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1940-00-20206

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington DC 20555

Dear Sir:

Subject: Oyster Creek Generating Station
Docket No. 50-219
Reply to RAI on IPEEE

In December 1995, GPU Nuclear Corporation replied to Generic Letter 88-20 "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities – 10 CFR 50.54(f)". On December 10, 1997, the staff requested additional information in several areas. By letter dated May 21, 1998, GPU Nuclear Corporation replied to all but two of the questions in the Fire and PMP areas. The replies to these two questions were then delayed and subsequently cancelled, as the decision had been made to decommission Oyster Creek.

Recently, AmerGen Energy, LLC, has purchased the Oyster Creek site and will continue operation. Attached to this cover is the reply to the two remaining IPEEE questions. AmerGen Energy, LLC, believes that the IPEEE submittal, when taken in combination with the replies to the two RAIs, complete the work on GL 88-20, Supplement 4.

If any additional information or assistance is required, please contact Mr. John Rogers of my staff at 609.971.4893.

Very truly yours,

Ron J. DeGregorio
Vice President, Oyster Creek

SL/JJR

cc: Administrator, Region I
NRC Project Manager
Senior Resident Inspector

A011

AMERGEN ENERGY RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION REGARDING OYSTER CREEK GENERATING STATION IPEEE SUBMITTAL (TAC NO. M83652)

In the original request for additional information (RAI) on the Oyster Creek Nuclear Generation Station (OCNGS) Individual Plant Examination of External Events (IPEEE) (Reference 1) the NRC requested information on the Seismic, Fire and Other External Events. GPU Nuclear responded (Reference 2) by providing information on all but two of the questions in the RAI. GPU Nuclear postponed responses to a single question on the Fire Analysis and a single question on other external events of the IPEEE. The response to these questions was later cancelled given the impending decommissioning of Oyster Creek.

Since that time, AmerGen has purchased Oyster Creek for the purposes of continued operation. Given the continued operation of the Oyster Creek Station, AmerGen Energy is providing the responses to the remaining Fire Analysis and Other External Event Analysis questions.

AmerGen Energy believes that the original Oyster Creek Individual Plant Examination for External Events combined with the responses provided to the recent Replies to the Request for Additional Information, at a minimum, meet the intent of Generic Letter 88-20 Supplement 4.

FIRE ANALYSIS

1. NRC Question

In the detailed evaluation, use of a fire severity factor was applied for five of the eight zones that had not been screened up to this point in the analysis. The formulation and application of the fire severity factor is considered to have technical flaws. The formulation of the factor is based on fire events that have been recorded in the EPRI Fire Events Database. Consideration of the extent of automatic or manual fire suppression on mitigation of these events was not addressed in the formulation of the severity factor. (It is anticipated that these types of suppression were employed in some of the events, thereby limiting severity.) Because the frequency associated with the fire can not be totally independent from the fire severity factor, use of the factor artificially decreases the fire frequency. When the fire severity factor was applied in an area where fire suppression was credited, the fire severity factor was only applied to the scenario where fire suppression was unavailable; this is inconsistent with the formulation of the factor. The engulfing fire assumed when using the fire severity factor is not always the limiting case; i.e., a smaller fire of higher frequency could pose as much risk if not more risk. The use of fire severity factor is considered technically unsubstantiated, therefore, assessment of fire damage is warranted. For the five zones mentioned above, in which fire severity factors were used, please model fire suppression and propagation to determine the probability that the fire will damage critical targets before it is suppressed, and provide the results of the analysis.

RESPONSE

The initial response to this question is provided in Reference 1. The conclusion of the initial response was as follows:

> *"In conclusion, the use of severity factor to address weaknesses in the fire events database is not considered technically flawed. Careful application of the severity factor and preservation of initiating event frequency (to capture smaller fire events potentially risk significant with higher frequency) was the original intent. For the areas in which fire severity factor was applied in conjunction with automatic fire suppression, additional sensitivity studies and analysis should be performed to demonstrate that overall conclusions regarding the core damage frequency is not significantly impacted.*

GPU Nuclear will perform a re-evaluation of all five fire zones which utilized fire severity factor and provide the results of the analysis to the NRC no later than October 1998. "

The following paragraphs summarize the re-evaluation of the five fire zones that utilized severity factor in the estimation of the core damage frequency. The detailed analysis is included in Attachment A.

Five (5) fire zones modeled a fire severity factor in estimation of the core damage frequency due to fire initiated events. These five fire zones are:

- OB-FZ-04 – Cable Spreading Room
- OB-FZ-08C – A and B Battery Room, Tunnel and Electric Tray Room (35 foot elevation)
- TB-FZ-11D – Turbine Building Basement Floor South end
- RB-FZ-01D – Reactor Building 23 Foot Elevation
- RB-FZ-01F – Reactor Building 53 Foot Elevation

For each of the five fire zones listed above, a three step process was performed to complete the analysis. The process uses fire modeling of fire propagation and suppression to establish the probability that a fire will damage the critical targets before it is suppressed. The three step process is as follows:

1. Severity factors were revised to consider the extent of automatic or manual suppression on mitigating the events on which the severity factors are based;

2. Fire propagation and suppression were modeled to determine the probability that the fire will damage the critical targets before it is suppressed; and

3. Core damage frequencies for the zones of interest were revised based on the previous tasks where appropriate.

Details of the evaluation are provided in Attachment A. A summary of the results is provided in the table below. The table provides the results from the 1995 IPEEE submittal for comparison.

Fire Zone Total Core Damage Frequency	1995 IPEEE Result	2000 Revised Result
OB-FZ-4 – Lower Cable Spreading Room	2.60E-06	8.6E-06
OB-FZ-8C – A & B Battery Room, Tunnel and Tray Room	5.10E-07	4.68E-07
TB-FZ-11D – Turbine Building Basement (South end)	2.10E-07	1.9E-06
RB-FZ-1D – Reactor Building 51 Foot Elevation	2.70E-07	2.4E-07
RB-FZ-1E – Reactor Building 23 Foot Elevation	1.30E-07	1.2E-07

As can be seen from the table above, the revised analysis produces a limited change in the total core damage frequency.

One significant change does occur for the Turbine Building Basement (fire zone TB-FZ-11D). The revised core damage frequency associated with the turbine building basement fire zone is fire is 1.91E-06 per year which is above the 1E-06 per year screening criteria. Therefore, the turbine building basement fire zone does not screen. Additional efforts could be expended to remove conservatism from the analysis of the turbine building basement fire zone. Although this additional effort could result in the fire zone screening from consideration, the turbine building basement would remain a significant contributor to fire risk. Therefore, AmerGen Energy will conduct fire brigade training for the turbine building fire zone.

3. NRC QUESTION

As noted in NUREG-1407, section 2.4, the latest probable maximum precipitation criteria published by the National Weather Service call for higher rainfall intensities over shorter time intervals and smaller areas than have previously been considered; this could result in higher site flooding levels, and greater roof ponding levels. Please assess the effects of applying these new criteria to Oyster Creek. Additional information is given in Generic Letter 89-22.

RESPONSE

The initial response to this question is provided in reference 1. The initial response stated:

> *"Oyster Creek has not assessed the effect of higher rainfall intensities over shorter time intervals and smaller areas than have previously been considered (GL 89-22). GPU Nuclear plans to assess the affects and will provide the result of the analysis to the staff no later than October 1998. "*

Attachment B provides the detailed analysis of the latest probable maximum precipitation (PMP) criteria published by the National Weather Service.

In summary, the potential for effects of current PMP criteria leading to severe accident have been evaluated for the OCNGS site. An analysis of local flooding due to PMP overland runoff showed that water will not intrude into buildings housing equipment or systems whose failure could lead to severe accident. An analysis of roof ponding loads shows that the roof support trusses will not fail; therefore the roof ponding cannot affect equipment or systems whose failure could lead to severe accident. Therefore, it is concluded on the basis of bounding analysis that probable maximum precipitation does not contribute to severe accident risk at OCNGS.

REFERENCES

1. GPU Nuclear Corporation, "Oyster Creek Individual Plant Examination for External Events", December 1995.

2. Nuclear Regulatory Commission, "Request for Additional Information Regarding Oyster Creek Nuclear Generating Station IPEEE Submittal (TAC No. M83652)", December 10, 1997.

3. GPU Nuclear Corporation, "Individual Plant Examination for External Events – Response to Request for Additional Information", 1940-98-20188, May 21, 1998.

ATTACHMENT A

FIVE FIRE MODELING TO ASSESS THE SEVERITY OF FIRES

IN SELECTED FIRE ZONES

1.0 PURPOSE

On December 29, 1995 GPU Nuclear submitted the Oyster Creek Individual Plant Examination for External Events (IPEEE) [Reference 1] to the NRC in response to Generic Letter 88-20 [Reference 2]. On December 10, 1997, the NRC issued a Request for Additional Information (RAI) [Reference 3] regarding the IPEEE submittal. Fire Question 1 of the RAI expressed concerns about the formulation and application of the fire severity factors credited in the analysis. The purpose of this analysis is to address those concerns.

2.0 APPROACH

This analysis consisted of three tasks:

- Severity factors were revised to consider the extent of automatic or manual suppression on mitigating the events on which the severity factors are based;
- Fire propagation and suppression were modeled to determine the probability that the fire will damage the critical targets before it is suppressed; and
- Core damage frequencies for the zones of interest were revised based on the previous tasks where appropriate.

2.1 Revised Severity Factors

Fire severity was assessed based in part on the ignition source severity factors provided in EPRI's Fire PRA Implementation Guide [Reference 4], and in part on fire modeling calculations. The database of fire events from which the EPRI fire severity factors were derived includes fields recording the means of suppression. The method for developing severity factors explicitly considered the means of suppression in determining whether or not a fire was severe. Actuation of an automatic suppression system, the use of hose streams, or the use of portable extinguishers was taken as evidence of a severe fire. Therefore, the EPRI severity factors are independent of the probability of automatic suppression.

2.1.1 Severity of Fixed Ignition Sources.

The following severity factors from the Implementation Guide were used in this analysis:

Switchgear room electrical cabinets	0.12
Indoor transformers	0.1
Motor generator sets	0.14
Pumps	0.2

The severity factor for switchgear room electrical cabinets was applied to switchgear, battery chargers and other electrical panels not containing large quantities of relays and circuit cards. The severity factor for pumps was applied to pumps and air compressors.

2.1.2 Severity of Transient Fires

Severity factors for transient fires were approximated based on fire durations provided in Appendix K of the Implementation Guide. The severity factors represent the fraction of fires manually suppressed in the incipient stage, which was taken to be the first fire minutes of fire growth. From Figure K-3 of the Implementation Guide, 88% of transient fires caused by welding are suppressed within the first five minutes. The probability that a transient fire due to welding will not be suppressed in its incipient stage is therefore (1.0 - .88) or 0.12. From Figure K-4, 35% of transient fires caused by transient sources other than welding are suppressed in the first five minutes. The probability that a transient fire caused by an ignition

source other than welding will not be suppressed in the first five minutes is (1.0 - .35) or 0.65. The severity factor for transient fires due to welding was also applied to cable fires due to welding.

