MURR

Fighting cancer with tomorrow's technology

UNIVERSITY OF MISSOURI RESEARCH REACTOR (MURR)

Environmental Report for License Renewal

Facility License No. R-103

Docket No. 50-186

MISSOURI UNIVERSITY RESEARCH REACTOR
ENVIRONMENTAL REPORT

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1.0 PURPOSE / METHODOLOGY

1.1 Purpose of and Need for Action

The Missouri University Research Reactor (MURR) is a pressurized, reflected, light-water moderated, open pool-type research reactor. The reactor is used to conduct experiments, irradiate materials, and produce isotopes for use in various fields of medicine. In addition, the reactor is used for training, research, and demonstration purposes associated with undergraduate and graduate level degree programs. MURR is located in University Research Park, an extension of the Missouri University-Columbia, Missouri and is licensed to the Board of Curators of the Missouri University. A detailed description of the facility's specific location is presented in Section 2.0. Facility Operating License No. R-103 (NRC Docket 50-186) was originally issued as a Construction Permit on November 21, 1961, and will expire on October 11, 2006.

MURR is a multi-disciplinary research and education facility that provides a wide range of analytical, radiographic, and irradiation services to the research community and the commercial sector. Researchers from the University and MURR have developed and commercialized three novel radiopharmaceuticals: Quadramet™, Ceretec™, and TheraSphere™.

- Quadramet™ is a therapeutic radiopharmaceutical designed to relieve the pain associated with metastatic bone cancer. MURR is currently the sole U.S. supplier of Sm-153, the active ingredient. It is approved for use in the U.S. and marketed by Berlex.

- TheraSphere™ is used for treatment of liver cancer. It is approved in Canada and the U.S. and marketed by Nordion.

- Ceretec™ is the first radiopharmaceutical to effectively image blood flow abnormalities in the brain for the diagnosis and assessment of stroke victims. It is approved for use in the U.S. and marketed by Nycomed Amersham.

- In addition to Quadramet™ and TheraSphere™, MURR has made significant contributions to the fight against cancer by producing radioisotopes that treat or diagnose cancer. These include:

    1. Ho-166-DOTMP, produced by MURR in conjunction with ABC Laboratories, is used to treat multiple myeloma, a type of leukemia. Phase III FDA trials were initiated in October 2000.

    2. Selstat is a testing kit, developed by MURR in partnership with ABC Laboratories, which determines the level of selenium in the body. In epidemiological studies with Harvard and the Massachusetts Institute of Technology, MURR scientists determined that there is an inverse correlation between selenium levels and the onset of prostate cancer. Decreased selenium levels have also been associated with an increased incidence of breast cancer and cardiovascular disease.

3. Lu-177 is increasingly being used in clinical trials for the treatment of various tumor types.

4. Ir-192 is used in brachytherapy sources for the treatment of prostate and other cancers.

Radiopharmaceuticals now being developed at MURR will aid in the diagnosis and treatment of heart disease, arthritis, and cancers of the bone, kidney, liver, prostate, breast, ovaries, and blood. Beyond its research and development role, MURR is a producer of a broad spectrum of radioisotopes. These radioisotopes are used for radiopharmaceuticals currently on the market and for research, clinical trials, and medical applications. MURR routinely ships radioisotopes to researchers, medical institutions, and private companies around the world. Each year, over 200,000 cancer patients depend on MURR for the radiopharmaceuticals used to treat their cancer and provide pain relief. Without MURR-produced radioisotopes, many patients would be denied treatment options.

As the highest-powered University research reactor in the U.S., MURR also provides a wide range of research and training opportunities for graduate and undergraduate students. Currently, there are only 27 operating research and training reactors in the U. S., over a 50 % decline since 1980. Terminating operations at MURR would adversely impact a situation that is described in Senate Bill S.242, "Department of Energy University Nuclear Science and Engineering Act," as a threat to health and national security.

Additionally, MURR supports research in other fields including life sciences, chemistry, archaeology and veterinary medicine. P-33 is increasingly being used to augment or replace P-32 in studies related to DNA mapping and other genomic studies. While not directly involved in cancer treatment, this isotope has great use in the biochemical and biological field.

Scientific programs performed at MURR include conducting research in archaeometry, epidemiology, health physics, human and animal nutrition, nuclear medicine, radiation effects, radioisotope studies, radiotherapy, and nuclear engineering. Research techniques, including neutron activation analysis, neutron and gamma-ray scattering, and neutron interferometry are used by the reactor staff.

The purpose and need for the renewal of the operating license for MURR is to provide an option that allows continued studies in nuclear-related undergraduate and graduate level degree programs along with continued production of radioactive isotopes for cancer treatment and research beyond the current term of the operating license. Due to the importance of the research being conducted at MURR, as well as the importance of the production of radioisotopes, the Board of Curators of the University is submitting a request for license renewal for a term of 20 years to permit operation until October 11, 2026.

1.2 Approach to Conducting the Environmental Reviews

NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Nuclear Reactors" (Reference 9.10), identifies that license renewal of research reactors is an action that requires an environmental assessment. The staff of MURR has prepared this Environmental Report (ER) to support the NRC's review of the environmental regulations pertinent to MURR's license renewal request.

Regulatory guidance for the preparation of ERs for research reactors is minimal. However, the guidance originating from the renewal of operating licenses for commercial nuclear power plants is both significant and comprehensive. To provide a thorough and comprehensive ER, MURR has used this guidance to identify and evaluate issues related to license renewal of a research reactor.

This ER has been prepared in accordance with Supplement 1 to Regulatory Guide 4.2, "Preparation of Supplemental Environmental Reports for Applications to Renew Nuclear Power Plant Operating Licenses" (Reference 9.12) and its companion document, NUREG-1555, Supplement 1, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants" (Reference 9.13). Information contained in NUREG-1437, "Generic Environmental Impact Statement (GEIS) for License Renewal of Nuclear Plants" (Reference 9.11) was reviewed for applicability to research reactors in general and MURR in particular. While the use of Supplement 1 to Regulatory Guide 4.2 and NUREG-1555 is not required, these documents provided guidance for comparison purposes only and to ensure a thorough review of any potential environmental issues that could be affected by the continued operation of the MU Research Reactor.

In the GEIS, the NRC presented the results of their review of the 92 issues that have the potential to be impacted by license renewal of nuclear power plants. As a result of this review, each of the 92 issues was placed into one of two categories. Category 1 issues (69) are those issues for which the NRC has determined that:

- Environmental impacts associated with the issue have been determined to apply to either all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

- A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for collective off-site radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal).

- