ATTACHMENT 7

MCGUIRE NUCLEAR STATION
SPENT FUEL POOL SOLUBLE BORON
CREDIT BORON DILUTION ANALYSIS
(SUMMARY OF APPLICABLE PORTIONS)

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Evaluation Of Potential Boron Dilution Accidents For The McGuire Spent Fuel Pools

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Evaluation Of Potential Boron Dilution Accidents

For The McGuire Spent Fuel Pools

1.0 INTRODUCTION/BACKGROUND

The current criticality analysis for the McGuire Spent Fuel Pool (SFP) takes credit for a solid boron material in the fuel racks known as Boraflex. This material has unexpectedly degraded over time and has lead to a loss of boron in the material. As this degradation has continued, it has become necessary to reduce or eliminate credit for the solid boron in the racks in the criticality analysis. In order to continue meeting criticality design criteria, it is necessary to take credit for soluble boron contained in the SFP water. This calculation will evaluate potential accidents that could add significant amounts of unborated water to the Spent Fuel Pool causing dilution of the pool boron concentration. This calculation will evaluate the minimum possible boron concentration which could result from a credible boron dilution accident event. The results will also provide timing estimates of boron concentrations resulting from these accidents.

This analysis is related to reactivity management for the McGuire Spent Fuel Pools. Although no plant operational parameters or design features are affected by this calculation, it is an input to another calculation of the reactivity impact of various postulated accidents in the McGuire Spent Fuel Pool (Attachment 6). The criticality analysis which takes credit for soluble boron is also required to address a bounding case with complete loss of all soluble boron to show that the value of k_{eff} remains less than 1.0.

The overall governing methodology for crediting soluble boron is described in WCAP-14416-NP-A (Reference 1). This approach requires that a boron dilution analysis be performed to ensure that sufficient time is available to detect and mitigate the dilution before the 0.95 k_{eff} design basis criterion is exceeded. This approach further states that the dilution analysis should include an evaluation of the following plant-specific features:

1. Spent Fuel Pool and Related System Features
   - Dilution Sources
   - Dilution Flow Rates
   - Boration sources
   - Instrumentation
   - Administrative Procedures
   - Piping
   - Loss of Off-Site Power Impact
2. Boron Dilution Initiating Events (including operator error)
3. Boron Dilution Times and Volumes

The staff has concluded that the new methodology in WCAP-14416 can be used in licensing actions. All licensees proposing to use the new method for soluble boron credit should identify potential events which could dilute the spent fuel pool boron to the concentration required to maintain the 0.95 k_{eff} limit and should quantify the time span of these dilution events to show that sufficient time is available to enable adequate detection and suppression of any dilution event. The effects of incomplete boron mixing should be considered.

The methodology employed uses four basic steps:

1. Develop Preliminary List of Potential Events
2. Screen Events that are not Credible or are Irrelevant
3. Evaluate Events for Dilution Times and Volumes
4. Summarize Results and Conclusions

A preliminary list of events for review was developed through the review of several industry studies and review of the design of the McGuire Spent Fuel Pool and related systems. A plant walkdown was conducted to examine SFP structural features and the spatial relationships between the SFP and related plant systems. Furthermore, a review of industry operating experience was conducted to check for possible failures modes not previously considered. Many types of postulated events were screened out because they lead to consequences different than deboration, and others were screened out because they are not credible with the McGuire pool design.

Events which were not initially screened out were evaluated further to determine the potential impact of those events on pool boron concentration. In some cases, the accident source of unborated water comes from a finite source that is relatively small compared to the volume of the pool. These events were evaluated to show the resulting boron concentration if the entire source were added to the pool. On the other hand, some sources of unborated water could come from continuously flowing systems. These "infinite" water sources were evaluated for the highest flow rate as the bounding case. Events involving continuously flowing systems are also evaluated to determine the available time for operator action to show that sufficient time is available to terminate the flow into the pool.

A number of important assumptions were made to perform this assessment. Most of the major assumptions are discussed below.

2.0 ASSUMPTIONS

2.1 Unit 1 and Unit 2 Spent Fuel Pool Similarity

The layout and overall dimensions of the Unit 1 and Unit 2 Spent Fuel Pools are the same except that each is a "mirror image" of the other. As a result, the estimated volumes are also the same. No significant differences were found in design parameters between the interfacing systems for each unit. Although there were some differences in piping layout around the pool areas, no differences in the piping system were found that would have any obvious effect on the rate or magnitude of dilution in either pool. Therefore, only one set of calculations is made and the results are applicable to both McGuire Spent Fuel Pools.