Partitioning factors were used to implement the results of the fire modeling calculations. Implementation of the partitioning factors is described in the next section.

2.2 Fire Modeling

Fire modeling provided the technical basis for assessing the frequency contribution for the scenarios representing the most severe consequences. Fire modeling analysis was performed using the techniques described in the FIVE method [Reference 5].

Electrical cable purchased and installed at Oyster Creek in the past decade meets the requirements of IEEE-383. However, older cable may not meet this standard. Therefore, the analysis conservatively treated all cable as unqualified cable. [Reference 6].

No allowance was made in the calculations for the volume of the room occupied by installed equipment. The installed equipment is composed largely of metal, and therefore has a heat storage capacity greater than the air it displaces. Other conservative assumptions inherent in the calculations more than offset any potential non-conservatism introduced by ignoring the equipment volume, for example:

- Timing calculations ignore the growth phase of fires, assuming that all fires reach their peak heat release rates instantaneously.
- Room heatup calculations ignore the effects of ventilation including natural ventilation provided by openings in the ceilings of the Turbine Building and Reactor Building zones.
- Room heatup calculations ignore the potential for oxygen limited fires in smaller spaces where forced ventilation trips in case of fire events (i.e., no credit for fire dampers).

The fire modeling results were implemented by means of partitioning factors. Partitioning factors eliminated the frequency contribution of those sources shown to be incapable of causing the extreme damage represented by the Case 1 scenario defined for each zone.

For example, only 7 of 16 pumps in Turbine Building zone TB-FZ-11D were found to be capable of causing critical conditions or propagating to enough combustibles to produce critical conditions in the zone. A partitioning factor of 7/16 was applied to the pump frequency for Case 1 in zone TB-FZ-11D. Partitioning factors were only applied to the scenarios representing the most limiting fires (i.e., the Case 1 scenarios). The ignition frequency contributions removed from the Case 1 scenarios were accounted for in either the Case 2 or Case 3 scenarios. The analysis therefore accounts for those fires whose consequences are less severe than the limiting case, but could occur more frequently.

2.3 Re-Evaluation of Core Damage Frequencies

Following fire modeling and adjustment of the ignition frequency contributions for the Case 1 scenarios, the core damage frequencies were reevaluated. Automatic suppression was credited for the Case 1 scenarios where the fire modeling calculations showed that it was appropriate to do so. Manual suppression by the fire brigade was conservatively not credited in this analysis. The consequences of damage from less severe fires or fires where automatic suppression actuated successfully were reassessed if indicated by the fire modeling calculations, and the results incorporated into the revised CDFs.

3.0 FIRE ANALYSIS

Fire Question 1 of the RAI focused on the five fire zones listed below [Reference 1, Table 4.6-3]. The sections that follow describe the analysis and provide the results for each of the five zones.

- OB-FZ-4 Cable Spreading Room - 36' Elevation
- OB-FZ-8C A and B Battery Room, Tunnel and Electric Tray Room (35' Elevation)
- TB-FZ-11D Turbine Building Basement Floor, South End
- RB-FZ-1D Reactor Building 51 Foot Elevation
- RB-FZ-1E Reactor Building Main Floor (23 Foot Elevation)

3.1 Cable Spreading Room - 36' Elevation (OB-FZ-4)

The Cable Spreading Room is located on 36-foot elevation of the Office Building. It has a floor area of 2,543 ft^2 [Reference 7] and ceiling height of 9-1/2 ft (estimated from Fire Area Layout Drawings), yielding a volume of 24,158 cu. ft. The area is protected by an open-head water spray system actuated by a cross-zoned smoke detection system. The water spray system is designed to limit a fire in the cables to the tray of origin.

3.1.1 Fire Modeling Analysis

The amount of heat required to cause critical conditions in OB-FZ-4 is 351,909 Btu. This is approximately equivalent to burning 4.2 linear feet of cable tray.

Self-Ignited Cable Tray Fires. A fire must grow to sufficient size in order to actuate the smoke detectors on the ceiling. To approximate the size of a fire capable of actuating the smoke detectors, the analysis treated the smoke detectors as sensitive heat detectors with an actuation temperature of 38 °F and a time constant of 10 s [Reference 8, Section A.2.1.1]. The analysis predicted that in order to yield this temperature in the ceiling jet at a radial distance of 10 feet, a fire with a heat release rate of 52 Btu/s is required. This is roughly equivalent to a fire involving 2.2 square feet of burning cable tray. The analysis further predicted that once the fire reached this size, the smoke detectors would actuate in 13 seconds.

The critical temperatures throughout the room could be reached when the fire involves 4.2 linear feet of cable tray. The heat release rate for this amount of burning cable is estimated to be 98 Btu/s. At the estimated heat release rate, more than 40 minutes would elapse before the critical amount of heat would be released into the room. This allows ample time for the suppression system to actuate before critical conditions develop.

However, localized damage could occur before the water spray system suppresses the fire in the first tray. The critical radiant heat distance for a fire with a heat release rate of 52 Btu/s was determined to be 1.8 ft. This indicates that a tray immediately above or within 1.8 feet adjacent to the burning tray could be damaged before the suppression system actuates.

Based on the discussion above, the contribution for self-ignited cable trays was included in the frequency contribution for Case 1.

Electrical Cabinet Fires. Only seven cabinets in the zone could potentially support a fire capable of causing critical conditions throughout the zone. Other cabinets in this zone are small wall-mounted panels containing only small amounts of combustible material and incapable of propagating a fire to the overhead cable trays. Therefore, the contribution for seven electrical cabinets was included in the frequency contribution for Case 1.

Battery Fires. The primary combustibles associated with the batteries are the plastic battery cases. The most severe battery fire reported in the Fire Events Database [Reference 9, Incident

#140] involved the plastic tops of two cells. The maximum heat release rate for a battery fire involving the tops of two cells was predicted to be 240 Btu/s. Such a fire could ignite cables within 6.4 feet of the top of the battery.

Battery Charger Fires. The battery chargers do not contain sufficient combustible material to support a fire that could cause critical conditions throughout the zone. However, two of the battery chargers (B-1 and B-2) are located directly beneath cable trays where the trays enter the zone at a height of 7 feet in the northwest corner of the room. A fire in one of these two battery chargers could propagate to the overhead trays thereby involving additional combustible material. Therefore, the contribution for two battery chargers was included in the frequency contribution for Case 1.

RPS MG Set Fires. The RPS MG sets contain no oil. Fires at the MG sets are expected to be electrical fires involving only small amounts of combustibles. Overhead spray shields installed above the MG sets will prevent propagation of fires at the MG sets to the overhead trays. Therefore, the MG Sets were eliminated from the frequency contribution for Case 1.

Transient Fires. Transient fires involving typical transient materials could ignite cables in overhead trays below a height of 5 feet above the floor, and damage cables in trays below an elevation of 7 feet. Because there are trays below a height of 5' throughout most of the cable spreading room, transient fires were included in the frequency contribution for Case 1.

3.1.2 Revised Severity Factors

The severity of fires in zone OB-FZ-4 was reassessed based on the EPRI component severity factors and the results of fire modeling. The EPRI severity factors and partitioning factors were applied as shown in the table below. The equivalent zone severity factor = 2.47E-03 / 1.22E-02 = 0.20.

Table 1 – Cable Spreading Room Revised Severity Factors

Ignition Source	Ignition Frequency Contribution	Partitioning Factor	Severity Factor	Adjusted Frequency	Percent Contribution
Generic Fire Frequency					
Cabinets	8.00E-04	7/17	0.12	3.95E-05	2%
Batteries	1.07E-03	1	1	1.07E-03	43%
Component Fire Frequency					
Fire panels	1.50E-04	1	1	1.50E-04	6%
Cables	8.92E-04	1	1	8.92E-04	36%
Transformer fires	9.29E-04	1	0.1	9.29E-05	4%
RPS MG sets	5.50E-03	0	0.14	0.00E+00	0%
Battery chargers	2.00E-03	1/2	0.12	1.20E-04	5%
Cable fires (welding)	1.21E-04	1	0.12	1.45E-05	1%
Transient fires (welding)	7.38E-04	1	0.12	8.86E-05	4%
Transient fires (other)	7.85E-06	1	0.65	5.10E-06	0%
Totals	1.22E-02[1]			2.47E-03	100%

1 The 1995 study did not include a contribution for the batteries in the cable spreading room. For this study, the battery room frequency has been calculated by distributing the generic battery room frequency to three zones. The battery room frequency for each zone becomes (3.2E-03 / 3) or 1.07E-03. This adjustment resulted in a slight increase in the overall fire frequency from 1.11E-02 to 1.22E-02.

3.1.3 Re-Evaluation of the Core Damage Frequency

The revised fire frequency for Case 1 in OB-FZ-4 was calculated as the product of the zone frequency calculated above and the probability of failure of the automatic suppression system .
(2.47E-03 x 0.05) or 1.23E-04.

In case 1 all equipment which is either contained in the Cable Spreading Room or whose cables transit the Cable Spreading Room are failed. Suppression of the fire is failed.

In case 2 the impacts of a fire in the 125VDC panel are evaluated.

In light of fire modeling results, the consequences of damage resulting from the case 3 scenario were reassessed. In case 3, a self-ignited cable fire is assumed to occur. This cable fire produces a demand on the fire suppression system which is successful.

During the fire development phase, the MSIV control cables are assumed to be damaged. The result is an MSIV Closure initiating event. The MSIV control cables transit the cable spreading room fire zone and represent the most challenging transient initiating event given a fire in this zone.

Although the fire has been successfully suppressed, it is further assumed that all power and control cables fail. The same assumptions were modeled in the all engulfing fire scenarios (case 1). The major difference between case 1 and case 3 is that operator action to manually control systems is modeled. In case 1, any impacted system, regardless of the type of impact, is assumed to fail. Manual control of system is not modeled due to the fact that the fire event has not been suppressed and will significantly impact the ability of operators to manually control system.

In case 3, the human action error rates for manual control of systems are those used in the Level 1 OCPRA. The basis for the use of the Level 1 OCPRA human action values is that the fire has been successfully suppressed. Also, it is conservative to assume that all modeled systems will require manual action. In the successful suppression case, the majority of systems will remain unaffected and the fire event will be suppressed in short order.

Therefore, for case 3, all modeled systems are assumed to be manual with the exception of RPS. The RPS system is assumed to scram on the closure of the MSIVs, the resulting turbine trip or a loss of power. The following presents the impacts for the successful suppression of a self ignited cable fire in the Lower Cable Spreading Room:

- MSIV Closure initiating event (Initiator CMSIV)
- All power cables are assumed failed which fails
  - Core Spray System I
  - ADS/EMRVs are assumed failed (Top Event AD with AD7 exception)
- All modeled logic systems are assumed to fail (Top Events DP, PR and RL)
- An automatic reactor scram is assumed on either MSIV closure, turbine trip or loss of RPS power.

The core damage frequency result from the evaluation of the cable spreading room fire zone are given in Table 2, below. The cases evaluated for the cable spreading room remain conservative since manual fire fighting and use of the remote shutdown panel are not modeled. In addition, several fire zone protective features, such as radiant heat shields are not modeled.

Table 2 – Cable Spreading Room Core Damage Frequency (revised)

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail DB, SW, CW, DP, PR, RL, ME, MS, CP, OL, PI, CD, CC, RC, OV and CS, manual IC actuation, LOFW logic	1.23E-04	7.23E-06
Case 2	Fail DB	8.00E-04	4.80E-07
Case 3	MSIV Closure Initiator, CS System I, ADS, Logic Systems (DP, PR, and RL), Auto rx scram on MSIV closure	1.14E-02[2]	8.90E-07
Total Core Damage Frequency for Fire Zone OB-FZ-4			8.60E-06

3.2 A and B Battery Room, Tunnel And Electric Tray Room (35' Elevation) (OB-FZ-8C)

The A and B Battery Room, Tunnel and Electric Tray Room is located on 35 foot elevation of the Office Building. It has a floor area of 1,292 ft^2 [Reference 7] and ceiling height of 10-1/2 ft (estimated from Fire Area Layout Drawings), yielding a volume of 13,566 ft^3. The area is protected by a total flooding Halon 1301 extinguishing system actuated by a cross-zoned smoke detection system.

3.2.1 Fire Modeling Analysis

The critical amount of heat to cause critical conditions in OB-FZ-8C is 197,611 Btu. This is approximately equivalent to burning 2.3 linear feet of cable tray. The analysis to estimate the time to actuation of the cable spreading room smoke detectors is applicable to OB-FZ-8C. Suppression in this zone is provided by a Halon 1301 system. There will be an additional short delay following receipt of the signal from the smoke detectors before the Halon is released.

The time available to suppress a fire in the OB-FZ-8C will be shorter than in the cable spreading room, proportional to the critical amount of heat. At a heat release rate of 170 Btu/s or less, it would take a minimum of 34 minutes (31 minutes x 197,611 Btu / 351,909 Btu) for the critical amount of heat to be released into the room. This allows ample time for the suppression system to actuate before critical conditions develop.

Partitioning factors were not applied in this room. Therefore, no additional fire modeling was performed.

3.2.2 Revised Severity Factors

The severity of fires in zone OB-FZ-8C was reassessed based on the EPRI component severity factors. The EPRI severity factors were applied as shown in the table below. Partitioning factors were not applied to the frequencies in zone TB-FZ-8C. The equivalent zone severity factor = 1.54E-03 /3.18E-03 = 0.49.

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[2] The frequency for this scenario is slightly increased from the 1995 study due to the contribution added for the batteries.

Table 3 – A/B Battery, Tunnel and Electric Tray Room Revised Severity Factors

Ignition Source	Ignition Frequency Contribution	Partitioning Factor	Severity Factor	Adjusted Frequency	Percent Contribution
Generic Fire Frequency					
Battery	1.07E-03	1	1	1.07E-03	69%
Component Fire Frequency					0%
Cables	2.49E-04	1	1	2.49E-04	16%
Battery chargers	1.00E-03	1	0.12	1.20E-04	8%
Cable fires (welding)	1.21E-04	1	0.12	1.45E-05	1%
Transient fires (welding)	7.38E-04	1	0.12	8.86E-05	6%
Transient fires (other)	7.85E-06	1	0.65	5.10E-06	0%
Totals	3.18E-03			1.54E-03	100%

3.2.3 Re-Evaluation of the Core Damage Frequency

The revised fire frequency for Case 1 in OB-FZ-8C was calculated as the product of the zone frequency calculated above and the probability of failure of the automatic suppression system: (1.54E-03 x .05) or 7.72E-05. The revised damage frequency for OB-FZ-8C is then:

Table 4 – A/B Battery, Tunnel and Electric Tray Room Revised Core Damage Frequency

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail Top Events BI, CC, CD, CW, DB, DP, EB, ED, PI, OV	7.72E-05	1.37E-07
Case 2	Fail Top Event DB	5.33E-04	3.20E-07
Case 3	No impact, beyond plant trip	2.65E-03	9.73E-10
Total Core Damage Frequency for Fire Zone OB-FZ-8C			4.58E-07

3.3 Turbine Building Basement Floor, South End (TB-FZ-11D)

Fire Zone TB-FZ-11D is at the south end of the Turbine Building on the 3'-6" elevation. It has a floor area of 9,668 ft^2 [Reference 7] and ceiling height of 17 ft (estimated from Fire Area Layout Drawings), yielding a volume of 164,356 ft^3. The area is protected by a closed head automatic sprinkler system. The hydrogen seal oil unit is provided with a water spray system with directional nozzles. A 15' x 16' equipment hatch in the ceiling at the D3 column line will vent hot gases from the area in the event of a fire.

3.3.1 Fire Modeling Analysis

It is not likely that hot gases will accumulate in this zone. The equipment hatch at the D3 column line will vent hot gases to the elevation above. However, the FIVE fire modeling tools do not provide a method for analyzing heat lost through openings in the ceiling. For the purpose of this analysis, we have conservatively treated the zone as a closed room without natural ventilation. The amount of heat required to cause critical conditions (if TB-FZ-11D is treated as a closed room with no natural ventilation) is 2,675,780 Btu. This is roughly equivalent to burning 21 gallons of oil or 31.5 linear feet of cable tray.

The hazards in the zone containing enough fuel to produce the critical amount of heat consist of:

- H2 seal oil unit - 300 gallons of oil [Reference 10]. The ignition sources associated with the H2 Seal Oil Unit consist of four pumps.
- Oil-filled transformers - 190 gallons of mineral oil in each transformer. There are two oil-filled transformers

Ignition sources containing less than the critical amount of fuel could propagate to other combustibles, primarily overhead cable trays, to involve additional fuel. Ignition sources capable of propagating to overhead cable trays are:

- **Instrument Air Compressors.** The Instrument Air Compressors do not contain enough oil to cause critical conditions throughout the zone. However, two of the three compressors, Air Compressors 1-2 and 1-3, are located beneath overhead cable trays at heights of 13.5 feet and 10.5 feet above the floor, respectively. A heat release rate of 1570 Btu/s could produce ignition temperatures (700 °F) at an elevation of 13.5 feet (interpolated from FIVE Table 4E, Reference 5). A heat release rate of 1570 Btu/s corresponds approximately to an oil pool fire with a surface area of 11.6 ft^2 (3.8 ft in diameter) involving about 1 quart of oil. The Instrument Air Compressors each contain 7 gallons of oil, and therefore such a fire appears to be feasible.

- The third Instrument Air Compressor (Air Compressor 1-1) is located more than 9 feet horizontally from the nearest overhead cable tray. The top tray in the tray stack on the east wall of the air compressor area is within the ceiling jet region of a fire at Air Compressor 1-1. An oil fire involving 1/2 gallon of oil and a diameter of 5.7 feet could produce critical temperatures in the ceiling jet at the location of the tray. However, sprinklers on the ceiling would actuate before the fire reaches the critical size.

- **Turbine Building Closed Cooling Water Pumps.** The TBCCW pumps do not contain enough oil to cause critical conditions throughout the zone. However, two of the three TBCCW pumps (TBCCW Pumps 1-1 and 1-2) are located in close proximity to overhead cable trays, at a height of 13.5 feet above the pump pedestal. The overhead trays could experience temperatures sufficient to cause ignition of the trays. The third TBCCW Pump (TBCCW Pump 1-3) is located about 3-1/2 feet horizontally and 13.5 feet below the nearest overhead cable tray. However, the trays could experience critical radiant heat flux levels from a fire at the pump.

- **Electrical cabinets.** The most significant cabinet fires are expected to occur at the switchgear or motor control centers. Three such electrical cabinets are located in close proximity to significant amounts of cable in overhead cable trays. The 460V Unit Substation Switchgear 1A1 is located directly beneath a stack of three cable trays; MCCs 1A11 and 1B11 are located about 1 foot horizontally and 3 feet below a stack of four trays. In addition, trays located with 2 feet horizontally of the MCCs could be within the critical distance for radiant heat flux from a fire in these cabinets.

Other ignition sources in the zone were judged to be incapable of causing critical temperatures throughout the zone, even if propagation to overhead cable trays occurred. These include:

- **Other pumps.** Other pumps in the zone do not have significant oil inventories. Pump fires that do not involve oil are not expected to produce temperatures in the plume high enough to ignite overhead cable trays.

- **Other electrical cabinets.** Other electrical cabinets in the zone consist of the 460V Unit Substation Switchgear 1B1, Motor Control Centers 1A13 and 1B13, the Spare Exciter Neutral Reactor Panel, and various control panels, switches and other small electrical panels. There are no cable trays located in close proximity to the Spare Exciter Neutral Reactor Panel. Only single trays are located above Switchgear 1B1 and MCCs 1A13 and 1B13. Other small miscellaneous

panels were not specifically examined. However, their frequency contributions are insignificant compared to the switchgear and motor control centers.

- **Self-ignited cable fires.** If a fire occurred in a 4-tray stack and initially involves a one-foot section of the lowest tray, the amount of tray burned due to vertical propagation up the stack was estimated to be 12.4 linear feet. In addition to vertical propagation, the fire is also assumed to propagate horizontally along the tray stack. The total additional length of cable trays that must become involved in order to produce the critical conditions was estimated to be 19.1 feet. At a horizontal propagation rate of 10 feet per hour, the minimum time needed 19.1 additional feet of tray was determined to be 14 minutes.

  Similar calculations were performed for 3-tray, 2-tray and single tray stacks. The results are as follows:

Number of trays	Amount of tray burned due to vertical propagation in the stack	Additional length of tray needed to produce critical conditions	Minimum time to involve additional length of tray
4 trays	12.4 ft	19.1 ft	14 min
3 trays	7.2 ft	24.3 ft	24 min
2 trays	3.4 ft	28.1 ft	42 min
1 tray	1 ft	30.5 ft	1.6 hour

- **Transient ignition sources.** Cable trays in this zone are located 10 feet or more above the floor. The heat release rate needed to ignite overhead cable trays at a height of 10 feet above the floor is 741 Btu/s. This is well above the heat release rate for typical transient materials (138 Btu/s, Reference 4). Therefore, the contribution from transient ignition sources was removed from the frequency for Case 1.

3.3.2 Revised Severity Factors

The severity of fires in zone TB-FZ-11D was reassessed based on the EPRI component severity factors and the results of fire modeling. The EPRI severity factors and partitioning factors were applied as shown in the table below. The equivalent zone severity factor is (1.53E-03 / 9.89E-03) or 0.16.

