7.0 TUNNEL INSTRUMENTATION AND DATA

7.1 INTRODUCTION

Nye County, in an effort to demonstrate the importance of the climatological monitoring in the exploratory test facility and its potential application to alternative repository design, has continued monitoring barometric pressure, temperature, humidity, and air flow velocity in various locations and schemes within the underground workings of the ESF. Nye County has also been analyzing the data collected periodically to evaluate the need for additional data and implications of the results on the performance and operation of the repository.

7.2 ATMOSPHERIC MONITORING

Nye County has installed instruments to measure temperature, pressure, humidity and air flow velocity within the ESF tunnel to understand and evaluate the interaction of the ventilation air in the tunnel and its potential impacts on the performance of the repository. An underground climatological monitoring station was installed in August 1995 behind the ESF tunnel boring machine (TBM) to measure the temperature, pressure, and relative humidity of the ventilation air. Figure 7-1 is a schematic drawing that shows the relative position of the instruments. This monitoring station moved with the tunnel boring machine frame. As the TBM broke through at the South Portal on May 20th, 1997 the instrumentation was disassembled and monitoring was discontinued. In November of 1997 another monitoring station was setup along the wall of the ESF tunnel approximately located at Station 35+63, near Niche 1. In addition to temperature, pressure and relative humidity, an anemometer was used to measure the air flow velocity in the tunnel. Also, soil moisture probes were installed at two locations in the rock along the wall of the tunnel at this location. Data was collected at this monitoring station for a period of a month and was then analyzed to determine how atmospheric conditions in the tunnel may be affected by

ventilation. Variations in the water content of the rock were also observed and this data was analyzed in relation to changes in atmospheric conditions in the tunnel. In December of 1997 construction commenced on the Enhanced Characterization of the Repository Block (ECRB) drift. This drift is in approximately an east-west direction and traverses across the ESF main loop at ESF sta. 31+00.

A climatological monitoring station was set up in the ECRB in May of 1998 at ECRB sta. 1+00 (Figure 7-2 and Photograph 7-1). This station was designed to be easily disassembled, so that it could be relocated at another position within the ECRB. As the TBM bores through the rock during the construction of the ECRB, Nye County plans to relocate the monitoring station approximately every 500 feet as the TBM progresses through the rock. Results of Nye County's monitoring in the ESF are presented in a series of graphs in the enclosed media (see ESFInstall.ppt and ESF_TBM.ppt).

Both temperature and relative humidity data show a period of almost chaotic perturbations followed by a smooth recovery. The perturbations coincide with the tunnel operating days (Monday through Friday). The smooth recoveries correspond to the weekends and holidays when the ventilation is not in operation. It is noticeable that the values of the temperature and relative humidity of Probe 2, which is in the center of the tunnel, are almost always smaller than the values of the other two probes.

7.3 EVALUATION OF THE USE OF WATER IN THE TUNNEL

As reported previously (Multimedia Environmental Technology, Inc., 1997), Nye County's Nuclear Waste Repository Project team visited the Exploratory Studies Facility (ESF) tunnel in 1996. One of the observations made by the team was related to the water usage in the tunnel. Nye County has observed on several

occasions standing water throughout the entire length of the tunnel boring machine (TBM) and its attachments. Also it was noted that water spraying with a high-pressure hose is routinely being used by the miners to wash the walkways and other seemingly unnecessary areas. In fact, in May of 1998 a DOE Stop Work Order was issued to the mining sub-contractor due to inadequate management of water usage and measurement/accountability for water use in the main tunnel and the ECRB. Nye County has developed a database (refer to the media attached, ecrb.xls and esf.xls) containing information on site construction activities which includes water usage data. This database is updated continuously and is based upon water usage logs and site activity reports provided to Nye County through YMP subcontractors. Furthermore, recent evaluation of the report on chlorine 36 (^{36}Cl) has revealed that the majority of the samples were contaminated with the J-13 water (tagged with lithium bromide) which is the main source of the ESF tunnel water. It is noteworthy that these samples have been taken at least 4 inches into the rock and from the walls of the tunnel, which are not subjected to standing water and are only sprayed for cleaning purposes. Also, Nye County has noted that, in some of the closely-space ^{36}Cl sampling locations in the South Ramp, ^{36}Cl was detected only in some of the samples. Considering the highly fractured nature of the rock, it is conceivable that the traces of ^{36}Cl have been washed away by washing the walls for geologic mapping purposes. Nye County has also learned that the lithium bromide has been detected up to several tens of feet in some of the boreholes drilled by DOE for the purpose of investigating the extent of the construction water invasion. Most of these boreholes show at least a few feet of invasion of the construction water.

Nye County has recently performed preliminary mass balance calculations to evaluate the water usage in the tunnel. These calculations augment Nye County's previous work on the impact of ventilation on water removal from the ESF.

In order to demonstrate the significance of the wet surfaces in the tunnel, a simple conceptual numerical model of the situation was setup. The conceptual model

was 16.4 feet wide by 82 feet deep. A vertical fracture zone of about 1.6 feet thickness was placed in the middle of the model. The properties of this fracture zone are equivalent to a broken Topopah Springs Welded Unit. The surrounding rock has the properties of the matrix of this unit. The floor of the tunnel was kept wet (at a 95% saturation) for the entire duration of simulation. Evaporation equivalent to that induced by the ventilation was imposed at the tunnel floor. The rock matrix was initially set at 65% saturation and that of the fracture zone was set at 20% saturation (to simulate a drained fracture). The wetting (saturation) front in the fracture travels a distance of 30 ft in about 0.003 days (4 minutes). After this time, the wetting front travels at a relatively slower rate. However, after 8 days it reaches the lower boundary of this model which is at 6 feet below the floor of the tunnel. Although this model is very simplified, it demonstrates the potential for propagation of even a slight wetness in a fractured zone.

It is Nye County's position and recommendation that the water use during the tunnel construction be minimized to the extent possible without compromising the safety of the workers.

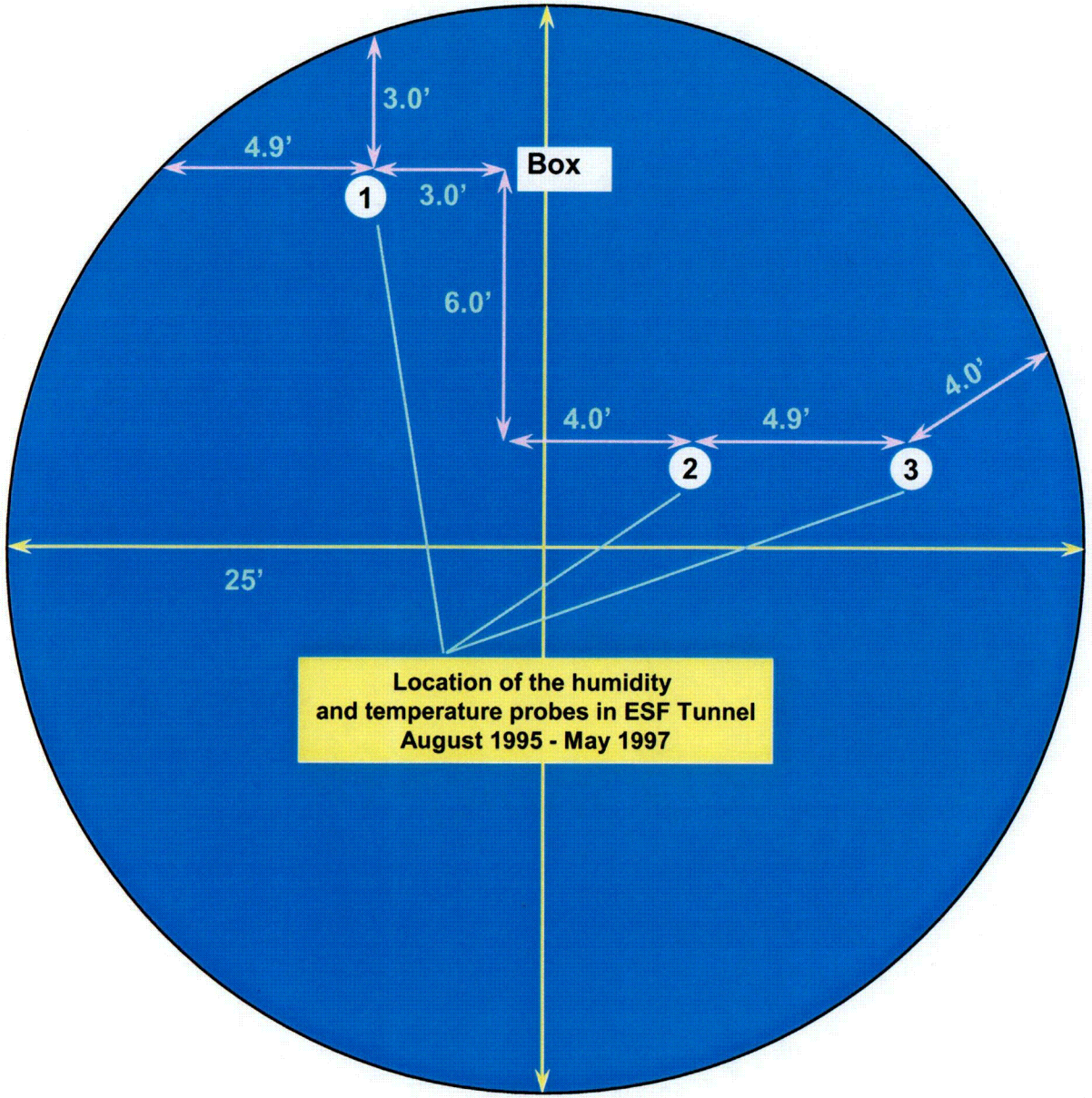


Figure 7-1 Configuration of instrumentation frame for 25' diameter ESF.
August 1995 - May 1997