2.2 Boron Concentration

The initial pool boron concentration is conservatively assumed to be 2475 ppm. This corresponds to the COLR limit for McGuire Unit 1 Cycle 12 which is the lowest limit currently in use at McGuire. However, the Unit 1 Cycle 13 limit is scheduled to be raised to 2675 ppm matching the current limit for McGuire Unit 2. Choosing the lower value provides some additional safety margin as well as allows the COLR limit to be lowered for future reactor designs (if needed or desired) without impacting this analysis. Based on the double contingency principle, it is not necessary to postulate that the pool boron concentration is below its TS minimum concentration concurrently with a second event that puts a large volume of unborated water into the pool (Reference 1).

2.3 Spent Fuel Pool Water Level

The initial pool water level is assumed to be at the normal level at elevation 771' + 4.75". The volume of water in the Spent Fuel Pool at this water level is 43,108 cubic feet, which corresponds to approximately 322,450 gallons. This value will be used for the initial water volume in dilution calculations. This volume includes the cask loading pit and the fuel transfer canal, but excludes the volume of water within the fuel pin area. It also excludes the volume in the gate openings between the main pool and the transfer canal and between the main pool and the cask loading pit. The Tech Spec minimum level is 23 feet above the fuel, which corresponds to an elevation of 769'. Again due to the double contingency principle, it is not necessary to postulate that the spent fuel pool level is below its normal level concurrently with a second event that puts a large volume of unborated water into the pool. Furthermore, the additional volume of water in the fuel pin area should more than account for any slight level variations that might occur prior to a postulated boron dilution event. Thus it is concluded that the assumption of normal pool level with 322,450 gallons of water volume is acceptable.

Note that SFP level is not measured using the control room instrument but rather by a physical marking on the pool wall for the purposes of normal routine surveillance and normal makeup to the SFP for evaporation. The control room SFP level instrument instead serves to provide a high and low level alarm function. Given that such a physical marking is not subject to "instrument drift" and that the water volume estimate is conservative, it is unnecessary to account for "instrument error" in the water volume estimation.

This analysis is only addressing dilution events where there is the potential to add large amounts of unborated water to the SFP. Events involving a large loss of SFP coolant inventory are not evaluated for boron dilution from emergency makeup used to restore SFP level. Certain catastrophic failures of the pool could result in a large loss of SFP inventory that could cause a zircaloy cladding fire. However, it is assumed that plant procedures will address boron addition as a part of the emergency makeup response. In addition, the new SFP criticality analysis will examine a case where there is no soluble boron in the SFP. Emergency makeup without boration could lead to a loss of all boron and thus a loss of the 5% safety margin; however, the "no boron" case will show that k_{eff} will remain still less than 1.0.

2.4 Mixing Factors

It is conservatively assumed that any unborated water that enters the pool will mix completely with the existing water in the pool. Complete mixing generally maximizes the rate of boron dilution. This assumption is consistent with the approach used in Reference 2 and in similar licensing submittals made by other licensees.

Good mixing is expected for the dilution events of interest. Operation of the KF system in conjunction with thermal mixing of warmer water rising from the fuel help ensure good mixing in the pool. Specifically, the KF pumps continuously recirculate approximately 1000 gpm from the South end of the main pool to the North end. Also the Spent Fuel Pool Skimmer Pump provides an additional 100 gpm of flow from the South end of the pool back to the opposite ends of the main pool, fuel transfer canal and cask loading pit. Partial mixing may occur in cases where a pipe breaks in the pool area and causes the pool to overflow.

In this case, the water entering the pool may not fully mix with the rest of the pool inventory before exiting the pool. Partial mixing in this case would serve only to slow-down the dilution of the rest of the pool. The potential for "pockets" of lower boron concentration are bounded by the "no boron" criticality case and do not need to be considered further.

2.5 Piping Break Sizes

For random piping breaks, the break size is determined using the method in FSAR Section 3.6.2.2. While high-energy systems must consider double-ended pipe breaks, moderate energy systems are only required to assume through-wall cracks. The through-wall crack break area considered for this event is based on a length equal to one-half the nominal inside diameter and a width equal to one-half the minimum wall thickness of the system piping material.

For this assessment, piping breaks caused by seismic or tornado events are also considered for non-seismic piping or piping not protected from tornado winds or missiles. For these breaks a larger through-wall crack size was assumed than for random break events. The through-wall crack break area assumed for these events is based on a length equal to the circumference of the pipe at its inside diameter and a width equal to one-half the minimum wall thickness of the system piping material.

3.0 Identification and Screening of Dilution Initiating Events

A preliminary list of events for review was developed through the review of several industry studies (References 2 and 3) and review of the McGuire Spent Fuel Pool and related systems. Table 1 provides a listing of the types of events considered and how these events were dispositioned. Many types of postulated events were screened out because they lead to consequences different than boron dilution, and others were screened out because they are not credible with the McGuire pool design.