Table 5 – Fire Zone TB-FZ-11D Revised Severity Factors

Ignition Source	Ignition Frequency Contribution	Partitioning Factor	Severity Factor	Adjusted Frequency	Percent Contribution
Generic Fire Frequency					
Cabinets	2.60E-03	½	0.12	1.56E-04	10%
Pumps	1.26E-03	7/16	0.2	1.10E-04	7%
Component Fire Frequency					
Cables	7.04E-04	1	1	7.04E0-4	46%
Transformer fires	9.29E-04	1	0.1	9.29E-05	6%
Air compressors	3.53E-03	2/3	0.2	4.71E-04	31%
Cable fires (welding)	1.21E-04	0	1	0.00E+00	0%
Transient fires (welding)	7.38E-04	0	1	0.00E+00	0%
Transient fires (other)	7.85E-06	0	1	0.00E+00	0%
Totals	9.89E-03 [3]			1.53E-03	100%

[3] The total frequency for the zone reported in the 1995 submittal was 1.09E-02 per year. The current analysis was unable to reproduce that reported value using the component frequencies reported in the submittal. The value show here is correct for the values reported.

3.3.3 Re-Evaluation of the Core Damage Frequency

The revised fire frequency for Case 1 in TB-FZ-11D was calculated as the product of the frequency calculated above and the probability of automatic suppression failure: (1.53E-03 x .02) or 3.07E-05.

Table 6 – Turbine Building Basement South end Revised Core Damage Frequency

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail top events CW, SW, TB, IA, FW, CS, CC and RC.	3.07E-05	1.83E-06
Case 2	Fail top event IA.	5.45E-03	2.40E-09
Case 3	Fail top event TB, CW and SW.	5.45E-03	7.60E-08
Total Core Damage Frequency for Fire Zone TB-FZ-11D			1.91E-06

The Turbine Building Basement – Southend fire zone was screened in the original Oyster Creek Fire IPEEE with a total core damage frequency of 2.1E-07 per year. This area no longer screens with a total core damage frequency of 1.9E-06 per year. This new result is primarily a product of the use of a revised severity factor.

3.4 Reactor Building – 51 Foot Elevation (RB-FZ-1D)

Fire Zone RB-FZ-1D is the 51-foot elevation of the Reactor Building. It has a floor area of 9,100 ft^2 [Reference 7] and a ceiling height of 21 ft (estimated from Fire Area Layout Drawings), yielding a volume of 191,100 ft^3. Cable trays in the area are protected by an automatic water spray system actuated by ionization smoke detectors in the area. The southeast equipment hatch, an 18' x 20' opening in the ceiling of RB-FZ-1D and an open stairwell in the northwest corner will vent hot gases from the area in the event of a fire.

3.4.1 Fire Modeling Analysis

It is not likely that hot gases will accumulate in this zone. The southeast equipment hatch and the open stairwell in the northwest corner will vent hot gases to the elevation above. However, the FIVE fire modeling tools do not provide a method for analyzing heat lost through openings in the ceiling. For the purpose of this analysis, we have conservatively treated the zone as a closed room without natural ventilation. The amount of heat required to cause critical conditions in RB-FZ-1D (if it is treated as a closed room with no natural ventilation) is 2,783,690 Btu. This is roughly equivalent to burning 22 gallons of oil or 32 linear feet of cable tray.

There are no hazards in the zone containing enough fuel to produce the critical amount of heat. Ignition sources containing less than the critical amount of fuel could propagate to other combustibles, primarily overhead cable trays, to involve additional fuel. Ignition sources capable of propagating to overhead cable trays are the following:

- **Core Spray Booster Pumps.** The CS Booster pumps (NZ-03-A and NZ-03-C) each contain 2 gallons of lube oil [Reference 6], not enough to cause critical conditions throughout the zone. However, the CS Booster pumps are located beneath cable trays in the NW corner of the zone. A severe fire at the pumps could subject the trays (at an elevation of 10-1/2 feet above the floor) to temperatures high enough to ignite cables in the trays.

- **Electrical cabinets.** MCC 1B21, Panels ER-754-144A, B and C, and the Nitrogen Compressor Panel are located directly beneath cable trays in the NE corner of the zone.

- **Self-ignited cable fires.** The amount of burning cable required to produce the critical amount of heat (in a closed room with no natural ventilation) was estimated to be 32 feet. If the heat lost through the stairwell and equipment hatch could be accounted for, the amount of cable required to burn would be significantly greater.

  Cable trays in the zone are arranged side-by-side in a single layer. A fire propagating along two-side-by-side trays requires more than 50 minutes to involve 32 feet of cable. If the heat lost through the stairwell and equipment hatch could be accounted for, the time required would be significantly longer.

  The most severe fire at this location could involve a 3-tray stack near the northwest stairway. Although the heat from a fire arising at this location is likely to be vented via the open stairway, a self-ignited cable fire at this location could consume more than 32 feet cable. If the heat lost through the stairwell and equipment hatch could be accounted for, the amount of cable required to burn would be significantly greater. Calculations performed for fires in tray stacks in TB-FZ-11D are applicable to this case. The amount of tray burned due to vertical propagation in a 3-tray stack was estimated to be 7.2 linear feet. The total additional length of cable trays that must become involved in order to produce the critical conditions in RB-FZ-1D is 32 ft - 7.2 ft = 25.8 ft. Propagating along both ends of three trays at a horizontal propagation rate of 10 feet per hour, the minimum time needed to involve 25.8 additional feet of tray is 25.8 ft / 6/ 10 ft/hr = .43 hr or 25.8 minutes.

- **Transient fires.** Cable trays are located 9 feet or more above the floor in this zone (except at the location described above near the northwest stairway. The heat release rate required to ignite overhead cable trays at a height of 9 feet above the floor is 570 Btu/s. This is well above the heat release rates for typical transient materials found in the zone. The fraction of the total floor area in the location of trays near the northwest stairway is (165 ft^2 / 9100 ft^2) or less than 2% of the total area where transient fires could occur.

3.4.2 Revised Severity Factors

The severity of fires in zone RB-FZ-1D was reassessed based on the EPRI component severity factors and the results of fire modeling. The EPRI severity factors and partitioning factors were applied as shown in the table below. The equivalent zone severity factor is (3.58E-03 / 2.53E-02) or 0.14.

Table 7 – Reactor Building – 51 Foot Elevation Revised Severity Factors

Ignition Source	Ignition Frequency Contribution	Partitioning Factor	Severity Factor	Adjusted Frequency	Percent Contribution
Generic Fire Frequency					
Cabinets	1.73E-02	1	0.12	2.08E-03	58%
Pumps	5.83E-03	2/7	0.2	3.33E-04	9%
Component Fire Frequency					
Fire panels	1.50E-04	1	0.12	1.80E-05	1%
Cables	1.15E-03	1	1.0	1.15E-03	32%
Cable fires (welding)	1.21E-04	0.02	0.12	2.90E-07	0%
Transient fires (welding)	7.38E-04	0.02	0.12	1.77E-06	0%
Transient fires (other)	7.85E-06	0.02	0.65	1.02E-07	0%
Totals	2.53E-02			3.58E-03	100%

3.4.3 Re-Evaluation of the Core Damage Frequency

In all cases the severe damage postulated for Case 1 requires propagation of an exposure fire to the overhead cable trays. Therefore, it is appropriate to credit the automatic water spray system protecting the cable trays. The probability of failure of a water spray (deluge) system is 0.05 [Reference Table 2, Reference 5].

The revised fire frequency for Case 1 in RB-FZ-1D was calculated as the product of the frequency and the probability of failure of a deluge suppression system: (3.58E-03 x .05) or 1.79E-04.

Table 8 – Reactor Building 51 Foot Elevation Revised Core Damage Frequency

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail DP, IC, OV, PI, PR, RI, RL, SD, VR and train 1 of core spray and containment spray (top events CC, RC and CS)	1.79E-04	7.78E-08
Case 2	Fail DP, RL, SD and train 1 of core spray, containment spray (top events CC, RC, CS)	6.33E-03	1.50E-08
Case 3	Fail IC, OV, RI	1.87E-02	1.50E-07
Total Core Damage Frequency for Fire Zone RB-FZ-1D			2.43E-07

3.5 Reactor Building Main Floor - 23 Foot Elevation (RB-Z-1E)

Fire Zone RB-FZ-1E is the 23 foot elevation of the Reactor Building. It has a floor area of 12,140 ft^2 [Reference 7] and ceiling height of 25 ft (estimated from Fire Area Layout Drawings), yielding a volume of 303,500 ft^3. Cable trays in the area are protected by an automatic water spray system actuated by ionization smoke detectors in the area. The southeast equipment hatch, an 18' x 20' opening in the ceiling of RB-FZ-1E and an open stairwell in the northwest corner will vent hot gases from the area in the event of a fire.

3.5.1 Fire Modeling Analysis

It is not likely that hot gases will accumulate in this zone. The southeast equipment hatch and the open stairwell in the northwest corner will vent hot gases to the elevation above. However, the FIVE fire modeling tools do not provide a method for analyzing heat lost through openings in the ceiling. For the purpose of this analysis, we have conservatively treated the zone as a closed room without natural ventilation. The amount of heat required to cause critical conditions in RB-FZ-1E (if it is treated as a closed room without natural ventilation) is 4,420,983 Btu. This is roughly equivalent to burning 35 gallons of oil or 52 linear feet of cable tray.

There are no hazards in the zone containing enough fuel to produce the critical amount of heat. Ignition sources containing less than the critical amount of fuel could propagate to other combustibles, primarily overhead cable trays, to involve additional fuel. Ignition sources capable of propagating to overhead cable trays are:

- **Pumps.** The CS Booster pumps (NZ-03-B and NZ-03-D) each contain 2 gallons of lube oil [Reference 6], not enough to cause critical conditions throughout the zone. However, CS Booster pump NZ-03-D is located beneath cable trays in the SW corner of the zone. Based on calculations performed for RB-FZ-1D a severe fire at this pump could subject the trays (at an elevation of 9 feet above the floor) to temperatures high enough to ignite cables in the trays.

- **Electrical cabinets.** MCC 1A21A, MCC-1A21B, MCC-1B21B, MCC-1B21A are located directly beneath or within a line-of-sight distance of 1 foot of cable trays in RB-FZ-1E.

- **Self-ignited cable fires.** The amount of burning cable required to produce the critical amount of heat (in a closed room with no natural ventilation) was estimated to be 52 feet. If the heat lost through the stairwell and equipment hatch could be accounted for, the amount of cable required to burn would be significantly greater. Cable trays in the zone are arranged in two side-by-side stacks with two trays in each stack. A fire propagating along both ends of four trays requires more than 39 minutes to involve 52 feet of cable.

Other ignition sources in the zone were judged to be incapable of causing critical temperatures throughout the zone, even if propagation to overhead cable trays occurred. The ignition sources that are not capable of causing critical temperatures in the zone are:

- **Transient fires.** Throughout most of this zone cable trays are located 17 feet or more above the floor. In the northwest portion of the zone, trays are 7-1/2 and 8-1/2 feet above the floor, with one short section (16 feet) at 6 feet above the floor. The heat release rate needed to ignite overhead cable trays at a height of 7-1/2 feet above the floor is 361 Btu/s; at a height of 6 feet above the floor the heat release rate needed is 207 Btu/s. This is well above the heat release rates for typical transient materials (138 Btu/s, Reference 4). Therefore, transient ignition sources were not considered further.

3.5.2 Revised Severity Factors

The severity of fires in zone RB-FZ-1E was reassessed based on the EPRI component severity factors and the results of fire modeling. The EPRI severity factors and partitioning factors were applied as shown in the table below. The equivalent zone severity factor is (2.68E-03/ 1.56E-02) or 0.17.

Table 9 – Reactor Building 23 Foot Elevation Revised Severity Factors

Ignition Source	Ignition Frequency Contribution	Partitioning Factor	Severity Factor	Adjusted Frequency	Percent Contribution
Generic Fire Frequency					
Cabinets	9.62E-03	4/6	0.12	7.70E-04	29%
Pumps	3.33E-03	1/4	0.2	1.67E-04	6%
Component Fire Frequency					
Cables	1.74E-03	1	1	1.74E-03	65%
Cable fires (welding)	1.21E-04	0	0.12	0.00E+00	0%
Transient fires (welding)	7.38E-04	0	0.12	0.00E+00	0%
Transient fires (other)	7.85E-06	0	0.65	0.00E+00	0%
Totals	1.56E-02			2.68E-03	100%

3.5.3 Re-Evaluation of the Core Damage Frequency

In all cases the severe damage postulated for Case 1 requires propagation of an exposure fire to the overhead cable trays. Therefore, it is appropriate to credit the automatic water spray system protecting the cable trays. The probability of failure of a water spray (deluge) system is 0.05 [Reference Table 2, Reference 5].

The revised fire frequency for Case 1 in RB-FZ-1E was calculated as the product of the frequency calculated above and the probability of automatic suppression failure: (2.68E-03 x .05) or 1.34E-04.

Table 10 – Reactor Building 23 Foot Elevation Revised Core Damage Frequency

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail CC, RC, CD, DP, IC, OV, PI, SD and train 2 of core spray and outboard MSIVs	1.34E-04	9.50E-08
Case 2	Fail DP and train 2 of core and containment spray (top events CC, RC and CS), train 2 IC and outboard MSIVs	7.67E-03	2.80E-09
Case 3	Fail DP, SD and train 1 of containment spray (top events CC and RC), train 1 IC and outboard MSIVs	7.67E-03	1.80E-08
Total Core Damage Frequency for Fire Zone RB-FZ-1E			1.16E-07

4.0 RESULTS SUMMARY

The analysis results are summarized in the Table 4.1, which provides the results from the 1995 IPEEE submittal for comparison.

Fire Zone Total Core Damage Frequency	1996 IPEEE Result	2000 Revised Result
OB-FZ-4 – Lower Cable Spreading Room	2.60E-06	8.60E-06
OB-FZ-8C – A & B Battery Room, Tunnel and Tray Room	5.10E-07	4.58E-07
TB-FZ-11D – Turbine Building Basement (South end)	2.10E-07	1.91E-06
RB-FZ-1D – Reactor Building 51 Foot Elevation	2.70E-07	2.43E-07
RB-FZ-1E – Reactor Building 23 Foot Elevation	1.30E-07	1.16E-07

5.0 REFERENCES

1. GPU Nuclear Corporation, "Oyster Creek Individual Plant Examination for External Events (IPEEE)", December 1995.

2. Nuclear Regulatory Commission, "Generic Letter 88-20, Supplement 4, "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities – 10CFR50.54(f)," June 28,1991.

3. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, "Request for Additional Information Regarding Oyster Creek Nuclear Generating Station IPEEE Submittal," December 10, 1997.

4. W. J. Parkinson, et al., *Fire PRA Implementation Guide*, EPRI TR-105928, Electric Power Research Institute, Palo Alto, CA, Final Report, December 1995.

5. *Fire-Induced Vulnerability Evaluation (FIVE) Methodology*, EPRI TR-100370, Electric Power Research Institute, Palo Alto, CA, April 1992.

6. GPU Nuclear Corporation, "Oyster Creek Evaluation of Thermo-Lag Fire Barriers", Topical Report, TR 102, Revision 0, December 1995.

7. GPU Nuclear Corporation, "GPU Nuclear Oyster Creek Nuclear generating Station Fire Hazards Analysis Report (FHAR)," No. 990-1746, Revision 10.

8. F. W. Mowrer, *Methods of Quantitative Fire Hazards Analysis*, EPRI TR-100443, Research Project 3000-37, Electric Power Research Institute, Palo Alto, CA, May 1992.

9. Electric Power Research Institute, "Fire Events Database for U.S. Nuclear Power Plants", NSAC 178L, June 1992.

10. Manufacturer's drawing for the H2 Seal Oil Unit

11. *Guidance for Development of Response to Generic Request for Additional Information on Fire Individual Plant Examination for External Events (IPEEE)*, EPRI SU-105928, Electric Power Research Institute, Palo Alto, CA, March 2000.

12. GPU Nuclear Corporation, *Combustible Heat Release Energy Values,* Calculation No. C-9000-810-5360-001, Revision 4.

13. *Methods for Evaluation of Cable Wrap Fire Barrier Performance*, EPRI TR-106714, Electric Power Research Institute, Palo Alto, CA, Final Report, August 1996.

14. GPU Nuclear Corporation, "Oyster Creek Individual Plant Examination for External Events (IPEEE)", December 1995.

APPENDIX B:
EFFECTS OF PROBABLE MAXIMUM PRECIPITATION
EXTERNAL FLOOD PORTION OF THE OYSTER CREEK
INDIVIDUAL PLANT EXAMINATION OF EXTERNAL EVENTS (IPEEE)

I. INTRODUCTION

Generic Letter 88-20 Supplement No. 4 asks that licensees evaluate the effects of new Probable Maximum Precipitation (PMP) criteria as part of the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities. This report presents the results of the evaluation for the Oyster Creek Nuclear Generating Station (OCNGS). The evaluation was performed by EQE International as consultant to GPU Nuclear.

The issue of PMP was studied by the NRC under Generic Issue 103, "Design for Probable Maximum Precipitation (PMP)," as a related external flooding issue. The NRC staff provided the resolution of this issue in Generic Letter 89-22, dated October 19, 1989. Specifically, the NRC requested that future plants be designed against new PMP criteria since the National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS) have revised the PMP criteria to include drainage areas as small as one square mile and durations as short as five minutes.

The previous hydrometerological reports by NWS generally provided PMP estimates for areas of ten square miles or greater and durations of six hours or more. There were empirical methods to subdivide the six hour duration to smaller increments, but there was never any methodology to estimate PMP for areas less than ten square miles. Thus the ten square mile PMP values were used for site and roof drainage design. Currently one square mile short duration PMP estimates are more intense than those previously used. In general, the latest NWS criteria call for higher rainfall intensities over shorter time intervals and smaller areas than have been previously considered. In some cases, such events could result in higher site flooding levels and greater roof ponding loads than have been used in previous design studies. For the IPEEE of existing plants, the NRC requested that severe accident risk from PMP should be assessed. It asked that licensees assess the effects of applying the most recent PMP criteria to their plants in terms of onsite flooding and roof ponding, and to determine whether this would lead to severe accidents.

Onsite flooding and roof ponding can lead to severe accidents through significant water intrusion into buildings housing critical equipment or systems, or through a building roof failing and falling onto critical equipment or systems. The only buildings which contain such equipment or systems at OCNGS are the reactor building, the turbine building and the emergency diesel generator building.

II. PRIOR EVALUATIONS OF SITE DRAINAGE AND ROOF PONDING

An evaluation of the OCNGS site for the Systematic Evaluation Program (SEP) hydrologic topics was performed by Burns and Roe and submitted by GPUN for NRC review in 1982. Section V.3 of this report presented the results of an analysis of local site drainage due to PMP.

The analysis was performed for a six hour point PMP of 27 inches. The analysis considered the site topography and the existing storm sewer drainage system consisting mostly of 8-inch diameter sewers leading through a 10-inch size to a 30-inch diameter outfall into the discharge canal north of the emergency diesel generator building.

The report stated that surface contours tend to divide the plant island into three separate drainage area, the largest of which lies on the north. This covers the store room, mobile offices, old and new radwaste buildings, office building, boiler house area and part of the reactor building. The area has two low points serving as shallow exits for the surface drainage: (1) in the paved road northeast of the off gas building, and (2) on the southeast corner of the boiler house. Flooding of this area during a PMP event was considered to be relatively more likely than that of the other two areas.

The report stated that the analysis for surface drainage using PMP as a design basis showed the following results.

- The existing storm drains can pass about 6 cfs of flow.

The revised fire frequency for Case 1 in RB-FZ-1E was calculated as the product of the frequency calculated above and the probability of automatic suppression failure: (2.68E-03 x .05) or 1.34E-04.

Table 10 – Reactor Building 23 Foot Elevation Revised Core Damage Frequency

Case	Fire Risk Model Impacts	Revised Fire Frequency	Revised Damage Frequency
Case 1	Fail CC, RC, CD, DP, IC, OV, PI, SD and train 2 of core spray and outboard MSIVs	1.34E-04	9.50E-08
Case 2	Fail DP and train 2 of core and containment spray (top events CC, RC and CS), train 2 IC and outboard MSIVs	7.67E-03	2.80E-09
Case 3	Fail DP, SD and train 1 of containment spray (top events CC and RC), train 1 IC and outboard MSIVs	7.67E-03	1.80E-08
Total Core Damage Frequency for Fire Zone RB-FZ-1E			1.16E-07

4.0 RESULTS SUMMARY

The analysis results are summarized in the Table 4.1, which provides the results from the 1995 IPEEE submittal for comparison.

Fire Zone Total Core Damage Frequency	1995 IPEEE Result	2000 Revised Result
OB-FZ-4 – Lower Cable Spreading Room	2.60E-06	8.60E-06
OB-FZ-8C – A & B Battery Room, Tunnel and Tray Room	5.10E-07	4.58E-07
TB-FZ-11D – Turbine Building Basement (South end)	2.10E-07	1.91E-06
RB-FZ-1D – Reactor Building 51 Foot Elevation	2.70E-07	2.43E-07
RB-FZ-1E – Reactor Building 23 Foot Elevation	1.30E-07	1.16E-07

5.0 REFERENCES

1. GPU Nuclear Corporation, "Oyster Creek Individual Plant Examination for External Events (IPEEE)", December 1995.

2. Nuclear Regulatory Commission, "Generic Letter 88-20, Supplement 4, "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities – 10CFR50.54(f)," June 28,1991.

3. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, "Request for Additional Information Regarding Oyster Creek Nuclear Generating Station IPEEE Submittal," December 10, 1997.

- The peak overland flow due to runoff during PMP from the 5.2 acre main building area would be approximately 60 cfs.
- The local site flooding during PMP would occur only to about 5 inches above grade elevation of 23.0 feet.

The report stated that the sill level of all of the exterior doorways to the different buildings is at least six inches above grade so the plant is safe against the effects of local site flooding during the PMP event.

The actual runoff calculations, which would provide more details, have not been located.

The report also discusses roof ponding in Section IV.3.4. It states that analytical determinations were made for ponding on the roofs of the reactor building and turbine building. The PMP used for the analysis was the six (6) hour point PMP of 27 inches. The resultant ponding was 10 inches if the drains are assumed 100% ckear, and 12 inches if the drains are assumed 25% clogged. It was stated that this ponding depth is at the low points in the cambered roofs, and the resultant average roof load due to ponding is approximately 20 psf, which is less than the 30 psf live load used in the design of the roof support structures. The detailed calculations have not been located.

The report was reviewed for the NRC by the Franklin Research Center (FRC). The FRC report noted that the actual runoff calculations had not been submitted and thus could not be reviewed. Instead, the reviewers performed a site walkdown. The reviewers agreed with the Burns and Roe onsite flooding conclusions; however, they noted that there was a low spot at the entrance of the off gas building which could entrap water and permit entry into the building.

The FRC reviewers did not agree with the Burns and Roe conclusions regarding roof ponding. The reviewers stated that if the roof drains were assumed fully blocked, the water load could exceed the 30 psf live load used in design. As a result of this finding, GPU installed scuppers in the parapets of the reactor and turbine buildings, which prevent buildup of water if the roof drains are clogged.

III. SITE VISIT AND WALKDOWN

Paul Baughman and M.K. Ravindra of EQE visited OCNGS on June 13, 2000, to collect information on the design of roof and surface drainage systems, and to observe the existing conditions of these systems. Robert Barbieri and Barry Gregg of GPUN accompanied the EQE team. The following drawings and were obtained and reviewed:

- 2188-5, "Roof Drains, Turbine, Reactor, Office, Radwaste, Machine Shop and Storage Buildings."
- AD-C-5399-5, "Overboard Discharge System."
- 2192, "Composite Yard Piping Key Plan."
- 2193, "Composite Yard Piping."
- 3E-121-07-001, "General Arrangement, Storm Sewer & Yard Drainage."
- JC-19701, "Site Plan - Topograhpic Survey," Sheets 6,7,8, 9, 10, 11 and 12.
- JC-19702, "Site Plan."

The reactor building and turbine building roofs were accessed from the interior of the buildings through hatches. Since the roof of the diesel generator building has no parapet, access to the roof was not essential.

The team observed that the roofs of turbine building and reactor building have been designed to prevent roof ponding. Specifically, the roofs slope from the center to the parapet, and drains are installed along the parapets to drain off water. The roof drains are 4-inch diameter with dome type grates. The reactor building has four drains, and the turbine building has six drains (half are on each side of the center ridge line.) This agrees with the plant drawings and the SEP submittal.

Additionally, there are 6-inch diameter scuppers (pipes) in the parapet, installed nine inches above the roof low point, which would prevent excessive water buildup if the drains were clogged (See Figures 1 through

5). This confirms that the modifications to the parapets recommended by Franklin Institute were made. The reactor building has two scuppers and the turbine building has four scuppers.

However, the team observed that the roofs are clear of debris and no debris was observed at the drain grates. Since the no debris could be blown onto the top of the buildings from site itself, it is unreasonable to expect the drains to become clogged during the PMP.

One drain on turbine building roof appeared to be plugged with roofing tar. A work order was initiated to clear the tar from the drain.

It was confirmed that the emergency diesel generator building roof did not have any parapets and would allow the rainwater to run off freely (Figure 6).

A second site visit took place on July 15, 2000. Paul Baughman of EQE performed a review of the site topography and inspected the catch basins. He was accompanied by Tom Powell and Barry Gregg of GPUN.

Prior to the site visit, Drawing 3E-121-07-001, which showed the locations of the plant buildings and storm drains, was marked up to show the topographic contours from the site topographic survey drawings. This marked up site plan is shown in Figure 7.

The site walkdown concluded that the elevations and storm sewer catch basin locations noted on the topographic site plans are still valid, with the following exceptions:

- The intake and discharge canals have banks at about Elevation 24 feet which keep runoff from leaving the site except at specific places.

- New catch basins have been installed at the southeast corner of the off gas building, in the area noted by the Franklin Institute reviewers as having local ponding potential.

- New drainage catch basins and sewer piping have been installed on the north and east sides of the machine shop and on the north side of the turbine building.

- A new catch basin and drain piping has been installed between the old radwaste building and the east side of the reactor building.

- The overland runoff path to the southeast was substantially reduced due to the addition of the new administration building. This building was constructed after the SEP evaluation.

- The ground surface is even with the top of the ramp at the Emergency Diesel Generator Building at Elevation 23.5 feet, and slopes down to the road at the north end of the building and the south side of the site to the south of the building. Precipitation will thus flow away from the entry without ponding.

A more recent site plan was obtained which showed the addition of the administration building at the southeast portion of the site.

IV. CURRENT PMP CRITERIA

The new criteria are contained in NOAA/NWS Hydrometeorological Reports (HMR) Nos. 49 (1977), 51 (1978), 52 (1982), 53 (1980) and 55 (1984). Reports 51, 52 and 52 deal with sites east of the 105th meridian. Applying these to the location of Oyster Creek yields the following PMP storms.

Duration (min)	PMP (in)	Intensity (in/hr)
5	6.1	73.2
15	9.5	38.0
30	13.6	27.2
60	18.0	18.0
24 hours	35.0	Varies

It is clear that the new PMP criteria call for higher intensities than the six hour, 27 inches criterion (4.5 in/hr) used in the SEP analysis. With the higher intensities, there is the possibility that local flooding could occur to elevations higher than 23.5 feet MSL. Since the original calculations were not available to use for extrapolation, a new analysis was required. The analysis was performed by Prof. Robert Moynihan of the University of New Hampshire acting as a consultant to EQE. A report of this analysis is attached.

V. RESULTS OF SITE FLOODING ANALYSIS DUE TO NEW PMP CRITERIA

The Oyster Creek site was divided into nine distinct watershed areas, or subcatchments, based on the topography of the site. The nine areas are shown in Figure 8. The watersheds generally drain water away from the site buildings without local accumulation. Two of the watershed areas, however, retain water before it begins to run off through the various pathways. These are areas 3 and 6.

The tributary areas for these watersheds include the roof areas of the buildings abutting them, even though these roofs contain roof drains. This was done because the roofs drain to the storm drain system; when the storm drain system capacity is exceeded the water from the roofs will back up into the watershed. However, the roofs of the reactor, turbine and old radwaste buildings are routed directly to the 30-inch overboard discharge piping which will not become backed up. Therefore, there is some conservatism in the tributary areas.

The analysis also took into account the variations in elevation in the watersheds that were indicated in the topographic survey drawings. This would give smaller retention volumes per inch of water height above Elevation 23.0 compared to assuming a constant grade elevation of 23.0 feet MSL, and would lead to higher onsite flood elevations for a given volume of water retained in the watershed.

The analysis showed that the water level could rise in areas 3 and 6 to Elevation 23.6 feet MSL under current PMP criteria. These areas contact the north, east and south sides of the reactor building. Water intrusion into the other buildings contacted by these areas would not lead to severe accidents. The areas do not contact the turbine building or the diesel generator building. Therefore, the only potential water entry would be to the reactor building. The entrances to the reactor building are airlocks which are kept closed during normal operation. The interior of the building is maintained at a negative pressure of 0.25 inches of water. It is clear that the force exerted on the airlock doors by approximately one inch of water along the base is negligible compared to the pressure of 0.25 inches of water over the entire door surface. Thus the doors would remain in place and minimize water intrusion into the building.

VI. ANALYSIS OF ROOF PONDING DUE TO CURRENT PMP

The SEP PMP analysis by Burns and Roe showed that the existing storm drains would limit water buildup to 12 inches above the low point, even assuming the drains are 25% blocked by debris. The inspection of the roofs indicated that there is no potential for blockage of the drains during PMP. However, the roofs have been fitted with scuppers which in the event of complete drain blockage would limit the water level to 13.5 inches. The design of the scuppers is documented in GPUN Calculation 1302-576-5320-001, "Ponding of R.B. and T.B. Roof Loading Analysis." According to the calculation, this level results in an effective live load on the roof of 24 psf compared to the design live load of 30 psf.

The Burns and Roe and GPUN calculations were done for a PMP of 27 inches in 6 hours, an intensity of 4.5 in/hr. The current PMP criteria call for greater intensities of rainfall; thus, there could be more accumulation of water on the roofs. Since the Burns and Roe calculations were not available, a new analysis was performed. This analysis was also done by Prof. Moynihan and reviewed by Paul Baughman.

The analysis considered each roof as a subcatchment. Each subcatchment led directly to a pond (the volume of the pond is the volume of water retained on the roof.) Since the roofs are sloped, the volume of the pond is not linear with height. Therefore, the ponds were modeled as having stepwise linear volume with height in 0.2 foot increments up to the height of the peak of the roof, then as a constant area above that. The dimensions of the roofs were taken from GPUN Calculation 1302-576-5320-001.

There were two exit paths (reaches) from each pond: (1) the roof drains, and (2) the scuppers. The roof drains were modeled as 4-inch diameter pipes (four for the reactor building and six for the turbine building) with an average length and slope as determined from Drawing 2188. The scuppers were modeled as 6-inch pipes (two for the reactor building and four for the turbine building) with an estimated length of 2 feet and slope of 0.0001 ft/ft. The invert elevations were taken as the average elevation of the beginning of the horizontal runs for the roof drains and as the bottom of the pipe for the scuppers. Sensitivity analyses were done with large variations in the lengths and slopes of the reaches, and there was little change in the results. It was judged that values used were on the conservative side.

An analysis of each storm was carried out using the HydroCAD program as described for the site runoff analysis. The water height, exit flows and retained pond volume were calculated as a function of time for each storm. The results are tabulated below.

Building	Duration (min)	PMP (in)	Intensity (in/hr)	Pond Volume (cu ft)	Effective Load (psf)
Reactor	5	6.1	73.2	4035	16
	15	9.5	38.0	9764	39
	30	13.6	27.2	12562	50
	60	18.0	18.0	13617	54
	24 Hour	35.0	Varies	10959	44

Building	Duration (min)	PMP (in)	Intensity (in/hr)	Pond Volume (cu ft)	Effective Load (psf)
Turbine	5	6.1	73.2	4483	14
	15	9.5	38.0	10424	32
	30	13.6	27.2	12674	39
	60	18.0	18.0	12439	38
	24 Hour	35.0	Varies	10751	33

The pond volumes shown are the peak values, in cubic feet, of the water volume impounded on the roofs. The effective load is the weight of this volume of water divided by the roof area. Since the roofs are sloped to the outside, the actual water pressure varies, decreasing toward the centerline of the roof. However, the roofs are supported on steel trusses which span across the roof from east to west (the same direction as the slope.) The maximum stress in the roof trusses occurs at midspan, and approximating the loading as a uniform load is conservative.

