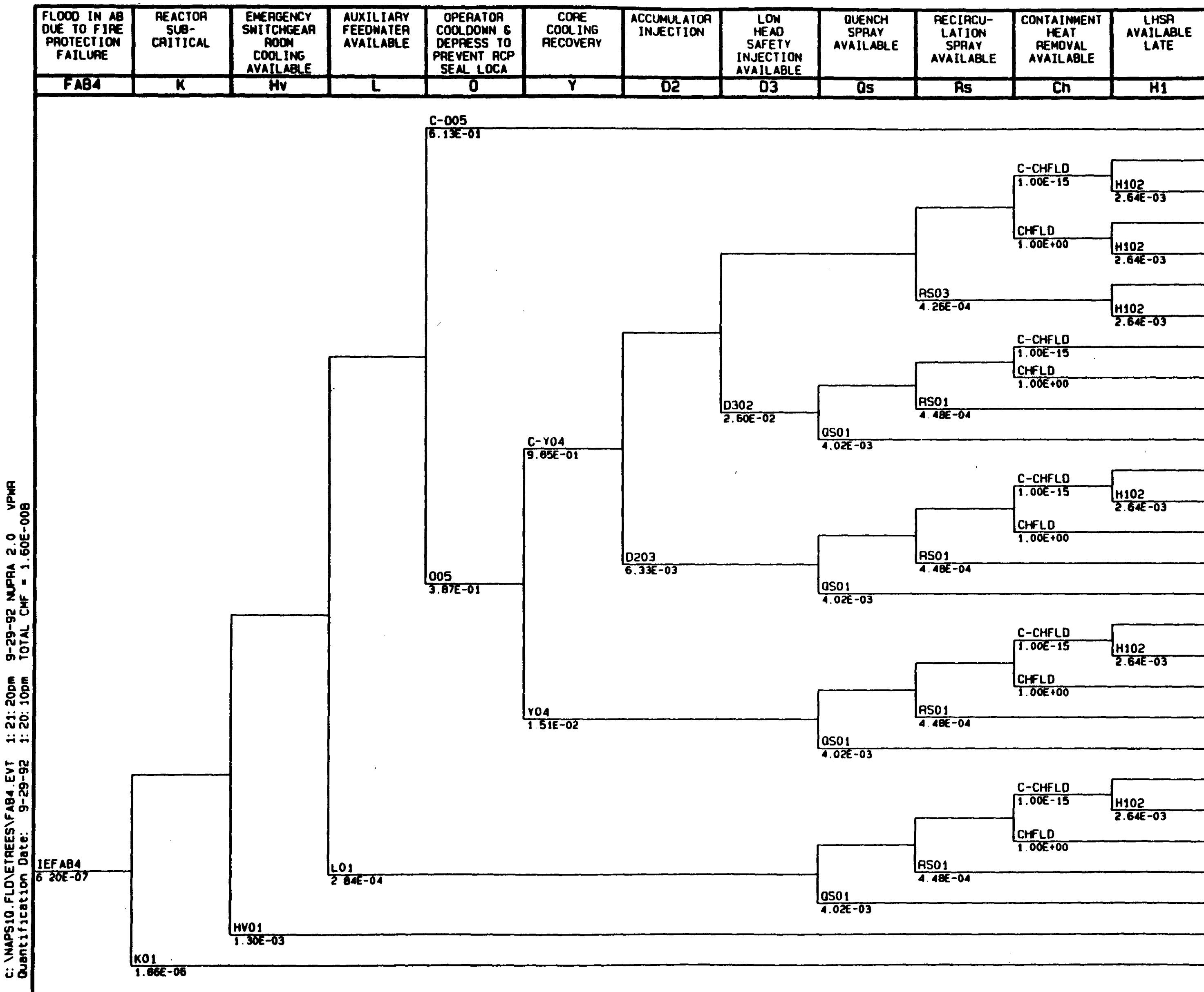


SEQ #	SEQUENCE DESCRIPTOR	PDS #	FREQUENCY
P01	FAB2	OK	
P02	FAB2O	OK	
P03	FAB2OH1	21	0.00E+00
P04	FAB2OCh	1	7.61E-07
P05	FAB2OChH1	22	4.17E-08
P06	FAB2ORs	2	1.43E-08
P07	FAB2ORsH1	23	1.90E-09
P08	FAB2OD3	21	0.00E+00
P09	FAB2OD3Ch	22	9.91E-07
P10	FAB2OD3Rs	23	2.87E-10
P11	FAB2OD3Qs	23	3.75E-09
P12	FAB2OD2	20	0.00E+00
P13	FAB2OD2H1	21	0.00E+00
P14	FAB2OD2Ch	22	2.41E-07
P15	FAB2OD2Rs	23	3.52E-11
P16	FAB2OD2Qs	23	2.99E-10
P17	FAB2OY	20	0.00E+00
P18	FAB2OYH1	21	0.00E+00
P19	FAB2OYCh	22	5.58E-07
P20	FAB2OYRs	23	1.75E-10
P21	FAB2OYQs	23	1.84E-09
P22	FAB2L	8	0.00E+00
P23	FAB2LH1	9	0.00E+00
P24	FAB2LCh	10	2.77E-08
P25	FAB2LRs	11	0.00E+00
P26	FAB2LQs	11	1.39E-11
P27	FAB2Hv	TR	1.30E-07TB
P28	FAB2K	TR	1.80E-10TH

NORTH ANNA INDIVIDUAL PLANT EXAMINATION