C-01

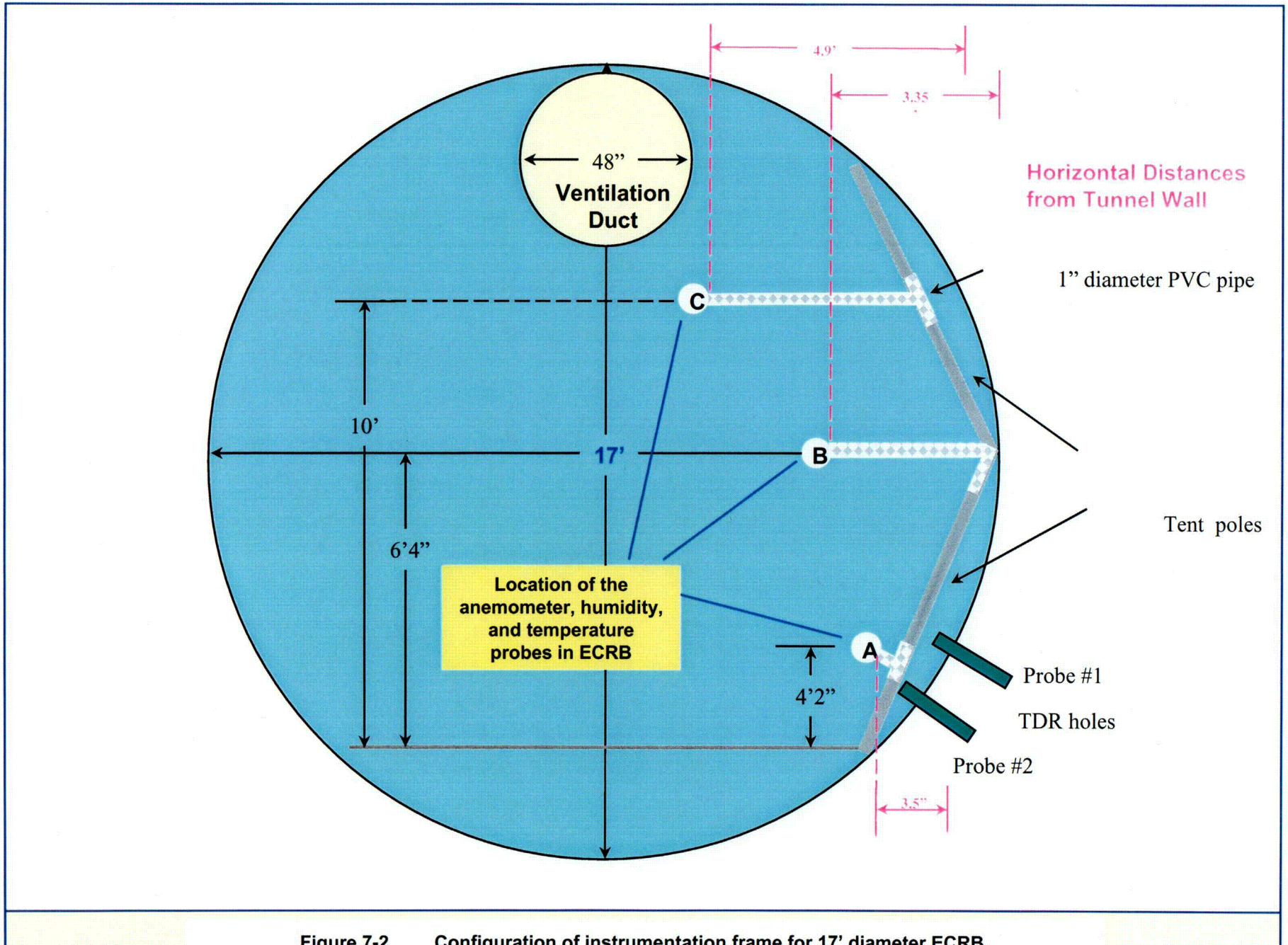


Figure 7-2 **Configuration of instrumentation frame for 17' diameter ECRB.**

C-02

8.0 ALTERNATIVE REPOSITORY DESIGN

8.1 INTRODUCTION

Thermal and moisture conditions of the repository are two of the most important processes that may influence containment of the radionuclides. To contain the radionuclides, the current concept is to seal (or backfill) the repository with crushed tuff or similar material after 100 years. Although some considerations have been given to the design with no sealing of the repository, the results have not been satisfactory in the past due to the predicted high temperature levels (above 100 degree Celsius). The uncertainty in water flux through the repository, the long-term hydrological, chemical, and mechanical effects of the elevated rock temperatures, and the long-term geochemical effects of concrete lining have been some of the most investigated subjects and probably the least resolved issues in the HLRW projects. Because of the large heat load, waste packages must be spaced far apart from each other, requiring a relatively large acreage. Natural ventilation may be used to alleviate some of these problems.

The heat generation rate by each canister of high-level radioactive waste is not substantial and is on the order of about 8 kilowatt. This amount of heat is equivalent to the amount of heat generated by about ten 1000-watt light bulbs. This amount of heat can be removed with a relatively small amount of ventilation. To demonstrate this, an observation from one of Nye County's instrumentation is presented in Figure 8-1.

In this figure, the temperature in probe 1 was noticed to behave anomalously during the time when tunnel forced ventilation was not active (11/6/97 to 11/11/97 and during weekends beginning on 11/17 and 11/24). The reason for this anomaly was determined to be the presence of a flood light less than four feet away from the probe. The flood light is a 500-watt halogen lamp. The amount of heat it generates is approximately 400 watts. During active ventilation period,

there is no noticeable deviation from the normal trend. This is because the small (approximately 1.6 ft/s) air flow rate is sufficient to dissipate the heat generated from this lamp. During inactive ventilation periods, the air flow is too small to dissipate the heat near probe 1. Once the lamp was removed, this anomaly was alleviated. This observation indicates that a relatively small amount of air movement is required to remove heat generated from objects in the tunnel. Calculations have shown that a 3.3 ft/s air flow can remove 16 mega watts of heat in a 25-ft diameter tunnel connected to a 10 ft diameter shaft (Multimedia Environmental Technology, Inc., 1997). The amount of heat generated from the canisters is estimated to be about 64 mega watts. Therefore, four shafts connected to a 25 ft diameter tunnel may be sufficient to remove the entire heat generated by the waste.

Long-term (1000 yrs) forced ventilation may not be practical in terms of cost and maintenance. One of the advantages of Yucca Mountain claimed by DOE is its open and well-drained host rock. Numerous studies, including Nye County's (Multimedia Environmental Technology, Inc. 1995, 1996, 1997), have indicated that the air permeability of the host rock is large which promotes air movement in the host rock. This open system combined with an engineered underground structure can be taken advantage of to provide natural ventilation to remove the heat from the radioactive waste. The underground structure may consist of a series of interconnected tunnels and shafts that provide a chimney-like configuration where the heat from the radioactive-waste decay promotes natural ventilation. This natural ventilation removes the heat from the canisters. The air movement in the emplacement drifts removes moisture from the host rock. By removing moisture from the host rock the capillary pressure will be increased (more negative) in the host rock. This reduction in capillary pressure will produce a strong potential gradient toward the emplacement tunnel. Moisture removal is enhanced by the movement of the air, which is nearly saturated with water vapor, through the fractures in the host rock into the tunnel.

The overall results are:

- The heat from the canisters gradually dissipates through ventilation in the tunnels.
- The liquid flow in the host rock moves toward the emplacement tunnels.
- This liquid is removed by evaporation as soon as it reaches the tunnel and will never contact the canisters.
- Radionuclide migration (if any) will be toward the tunnels and not away from the tunnels. That is, even if there is an accidental release in a portion of the tunnel, the migration will be toward another section of the tunnel and not in the direction that may intersect the pathway to the groundwater.

Recent observations in the Exploratory Studies Facility (ESF) tunnel at Yucca Mountain by Nye County staff, have indicated that ventilation can remove substantial amounts of moisture and heat from the tunnel host rock in a very short period of time. Therefore, by naturally ventilating the repository and taking advantage of the thermal drive of the waste packages, the repository host rock may be kept dry for over 10,000 years. The amount of moisture removed from the rocks during this time will create a thick low-saturation skin around the drifts that will require thousands of years to re-saturate. Ventilation can also remove large amounts of heat generated by the waste canisters.

Based on the present accumulation of the spent-fuel rods, it is estimated that more than 63000 kilo watts of heat can be generated from the spent fuel rods. Computer simulations have shown that this amount of heat can generate a substantial amount of air flow if properly placed in a tunnel connected to a shaft or any compartment that is connected to a chimney.

8.2 OBSERVATIONS IN THE YUCCA MOUNTAIN ESF TUNNEL

An underground climatological monitoring station was installed in August 1995 behind the Exploratory Studies Facility (ESF) tunnel boring machine (TBM) to measure the temperature, pressure, and relative humidity of the air. Several other measurement stations have been recently installed by DOE, following the recommendation of Nye County, along the main axis of the tunnel and in radial alcoves to characterize the spatial variation of these parameters in the underground tunnel system.

The data indicated substantial heat and moisture loss from the rock as a result of forced ventilation air.

8.3 PRELIMINARY SIMULATIONS

Simulations were made to evaluate the effect of ventilation on removal of moisture and heat from the repository host rock. The coupling of the atmospheric processes with the rock was simulated using A-TOUGH (Multimedia Environmental Technology, Inc. 1994 and Multimedia Environmental Technology, Inc. 1995), a numerical code which was developed for simulation of coupled atmospheric-soil processes.

Figure 8-2 shows the model that was used to calculate the amount of air flow generated from a small portion of the fuel rod assemblies. The simulated tunnel has a diameter of about 25 feet. A ventilation shaft, 1000 feet high and 10 feet in diameter was connected to the main tunnel. An equivalent heat provided by 52 waste packages (445 kilo watts) was applied with a packing density of one per 25 feet of tunnel length. The main driving force for the air movement in the tunnel and along the shaft was the buoyancy caused by the temperature of the waste package and the host rock. The initial pressure conditions were the same as a

static atmosphere. A temperature of 15 °C and relative humidity of 10 percent was assumed for the atmosphere.

8.4 SIMULATIONS USING THE SITE-SCALE UZ MODEL

The site-scale unsaturated zone (UZ) model (Bodvarsson, 1997) was modified to perform simulations presented here. The mesh was reduced by removing layers from the bottom of the model (the saturated zone section). The area of the model was also reduced. A series of nodes representing the ESF and a conceptual repository were introduced. Four shafts were introduced into the model. The overall dual-porosity node configuration consisted of 40000 nodes (from original 72000 nodes of the LBL UZ model).

The oblique view of the modified mesh is shown in Figure 8-3. The first set of simulations that were completed in this reporting period included an experimental simulation. In this experimental simulation, the heat source was placed in the ESF tunnel only. The placement of the canisters in the shaded conceptual repository area is currently underway.

8.5 RESULTS OF SIMULATION

The results of the preliminary simulations are presented in Multimedia Environmental Technology, Inc. (1997) and Montazer (1998) and will not be repeated here. The results of the experimental simulation using the modified UZ mesh are shown in Figures 8-4 and 8-5 for eddy diffusivity of .01 m^2/s. The hot spot in the tunnel near the waste package reaches a maximum of 45 °C in a few days. The rock temperature near the tunnel continues to drop to below 10 °C until after about 20 years when it rises back to approach 15 °C. Only the first 200 years of simulation are shown here. An infiltration rate of .16 inches/yr was used for this simulation. Air flows at about 60,000 cfm.

These results show that conceptually such a design would be beneficial in maintaining the temperature of the host rock within the ambient conditions while drying the host rock in the vicinity of the waste.

8.6 REPOSITORY DESIGN

Application of natural ventilation aided by heat source generated by the fuel-rod assembly may provide a cool and dry host rock with a capillary-pressure gradient toward the emplacement tunnels during the first 10,000 years.

A few shafts may be required to implement a full-scale naturally-ventilated repository. These shafts may be designed to have their exit into the Solitario Canyon as conceptually shown in Figure 8-6

Engineering of an open repository could be complicated and would need special studies. The emission of the gaseous radionuclides do not seem to be of major concern at this time because the large amount of flow will dilute any accidental release of gaseous radionuclides. Particulate matter can be trapped by creating large diameter rooms along the shafts. These rooms will serve as velocity traps and eliminate the need for filters. Filters would reduce the efficiency of the ventilation system.

The complex underground system may not readily lend itself to efficient air circulation in all areas of the system. In these areas, forced ventilation can be used potentially powered by the electricity generated from natural ventilation. According to Montazer (1998) there will be ample electricity that can be generated from the natural ventilation.

Because the heat can be removed readily, the canisters may be much more closely-spaced than current design allows. With high density of packing, a much smaller area (about ¼) will be required for disposal. This will also provide the opportunity to select the best part of the available area for disposal. The cost savings for reduced area is considerable and should be studied further.

The potential for intrusion is an aspect that will need to be studied further. The entrance to the repository can be blocked by bars and by providing raises that could only be accessed by special equipment. For example, the bars can be electrified or the entrance can be through a 100 ft shaft only accessible by special equipment.

The invasion of the underground opening by biological activity such as plants and animals is unlikely to a great distance. However, traps can be placed along the way to minimize such potential invasions.

There are many other issues such as stability due to geological activities, flooding, and other issues that need to be thoroughly investigated before such a design is accepted. However, it appears that such a repository would increase safety and reduce uncertainty to such a degree that makes it worth further investigation.

It is not Nye County's position to recommend such a design. The purpose of presenting such a potential change in the repository design is merely to encourage DOE to more carefully look at this alternative and provide more detailed information to be evaluated by the affected communities.

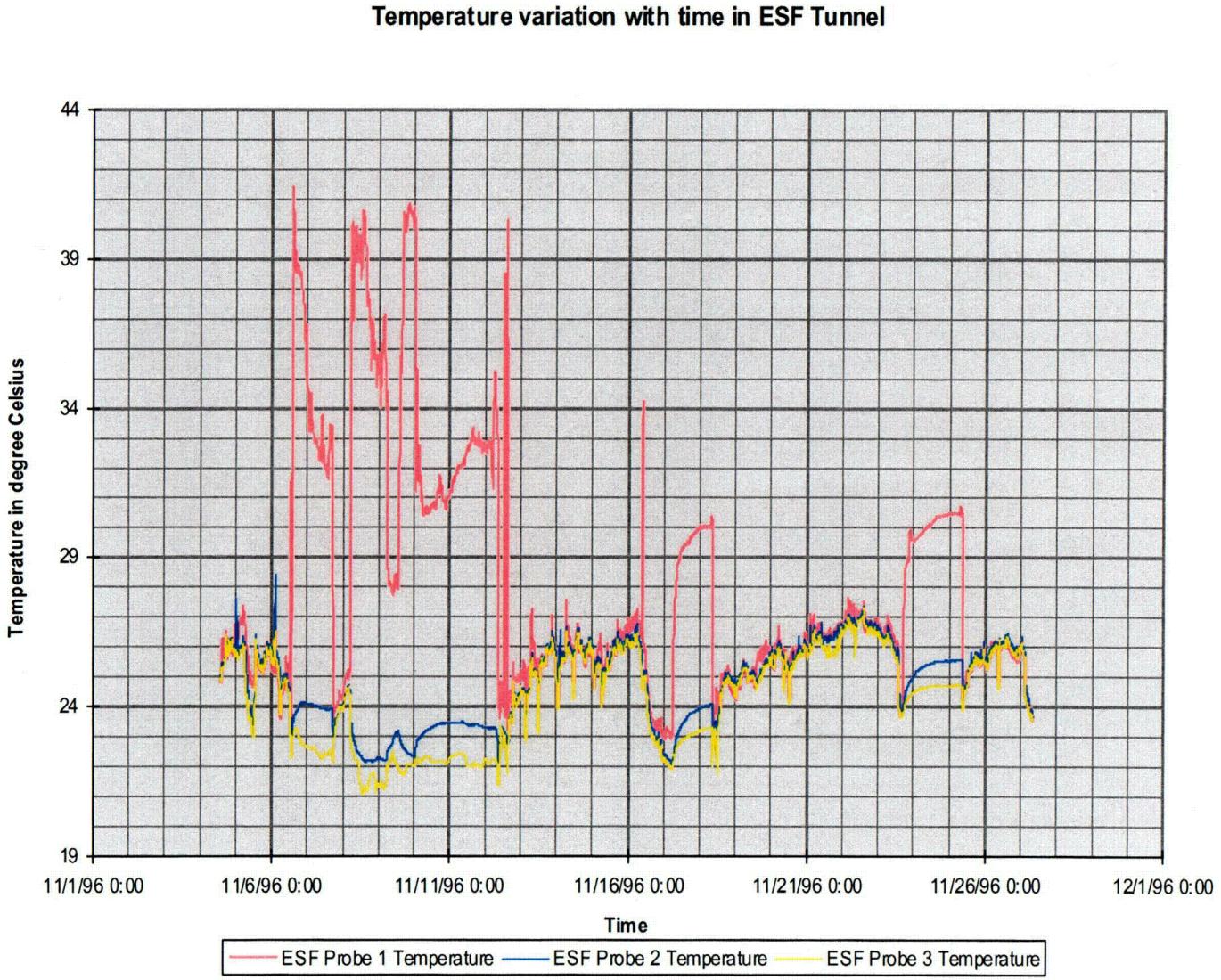
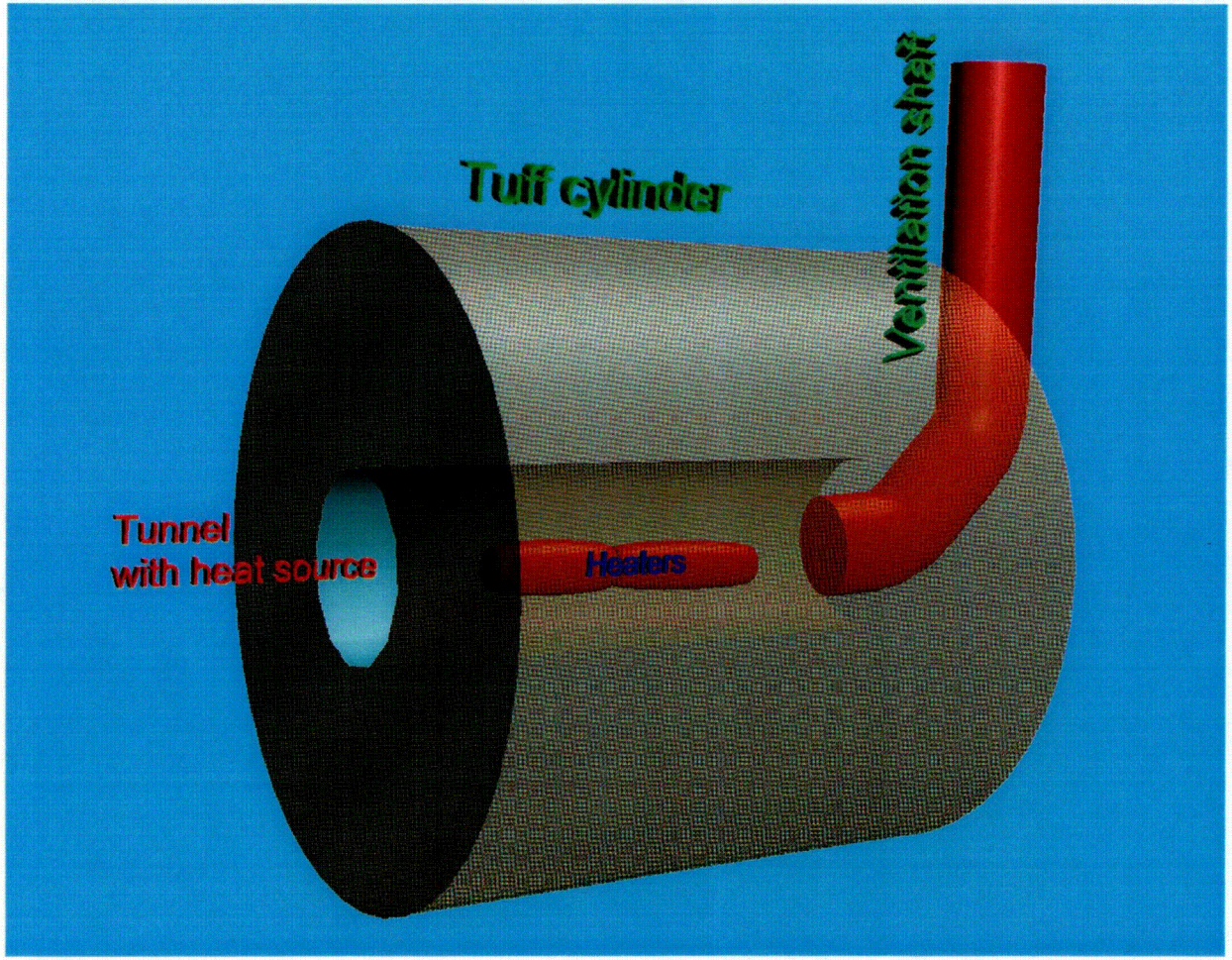


Figure 8-1 **Temperature anomaly caused by a flood lamp near Nye County's instrumentation.**

C-03



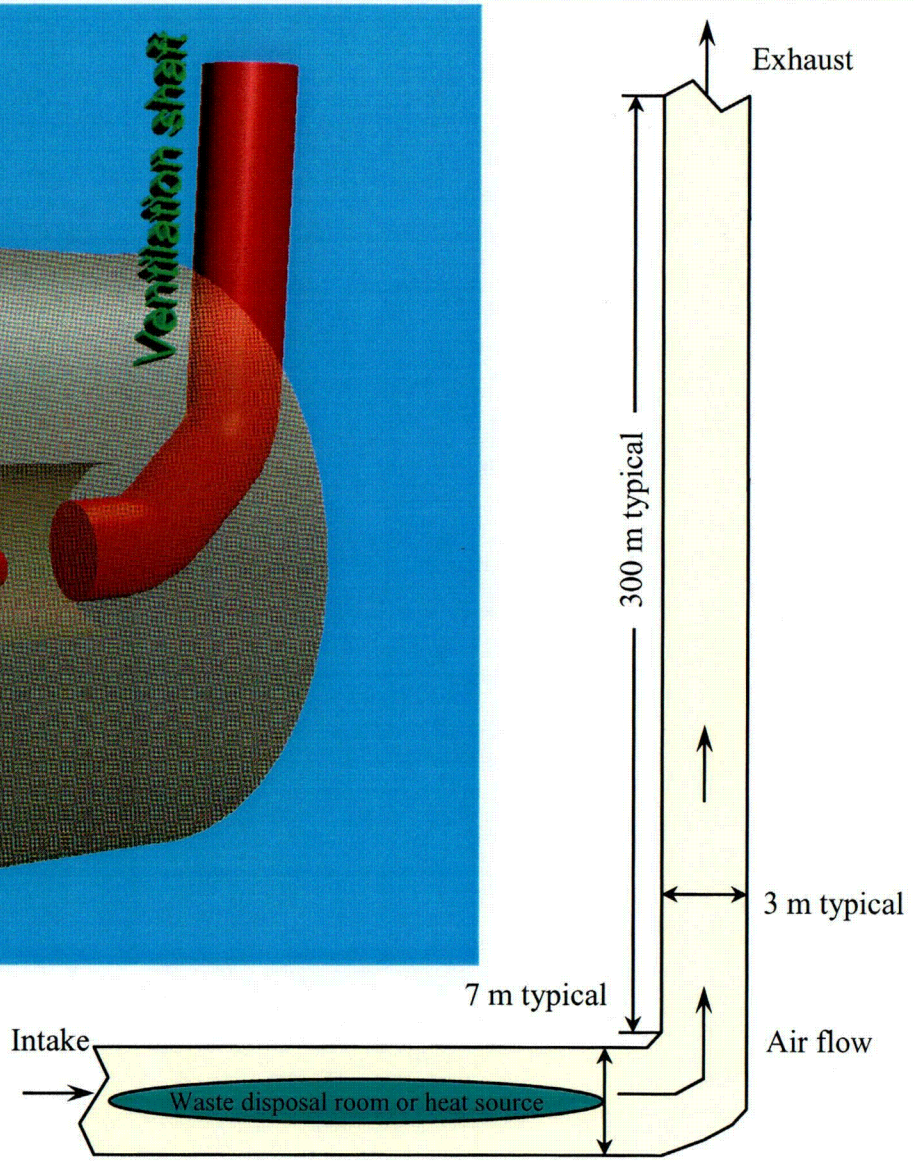


Figure 8-2 Three-dimensional simulated tunnel model and cross-sectional view.

