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MEMO TO: R. P. Denise, A/D for Site Technology, DSE
W. Kreger, A/D for SA, DSE

FROM: L. G. Hulman, Chief, Hydrology-Meteorology Branch, DSE

SUBJECT: THREE MILE ISLAND, UNIT 2, LESSONS LEARNED IN METEOROLOGY AND HYDROLOGY, DOCKET NO. 50-320

Per your request, enclosed are summaries of the involvement of the Meteorology and Hydrologic Engineering Sections in the TMI-2 incident.

Original Signed by
L. G. Hulman

L. G. Hulman, Chief
Hydrology-Meteorology Branch
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Enclosures:
1. Meteorology Section Summary
2. Hydrologic Engineering Section Summary

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HYDROLOGIC ENGINEERING SECTION
EVALUATION OF
THREE MILE ISLAND INCIDENT RESPONSE

I. INTRODUCTION

On March 28, 1979, an accident at Three Mile Island Nuclear Station, Unit 2 (TMI-2), initiated many actions and reactions by the Hydrologic Engineering Section staff which have continued through the preparation of this report. The purpose of this report is to provide a synopsis of those actions and reactions, to present conclusions the staff has reached with respect to their actions, and to present a proposed contingency plan based on the needs identified during the event.

Section II of this report contains a synopsis of the events and actions which involved the Hydrologic Engineering Section personnel. Conclusions reached during these events are noted. A summary conclusion completes the Section.

Section III presents a suggested contingency plan which would result in a quality response and support by the Hydrologic Engineering Section in the event of a plant accident having hydrologic implications.

Appendix A is a groundwater study of TMI-2 which was initiated by the HES staff. The study presents data, information and contingency procedures which the staff developed to mitigate the effects of a melt-through, should that have occurred.

II SYNOPSIS OF EVENTS FOLLOWING THE THREE MILE ISLAND ACCIDENT

- March 28 - 8:45 a.m. on: The Hydrologic Engineering Section Leader (W. S. Bivins), acting for the Hydrology-Meteorology Branch Chief (L. G. Hulman), was notified that a member of the Meteorology Section (J. E. Fairobent) had been requested to support an Incident Response Center "exercise". The staff was unaware that the exercise had more serious implications until later in the day. The Meteorology Section responded to the Incident Response Center (IRC) on an as-needed basis through March 30, 1979, when the Section began providing around-the-clock support at the Center.

- April 1, 1979 - L. G. Hulman and W. S. Bivins met to discuss the incident. After coordination with G. Knighton in the IRC, they decided that a contingency plan of action to cope with a melt-down should be prepared. Isolation and dewatering were selected as the most feasible methods. (Previous work on the Liquid Pathway Generic Study including information, data and models, was beneficial and contributed to the prompt decision on this issue.)

  The Corps of Engineers (COE) was contacted via the Pentagon duty officer to explore whether COE had the resources to support an emergency-basis construction effort. The effort was conceived as the construction of a slurry wall to isolate the groundwater beneath TMI from the Susquehanna River followed by a dewatering program. Contact was made with the Baltimore District Engineer of the Corps with respect to (1) the practicability of providing construction equipment at TMI on short notice to install wells, pumps and a slurry wall; (2) the time required to begin site activities; (3) the time required to complete the construction; and (4) administrative requirements necessary to allow the Corps to proceed. The responses to each item were (1) practicable, (2) the first equipment could be onsite within 48 hours, (3) wells could be completed within about two weeks and the slurry wall within 30 to 60 days depending on construction difficulties encountered onsite, and (4) a responsible verbal request was adequate for initiation. A subsequent conversation on about April 2 was held with Mr. E. Dodson in the Chief's office of the Corps to confirm the Corps capability.

  The investigation of the mitigation program was hampered by the lack of site maps (topographic and stratigraphic). The only available SAP could not be removed from the Docket Room and considerable reproduction was required. Preliminary estimates of groundwater movement were prepared by W. Bivins.

- April 2, 1979 - Mr. T. Nicholson's services were requested from OSD. His experience working in DSE on the Bailly NPP dewatering program was valuable. Between April 3 and about April 6, a groundwater study for TMI was developed. Additionally, a plan to isolate the groundwater beneath the Island was completed. The results are presented in Appendix A.

Downstream surface water users were identified by W. Bivins and T. Johnson. Dispersion models were modified for application to the site specific conditions. Maps and displays showing downstream water users were prepared and transmitted to the IRC.

The study was hampered by the lack, or unavailability, of adequate mapping and other site specific hydrologic data. This deficiency is addressed in Section III of this report and is the basis for recommending creation of plant file packages.

- April 3, 1979 - W. Bivins contacted the River Forecast Center, Harrisburg, Pennsylvania. Mr. Dave Zanzalari provided both current river flows and projected river flows based on the quantitative precipitation forecast, and suggested adjustment factors for locations downstream of TMI. Contact with the Center continued twice a day through April 6, 1979.

- April 4, 1979 - IRC requested W. Bivins obtain a summary dose model which could use variable river flows and provide estimated impacts on a real-time basis. The model was developed by S. Archarya, J. Osloond, H. Krug, and W. Pasciak. The model was sent to IRC by 4:00 p.m. on April 4, 1979.

- April 4, 1979 - The IRC support group requested recommendations for a "tank farm" for TMI. The purpose was to store contaminated water from the facility. M. Fliegel, T. Johnson and W. Bivins provided recommendations on about April 6, 1979.

MANAGEMENT RECOMMENDATIONS

The level of confusion during the incident and limited prior incident response planning significantly impacted the timeliness of both responses to requests for input and staff initiatives. Since timeliness is a primary requisite for effective incident response, the following management recommendations are made to improve the future incident response capability of the staff:

- Intra-agency communication must be improved, concentrating on keeping the entire agency abreast of plant incidents. In addition, contact with the IRC was, on occasion, difficult.
- Plant specific data should be retained by organizations needing the data.
- Interagency contacts should be developed and maintained.
- A plan of action should be prepared to assure prompt response by the staff.