4.0 Evaluation of Boron Dilution Times and Volumes

In order to determine the boron concentration for various flow rates and volumes it is necessary to examine the dimensions and configuration of the spent fuel pool. A sketch of the Unit 1 SFP is provided in Figure 1. The pool consists of three connected compartments: the main pool area where fuel is stored, the cask loading area, and the transfer canal area. Normally all three areas are connected, but gates can be installed for infrequent activities such as maintenance on the "upender" in the Transfer Canal, or the loading or unloading of a cask in the cask loading area. For the base case analysis, the initial pool volume is 322,450 gallons which includes all three areas (i.e., gates removed). Other modes are evaluated separately.

All of the events to be evaluated involve the addition of unborated water to the existing water volume. It is important to note that the normal water level (771' + 4.75") is well below the top of Spent Fuel Pool operating floor (Elevation 778'+10"). Since no water is assumed to flow out of the pool at the initiation of a dilution event, unborated water enters the pool and fills the pool continuously until it reaches the top of the pool and overflows. Figure 1 provides an illustration of the various water and pool elevations.

Three stages of boron dilution flow are examined. The first stage involves filling up the pool to the top of the Transfer Canal wall at elevation 773' + 6". The second stage involves filling the pool from the top of the Transfer Canal wall up to the top of the pool operational deck at elevation 778' + 10". The third stage involves the flow of unborated water into the pool with an equal amount of the diluted mixture flowing out of the pool into the lower areas of the Spent Fuel Pool Building.

The volume of water required to fill the pool up to the top of the Transfer Canal wall is 23,995 gallons. The volume of water required to fill the pool from the top of the Transfer Canal wall up to the top of the pool is 68,029 gallons.

The pool boron concentration at the end of stage 1 (C_1) is found using:

$$C_1 = \frac{C_o * V_o}{V_o + V_c}$$

where C_o = Initial Pool Boron Concentration (2475 ppm),
V_o = Initial Pool Water Volume (322,450 gallons), and
V_c = Volume of water to fill to top of Transfer Canal Wall (23,995 gallons)

This yields a value for C_1 of 2304 ppm. The length of time to reach this concentration is dependent on the dilution flow rate into the pool. This length of time can be found by dividing V_c by the flow rate. Table 2 provides a listing of times required to fill the pool to the top of the Transfer Canal Wall for various flow rates. To find the pool concentration at any specific time during stage 1, the following equation is used:

$$C = \frac{C_o * V_o}{V_o + (Q*60*t)}$$

where C_o = Initial Pool Boron Concentration (2475 ppm),
V_o = Initial Pool Water Volume (322,450 gallons),
Q = Flow rate into Pool (gpm),

t = Length of time after initiation of dilution flow (hours), and

60 = Conversion factor for converting hours to minutes.

The pool boron concentration at the end of stage 2 (C_2) is found using:

$$C_2 = \frac{C_o * V_o}{V_o + V_c + V_T}$$

where C_o = Initial Pool Boron Concentration (2475 ppm),

V_o = Initial Pool Water Volume (322,450 gallons),

V_c = Volume of water to fill to top of Transfer Canal Wall (23,995 gallons)

V_T = Volume to fill from Canal Wall to Top of Pool (68,029 gallons)

This yields a value for C_2 of 1925 ppm. The length of time to reach this concentration is dependent on the dilution flow rate into the pool. This length of time can be found by dividing the sum of V_c and V_T by the flow rate. Table 1 provides a listing of times required to fill the pool to the top for various flow rates. To find the pool concentration at any specific time during stage 2, the following equation is used:

$$C = \frac{C_o * V_o}{V_o + V_c + (Q * 60 * (t - t_c))}$$

where Q = Flow rate into Pool (gpm),

t_c = Length of time to fill to top of Transfer Canal Wall (hours),

t = Length of time after initiation of dilution flow (hours), and

60 = Conversion factor for converting hours to minutes.

*By definition, t must be greater than t_c and less than t_T. Value of t_c and t_T are pr[illegible]ded in Table 2.

After the pool reaches stage 3 where the pool is overflowing, the boron concentration is found using:

$$C = C_2 e^{(-Q/V_M)(t-t_T)}$$

where C_2 = equals the pool concentration at the end of stage 2 (1925 ppm)

Q = Flow rate into Pool (gpm),

V_M = Total SFP Mixing Volume ($V_o+V_c+V_T$=414,474 gal)

t_T = Length of time to fill to top of pool (hours),

t = Length of time after initiation of dilution flow (hours), and

Using the equations above, the pool boron concentration was estimated for a range of flow rates for various times from 1 to 72 hours with the results presented in Table 1.

In some of the events evaluated, the source of dilution flow is defined by a fixed volume instead of a continuous dilution flow. If the total volume added to the pool does not overflow the pool (less than 92 024 gallons), the pool boron concentration is found using:

$$C = \frac{C_o * V_o}{V_o + V}$$

where C_o = Initial Pool Boron Concentration (2475 ppm),

V = Water Volume added to the pool (gallons), and

V_o = Initial Pool Water Volume (322,450 gallons).