FAB2: FLOOD IN AUX BLDG DUE TO SW PIPE/COMP FAILURE

FIGURE E-FAB2



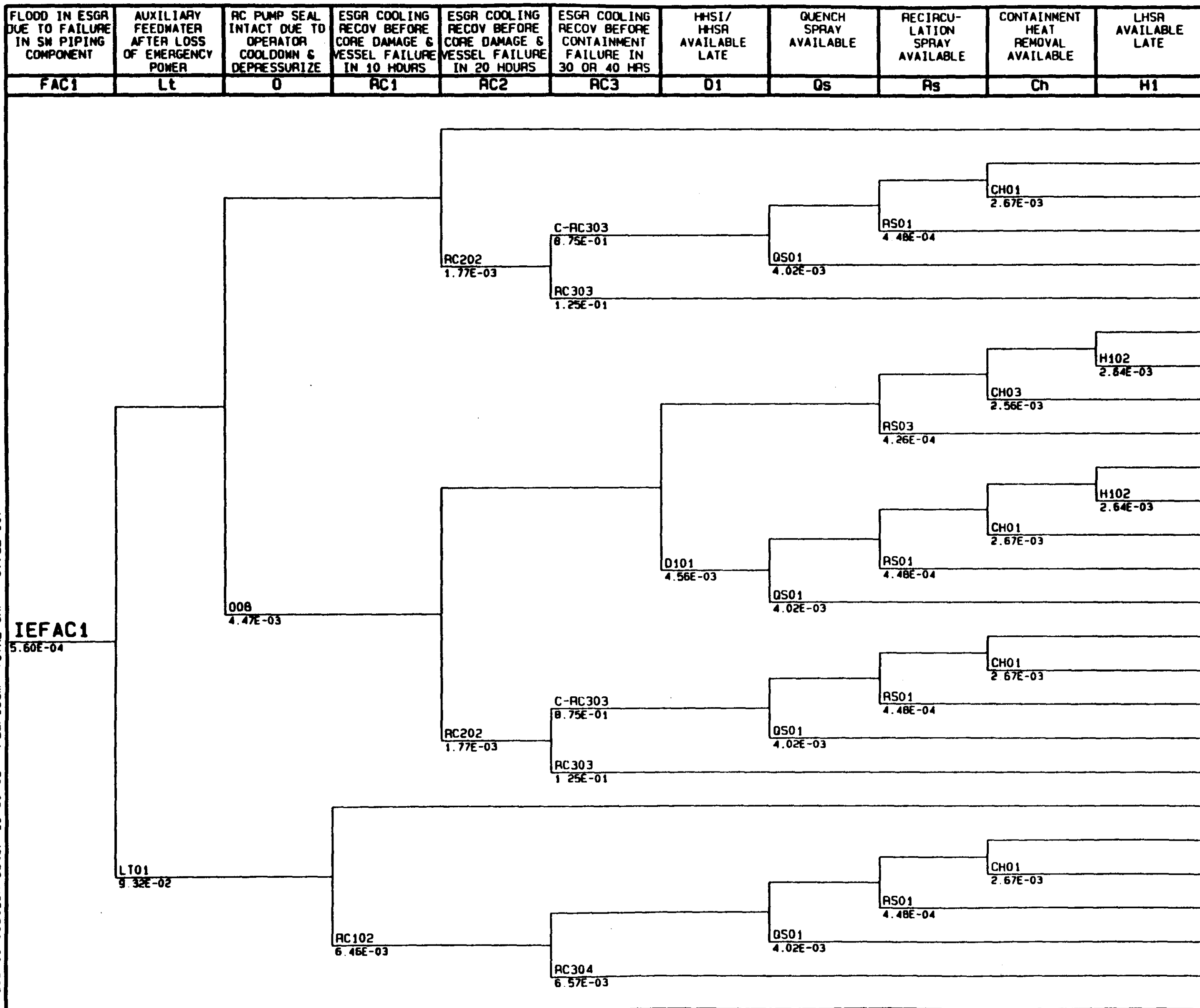
SEQ #	SEQUENCE DESCRIPTOR	PDS #	FREQUENCY
P01	FAB4	OK	
P02	FAB4O	OK	
P03	FAB4OH1	21	0.00E+00
P04	FAB4OCh	1	4.72E-09
P05	FAB4OChH1	22	2.19E-10
P06	FAB4ORs	2	8.85E-11
P07	FAB4ORsH1	23	1.18E-11
P08	FAB4OD3	21	0.00E+00
P09	FAB4OD3Ch	22	6.08E-09
P10	FAB4OD3Rs	23	0.00E+00
P11	FAB4OD3Qs	23	0.00E+00
P12	FAB4OD2	20	0.00E+00
P13	FAB4OD2H1	21	0.00E+00
P14	FAB4OD2Ch	22	1.49E-09
P15	FAB4OD2Rs	23	0.00E+00
P16	FAB4OD2Qs	23	0.00E+00
P17	FAB4OY	20	0.00E+00
P18	FAB4OYH1	21	0.00E+00
P19	FAB4OYCh	22	3.22E-09
P20	FAB4OYRs	23	0.00E+00
P21	FAB4OYQs	23	0.00E+00
P22	FAB4L	8	0.00E+00
P23	FAB4LH1	9	0.00E+00
P24	FAB4LCh	10	1.58E-10
P25	FAB4LRs	11	0.00E+00
P26	FAB4LQs	11	0.00E+00
P27	FAB4Hv	TR	6.29E-10TB
P28	FAB4K	TR	0.00E+00TH