APPENDIX A

III. CONTINGENCY PLANS FOR PLANT ACCIDENTS HAVING HYDROLOGIC IMPLICATIONS

The following outlines recommendations for contingency plans for nuclear plant accidents having hydrologic implications. These recommendations are in response to R. P. Denise's memorandum of April 13, 1979, to L. G. Hulman dealing with the subject, "Lessons Learned From Three Mile Island." The bases for the organizational recommendations are both the experience of the TMI response, and staff experience in other Federal agencies for coping with severe floods. The following items generally define informational needs which are not now readily available. Further, the recommended Section plant files do not exist or are incomplete. Creation of these files will be made a part of the review's responsibility for plants undergoing CP or OL review. Operating plant files will be considered for creation on a time available basis. Although this report could apply to all nuclear plants and different types of incidents, it was generated as a result of the accident at Three Mile Island Nuclear Station Unit 2 on March 28, 1979.

Basic Hydrologic Information Needed

During a plant accident certain basic hydrologic information would be needed. The following information should be included in a plant file maintained within the Section for read reference:

1. Water levels for nearby surface and ground water bodies (FSAR 2.4.1.2 and 2.4.13.1);
2. Streamflow information including stage-discharge and flow-frequency curves (FSAR 2.4.1.2);
3. Stratigraphic cross-sections (FSAR 2.5.1.2);
4. Well locations and historic ground water level information (FSAR 2.4.13.2);
5. Hydraulic characteristics of the hydrostratigraphic units (FSAR 2.4.13.2 and 2.5.4.2); and
6. Dispersion and dilution factors for nearby water bodies between the potential contaminant source and users (FSAR Sections 2.4.13 and 2.4.13.3).

Description of Water Users

A description of the nearby water users should also be included in the Section plant files and should include:

1. Location;
2. Water body source; and
3. Water use (ER 2.3.2 Water Use (FSAR 2.4.1.2 and 2.4.13.2).

Identification of Hydrologic Monitoring System

The location, instrumentation, period of record, history, and nature of the monitoring systems in the plant vicinity also should be specified in the section plant files (FSAR 2.4.13.4 ER, 6.3).

Directory of Federal, State and Local Sources of Information

For each section plant file, a telephone list of potential sources of information with numbers (and to the extent possible of the names of people to contact) in the event of an emergency should be kept. The list should include:

1. NOAA River Forecasting Center;
2. U. S. Geological Survey District and Subdistrict offices;
3. EPA regional office; and
4. State environmental department.

Directory of Federal, State, and Local Sources for Remedial Action

In the event of an emergency situation, remedial action may be needed. A list of Federal, State and local agencies including telephone numbers and contact names should be included in the section files and should include:

1. Army Corps of Engineers District and Chief of Engineers office;
2. State environmental departments; and
3. County emergency officials.

Periodic Update of the Section Plant Files

At least once every two years the assigned reviewer should update the plant file with any readily available information. Specifically, this period would provide for reestablishing personal contact with agency representatives noted above.

Implementation Procedures

Following the notification to HES personnel of an emergency situation by the Incident Response Action Coordination Team (IRACT), the following procedures should be implemented:

1. Identify HES response individuals;
2. Locate the individual contingency file for the subject nuclear power plant;
3. Coordinate with Division of Operating Reactors (DOR), Radiological Assessment Branch (RAB), and IRC;
4. Contact cognizant individuals using the "Directory of Federal, State, and Local Sources of Information" for further data if needed;
5. Calculate the transport and diffusion concentrations using HES in-house dilution and dispersion models;
6. Notify IRC, DOR, and RAB of model calculations;
7. Initiate a remedial action plan using the "Directory of Federal, State, and Local Sources for Remedial Action" if necessary; and
8. Submit the remedial action plan to DOR, RAB, and IRC.

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THREE MILE ISLAND NUCLEAR STATION

UNIT 2

GROUNDWATER STUDY

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THREE MILE ISLAND NUCLEAR STATION UNIT 2

I. BACKGROUND

On March 28, 1979 an accident at Three Mile Island Nuclear Station near Middletown, Pennsylvania caused the staff to initiate a study of the groundwater regime in the area of Three Mile Island Nuclear Station. The purpose of this report is to summarize and document the results of that study.

II. OBJECTIVES

The objectives of the study were to (1) characterize the groundwater regime, (2) study the feasibility of isolating and dewatering the groundwater regime at the reactor site, and (3) determine the potential for groundwater contamination offsite.

III. SITE CHARACTERISTICS

A. <u>Stratigraphy</u>

As illustrated in Figure 2.5-3 of the Final Safety Analysis Report (FSAR, see bibliography) for Three Mile Island (TMI) Nuclear Station, the island is underlain by:

(1) Medium dense sandy silt with some gravel grading laterally to loose to medium dense sand and gravel directly under the reactor building (elevation 300 ft plus to 282 ft msl (mean sea level) with considerable bottom variations).

(2) Medium-dense to very-dense silty sand and gravel (elevation 282 ft to 277 ft msl with considerable upper variations).

(3) Medium hard to hard red siltstone known as the Gettysburg Formation of the Newark Group of Triassic Age (bedrock elevation 277 ft msl with relatively uniform surface).

The interface between the Gettysburg Formation and overlying unconsolidated materials is 1 to 3 feet of weathered rock.

Regionally, the bedrock strikes N 65°-80°E and dips 35° to 70° to the northwest. (FSAR Section 2.5.1.2.2 p. 2.5-3) Drill cores indicated a more consistent dip of 37-1/2° and 45° at TMI. (FSAR Section 2.5.1.2.2 p. 2.5-3) Previous investigations also discovered well developed, nearly vertical jointing along a N10E trend with some joints healed and others altered by oxidation. (FSAR Section 2.5.1.2.2 p. 2.5-4)

One mile upstream, and 0.2 mile downstream are two easterly trending diabase intrusions that cut across the Gettysburg Formation. (See FSAR Figure 2.5-1)

The bedrock surface although generally uniform at elevation 277 ft msl does exhibit low swails at the southwest corner of the turbine building for Unit 2, and along the north wall of the diesel engine building for Unit 1. (See Figure 2.5-2)

B. Hydraulic Characteristics

1. Unconsolidated Materials

Previous site investigations using a pumping test indicated the hydraulic conductivity of the saturated soil zone on the eastern side of the island to be on the order of 10^{-2} cm/sec. A falling head test for similar material in the center of the island indicated a hydraulic conductivity of 10^{-3} cm/sec (FSAR Section 2.4.13.2). The specific yield of the materials was not stated; however, values would probably range between 0.10-0.20, being highly dependent upon the silt content.

2. Bedrock

The Gettysburg Formation has highly directional transmissivities. Reported values range from 1,200 gpd per ft to slightly less than 50,000 gpd per ft. (FSAR Section 2.4.13.2). The storage values are quite low since it is the jointing that contributes to the storage. A value of between 10^{-4} to 10^{-5} would be a reasonable estimate of the storage coefficient. The vertical to horizontal hydraulc conductivity ratio was reported to be 1 to 100 (Wood, 1979).*

The anisotropic properties coincide with the regional bedrock strike of N 65°-80°E. Wells in the Gettysburg Formations have variable yields between 0 to 300 gpm, depending upon the spacing and degree of jointing, and the presence of sandstone facies.

The diabase ridges to the north and south are relatively impermeable and are expected to have appropriately small hydraulic conductivity ($<10^{-7}$ cm/sec) and specific yield (<0.01).

C. Water Table Observations

The site has a water table at approximately 280 ft msl elevation and is dependant upon the Susquehanna River stage (a normal value is 277 ft msl). Site borings indicate the water table varies about 5 feet from a high at the island's center to the island shores. The water table gradient is approximately 0.006 toward the river (FSAR Section 2.4.13.2). At the 20 observation points, the water depth ranged from 14 to 19 ft below surface datum with corresponding saturated heads of 6.2 to 1 ft above the bedrock contact (FSAR Section 2.4.13.2)

*References are listed in the Appendix.

The nearest potable water supplies are three wells located on the east bank of the Susquehanna directly across from TMI (Wood, 1979). The reported elevations of groundwater in these wells in 1971 were from north to south:

1. 295 ft msl with a surface measuring point (M.P.) of 315 ft. msl for Well DA-511 located 1300 ft from the bank.

2. 284 ft msl and surface M.P. of 340 ft msl, for Well DA-510 located 120 ft. from the bank.

3. 300 ft msl and surface M.P. 3.5 ft msl for Well DA-523 located 200 ft from the bank.

D. Interrelationship of Groundwater to Surface Water Regimes

The Susquehanna River is a groundwater sink with a large portion of its discharge as base flow.

The nearest heavily pumped wells are in Middletown north of the diabase ridge boundary and, therefore, are hydraulicly separated from the influence of the plant. Further, nearby wells are not affected by site conditions because the hydraulic gradients slope to the river, and the diabase ridges act as no flow boundaries. The water table at TMI drains to the river. Although it can be affected by high river stages which reverse the gradient and create bank storage, this was not the case during the period of this investigation.

The Gettysburg Formation has basic artesian characteristics in the site area since the flow is along bedding planes and joints. Groundwater flow is highly anisotropic along the strike direction with specific capacities ranging from 0.33 to 15.0 gpm per foot of drawdown. The leakage of groundwater from the Gettysburg Formation would be anticipated to be upwar[illegible] but would vary considerably with the degree of jointing and relationship to strike direction. Therefore, effluents released in the plant should not migrate into the Gettysburg Formation.

III. PHYSICAL PLANT

A. Unit 2 Reactor

The Unit 2 reactor is located on the northern third of TMI. The elevation of the reactor building floor is 280.5 ft msl on a concrete mat directly over the Gettysburg Formation. The reactor vessel floor is at elevation 291.5 ft msl. For reference, the water table is at elevation 280 feet msl.

B. Onsite Drainage

Storm drainage is provided within the diked area. Drainage culverts drain to the southeast where a storm drainage and flood control area is located. A system of pumps and an outfall pipe carries the drainage out into the east channel of the Susquehanna River.

C. Flood Protection Embankments

A system of embankments was constructed around the northern third of TMI for flood protection against floods as severe as the Probable Maximum Flood (PMF). The dike elevation is 305 ft msl on the western shore, 304 ft msl along the southern border, and 310 ft msl on the northern point decreasing in height to 305 ft msl at the southeastern corner.

V. DEWATERING TECHNIQUES

A. Slurry Wall Containment

As a means for isolating contaminated surface and groundwater in the site area, the feasibility of constructing an impermeable barrier was studied. A slurry wall was thought to be the most efficient method of isolation. Different construction materials are discussed below:

1. Cement Bentonite (CB)

Based upon previous experience with the Bailly Generating Station, Nuclear 1, a cement bentonite slurry wall was investigated. Cement bentonite is used where slope support is needed for dewatering excavation sites (Siefkin, 1979). The cement bentonite requires 24 hours to cure. The bentonite can either be installed into 2-3 foot wide trenches up to 55 feet deep directly, or pumped by use of adapters to driven piles for depths of than 55 feet or greater. A clam shell dragline may be utilized for depths 30 feet or more. If only conventional backhoes are available, special backhoe adapters are available from ECI for depths 30-55 feet and widths of 2-3 feet (Shallard, 1979).

Cement bentonite construction is a much slower and expensive process than for soil bentonite, but provides added strength. With age, the cement bentonite may crack (Shallard, 1979).

2. Soil Bentonite (SB)

Soil bentonite is more flexible and less expensive since the trenching spoil is used in the backfilling. SB is quicker to install, but must be installed in a continuous fashion by a single backhoe and cementer unless the trench is keyed into a cement bentonite wall or impermeable feature (Shallard, 1979).

The native material can be used in the backfilling operation if it is sand and gravel, preferably a poorly graded mixture. No curing time is required for the SB and dewatering can begin immediately after construction, whereas CB requires 24 hours for curing prior to dewatering (Shallard, 1979).

Previous experience has shown that both CB and SB can be installed and be effective up to 110 feet in depth. With both SB and CB the ability to preclude groundwater flow is based on the ability to key the wall into a no flow boundary. Minimum permeabilities for CB is approximately 10^{-6} cm/sec. For SB the minimum permeabilities is 10^{-6} cm/sec for clean sands and gravel, and 10^{-8} cm/sec for reasonably well graded material such that 30% will pass a #200 sieve size (Shallard, 1979). At TMI the material ranged from a sandy silt with gravel to a silty sand with gravel.

Principal suppliers for bentonite, mined generally in South Dakota and Wyoming, are Baroid of Houston, Texas, and American Colloid of Chicago, Illinois. The speed of construction is highly dependent upon site conditions and the availability of equipment, bentonite, and experienced workers. Based upon previous experience (Davis Besse Nuclear Plant near Oak Harbor, Ohio and James H. Campbell Coal Fired Plant near West Olive, Michigan), optimal conditions could allow 250 feet of SB construction per day per unit backhoe (Shallard, 1979).

For the TMI site the fastest method for construction of the estimated 9200 foot slurry wall with numerous backhoes would be as follows:

a. Lay out a survey line for the slurry wall construction taking into consideration plant and site conditions.

b. On the first day construct numerous isolated 40 foot cement bentonite trenches spaced equally apart along the inside border of the flood protection dikes. Key into the Gettysburg Formation at or about 30-35 foot depth.

c. Construct numerous interfacing soil bentonite trenches between the CB trenches using the spoil as backfill such that the slurry wall ultimate encloses the site. Key the SB trenches to both the CB trenches and the Gettysburg Formation.

B. <u>Dewatering System</u>

The first remedial action in the event of a class 9 type accident would be to initiate installation of a dewatering system in the vicinity of the reactor building. The purpose of this action is to provide additional construction time for the slurry wall and to begin isolating potentially contaminated groundwater from the balance of the hydrosphere.

1. Well Points

   A series of uniformly spaced well points along the eastern, western, and southern sections of the slurry wall to bedrock would sufficiently dewater the site. Based on preliminary investigations of the bedrock depressions, the optimal location for dewatering would be the areas between the turbine building for Unit 2 and the circulating pump house, and between the parking area and diesel engine building for Unit 1. The method of installation would be as outlined in basic texts (see Mansar, 1962), or by using a fire truck pumping unit and jetting pipe with improvised steel wire mesh screen.

2. Gravity Drains with Pumps

   Owing to the shallow (19 to 14 foot depth) and relatively thin (6.2 to 1 foot) saturated zone above the bedrock, a series of trenches with slotted PVC or terra cotta pipe with gravel backfill draining to a sump pump would also effectively drain the subject area. The areas noted in the "well points" discussion would be the optimal locations.

3. Deep Wells

   In the event of a core melt-through the possibility of contamination to the deep aquifer should be considered. Due to hydraulic gradients and net upward leakage, the possibility of contamination of the deep aquifer beyond the limits of the island is highly unlikely. However, to preclude such a contingency, a series of deep wells located around the reactor into the bedrock to the south and west would effectively dewater any potential contaminants. Unless these actions were completed prior to meltdown, special precautions and construction techniques would be needed to safeguard the drilling crews. Additional discussion of precautionary measures is beyond the scope of this report.

C. Surface Storage and Treatment

The groundwater discharge would be stored and tested prior to treatment and eventual removal or, if uncontaminated, discharge into the Susquehanna River. The two cooling tower ponds could act as initial storage tanks with a series of secondary holding tanks for treatment or discharge. The choice of secondary holding tanks would be dependent upon plant operations. However, the cooling tower desilting basin and Unit 1 and 2 service water post cooling towers would be possibilities.

D. Contribution of Water Table and Confined Aquifer Flow

The area to be dewatered would be approximately 4,500,000 square feet with a volume of 135,000,000 cubic feet if totally saturated. The water table has a maximum head of about 6.2 feet and a low point of 1 foot. If the assumed specific yield of the saturated soil is

0.15 and, for conservative analysis, a maximum head of 6.2 feet is used, 4,185,000 cubic feet of water would be handled. The Gettysburg Formation will act as a leaky barrier in the direction of strike and in areas of intense jointing. The recharge through the slurry wall would be negligible (<0.003 cfs). The leakage from the Gettysburg Formation would be anticipated to be small but is not definable without further site investigations.

VI. MONITORING

A. Present System

At present there are no wells on TMI and no groundwater is being used for plant operations (FSAR section 2.4.13.1). The site investigation borings were sealed following the construction phase. The Final Environmental Statement, in section 2.4.13.4 states:

> "Radioactive liquid waste from Unit 2 can only be discharged to the Susquehanna River; no liquid waste is discharged directly to any groundwater supplies. Since the Susquehanna River is then the only source of radioactive liquids and since the hydraulic gradient on the island and on the shore slopes to the river, radioactivity from the river does not contaminate groundwater supplies and therefore there is no need for monitoring or safeguards."