If the total volume added to the pool does overflow the top of the pool (greater than 92,024 gallons), then the pool boron concentration is found using:

$$C = C_2 e^{-\left(\frac{V-92024}{V_0+92024}\right)}$$

where C_2 = equals the pool concentration at the end of stage 2 (1925 ppm),

V_o = Initial Pool Water Volume (322,450 gallons),

V = Water Volume added to pool (gallons), and

92024 = number of gallons to fill pool to overflowing (V_C+V_T).

5.0 Evaluation of SFP Dilution Events

5.1 Pipe Breaks

Both McGuire Spent Fuel Pools are located at an elevation above all adjacent buildings. Pipe breaks in adjacent buildings or areas can not flow into the pool and are excluded. Through the review of plant drawings and a plant walkdown, piping for the following systems was identified in the SFP area that, if broken, could flow into the SFP:

System	Largest Pipe	System Pressure
RF - Fire Protection Supply	4 inch	150 psig
YM - Demineralized Water Supply	2.5 inch	120 psig
YD - Drinking Water Supply	1 inch	100 psig
WE - High Pressure Decon Water	* System Abandon In Place *	

Note: KF system piping in the SFP area is excluded because it contains borated water.

Besides being the largest and highest pressure line in the SFP area, the RF header is supplied by the RF pumps taking suction from Lake Norman (an "infinite" source). For this reason, the RF line is taken to be the worst line break.

> The RF system is classified as a moderate energy system (FSAR Table 3-19). For random piping breaks of moderate energy systems, the size of the break is determined per the criteria provided in UFSAR Section 3.6 For the 4" RF line, the piping material is Schedule 40 Carbon Steel (McGuire Piping Specification 154.1) which has a thickness of 0.237" and an inside diameter of 4.026"

For the RF line, the equivalent diameter is 0.551 inches and the system pressure is 150 psig. This results in a break flowrate of 111.1 gallons per minute.

Since the RF line is not seismically qualified, it is also evaluated for a larger through-wall crack size. Using a pipe thickness 0.237" and an inside diameter of 4.026", the break area is 1.50 square inches.

For the RF line seismic break, the equivalent diameter is 1.382 and the system pressure is 150 psig. This results in a break flowrate of approximately 700 gallons per minute.

Table 2 provides a tabulation of the resulting boron concentration over time from a 700 gpm dilution flow rate.

5.2 Misalignment of Systems Interfacing with KF System

The potential exists for systems that interface (directly or indirectly) with the KF system to become misaligned due to operator errors or component malfunction or failure causing unborated water to be added to the Spent Fuel Pool. These interfacing systems are the Refueling Water (FW) System, Boron Recycle (NB) System, Liquid Waste Recycle (WL) System, Chemical and Volume Control (NV) System, Makeup Demineralized Water (YM) System, Filtered Water (YF) System, Drinking Water (YD) System, Fire Protection (RF) System, Nuclear Service Water (RN) System, and Component Cooling Water (KC) System. The potential impact of these systems is evaluated below. Attachment 2 provides additional information on the flow paths between these systems. The SSF Standby Makeup Pump also connects to the SFP through the Fuel Transfer Tube; however, the impact of SSF operation will be examine later (Loss of Off-site Power discussion).

5.2.1 Dilution From Reactor Makeup Water Storage Tank

While normal makeup to the Spent Fuel Pool is provided by the Refueling Water Storage Tank, an alternate makeup source is provided by the Boron Recycle (NB) System. This is accomplished by aligning the Reactor Makeup Water (RMW) Pumps from the Reactor Makeup Water Storage Tank (RMWST) to discharge directly into the pool. The RMWST has a usable volume of 112,000 gallons and the RMW pumps have a capacity of 150 gpm each.

If an error occurred that inadvertently caused the entire volume of unborated water in the RMWST to be pumped into the SFP, the resulting boron concentration is 1834 ppm.

5.2.2 Dilution From The Recycle Holdup Tanks

Another portion of the Boron Recycle (NB) System contains the Recycle Evaporator Feed Pumps and the Recycle Holdup Tanks (RHT). There are two pumps (30 gpm each) and two tanks with a usable volume of 112,000 gallons each. There is not a direct connection between this source and the KF system or the SFP;

however, it is possible to pump this water into the pool indirectly by misaligning the Refueling Water (FW) system makeup line to the SFP through manual valves KF-81 and KF-83.

However, another path from the RHTs to the SFP would be to align the Recycle Evaporator Feed Pumps to the RMWST and to "piggy-back" the RMW pumps into the SFP. This path is potentially worse because of the greater combined volume of both Recycle Holdup Tanks and the RMWST. However, the flow rate is limited to 60 gpm by the two Recycle Evaporator Feed Pumps. The total volume of these tanks is 336,000 gallons (112,000+112,000+112,000). The maximum pool dilution resulting from this event is 1068 ppm.