C-04

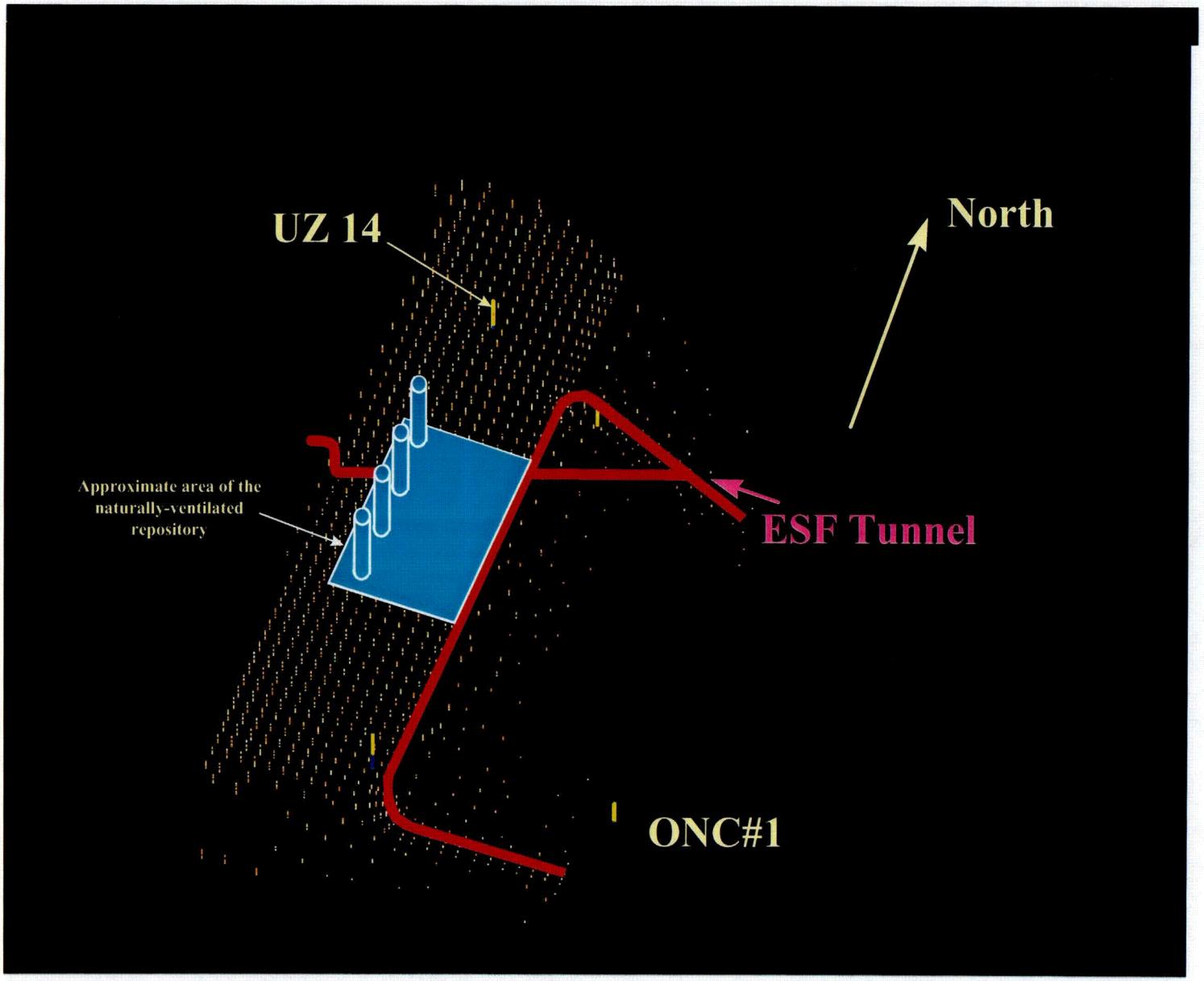


Figure 8-3 **Oblique view of the modified unsaturated zone mesh.**

C-05

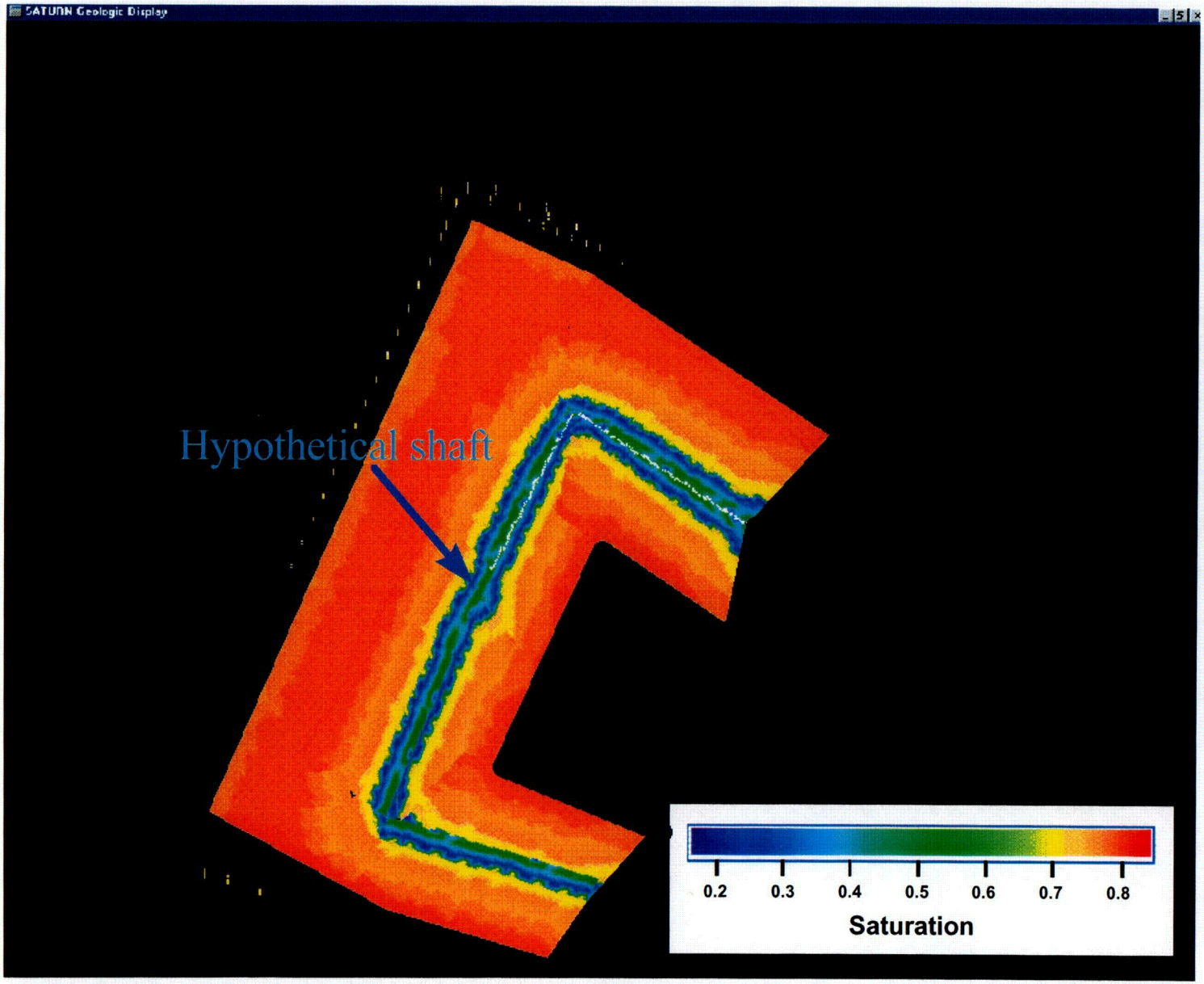


Figure 8-4 **Saturation level around ESF after 1000 Years.**

C-06

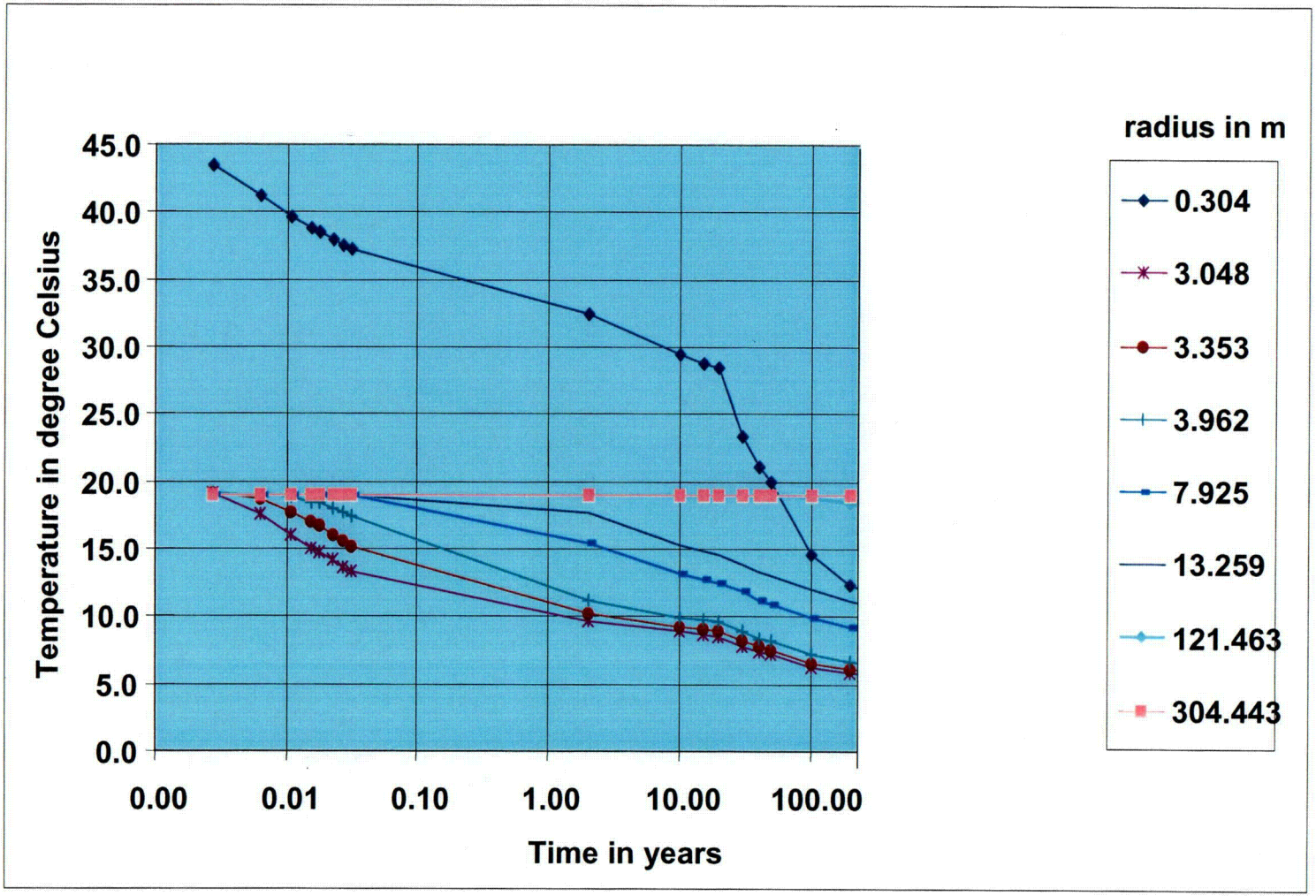


Figure 8-5 Temperature versus time for Datm = 0.01 with decayed heat load (4 mm/yr infiltration).

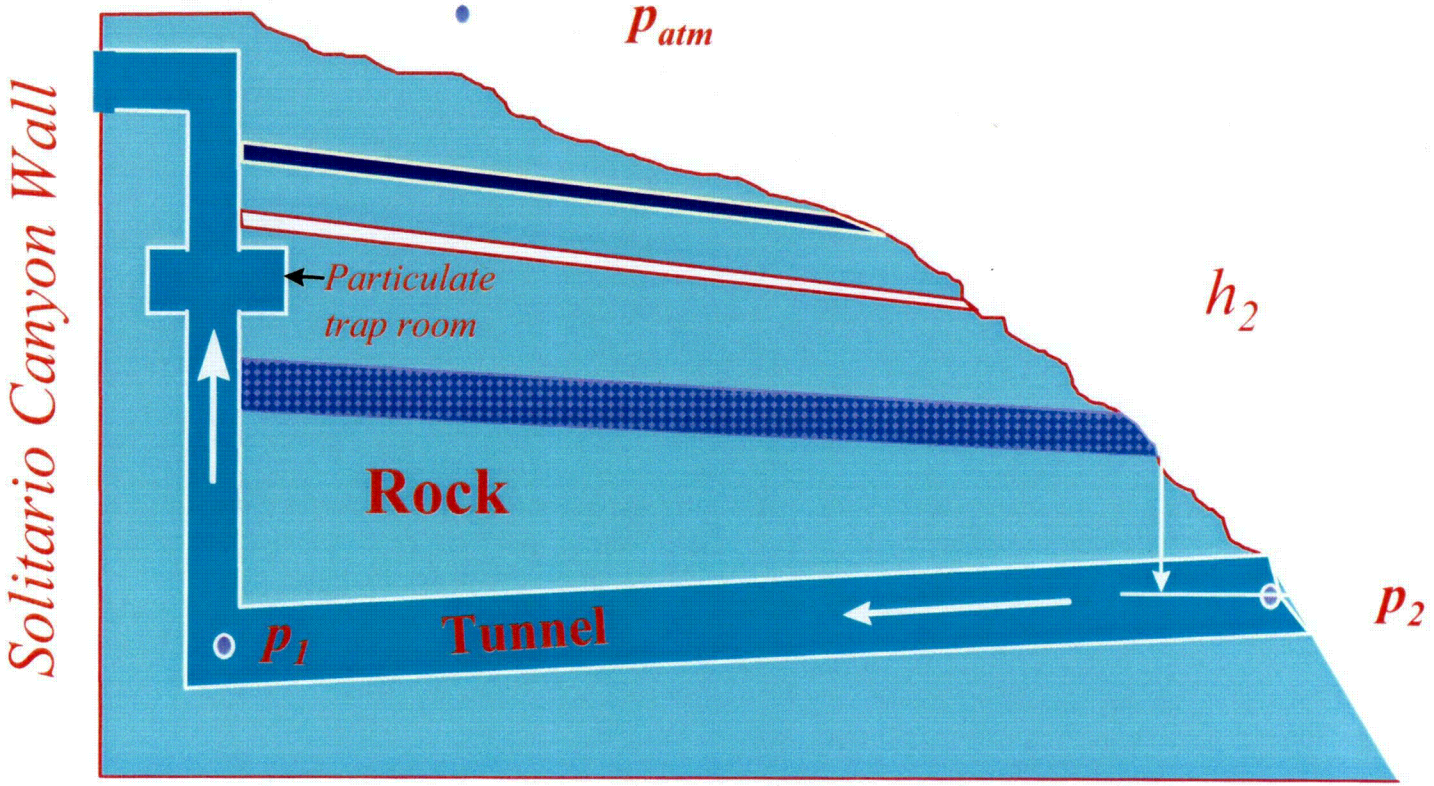


Figure 8-6 Conceptual cross section of a tunnel-shaft configuration for natural ventilation design.

9.0 DATABASE MANAGEMENT

Nye County has been developing a hydrogeologic database for the Death Valley Hydrologic Basin that includes information about all the wells, springs, and other pertinent hydrologic features in the basin (referred to as Nye County Database or NCD in this report). Nye County has made every effort to transfer the existing databases and geographical information systems (GIS), DOE maintained, into the NCD to minimize the duplication effort. The sources of the majority of the data transferred to the NCD were D'Agnese, et. al. (1997), DOE (1997), and the Technical Data Management Geographic Information Systems of DOE (1997). Additional data from the Nevada State Engineers Office and various published reports were entered into NCD and integrated with the GIS.

The NCD uses SATURN GEIS® which is a Microsoft® Access® based software system. The NCD SATURN GEIS allows querying the well and spring information based on sub-basins, groups of wells and springs, regional grouping, ranges of dates, types, and categories of data. Once a query is completed, the selected range of data can be visualized in two- or three-dimensional graphs and renderings. Geologic cross-sections, fence diagrams, and models can be visualized in either still or animated views as desired. The NCD is currently being used to prepare the input needed for the regional groundwater model by Nye County.

The attached media (compact disk) Nycoun97.mdb contains pressure and temperature data for UE-25 ONC#1 and USW NRG4 as well as data for continuous monitoring of the ESF climatic conditions during ESF construction. This database can be opened directly with Access version 2.0. Data access and sorting can be done with user-friendly menus. Tuneldata.mdb contains temperature, pressure, humidity, and air velocity data for various locations within the ESF and ECRB after November 1997. This database can be viewed using the Access program.

The file modelUTM.mdb contains a Saturn database with all the water level data. This database is preliminary and is undergoing quality assurance review. Also, not all the available data have been entered into this database yet.

10.0 GIS

The geographic information system activity has been limited to transfer of the coverages from the DOE Technical Data Management GIS into the SATURN database. No modification of the original graphic files has been made. Several hydrological and demographic coverages have been regrouped and reorganized into a SATURN compatible electronic file structure. The Nye County GIS files are not included in the media because the compilation and integration with the ongoing effort under the Oversight Program of Nye County has not been completed yet.

11.0 QUALITY ASSURANCE

11.1 NWRPO INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) defined a process whereby the Nation would site, construct, operate, and decommission a geologic repository for spent nuclear fuel and high-level radioactive waste. In its 1987 amendments to the Act, Congress designated Yucca Mountain, located in Nye County, Nevada, as the sole candidate site for a repository.

The NWPA assigned three roles to separate agencies of the executive branch. The Environmental Protection Agency is directed to promulgate generally applicable standards for protection of the general environment from off-site releases from radioactive material in repositories; the Department of Energy (DOE) is directed to characterize Yucca Mountain for its suitability for a repository, as well construct, operate and decommission the facility, if licensed; and the Nuclear Regulatory Commission (NRC) was charged with the role of establishing technical requirements and criteria for licensing, first the construction, then the operation, and ultimately, the closure and decommissioning, of a repository. The NRC is also responsible for evaluating DOE's license application and awarding a license, if appropriate.

DOE's site characterization program includes surface-based testing and the construction of an exploratory studies facility (ESF) to facilitate the study of underground site features. DOE's primary mission is to collect sufficient data to determine site suitability and to support a license application.

11.2 NYE COUNTY NUCLEAR WASTE REPOSITORY PROJECT OFFICE

Nye County has responded to Yucca Mountain being designated the Nation's

candidate site for disposal of spent nuclear fuel and high-level nuclear waste by organizing the Nuclear Waste Repository Project Office (NWRPO). NWRPO's purpose is to investigate the potential impact a repository at Yucca Mountain might have on the health, safety, environment and overall well being of the residents of Nye County.

To achieve this purpose, NWRPO administers a program of monitoring, oversight, independent scientific investigations, impact assessment and impact mitigation. In particular, NWRPO and its contractors/subcontractors (l) monitor DOE activities, (2) critically review and analyze plans, reports, data, and analysis from DOE and other sources, (3) conduct such independent investigations as may be needed to (a) evaluate and validate DOE data, assumptions, conclusions, and designs and (b) establish NWRPO's own database and analysis for potential licensing and impact mitigation proceedings.

11.3 QUALITY ASSURANCE PROGRAM

It is the policy of Nye County that the NWRPO establish and maintain a documented Quality Assurance Program. The purpose is to assure that NWRPO will continually achieve quality of performance in all areas of its responsibilities through the application of effective management systems, in conformance with its mission. This Program is designed to meet the requirements of ANSI/ASME NQA-1 and the criteria of 10CRF50 Appendix B.

All NWRPO personnel and its contractors/subcontractors who perform or manage quality-affecting functions work to the procedures that implement the Quality Assurance Program. The NWRPO Project Manager is responsible to assure that all quality-affecting work performed under his cognizance complies with the requirements of the Quality Assurance Program. The Project Quality Assurance Officer is responsible for the establishment, implementation, and verification of the Quality Assurance Program's compliance with this policy.

The intent of the QA Program is not merely to produce documentation, but more importantly, to provide assurance that the data derived from NWRPO's oversight and investigation program are of the highest quality. Furthermore, it is intended to assure that the NWRPO's scientific activities are conducted in a systematic manner using documented instructions and procedures that will ensure the validity, integrity, preservation, and retrievability of the data generated.

The NWRPO Quality Assurance Program is based upon the interpretation of Federal requirements (that is, ANSI/ASME NQA-1, 10CFR50, Appendix B) for nuclear power plants adapted for waste repository research and is designed to establish procedures for controlling activities that ultimately affect the final product of NWRPO oversight and investigation. The extent to which this Quality Assurance Program deals with QA and the responsibilities among the various NWRPO activities is consistent with their individual importance.

11.4 QA ACTIVITES - SUMMARY APRIL 1997 TO APRIL 1998

The current embodiment of the NWRPO QA Program was restarted in March 1997 after a suspension since October 1996. The primary focus this past year has been the establishment of several fundamental elements of the QA Program; specifically, the creation of the measuring and test equipment (M&TE) control system and the refinement of the QA records management system.

In addition to the development of the M&TE system and the records management system, ongoing work has included:

- The review, approval and issuance of various QA documents including Quality Administrative Procedures (QAPs), Work Plans, and Technical Procedures (TPs).
- The generation of a revised version of the NWRPO QA Program Plan.
- Ongoing communication with staff to determine areas where the QA

Program needs to be strengthened or new areas in need of coverage.

- Review of DOE, NRC, YMP QA audit reports and consideration of impact on NWRPO.
- Performance of two internal surveillances and one audit on technical and QA Program activities.
- Development of a QA Action database to track outstanding QA items and issues of concern.
- Initiation and disposal of a Nonconformance Report and related Suggested Corrective Action related to calibration of environmental monitoring probes. This included the securing of an independent technical review of the questionable probe data.
- Meeting with the Nuclear Regulatory Commission On-Site Representative to discuss the NCR's informal evaluation of the NWRPO QA Program.
- Assumption of the position of NWRPO Quality Assurance Officer by the contractor in March 1998.
- Increase of QA scrutiny of procurement activities involving analytical laboratory services and calibrated equipment.
- Holding continuing discussions with technical staff concerning the quality and traceability of hydrogeologic data.
- Preparation of monthly progress reports.

11.5 QA ISSUES

The primary issue facing the NWRPO QA Program is assuring the traceability and validity of data gathered by the program. The QA applied to the gathering and analysis of these data must be sufficient to ensure their conformance to regulatory controls.

The NWRPO QA Program also faces the following issues:

- The broad question of data pedigree and data quality as concerns data being used in models by the NWRPO.

- The probable increase of data gathering activities in the field associated with the drilling of new boreholes.

- The need for a more complete evaluation of vendor supplied items and services by the QA Program.

- The increase in the level of technical program activity will necessitate a concurring increase in QA audits, surveillances, and evaluation actions.

- As additional technical and administrative staff are added, there is a necessity that their QA responsibilities are clearly communicated and that they properly perform necessary QA.

12.0 SUMMARY AND CONCLUSIONS

Nye County Nuclear Waste Repository Project Office's (NWRPO) Independent Scientific Investigation Program (ISIP) is concerned with several key scientific issues that may impact the repository design and performance. The ISIP presently includes borehole and tunnel instrumentation, monitoring, data analysis, and numerical modeling activities to address some of these concerns.

Nye County has installed and is currently monitoring pressure and temperature instruments in boreholes UE-25 ONC#1 and USW NRG4 to evaluate the long-term pneumatic conditions at strategic depths in the subsurface both in response to fluctuations in atmospheric conditions and in response to other possible disturbances resulting from site characterization activities such as ESF tunnel construction. Nye County has also installed instruments to measure temperature, pressure, humidity, and air flow velocity within the ESF tunnel to characterize the air being used to ventilate the tunnel which could potentially impact the performance of the repository. Finally, Nye County is conducting numerical modeling simulations to evaluate factors (including tunnel ventilation) which affect both short-term and long-term pneumatic and moisture conditions in the repository host rock.

A summary of activities undertaken by ISIP during the past year are as follows:

- Evaluation of critical data and information as it became available from the DOE's YMP Site Characterization Office.
- Observed water usage in the tunnel and its potential impact on the repository horizon and the scientific investigation results.
- Prepared detailed review of procedures and methods used for in-situ air permeability tests and evaluated the results of some of these tests.

- Completed several letter reports to DOE on the interpretation of the results of the ^{36}Cl and other environmental and geological isotope studies. These communications have resulted in DOE giving more focused attention to the need for more detailed studies in the ESF tunnel, limiting the use of construction water, and enhanced interpretation of the results of the isotope sampling.

- Analysis of cuttings from bore hole UE-25 ONC#1 and focus on the petrographic characterization of past and present fluid pathways that support transport from the ground surface through the vadose and saturated zones. In addition, cutting samples have been analyzed for $^{36}Cl/Cl$ ratio.

- Analyzed pressure response of UE-25 ONC#1 to atmospheric pressure pulses through natural and man-made pathways.

- Monitored responses to vacuum tests that were conducted in UE-25 ONC#1 to obtain gas samples for laboratory analysis.

- Collected gas samples in the vadose zone in UE-25 ONC#1 and analyzed the samples for fluorocarbons, tritium, and carbon isotopes.

- Estimated the apparent ages of the gas samples from UE-25 ONC#1 and compared with the results of samples obtained from other boreholes at Yucca Mountain Site.

- Conducted research as to the potential impact of the construction and operation of the Yucca Mountain Repository on the County's resources. Developed and are in the process of refining a regional model of the Death Valley Hydrologic Basin.

- Establishment of several fundamental elements of the QA Program; specifically, the creation of the measuring and test equipment (M&TE)

control system and the refinement of the QA records management system.