B. Proposed System During Plant Emergency

A proposed monitoring system of wells would only be necessary following a core meltdown or potential releases from decontamination procedures. These wells would monitor both the unconsolidated materials and the bedrock in an area to the south and west of the reactor building. At present a gravel pack well or trench drain well would be sufficient to monitor any possible contamination. The monitoring could be accomplished in a rapid fashion, or on a more permanent basis if contaminated effluent is to be stored in surface tanks for an extended period of time. The monitoring well or trench should be located adjacent to and down gradient of the holding tanks and reactor building.

In the event of a core meltdown, a series of intermediate and deep monitoring wells located around the island would be advantageous. Again the emplacement and monitoring of these wells in the Gettysburg Formation should conform to safe operational procedures for the drilling crews and supervisory personnel.

Appendix

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METEOROLOGY SECTION EVALUATION
OF PARTICIPATION IN INCIDENT
RESPONSE FOR THREE MILE ISLAND

Meteorological assistance in incident response can provide assessments of atmospheric transport and diffusion of past, present and potential releases of radioactivity. To make such assessments meaningful, they must be made in a very timely manner and should be reasonably accurate. Furthermore, assessments of atmospheric transport and diffusion conditions made by various groups using different sources of meteorological data and models could produce contrary or confusing information to decisionmakers. During our involvement in the TMI accident response, we quickly learned that use of meteorological information within the NRC was not coordinated, some data were not available in a timely fashion, and several NRC offices often acted independently. As a result, there was no guarantee that the decisionmakers within the Commission were receiving the best meteorological information available. We believe that several of our recommendations will relieve this coordination problem.

Before the TMI accident, we had outlined procedures we would take during an accident response. During this response we learned how we could reinforce and streamline these procedures. Thus, our other recommendations are intended to achieve this goal.

Following our recommendations is a thorough summary of our participating observations and assessment of the actions taken.

RECOMMENDATIONS

1. All meteorological information needed by the NRC should be coordinated and disseminated through one focal point, staffed by NRC meteorologists. Information coordinated through this focal point should include real-time and forecast information from the National Weather Service, real-time onsite meteorological data, and meteorological information required or developed by support units, such as LLL or PAS.

   DISCUSSION

   One focal point will assure that all parties who need meteorological information (such as the IRC, DOR, IE) will have the best available information; and with a meteorologist as the focal point, the data will be interpreted correctly. If the NRC contact meteorologist obtains all the data sent to the NRC, he can guarantee that the most suitable information is used. If each working group within the NRC continues to use a different source for its meteorological data, no group could assure that it is using the most appropriate information to solve its problem.

2. One focal point (preferably a professional meteorologist) should collect, analyze, and exchange all meteorological information among the participating and interested Federal and State agencies.

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DISCUSSION

Just as the NRC needs a focal point for meteorological information, one focal point should gather and assess the available data for all Federal and State agencies. This assures that the proper information is sent to those who need to make decisions, such as evacuation planners. Since Federal and/or State agencies will handle any needed evacuations, they need proper interpretation of the complete weather picture and its effects on plume trajectory and diffusion. In a critical situation, they should have to consult only one well-informed contact.

3. Real-time information collected at the onsite meteorological tower should be available by remote access. This remote access can be made using a mini-computer installed at the site, a communications link, and access to a portable computer terminal.

DISCUSSION

Meteorological conditions are an integral part in estimating offsite doses. Thus, timely reception of the onsite tower data is of paramount importance. Meteorological data are monitored in most reactor control rooms. In only rare cases will offsite data be available (such as from a nearby National Weather Service (NWS) station) that are representative of site conditions.

During a crisis, control room personnel should not assume the added burden of constantly updating the NRC on these data. By remote access, the contact meteorologist will always have the current site conditions. The NRC support team can update dose estimates as often as needed, and NWS forecasters can use the data in meso-scale weather analyses.

4. NRC meteorologists at the IRC should have direct access to both the National Facsimile Network (NAFAX) to obtain a comprehensive set of charts depicting analyses, prognoses, and selected observed data, and to the Service C Teletypewriter System of the National Weather Service which distributes basic surface and upper air data. Both of these important sources of information could be linked to the IRC and used on an "as needed" basis.

DISCUSSION

In monitoring an accidental release, one must know where the plume will travel. Evacuation planners need this information to judge which localities may need evacuating and by what routes. Health physicists need this in ormation to most efficiently use their offsite monitoring equipment.

Synpotic- and meso-scale weather features are prime influences on the site area and long-range path of a plume. The NRC meteorologist discusses the predicted airflow patterns with the NWS Weather Service Forecast Office chief forecast meteorologist. However, the NWS forecaster must verbally describe the weather features affecting the site region. With the NAFAX equipment the NRC meteorologist can quickly view the entire weather pattern and would need to only discuss with the NWS forecaster the expected developments, rather than the description of conditions. Using the hourly updates of the Serv ce C he can monitor meso-scale developments, which are prime movers of the plume within the site area. Thus, these data sources will give the NRC a near real-time display of the airflow affecting regional trave of the plume, and allow more accurate predictions of transport and diffusi n to be made.

5. Portable meteorological instrumentat on (either at the site or with the NRC incident response team) should be available for use if the onsite meteorological program is out of service during an accident or to supplement the existing program.

DISCUSSION

As noted in (3), onsite data are of paramount importance for evacuation planning and dosimeter placement. Without these data, or very mobile, continuous monitoring, one will not be able to define plume travel. Portable towers would ensure that data would be available to estimate and confirm doses.

At sites in rugged terrain or near large bodies of water, the airflow direction changes within a few miles of the site, and data from one tower may not represent the airflow offsite. Portable instrumentation placed at predetermined locations where plume trajectories may be difficult to predict will ensure better evacuation planning and dosimeter placement.