5.2.3 Dilution From Demineralized Water (YM) System

While the normal makeup to the pool comes from the FWST, makeup water can also be added to the pool from the Demineralized Water (YM) System. There is not a direct connection between this source and the KF system or SFP; however, there are two indirect paths which could be used to add YM to the SFP. First, it is possible to attach a hose to a YM connection in the pool area and run the hose a few feet over into the pool. However, the flow rate is somewhat limited due to the smaller piping size. The second path is considered to be the worst case event in which the YM system is aligned through the RMWST. This event conservatively assumes that a misalignment occurs in which YM is "piggy-backed" on the RMW pumps putting water into the pool. The volume of water is assumed to be the sum of all the water available in the YM system plus the volume of the RMWST. The volume of water available in the YM system is assumed to include both Demineralized Water Storage Tanks (1000 gallons each) and both Filtered Water Tanks (42,500 gallons each). The total volume of the all these tanks is 199,000 gallons (2,000+85,000+112,000). The maximum pool dilution resulting from this event is 1489 ppm.

5.2.4 Dilution From The Recycle Monitor Tank

Another source of makeup water to the RMWST comes from the Liquid Waste Recycle (WL) System. The Recycle Monitor Tank Pumps can be connected to pump the Recycle Monitor Tank (RMT) inventory into the RMWST. Since there is not a direct connection between this source and the KF system or SFP, it is assumed to be misaligned where both RMT Pumps are "piggy-backed" on the RMW pumps putting water into the pool. For this event the volume of water is assumed to be the sum of both RMTs (5,000 gallons each) and the volume of the RMWST (112,000). The total volume of the all these tanks is 122,000 gallons (10,000+112,000). The maximum pool dilution resulting from this event is 1791 ppm.

5.2.5 Dilution From Nuclear Service Water System

The KF System is designed with a connection to the RN System "A" Header and a separate connection to the RN "B" Header. This is considered to be the safety-related "assured" makeup source to the Spent Fuel Pool which would only be used if no other demineralized water were available. Each connection is designed to provide 500 gallons per minute of makeup flow. Each line is isolated from the SFP by two "locked-closed" manual valves in series. The postulated dilution event is the unintentional opening of one of these lines resulting in an assumed dilution flow rate of 500 gpm. Table 2 provides a tabulation of the resulting boron concentration over time from a 500 gpm flowrate.

5.2.6 KC/KF Heat Exchanger Leak

The Component Cooling Water (KC) System provides cooling water to the KF heat exchangers for decay heat removal. There is no direct connection between the KC system and KF system. However, a connection would occur if a leak were to develop in a KF heat exchanger that is in service. In case of a leak, KC water would be expected to flow into the KF system since KC is at a slightly higher pressure. It is expected that the flow rate from such leakage would be very small due to the very small difference in system operating pressures.

Even if a significant flow rate resulted from a leak, the impact on the SFP boron concentration would be very small due to the limited volume of water available in the KC system. The total volume of water in the KC system is 31,214 gallons. Operator response to a loss of KC inventory includes manually aligning a demineralized water makeup source (YM) or using the "assured" makeup source from the RN system. The alarms from the KC surge tank and the SFP high level alarm would alert control room operators of the lost inventory and the source of the leak.

The boron concentration resulting from a dilution volume of 31,214 gallons is found to equal 2257 ppm, a change of only 218 ppm.

Because of the limited amount of water available for the KC system and the mechanisms available to operators to identify such leakage, a KF heat exchanger leak can not result in any significant dilution of the SFP and is not considered further.

5.2.7 Dilution From Drinking Water System

There is a Drinking Water (YD) System supply line located in the SFP area to dispense potable water for various cleaning and decontamination activities that take place in this area. Water for this system is supplied from the local Charlotte/Mecklenburg County water system. It is postulated that this source could be misaligned or inappropriately used causing unborated water to enter the pool. It is assumed that this source could not produce more than 50 gpm of flow from this connection. Table 2 provides a tabulation of the resulting boron concentration over time from 50 gpm of dilution flow. However, this dilution source is not a concern due to the much greater flow rates estimated for piping breaks for the RF System.

5.2.8 Boron Removal By Spent Fuel Pool Demineralizer

When the spent fuel pool demineralizer is first placed in service after being recharged with fresh resin it can initially remove boron from the water passing through it. The demineralizer normally utilizes a mixed bed of anion and cation resin which would remove only a small amount of boron before saturating. Because of the small amount of boron removed by the demineralizer, it is not considered a limiting dilution event for the purposes of this evaluation.