As a result of the evaluation of the ESF tunnel climatological data collected, Nye County concluded that substantial moisture was being removed from the rocks penetrated by the tunnel ventilation. In response to issues raised by Nye County, DOE assigned a task force to conduct observations in the ESF and perform numerical simulations for interpretation of the results in parallel with Nye County's effort. Nye County provided data, preliminary analytical and simulation results, and input for developing the proposal to this task force. Nye County data indicated that in addition to moisture, a substantial amount of heat is being removed by the ventilation. Nye County performed additional simulations using A-TOUGH, a computer code designed to simulate coupled-open air with geologic formations and discovered that there is a tremendous potential for natural ventilation at the site due to its climate and its physiographic setting. Simplified simulations using A-TOUGH were performed to evaluate the potential of a naturally ventilated repository. One conclusion is that it is possible to design a repository that is naturally ventilated with peak rock temperatures of less than 30 degrees Celsius over a 10,000-year period. These simulations also showed that the capillary pressure distribution would promote a strong gradient for water flow towards the emplacement tunnels during the entire 10,000 years. Nye County, believes that long-term waste containment implications of a naturally-ventilated repository warrants additional analysis.

Nye County is planning to perform several investigations in the near future to understand some of the issues that were outlined above, by installing new wells in both the saturated and unsaturated zones, testing and sampling these wells, and performing data analysis and modeling. These issues are related to the steep gradients in the saturated zone north and west of the site, the potential for dilution in the saturated zone as unsaturated zone moisture enters the saturated zone, the atmospheric and pneumatic boundaries in the Solitario Canyon that might impact

the repository performance, and the large-scale transport properties of the fractured formations in both saturated and unsaturated zones.

13.0 REFERENCES

Advance Resources International, 1995, Analysis of permeability tests at Yucca Mountain, Nevada.

Ambos, D.S. et al., 1995, Precipitation data for water years 1992 and 1993 from a network of nonrecording gages at Yucca Mountain, Nevada: USGS Open-File Report 95-146.

American Society for Testing Materials, 1994, Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information, Philadelphia, PA

Avon, L. and Durbin, T.J., 1992, Evaluation of the Maxey-Eakin method for calculating recharge to ground-water basins in Nevada", Las Vegas Valley Water District, Cooperative Water Project, Series Report No. 7, 44 p.

Bodvarsson, G.S. and Bandurraga, T.M., Eds., 1996, Development and calibration of the three-dimensional site-scale unsaturated zone model of Yucca Mountain, Nevada, Earth Sciences Division, Ernest Orlando Lawrence Berkeley National Laboratory.

Buscheck, T.A., J.J. Nitao, and L. Ramspot, 1995, Localized dry-out: An approach for managing the thermo-hydrological effects of decay heat at Yucca Mountain, Material Research Society Symposium on Scientific Basis for Nuclear Waste Management, 1995 Fall Meeting, Boston, Massachusetts.

Buqo, T.S., 1996, Baseline water supply and demand evaluation of southern Nye County, Nevada, Nye County Nuclear Waste Repository Office.

Claassen, H.C., 1985, Sources and mechanisms of recharge for ground-water in the west-central Amargosa Desert, Nevada - A Geochemical Interpretation: USGS Professional Paper 712-F.

Czarnecki, J.B., 1984, Finite-element simulation of ground-water flow in the vicinity of Yucca Mountain, Nevada-California: USGS, Water Resources Investigation Report 84-4349.

Czarnecki, J.B., 1990, Geohydrology and evapotranspiration at Franklin Lake Playa, Inyo County, California: USGS Open-File Report 90-356.

Czarnecki, J.B., 1985, Simulated effects of increased recharge on the ground-water flow system of Yucca Mountain and vicinity, Nevada-California: USGS, Water Resources Investigations Report 84-4344.

D'Agnese, F.A., C.C. Faunt, A.K. Turner, and M.C. Hill, Hydrogeologic evaluation and numerical simulation of the Death Valley regional ground-water flow system, Nevada and California: U.S. Geological survey, Water Resources Investigations Report 96-4300, Denver, Colorado, prepared in cooperation with the Nevada Operations Office, U.S. Department of Energy.

Dettinger, M.D. et al., 1995, Distribution of carbonate- rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah: USGS Water-Resources Investigations Report 91-4146.

Draper, N.R. and Smith, H., 1981, Applied regression analysis: John Wiley and Sons, New York.

Eakin, T.E. and Maxey, G.B., et al., 1952, Contributions to the hydrology of eastern Nevada: State of Nevada, Water Resources Bulletin No. 12.

Earlougher, R.C., Jr., 1977, Advances in well test analysis: Society of Petroleum Engineers, Dallas, Monograph 5, p. 105-122

Elmore, D., Fulton, B.R., Clover, M.R., Marsden, J.R., Gove, H.E., Naylor, H., Purser, K.H., Kilius, L.R., Beukins, R.P., and Litherland, A.E., 1979, Analysis

of 36Cl in environmental water samples using an electrostatic accelerator: Nature, v. 277, p. 22-25.

Fabryka-Martin, J.T., A.L. Flint, D.S. Sweetkind, A.V. Wolfsberg, S.S. Levy, G.J.C. Roemer, J.L. Roach, L.E. Wolfsberg, and M.C. Duff, 1997, Evaluation of flow and transport models of Yucca Mountain, based on chlorine-36 studies for FY97: YMP Milestone Report SP2224M3, Los Alamos National Lab. Rpt. LA-CST-TIP-97-010.

Fabryka-Martin, J.T., P.R. Dixon, S. Levy, D. Liu, H.J. Turin and A.V. Wolfsberg, 1996, Summary report of chlorine-36 studies: systematic sampling of chlorine-36 in the exploratory studies facility: Level 4 Milestone Report 3783AD, Los Alamos National Lab., pp. 53.

Falta, R.W., et al., 1995, TVOC User's Guide: LBL-36400, supported by the WIPP Project, Sandia National Laboratories, under Document No. 129847, March 1995.

Flint, L.E. and Flint, A.L., 1995, Shallow infiltration processes at Yucca Mountain, Nevada - Neutron logging data 1984-93: USGS Water Resources Investigations Report 95-4035.

Fischer, Jeffrey M., Sediment properties and water movement through shallow unsaturated alluvium at an arid site for disposal of low-level radioactive waste near Beatty, Nye County, Nevada.

Gee, G.W., and Wierenga, B.J. et al., 1994, Variations in water balance and recharge potential at three western desert sites: Soil Science Society of America Journal, Vol. 58, No.1.

Harrill, J.R., 1986, Ground-water storage depletion in Pahrump Valley, Nevada-California, 1962-75: U.S. Geological Survey, Water-Supply Paper 2279.

Harrill, J.R., A.H. Welch, D.E. Prudic, J.M. Thomas, R.L. Carman, R.W. Plume, J.S. Gates, and J.L. Mason, 1983, Aquifer systems in the great basin region of Nevada, Utah, and adjacent states; A study plan: U.S. Geological Survey, Open-File Report 82-445.

Harrill, J.R., J.S. Gates, and J.M. Thomas, 1988, Major ground-water flow systems in the great basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey, Hydrologic Investigations Atlas HA-694-C.

Hunt, C.B., 1975, Death Valley - Geology, ecology, archaeology: University of California Press, Berkeley, California.

IT Corporation, Underground test area project phase 1 data analysis task, volume III, draft", Las Vegas, Nevada, March 1996.

Joseph, J.A. and Koederitz, L.F., 1985, Unsteady-state spherical flow with storage and skin: Society of Petroleum Engineers Journal, Dec., p. 804-822.

Kane, T.G., Bauer, D.J., and Martinez, Clair M., 1994, Streamflow and selected precipitation data for Yucca Mountain region, southern Nevada and eastern California, Water Years 1986-90: USGS Open-File Report 94-312.

Kearl, P.M., 1982, Water transport in desert alluvial soil: Desert Research Institute, University of Nevada System.

Kilroy, Kathryn C., Ground-water conditions in Amargosa Desert, Nevada-California, 1952-87: USGS Report 89-4101.

Kolm, K.E. and Downey, J.S., 1994, Diverse flow patterns in the aquifers of the Amargosa Desert and vicinity, Southern Nevada and California: Bulletin of the Association of Engineering Geologists, Vol. XXXI, No. 1, pp.33-47.

Lichty, R.W. and McKinley, P.W., 1995, Estimates of ground-water recharge rates for two small basins in central Nevada: USGS Water Resources Investigations Report 94-4104.

Lyles, B. and Mihevec, T., 1994, Potential hydrologic characterization wells in Amargosa Valley: Desert Research Institute, Water Resources Center, Publication 45129.

Malmberg, G.T., 1967, Hydrology of the valley-fill and carbonate-rock reservoirs Pahrump Valley Nevada-California: USGS Water Supply Paper 1832.

Menzel, D.H., 1960, Fundamental formulas of physics: Dover Publications, New York, p. 74.

Montazer, Parviz, 1994, A-TOUGH, A computer code for simulation of atmospheric interface with fractured rocks: International High-Level Radioactive Waste Conference, Las Vegas, Nevada.

Montazer, Parviz, 1998, Generating electriciy, keeping repository cool, dry, and reducing acreage requirement: International High-Level Radioactive Waste Conference, Las Vegas, Nevada, May 1998.

Montazer, Parviz, and Wilson, W.E., 1984, Conceptual hydrologic model of flow in the unsaturated zone, Yucca Mountain, Nevada: U.S. Geological Survey, Water Resources Investigation Report 84-4345.

Montazer et. al. 1987, Characterization of unsaturated flow through fractured rocks: Groundwater Monitoring Review.

Montazer, Parviz and Stellavato, Nick, 1996, Simulation and observation of ESF tunnel effects on barometric conditions: International High-Level Radioactive Waste Conference, April 1996, Las Vegas, Nevada.

Montazer, Parviz and Stellavato, Nick, 1996, Moisture removal from the repository by ventilation and impacts on design: International High-Level Radioactive Waste Conference, April 1996, Las Vegas, Nevada.

Montazer, Parviz, 1982, Permeability of unsaturated fractured metamorphic rocks near an underground opening: Golden, Colorado School of Mines, Ph.D. Thesis, 630 p.