FIGURE E-FAB4

NORTH ANNA INDIVIDUAL PLANT EXAMINATION

FAB4: FLOOD IN AUX BLDG DUE TO RWST PIPE/COMP FAILURE

C:\NAPS10\ETREES\FAC1.EVT 7:28:15am 11-30-92 NUPRA 2.0 VPWR
Quantification Date: 11-30-92 7:28:15am TOTAL CMF = 9.73E-007



SEQ #	SEQUENCE DESCRIPTOR	PDS #	FREQUENCY
P01	FAC1	OK	
P02	FAC1RC2	4	5.57E-07
P03	FAC1RC2Ch	5	7.83E-09
P04	FAC1RC2Rs	6	1.94E-10
P05	FAC1RC2Qs	6	1.24E-09
P06	FAC1RC2RC3	7	8.06E-08
P07	FAC1O	OK	
P08	FAC1OH1	15	4.81E-09
P09	FAC1OCh	16	3.84E-09
P10	FAC1ORs	17	1.03E-09
P11	FAC1OD1	14	9.44E-09
P12	FAC1OD1H1	15	3.10E-10
P13	FAC1OD1Ch	16	0.00E+00
P14	FAC1OD1Rs	17	8.36E-13
P15	FAC1OD1Qs	17	8.36E-13
P16	FAC1ORC2	18	1.60E-09
P17	FAC1ORC2Ch	18	0.00E+00
P18	FAC1ORC2Rs	18	0.00E+00
P19	FAC1ORC2Qs	18	0.00E+00
P20	FAC1ORC2RC3	19	1.57E-10
P21	FAC1Lt	OK	
P22	FAC1LtRC1	4	3.01E-07
P23	FAC1LtRC1Ch	5	1.11E-09
P24	FAC1LtRC1Rs	6	1.14E-10
P25	FAC1LtRC1Qs	6	7.83E-10
P26	FAC1LtRC1RC3	7	1.84E-09

FIGURE E-FAC1

NORTH ANNA INDIVIDUAL PLANT EXAMINATION

FAC1: FLOOD IN CHILLER ROOM DUE TO SW PIPE/COMP FAILURE

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