6. Availability of upper air sounding units (pibal and radiosonde) for timely deployment following an accident should be discussed with the National Weather Service and the military.

DISCUSSION

As noted in (4), meso- and synoptic-scale weather features are prime movers of a plume. These weather systems are themselves moved by the airflow several thousand meters above the surface. Likewise, a plume from a large buoyant release (such as a core-melt) will travel by the upper-air winds. The onsite tower cannot measure this airflow aloft. Only some type of upper air soundings will provide these data.

The NWS samples upper-air conditions at a grid of stations across the country. However, these stations are spaced several hundred miles apart and observations are taken only twice daily. More soundings near the site would give the forecaster a better insight of features such as frontal locations, wind direction changes with height, upper level inversions which could affect plume dispersion. With this information better plume trajectory forecasts can be made to aid in evacuation planning.

7. The NRC should reexamine present practices relating to the use of meteorological information in formulating emergency plans and in implementing actual evacuations.

DISCUSSION

As we have noted in 1-6, meteorological information is extremely important to predict plume trajectories and to judge what areas to evacuate. The requisite of any evacuation plan is to guarantee that the person who must make a decision to evacuate has the best information available in a timely fashion. This includes meteorological information. To assure that evacuation planning is reasonable from a meteorological standpoint a meteorologist must review the current NRC procedures.

Examples of areas to review include:

- Assure that the effects that any unusual site or area features may have on plume travel and diffusion are considered.

- Assure that contacts are made with the plant's local NWS station to brief them on their role in emergencies.

- Assure that dose estimation procedures are consistent with the quality of the meteorological data used.

- Assure that meteorological data are recorded, exchanged, and analyzed in a reasonable manner.

8. The onsite meteorological programs at all operating plants should be reviewed for quality and representativeness of information and the availability of real-time information to control room operators.

DISCUSSION

Not all operating plants have meteorological monitoring programs that produce data with the quality needed to make reliable real-time dose estimates. This may be due to obsolete instrumentation or poor quality assurance programs. Many sites also have characteristics, such as rugged terrain, that make the tower data representative of only the immediate site vicinity. Data from these plants would, by themselves, be of questionable value to use in an emergency situation.

In an emergency situation, the contact meteorologist needs to know these limitations immediately and to consider them in any emergency response.

To ensure that quality and representative data are available in a timely manner from each operating plant for emergency planning usage, the meteorological monitoring program from each plant needs to be reviewed. Any limitations of the program or unusual site characteristics would be noted and would be available to the contact meteorologist.

SUMMARY AND ASSESSMENT OF ACTIONS

Role of the Meteorology Section

Shortly before 9 a.m. on March 28, 1979, the staff of the Meteorology Section, Hydrology-Meteorology Branch, was informed by G. Knighton that an "incident response exercise" was in progress, and that meteorological support would be required. Several hours later it was learned that it was a real incident, not an exercise. The staff of the Meteorology Section monitored real-time and forecast atmospheric dispersion conditions in the vicinity of the Three Mile Island site through about 10 p.m. on March 28, 1979. Intermittent monitoring of local meteorological conditions was performed throughout March 29, 1979, and continuous monitoring resumed about 10 a.m. on March 30, 1979. 24-hour coverage of meteorological conditions began at the Incident Response Center about 4 p.m. on March 30, 1979, and continued into April 7, 1979. Subsequently, meteorological conditions were monitored daily.

The initial role of the Meteorology Section in the incident response for Three Mile Island was to provide current short-term "accident" dispersion estimates to the NRR/DOR staff for assessments of immediate dose consequences following releases of radioactivity to the atmosphere. In addition to the monitoring of real-time atmospheric dispersion conditions, the Meteorology Section made daily forecasts of dispersion conditions to facilitate the evaluation of the consequences of planned or unanticipated releases. Expected significant changes in atmospheric dispersion conditions were particularly highlighted.

The Meteorology Section provided support to the NRR/DOR staff for radiological impact assessments and for estimating the amount of radioactivity released. Both instantaneous radiological monitoring, such as the samples taken by the ARMS unit, and the longer-term monitoring, such as TLD's, were reviewed for reasonableness and consistency based on an evaluation of atmospheric transport and diffusion conditions during the monitoring period. Relative concentration (X/Q) values were calculated for specified time periods corresponding to the radiological monitoring period. The amount of radioactivity released to the atmosphere was estimated from the results of radiological monitoring and the assessment of the atmospheric dispersion conditions.

The Meteorological Section also provided support to the Incident Response Center. This support included constant monitoring of current meteorological conditions in the site area, as well as providing general weather forecasts for the vicinity. Major weather patterns and expected developments were highlighted, along with expected changes in wind speed and direction and the likelihood of occurrence of precipitation. Particular attention was given to possible occurrences of severe weather conditions (e.g., thunderstorms, high winds, significant precipitation) which could have affected plant operations following the accident as well as possible evacuation plans.

Additional support was provided to IE in the review of the output of the Lawrence Livermore Laboratory Atmospheric Release Advisory Capability (ARAC) computer simulation of the radioactive plume, and in review of the daily preliminary notification statement. The Meteorology Section reviewed the output of the LLL/ARAC model for consistency and reasonableness of plume concentration and trajectory estimates based on an evaluation of the mesoscale airflow patterns and an assessment of general atmospheric dispersion conditions in the area. The staff also reviewed the daily IE preliminary notifications for "correctness" of meteorological information.

The Meteorology Section relayed information concerning plant status and the likelihood of large scale evacuations to the National Weather Service offices in Harrisburg and Philadelphia. The staff also discussed with the National Weather Services the type of information that the NWS could provide for immediate evacuation considerations and the additional information that could be available for an anticipated evacuation. Information to be provided for the short-lead time evacuation situation included a "best-estimate" for wind direction for the next few hours for several miles around the site. Information to be provided for a longer-lead time evacuation situation included meso-scale analyses and predictions that were more localized than the general area forecasts. With such localized analyses made by people familiar with the area, more reliable assessment of plume trajectory predictions would be available for evacuation considerations.