Multimedia Environmental Technology, Inc., 1995, User's manual for A-TOUGH, an atmospheric interface model based on V-TOUGH.

Multimedia Environmental Technology, Inc., 1995, Interim report on results of instrumentation and monitoring of UE-25 ONC#1 and USW NRG4 boreholes, Yucca Mountain, Nevada: Nye County Nuclear Waste Repository Office, Nye County, Nevada.

Multimedia Environmental Technology, Inc., 1996, Annual report of the Nye County Nuclear Waste Repository Project Office Independent Scientific Investigations Program.

Multimedia Environmental Technology, Inc., 1997, Results of first gas sampling from UE-25 ONC#1.

Multimedia Environmental Technology, Inc., 1997, Summary annual report May 1996 - April 1997 Nye County Nuclear Waste Repository Project Office Independent Scientific Investigations Program.

Multimedia Environmental Technology, Inc., 1997, Results of gas sampling from UE-25 ONC#1, June 1997.

Multimedia Environmental Technology, Inc., 1998, Numerical model of the Death Valley groundwater system, in preparation.

Multimedia Environmental Technology, Inc., 1998a, Simulation of ventilation effects using the modified UZ model, in preparation.

NOAA Coop. Stations & USDA-NRCS SNOTEL Stations (www.wrcc.dri.edu/summary)

NWRPO, 1995, Borehole UE-25 ONC#1 and USW NRG4 drilling and instrumentation report, Yucca Mountain, Nevada: Prepared by the Nuclear Waste Repository Project Office, Nye County Nuclear Waste Repository Program.

Naff, R.L., 1973, Hydrogeology of the southern part of Amargosa Desert in Nevada: Master of Science Thesis, University of Nevada Reno.

Naff, R.L. and Maxey, G.B. at al., 1974, Interbasin ground-water flow in southern Nevada: Report 20, Mackay School of Mines, University of Nevada Reno.

National Climatic Data Center Internet Site (www.ncdc.noaa.gov/pub/data/coop-precip/Nevada.txt).

Nevada Bureau of Mines, 1964, Mineral and water resources of Nevada: Bulletin 65, Mackay School of Mines, University of Nevada Reno.

Nichols, W. D., 1987, Geohydrology of the unsaturated zone at the burial site for low-level radioactive waste near Beatty, Nye County, Nevada: USGS Water-Supply Paper 2312.

Nichols, W.D., Laczniak, R.J., DeMeo, G.A., and Rapp, T.R., 1997, Estimated ground-water discharge by evapotranspiration, Ash Meadows area, Nye County, Nevada: USGS, Water Resources Investigations Report 97-4025.

Oatfield, W.J. and Czarnecki, J.B., 1989, Hydrogeologic inferences from driller's logs and from gravity and resistivity surveys in the Amargosa Desert, southern Nevada: USGS Open-File Report 89-234.

Pal Consultants, Inc., 1995, A conceptual model of the Death Valley ground-water flow system, Nevada, California: Prepared for: U.S. Department of Interior, National Park Service.

Pal Consultants, Inc., 1995, Evaluation of scientific literature pertaining to the conceptualization of the Death Valley ground-water flow system Nevada & California: San Jose, CA, prepared for the National Park Service.

Plume, R.W. and S.M. Carlton, 1988, Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey, Hydrologic Investigations Atlas HA-694-A.

Press, W.H., Teukolsky, S.A., Vetterling, W.T. and Flannery, B.P., 1992, Numerical recipes in Fortran: Cambridge University Press, p. 569 ff.

Prudic, D.E., J.R. Harrill, and T.J. Burbey, 1993, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent states: US. Geologic Survey, Open-File Report 93-170 (revision of Open-File Report 90-560), Carson City, Nevada.

Prudic, D.E., 1994, Estimates of percolation rates and ages of water in unsaturated sediments at two Mojave Desert sites, California-Nevada: USGS Water-Resources Investigations Report 94-4160.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah and adjacent states: USGS Professional Paper 1409-D.

Pruess, K. and Wang, J. S. Y., 1984, TOUGH - A numerical model for nonisothermal unsaturated flow to study waste canister heating effects: in Mat. Res. Soc. Symp. Proc., in G.L. McVay (editor), Vol. 26, Scientific Basis for Nuclear Waste Management, North Holland, New York, New York; pp. 1031-1038.

Pruess, K. and Narasimhan, T.N., 1985, A practical method for modeling fluid and heat flow in fractured porous media: Society of Petroleum Engineers Journal, February; pp. 14-26.

Pruess, K., 1987, TOUGH user's guide; Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California, LBL-20700; 78 pp.

Pruess, K., 1988, SHAFT, MULKOM, TOUGH: A set of numerical simulators for multiphase fluid and heat flow: Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California, LBL-24430; 25 pp.

Pruess, K., 1990, Editor, Proceedings of the TOUGH Workshop: Earth Sciences Division, Lawrence Berkeley Laboratory, LBL-29710, September; 157 pp.

Pruess, K., 1991, TOUGH2 - A general-purpose numerical simulator for multiphase fluid and heat flow: Earth Sciences Division, Lawrence Berkeley Laboratory, LBL-29400; 102 pp.

Pruess, K., and O'Sullivan, M., 1992, Effects of capillary and vapor adsorption in the depletion of vapor-dominated geothermal reservoirs: 17th Workshop on Geothermal Reservoir Engineering, Stanford University, January 29-31; 10 pp.

Raghavan, R. and Clark, K.K., 1975, Vertical permeability from limited entry flow tests in thick formations: Trans., AIME, v. 259, p. 65-73.

Rautman, Christopher A. and Engstrom, D.A., Geology of the USW SD-7 drill hole Yucca Mountain, Nevada.

Rautman, Christopher A. and Engstrom, D.A., Geology of the USW SD-9 drill hole Yucca Mountain, Nevada"

Rautman, Christopher A. and Engstrom, D.A., Geology of the USW SD-12 drill hole Yucca Mountain, Nevada.

Rice, W.A., 1984, Preliminary two-dimensional regional hydrologic model of the Nevada Test Site and vicinity: Pacific Northwest Laboratory, Richland, WA.

Roseboom, E.H., 1983, Disposal of high-level nuclear waste above the water table in arid regions: U.S. Geological Survey Circular 903, 21p.

Rush, F.E., 1971, Regional groundwater systems in the Nevada Test Site area, Nye, Lincoln and Clark Counties, Nevada: State of Nevada, Department of Conservation and Natural Resources, Water Resources Reconnaissance Series, Rpt. No. 54, 1971.

Savard, C.S., Selected Hydrologic Data from Forty Mile Wash in the Yucca Mountain Area, NV, Water Years 1993-94.

Schaffer, D.H. and Harrill, J.R., 1995, Simulated effects of proposed ground-water pumping in 17 basins of east-central and southern Nevada: USGS Water Resources Investigations Report 95-4173.

Scott, B.R., Smales, T.J., Rush, F.E., and Van Denburgh, A.S., 1971, Water for Nevada: Planning Report 3 - Nevada's Water Resources, Nevada Department of Conservation and Natural Resources, Division of Water Resources, State of Nevada, Carson City, Nevada.

Spaulding, W. G., 1985, Vegetation and climates of the last 45,000 years in the vicinity of the Nevada Test Site, South-Central Nevada: USGS Professional Paper 1329.

Stellavato, Nick, 1996, Borehole UE-25 ONC#1 drilling at Yucca Mountain, Nevada: High Level Radioactive Waste Management, Proc. Seventh Annual International Conf., Las Vegas, Nevada, April 29-May 3, 1996, p. 166-7.

Stellavato, Nick, Sims, S., Perry, J., Housel, M., Moyer, J., and McMaster, L., 1995, borehole UE-25 ONC#1 and USW NRG4 drilling and instrumentation report, Yucca Mountain, Nevada: Nye County Nuclear Waste Repository Project Office Rpt., 9/1/95.

TRW, 1995, Total System Performance Assessment -1995, An evaluation of the potential Yucca Mountain repository.

U.S. Department of Energy, 1997, Yucca Mountain Site Characterization Project Site Atlas.

U.S. Department of Energy, 1997, Regional groundwater flow and tritium transport modeling and risk assessment of the underground test area, Nevada Test Site: DOE/NV-477, UC-700, DOE Nevada Operations Office, Las Vegas Nevada.

U.S. Department of Energy, 1997b, Summary of public scoping comments related to the environmental impact statement for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada: U.S. Department of Energy, Yucca Mountain Site Characterization Office.

Waddell, R. K., 1982, Two-dimensional, steady-state model of ground-water flow, Nevada Test Site and vicinity, Nevada-California: USGS, Water Resources Investigations 82-4085.

Westenburg, G.L. and La Camera, R.J., Selected ground-water data for Yucca Mountain region, southern Nevada and eastern California, through Dec. 1994: USGS.

Witter, C. et al., Preliminary development of the LBL/USGS three-dimensional site-scale model of Yucca Mountain, Nevada.

Wittmeyer, G.W., Klar, R., Rice, G., and Murphy,W., 1995, The CNWRA regional hydrogeology information system database, NRC -02-93-005.

Wittmeyer, G.W. and Turner, D.R., 1996, Regional hydrologic processes of the Death Valley region: NRC High Level Radioactive Waste Research at CNWRA July-December 1995. B. Sagar (ed.), San Antonio, Texas, Center for Nuclear Regulatory Analysis, CNWRA 95-02S, 8-1 through 8-18.

Wood, J.L. and Andraski, B.J., 1995, Selected meteorological data for an arid site near Beatty, Nye County, Nevada, calendar years 1990-1991: USGS Open-File Report 94-489.

Yang, C., et al., 1996, Interpretation of chemical and isotropic data from boreholes in the unsaturated zone at Yucca Mountain, Nevada: USGS.

Zelinski, W. P. and Clayton, R.W., A 3D geologic framework and integrated site model of Yucca Mt.: Version ISM1.0 (Appendix A)

Zreda, M.G., Phillips, F.M., Elmore, D., Kubik, P.W., P., S., and Dorn, R.I., 1991, Cosmogenic chlorine-36 production rates in terrestrial rocks: Earth and Planetary Science Letters, v. 105, p. 94-109.