5.2.9 Dilution From Fire Protection System

The Fire Protection (RF) System is not directly connected to the pool. However, two fire protection hose stations located in the SFP area could be used to manually add water to the SFP. Each hose station has the capacity to deliver approximately 100 gpm of unborated water. Use of RF for this purpose would be as a last resort to restore pool inventory following the failure or depletion of all normal makeup sources to the pool as well as both trains of the RN "assured" makeup source. The impact of this dilution source is bounded by the consideration of a pipe break in the 4" RF supply header which feeds both hose stations. In addition, station procedures for emergency makeup to the SFP are assumed to address the addition of boron to the pool regardless of which makeup source is used. Therefore, this source will be addressed under "Pipe Breaks" in Section 5.1 and will not be considered further in the context of "Interfacing System".

5.3 Loss of Off-Site Power

Of the dilution sources considered, only the RN assured makeup, fire protection system, and drinking water system are capable of providing non-borated water to the spent fuel pool during a loss of off-site power. Each fuel pool cooling (KF) pump is supplied backup power by its corresponding emergency diesel generator at one hour after the loss of normal station power, however, the pumps must be manually started. The Fire Protection (RF) pumps are also supplied with emergency diesel power which must be manually connected. The Fuel Pool Skimmer Pump is not provided with a backup source of power. The spent fuel pool level instrumentation is powered from a battery-backed source which can be manually aligned to receive emergency diesel generator backed power if normal power can not be promptly restored.

Due to the low probability of a loss of power event concurrently with a pipe break or a misalignment of the RN, RF, or YD water sources, an accidental dilution of the spent fuel pool water is not considered credible. However, there is a scenario involving operation of the Standby Shutdown Facility (SSF) where the pool boron concentration may be intentionally lowered. The SSF includes an independent diesel generator ac power source and the Standby Makeup Pump which takes suction from the spent fuel pool to provide seal injection flow for the Reactor Coolant (NC) Pumps. The SSF was designed to respond to security events or Appendix R fire events, but is also credited for responding to station blackout scenarios if emergency diesel power fails.

Operation of the SSF is postulated for up to 72 hours. During this 72 hours, the Standby Makeup Pump draws approximately 26 gpm of flow from the pool. Plant procedures have provisions to provide makeup to the pool during SSF operation. The maximum volume of borated water taken from the pool is estimated to be (26 gpm x 60 min/hr x 72 hr) 112,320 gallons. If this water volume is replaced with non-borated water, the maximum dilution is calculated to be 1255 ppm.

5.4 Evaluation of Infrequent Spent Fuel Pool Configurations

Two configurations were identified that are significantly different than the normal SFP configuration. These would be if either the fuel transfer canal or cask loading pit were isolated from the main pool.

The purpose for isolating the transf r canal would be to drain the canal to gain access to the fuel handling equipment used to transport fuel assemblies between the SFP and the Refueling Canal. Under current policies and practices, the transfer canal is not drained unless the fuel handling equipment can not be repaired by using diving equipment. The use of high-quality underwater color television cameras at McGuire has also eliminated the need to drain the transfer canal to perform visual inspections of this equipment. Pool high-level alarms and plant personnel involved in the equipment repair would ensure very prompt detection prior to a significant amount of unborated water being added to the SFP. In fact, the pool would actually spill over into the fuel transfer canal and stop any work taking place there. Piping breaks in the pool area would also be obvious to crews working there. Also, the borated water drained from the transfer canal would be stored in the Recycle Holdup Tanks, effectively eliminating one of the more significant dilution sources. Because of the very low frequency of this configuration, the enormous volume of water required to significantly dilute the pool, and the effective means of early detection of an event, this configuration is not considered to be a part of a credible boron dilution accident scenario and is not considered further in this analysis.

The purpose of isolating and draining the cask loading pit is to prepare for the loading of fuel into a cask or for the actual movement of a cask into or out of the pit. While this activity has been very rare in recent past experience, some cask loading activities are planned for the future. Isolation of the cask loading pit removes approximately 46,423 gallons from the total volume of borated water available in the pool. For this special case, a new set of parameters is derived that exclude water volume in the cask loading area.

Using these new parameters, the previous dilution calculations for the worst case bounding events (the 700 gpm RF line break and the RHT/RMWST misalignment event) were performed again. For the 700 gpm RF line break, the results for this alternate configuration are provided in Table 3 which shows that it would take more than 12 hours for this dilution event to lower pool boron concentrations below the non-accident conditions minimum boron credit of 440 ppm (Attachment 6). For the RHT/RMWST misalignment event, the final pool boron concentration is 937 ppm which would require this dilution event continue unnoticed for more than 3 days. Neither of these events are likely since they would be detected by a spent fuel storage pool level alarm or by plant operations personnel walking through the area before the required volumes of water were added to a fuel pool.

6.0 Results

A summary of dilution event results is provided in the table below.