The design criteria for the design of the roof trusses required that the stress from the load combination of DL+LL+OBE not exceed normal AISC allowables. For an extreme environmental load, such as PMP, it is customary to allow stresses not to exceed 1.6 times AISC allowables. The design DL and LL for both roofs were 20 psf and 30 psf, respectively. Conservatively assuming the sum of the DL and LL brings the stress in the trusses to the AISC normal allowable, the extreme environmental load could reach 1.6*(20+30) = 80

psf without failure of the roof trusses. Thus, a conservative estimate of the PMP load which can be carried by the roof trusses is 80-20 = 60 psf, which is greater than the loads calculated for the PMP. This estimate is conservative because it neglects that the actual weight of the roof is less than the design load and that the actual stress from LL+DL is less than the normal AISC allowable.

VII. CONCLUSIONS

The potential for effects of current PMP criteria leading to severe accident have been evaluated for the OCNGS site. An analysis of local flooding due to PMP overland runoff showed that water intrusion will be minimized into buildings housing equipment or systems whose failure could lead to severe accident. An analysis of roof ponding loads shows that the roof support trusses will not fail; therefore the roof ponding cannot affect equipment or systems whose failure could lead to severe accident. Therefore, it is concluded on the basis of bounding analysis that probable maximum precipitation does not contribute to severe accident risk at OCNGS.