Sources of Meteorological Information

Meteorological information was provided by a variety of sources. The principal source of information was the National Weather Service. The Weather Service Office (WSO) in Harrisburg provided current meteorological conditions at locations throughout the area around Three Mile Island. Hourly observations of cloud cover, ceiling height, wind speed, wind direction, and precipitation were provided routinely for Middletown (Harrisburg International Airport), Capital City Airport (at Steelton), Lancaster, and Reading. Hourly observations of wind speed and wind direction at other locations in the area were provided as needed to clarify the local airflow pattern. The WSO in Harrisburg also provided radar information on the location and movement of areas of precipitation. National Weather Service personnel at Harrisburg also provided additional insight into local airflow characteristics in the Susquehanna River Valley.

The Weather Service Forecast Office (WSFO) in Philadelphia provided general weather forecasts concerning the movement of major weather systems and expected developments with these systems. In addition, the WSFO in Philadelphia also provided special forecasts of mixing heights and transport winds within the mixed layer. Once upper-air sounding units were in position at Middletown, radiosonde and pilot balloon information was relayed through the WFSO at Philadelphia.

The National Meteorological Center (NMC) of the National Weather Service provided trajectory analyses and daily weather maps and forecast conditions. The medium range predictions group of NMC provided 5-day forecasts of wind speed and direction at 1000-foot intervals above the surface. Additional long-range trajectory analyses and forecasts were provided by the Air Resources Laboratory of the National Oceanic and Atmospheric Administration.

The National Weather Service made special arrangements to position a pilot balloon unit at Middletown and to arrange for a military radiosonde unit to also locate at Middletown. The pilot balloon unit provided wind speed and wind direction information above the surface, and the radiosonde unit provided wind speed, wind direction, and temperature lapse rate information through the first ten thousand feet above the surface.

Professor John Cahir, of Pennsylvania State University, provided short-term weather forecasts for the Three Mile Island area. The extra insight into local conditions complemented the forecast information provided by the National Weather Service.

Lawrence Livermore Laboratory, under the auspices of the Department of Energy, provided computer-simulated plume configurations for releases from Three Mile Island through their ARAC program. These computer simulations of plume configurations were compared by the Meteorology Section with the airflow patterns and estimated dispersion conditions based on information provided by the National Weather Service.

Remote access to onsite meteorological information was not known to be available for almost a week after the accident. The meteorological consultant to the utility provided daily summaries of hour-by-hour observations of wind speed and wind direction from two levels of the onsite meteorological tower as well as hour-by-hour vertical temperature gradient measurements. The onsite meteorological information supplemented the observations provided by the National Weather Service.

Assessment of the Role of the Meteorology Section

The Meteorology Section was prepared initially to support the NRC "overseer" role, i.e., monitoring the accident situation and the response of the utility, and had established prearranged contacts with the National Weather Service. Coordination of meteorological information in the vicinity of the Three Mile Island site began immediately (9 a.m. March 28, 1979). Additional local upper-air information was initiated on the evening of March 31, 1979 with the arrival of an NWS PIBAL unit at Middletown.

The Meteorology Section was not included in the mobilization of an NRC response team at the site, and arrangements were not made for the response team to routinely receive current and forecast meteorological information. Such meteorological information was occasionally transmitted by the Meteorology Section to the NRC onsite "command post" with no acknowledgment.

Apparently, the only group at the site monitoring meteorological conditions were associated with LLL/ARAC and the role of these personnel in the incident response was confusing because of conflicting information. It appears that LLL was involved at the request of IE, although at various times throughout the incident it was suggested that LLL was involved either at the request of the utility or of DOE independently. There was no initial contact or coordination by the Meteorology Section staff with LLL personnel, although minimal coordination was discussed in a telephone conversation several days into the incident. LLL was essentially autonomous and apparently had a number-one priority on all meteorological information. LLL also apparently had independent contacts regarding meteorological information with IE and RES, as well as with the National Weather Service. Other independent contacts may also have been established. The output of the LLL computer simulation of plume configurations was apparently transmitted independently to representatives of the State of Pennsylvania at Harrisburg, IE Region 1, IE HQ, and DOE. The use of this computer code by officials of the State of Pennsylvania, the NRC, and probably other federal agencies (e.g., FDAA) for recommendations on evacuation and real-time radiological monitoring is still not known. The scale of the map used for the LLL simulations of plume configuration did not permit meaningful resolution of effluent concentrations at distances within about 5 miles of the site. The projected plume trajectories usually appeared reasonable based on evaluation of airflow patterns by the Meteorology Section staff. Predicted concentrations at distances on the order of 10 miles or more also appeared generally comparable to the concentrations predicted by the Meteorology Section staff.

Unlike the computer-intensive particle-in-cell atmospheric dispersion model used by LLL, the Meteorology Section staff used a more simple straight-line Gaussian plume model to estimate short-term atmospheric dispersion conditions. Calculations can be performed quickly by hand with this model, and the dispersion estimates are probably somewhat conservative at close-in distances (i.e., less than 2 km.). Information concerning building cross-sectional area and distances to the minimum exclusion area boundary and to the outer boundary of the low population zone were available from the Safety Evaluation Report. The model could also be easily modified to consider increased horizontal plume spread during low wind speed or unsteady wind direction conditions. Magnitudes of expected relative concentration (X/Q) values were generally not difficult to estimate; however, airflow trajectories during the prolonged periods of light and variable winds at Three Mile Island were much more difficult to predict. Long-range forecast airflow trajectories were provided by the Air Resources Laboratory/NOAA and through the National Meteorological Center/NWS. These long-range trajectories were based on forecasts of winds aloft and are not valid for local airflow trajectories for releases made at or near ground level.