Summary of Dilution Event Results

Event Scenario	Dilution Flow Rate or Dilution Volume	Boron Concentration
Pipe Break (4" RF Header)	700 gpm	Time Dependent (See Table 2)
Dilution From RMWST	112,000 gallons	1834 ppm
Dilution From RHT & RMWST	336,000 gallons	1068 ppm
Dilution From RMT &RMWST	122,000 gallons	1791 ppm
Dilution From RN System	500 gpm	Time Dependent (See Table 2)
Dilution From YD System	50 gpm	Time Dependent (See Table 2)

Event Scenario	Dilution Flow Rate or Dilution Volume	Boron Concentration
SSF Operation (Refill to Normal)	112,320 gallons removed and 112,320 added back	1613 ppm
SSF Operation (Refill to Overflow)	112,320 gallons removed and 204,344 added back	1255 ppm
Infrequent Configuration (Cask Loading Pit Isolated) (4" RF Pipe Break)	700 gpm	Time Dependent (See Table 3)
Infrequent Configuration (Cask Loading Pit Isolated) (RHT & RMWST Mialigned)	336,000 gallons	937 ppm

Table 2 also provides an estimate of the length of time required for various flow rates to fill the pool to the high level alarm setpoint and to reach the pool overflow level.

7.0 Conclusions

Potential deboration accident scenarios in the SFP have been evaluated over a range of possible conditions. These postulated events involve combinations of multiple human errors, medium to large pipe breaks, or infrequent SFP configurations that make a significant loss of boron in the SFP very unlikely. The impact of these accidents result in a range of values of boron concentration depending on dilution flow rates and pool volumes. The results also show that the dilution process requires many hours to significantly reduce pool boron concentration even under the most limiting conditions and provides sufficient time for operator actions to terminate the accident. Based on the analysis presented above, it is concluded that the worst case unplanned or inadvertent dilution events are not credible since, in the unlikely event they occurred, they would be detected by plant operators walking through the spent fuel pool areas or by spent fuel pool level alarms before sufficient water could be added to a pool to lower its soluble boron concentration to levels approaching the minimum non-accident conditions boron credit of 440 ppm.

8.0 References

1. WCAP-14416-NP-A, Revision 1, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Westinghouse Electric Corporation, November 1996.
2. NUREG-1353, "Beyond Design Basis Accidents in Spent Fuel Pools", U.S. Nuclear Regulatory Commission, April 1989.
3. WCAP-14181, "Westinghouse Owners Group Evaluation of the Potential For Diluting PWR Spent Fuel Pools," Westinghouse Electric Corporation, July, 1995.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Structural Failure - Missiles	Screened	Postulated missiles causing damage to the pool structure could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event.
Structural Failure - Aircraft Crashes	Screened	Postulated damage to the pool structure from an aircraft crash could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event. (See also below - "Piping Damage caused by Airplane Crashes")
Structural Failure - Heavy Load Drops	Screened	Postulated heavy load drop events causing damage to the pool structure could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event.
Seismic Structural Failure	Screened	Seismic structural failure is postulated to cause an unrecoverable loss of water in the SFP, and leads to a zircaloy cladding fire and cannot cause a dilution event.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Reactor Cavity Seal Failure and/or Nozzle Dam Failure	Screened	The design of the McGuire Reactor Cavity Seals makes a catastrophic failure of the seals extremely unlikely. Such failures would be quickly isolated by procedure by closing valve KF122 (Fuel Transfer Tube Isolation Valve). In addition, a catastrophic failure would result in a loss of SFP inventory that could cause a zircaloy cladding fire and is not a boron dilution initiating event. The same conclusion applies to other failures of the reactor coolant system piping during refueling operation (including nozzle dams).
Loss of Cooling/Makeup	Screened	Loss of cooling/normal makeup is not considered a deboration event since the loss of inventory through evaporation and/or boil off does not remove boron from the pool.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Inadvertent Drainage/Loss of Inventory	Screened	Most loss of inventory events are expected to be small. Design features of the KF system (e.g., siphon breaks) purposely limit the amount of water that could be removed from the pool due to KF system pipe breaks, system malfunctions, or operator errors. A boron dilution event could occur if unborated water is used to refill the pool. However, these events are not generally expected to remove enough water to deborate the pool significantly. Plant procedures will address the addition of boron to the pool in response to a significant loss of inventory which requires emergency makeup water.
Fires (at or near the pool)	Screened	Typically, combustible loadings around the pool area are relatively small. If the fire hose stations were used to extinguish a fire, the volume of water required to extinguish a local fire is not expected to be of sufficient magnitude to cause a significant change in pool boron concentration.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
External Floods	Screened	This type of event is not credible for McGuire Nuclear Station. FSAR analysis of potential external flood sources showed that the station embankment will protect the plant from worst case flooding scenarios. In addition, the elevation of the top of the pool is an additional 18 feet above grade.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Storms Causing Runoff into the Spent Fuel Pool	Screened	The location of the spent fuel pool is high enough to preclude storm water from entering the pool due to flooding of the site. However, the roof drains for the Spent Fuel Pool Building are located directly above the pool. This piping is Class B (QA-1) seismically designed, although the portion of this piping over the railroad bay is not tornado wind or missile protected. However, wind or missile damage to this piping is considered very unlikely in a tornado strike event on the plant site and is not considered further. The McGuire UFSAR does not postulate piping breaks in lines fed by gravity such as this line. Also, with a probable maximum precipitation (PMP) event (30" rain in 6 hours), the 8825 sq. ft area on the roof would only generate 165,000 gallons. Even with a significant crack in the piping, most of the water flow would go down the drain (path of least resistance). Thus even a PMP event could not produce a dilution event greater than other postulated events. This event is screened.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Pipe Breaks caused by seismic events, or tornadoes	Evaluate	Some piping in the SFP area (RF, YM, YD, etc.) is not seismically qualified and is not specifically protected from tornadoes. Realistically the probabilities of these failure events is lower than from random pipe breaks. In particular, the probability of tornado wind or missile damage is judged to be extremely low and do not need to be considered further. Since non-seismically qualified piping has been identified in the SFP area, this type of piping damage will be evaluated in Section 5.1.
Random Pipe Breaks	Evaluate	Piping in the vicinity of the pool will be evaluated for dilution accidents.
Other Damage caused by Airplane Crashes	Screened	The likelihood of an aircraft crash on either of the McGuire Spent Fuel Pools is extremely remote and is dismissed as a credible boron dilution initiating event
Tank Ruptures near the SFP	Screened	Review of plant drawings and a plant walkdown determined that no tanks in or around the plant could flow into the SFP if the tank ruptured.
Dilution Events Initiated in the Reactor Coolant System	Screened	No credible pathways could be identified for this type of event.
Misalignment of Systems Interfacing with KF system	Evaluate	There are several interfacing systems that will be evaluated.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Loss of Off-site Power	Evaluate	The impact of loss of ac power events will be reviewed and evaluated including possible SSF scenarios.
Loss of Boron Due To Demineralizers or other Purification Equipment	Evaluate	The potential impact of the purification system will be evaluated.
Infrequent SFP Configurations	Evaluate	Potential alternative configurations will be evaluated.