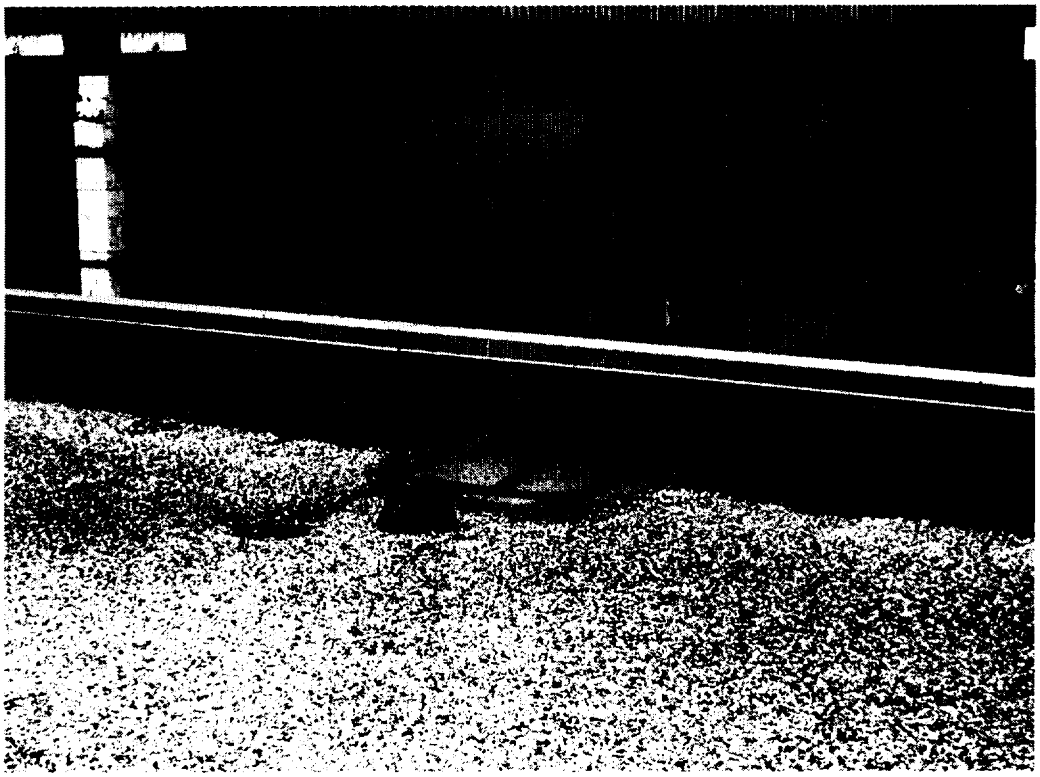

Figure 1: Turbine Building Roof: Detail of Roof Drain and Scupper

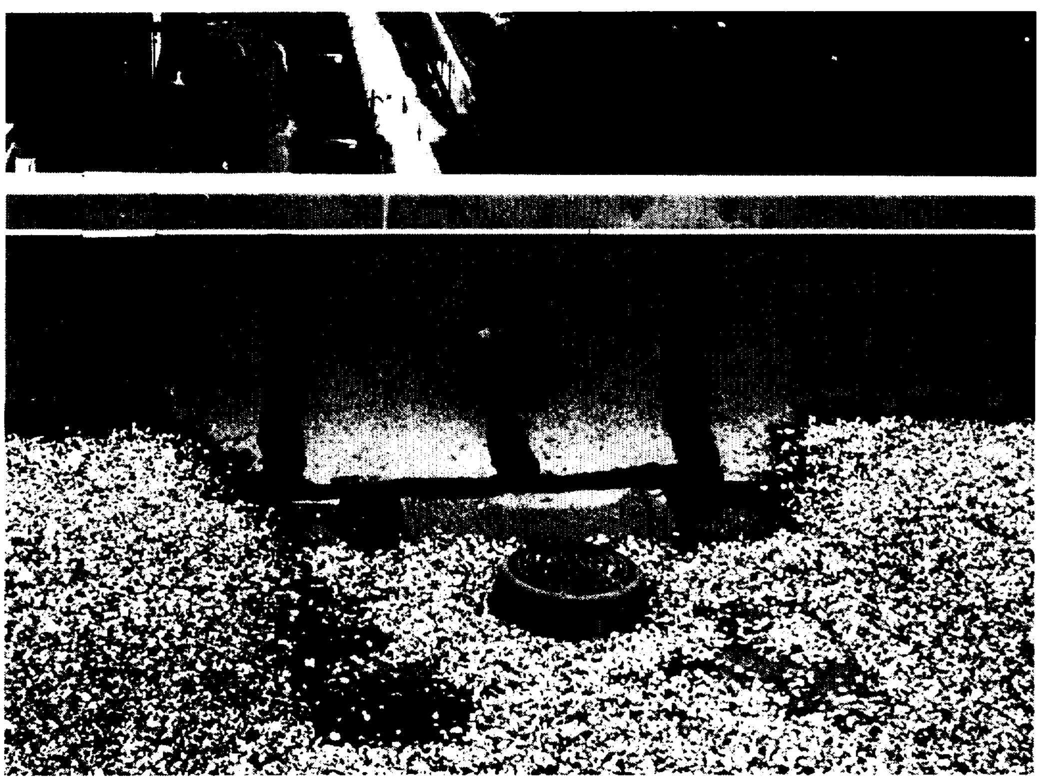

Figure 2: Turbine Building Roof Drain and Scupper Detail

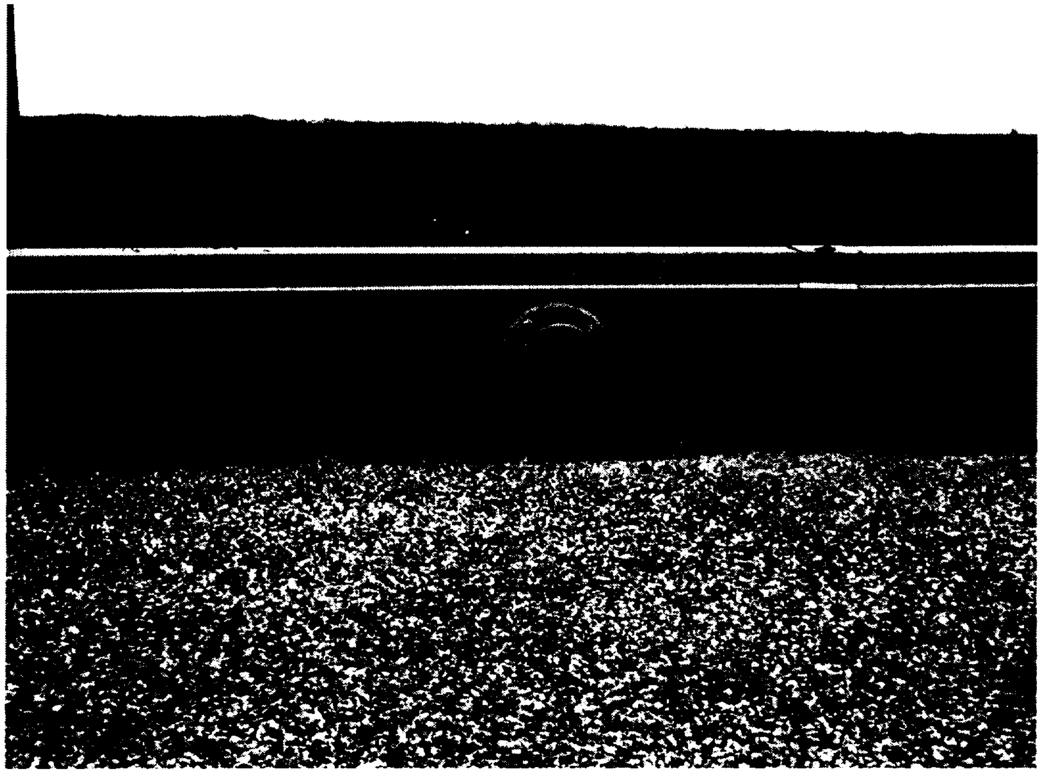

Figure 3: Opening in the Turbine Building Parapet

Figure 4: Roof Drain on Reactor Building Roof

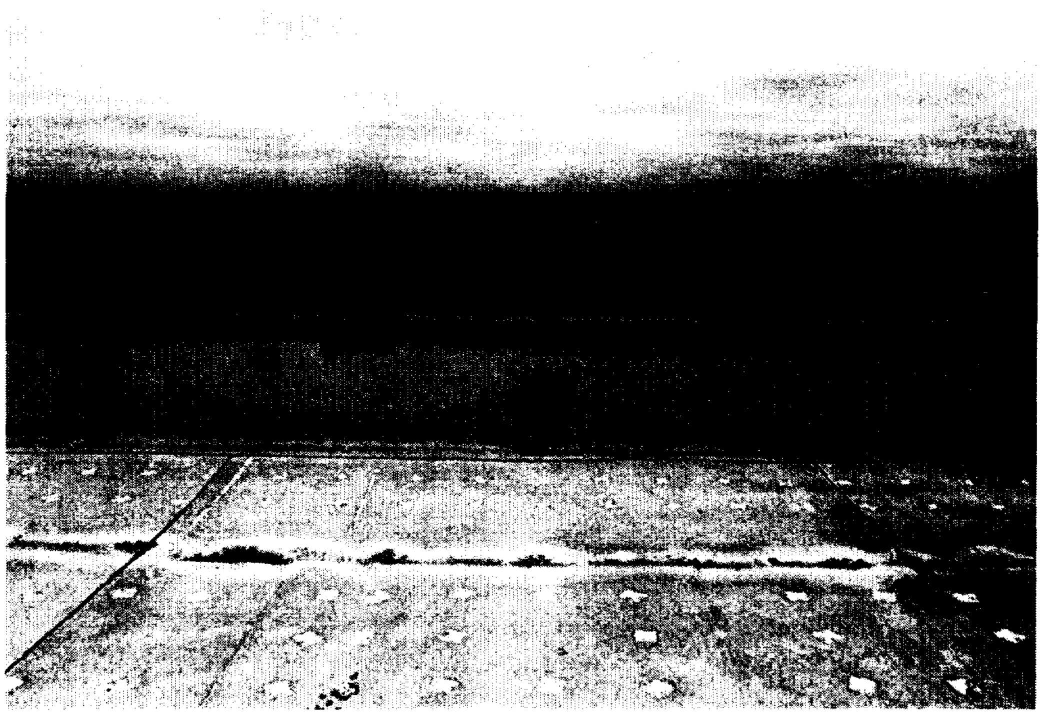

Figure 5: Parapet of Reactor Building Roof showing the Scupper

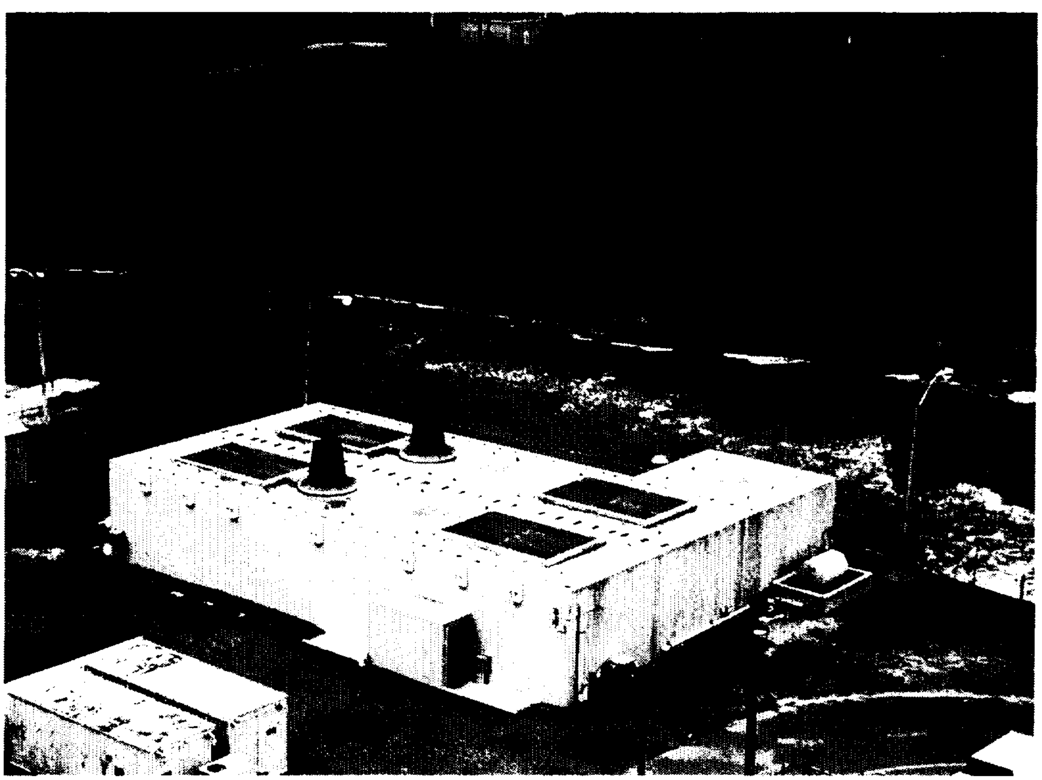

Figure 6: Roof of Emergency Diesel Generator Building

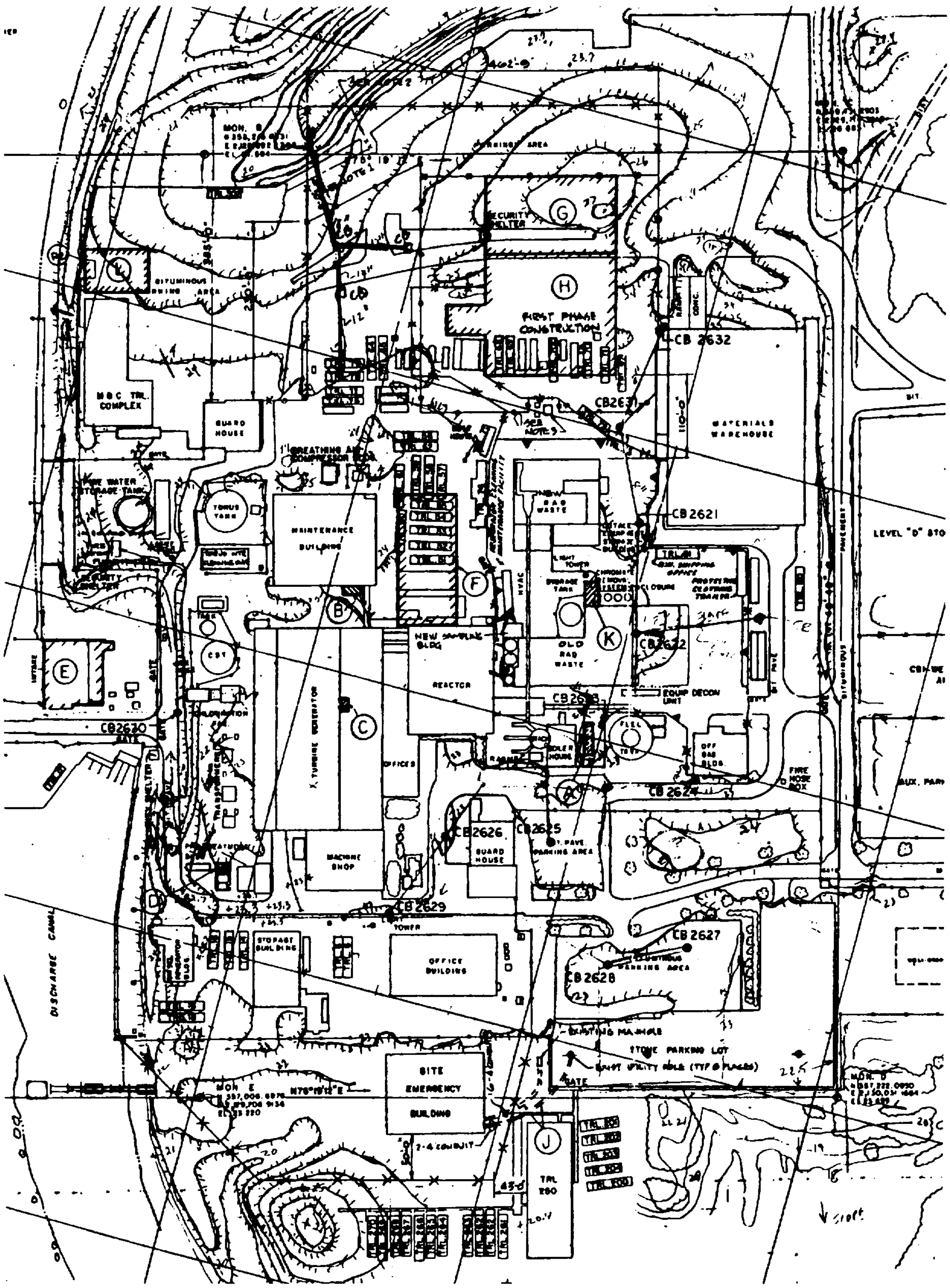

Figure 7. Site Plan with Topography

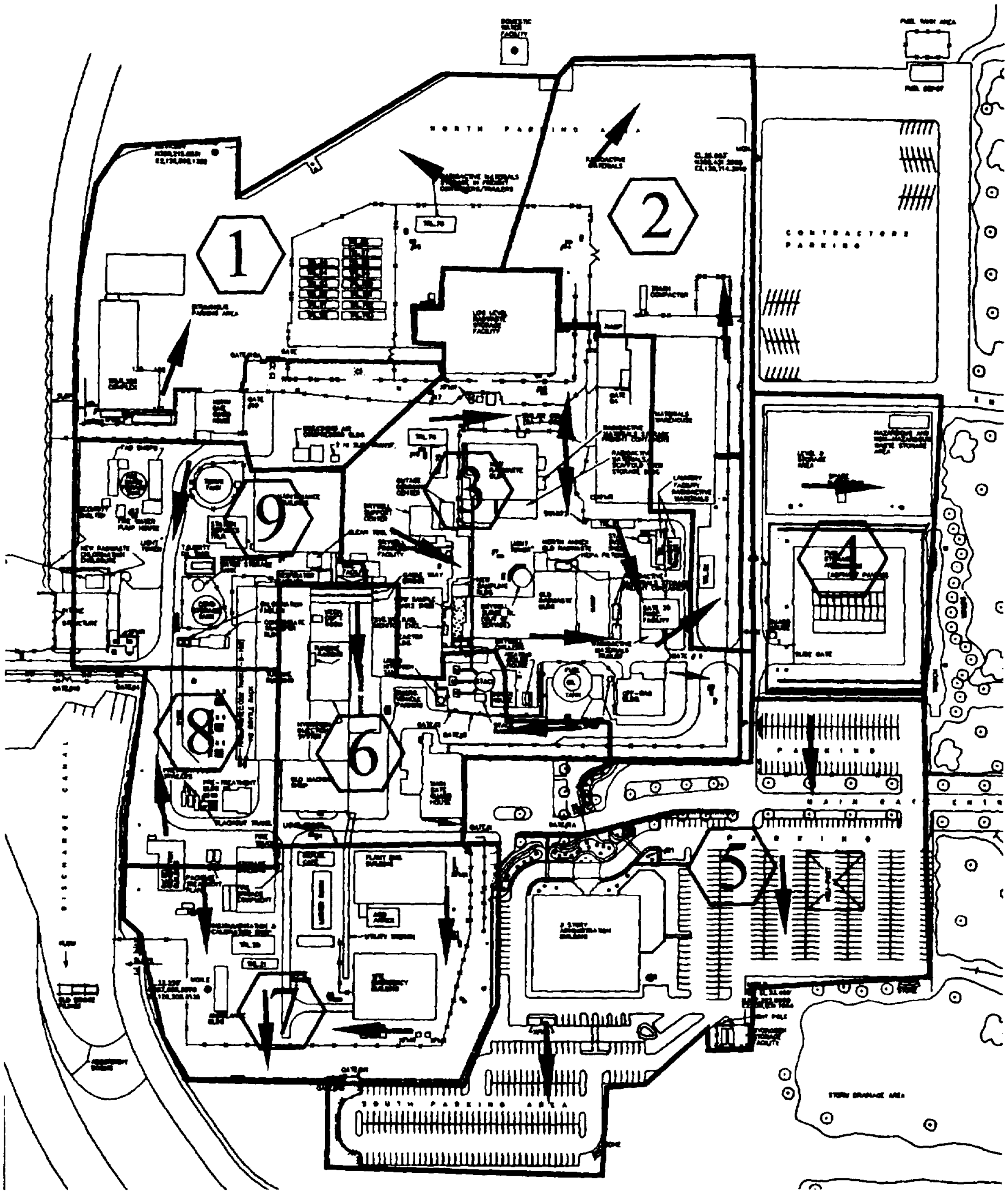

Figure 8. Site Plan showing Subcatchments