Short-term estimates of dry deposition were made by multiplying relative concentration by an assumed representative deposition velocity. Short-term estimates of wet deposition were made assuming a conservative washout coefficient.

The mode of release (i.e., ground level or elevated, buoyant or nonbuoyant) was never characterized for the Meteorology Section staff. Generally, the staff conservatively assumed a ground-level release for estimates of the magnitudes of short-term X/Q values for dose consequence assessments. However, predictions of airflow trajectories can be greatly affected by height and buoyancy of the release. For example, during low-wind speed conditions there was likely decoupling of airflow within the river valley, i.e., ground level releases would tend to follow the river downstream while elevated releases would be more likely to follow the gradient airflow. Without characterization of the mode of release, identification of appropriate downwind sectors or projected airflow trajectories for evacuation considerations is much more difficult, particularly during low wind speed conditions. The staff included this information in the dispersion forecasts.

The mode of release (including duration) is also necessary for assessments of actual radiological impact, which requires assessments of airflow trajectories toward locations of monitors. The Meteorology Section has used the straight-line Gaussian model for time periods from 24 to 72 hours, with subjective modifications to consider the effects of light and variable winds. Estimating time-averaged X/Q values for back-calculating source terms based on TLD monitoring is more difficult than estimating short-term X/Q values. A conservative time-averaged X/Q value results in a lower estimate of the amount released; therefore, the emphasis was to make the most realistic estimates of X/Q for radiological impact assessments based on radiological monitoring. The available radiological monitoring information (TLD's) used for these radiological impact assessments was sparse immediately following the accident.

However, a much more dense TLD network was established several days later which permitted an improved assessment of radiological impacts. Preliminary estimates of the amount released based on the atmospheric dispersion model used by LLL appear to be in good agreement with the amount released based on the more simple atmospheric dispersion model used by the Meteorology Section staff.

Characterization of atmospheric dispersion conditions and airflow patterns requires real-time availability of meteorological data from numerous sources. Real-time offsite meteorological information in the vicinity of Three Mile Island was provided through the National Weather Service Office at Harrisburg. Contact with the Harrisburg office was made via telephone every hour during critical time periods, and every several hours during less critical time periods. There was occasional difficulty making telephone contact because the NWS telephone line was tied up by other inquiries. The hourly observations transmitted by the NWS, available through a national teletypewriter circuit, would have been easier to access directly by the Meteorology Section staff and would have allowed NWS personnel to perform other tasks. Because of the availability of meteorological data from the two nearby airports, access to real-time data at Three Mile Island was not essential for general assessments of local atmospheric dispersion characteristics; and, with all the confusion at the site, the Meteorology Section staff did not want to add to the burden on onsite personnel to obtain hourly meteorological conditions at the site. However, unknown to the Meteorology Section staff, the licensee had installed a microprocessing unit at Three Mile Island which permitted direct access to hourly meteorological data via telephone. Once this capability was identified, onsite meteorological information was received by the staff and used to supplement the other sources for a more complete characterization of atmospheric dispersion conditions in the vicinity of the site. At sites without nearby offsite sources of meteorological information, remote access to real-time conditions at the site would be necessary to provide an assessment of local atmospheric dispersion conditions.

Forecast meteorological conditions (including severe weather phenomena which could have affected plant operation or evacuation considerations) were provided by the National Weather Service Forecast office in Philadelphia, the National Meteorological Center, the Air Resources Laboratory, and Pennsylvania State University. These sources provided excellent forecast coverage.

With all of this meteorological information available, the Meteorology Section encountered considerable difficulty in disseminating pertinent information to appropriate groups within the NRC. This difficulty can be partially attributed to the lack of a "contact" within the IRC who was responsible for including meteorological conditions in decisions on plant operations and evacuation considerations. Another factor in this difficulty was that, in addition to the Meteorology Section, at least three other groups in the NRC were either generating or receiving meteorological information. IE was receiving the computer-simulated plume configurations from LLL. The Probabilistic Analysis Staff/RES was using the computer code CRAC (from WASH-1400) to provide guidance in the development of evacuation contingency plans. This computer code requires meteorological data as input, and the input was not coordinated with the Meteorology Section. PAS apparently had independent contact with LLL personnel concerning meteorological information. The Office of the Director, RES, was also receiving telecopies of weather maps directly from the National Weather Service, sometimes at the expense of information received by the Meteorology Section.

Because of the several varied (and possibly inconsistent) sources of meteorological information, the Meteorology Section was unsure what information was available to groups examining evacuation contingency plans, not only within the NRC but to other Federal agencies (e.g., FDAA) and the State of Pennsylvania. The Meteorology Section was prepared, after an evaluation of the available information (includng the LLL computer simulations) to provide an assessment of current and forecast low-level airflow trajectories out to a distance of about 5 miles, and transit times to expected effluent considerations at specified points of interest. Uncertainties in this assessment, particularly with respect to airflow trajectories, would have been identified.

Comparison of Accident Conditions and Licensing Assumptions

The meteorological conditions used in licensing involve a quasi-statistical analysis of onsite data, and as a result cannot be compared directly with the conditions that occurred during the TMI incident. However, a comparison of short period (1 hour to 4 days) X/Q values at both the Exclusion Area and Low Population Zone boundaries indicates periods of both worse and better transport and diffusion conditions during the incident thar were used in licensing evaluations. Most of these periods exhibited better diffusion conditions. For longer time periods X/Q values were generally less than were used in licensing. In addition, wind direction likelihood and persistence during the course of the incident was substantially different than would be indicated from consideration of average annual conditions. Finally, the dispersion conditions during the accident were among the types that are considered by the staff during licensing reviews.