Table Two
SFP Boron Concentration (ppm)

Initial Pool Boron Conc. =	C_o	2475	ppm
Initial Pool Level =	L_o	771.396	feet
Initial Spent Fuel Pool Volume =	V_o	322,450	gallons
Volume to fill SFP to Top of Transfer Canal =	V_c	23,995	gallons
Volume to fill SFP from Canal Wall to Overflow =	V_T	68,029	gallons

			Flow Rate Into SFP (gpm)							
			50	100	200	300	500	700	1000	1500
Fill To Top of Canal Wall	T_c (hrs)		8.0	4.0	2.0	1.3	0.8	0.6	0.4	0.3
(Stage 1)	Concentration		2304	2304	2304	2304	2304	2304	2304	2304
Fill To Pool Overflow Level	T_T (hrs)		30.7	15.3	7.7	5.1	3.1	2.2	1.5	1.0
(Stage 2)	Concentration		1925	1925	1925	1925	1925	1925	1925	1925
High Level Alarm (Elev. 772'+7")	Detection Time (hrs)		4.51	2.26	1.13	0.75	0.45	0.32	0.23	0.15
		Time (hrs)	50	100	200	300	500	700	1000	1500
Pool Overflow (Stage 3)	Concentration (ppm) versus Time and Flowrate	1	2452	2430	2386	2344	2264	2190	2087	1935
		2	2430	2386	2304	2226	2087	1963	1800	1557
		4	2386	2304	2154	2023	1800	1603	1347	1009
		6	2344	2226	2023	1853	1557	1309	1009	653
		8	2304	2154	1907	1699	1347	1069	755	423
		10	2264	2087	1800	1557	1166	873	565	274
		11	2245	2054	1748	1491	1084	789	489	221
		12	2226	2023	1699	1428	1009	713	423	178
		16	2154	1907	1513	1200	755	475	237	74
		24	2023	1699	1200	848	423	211	74	13
		36	1853	1428	848	503	178	63	13	1
		48	1699	1200	599	299	74	19	2	0
		56	1603	1069	475	211	42	8	1	0
		64	1513	952	377	149	23	4	0	0
		72	1428	848	299	105	13	2	0	0

Table 3 - RF Line Break With Cask Loading Pit Isolated

Time (hrs)	Base Case Concentration (ppm)	Alternate Configuration Case Conc.	Difference
1	2190	2148	-42
2	1963	1897	-66
4	1603	1500	-103
6	1309	1186	-123
8	1069	937	-132
10	873	741	-132
11	789	659	-130
12	713	586	-127
16	475	366	-109
24	211	143	-68
36	63	35	-28
48	19	9	-10
56	8	3	5
64	4	1	-3
72	2	1	-1

Figure 1 - McGuire Spent Fuel Pool Elevations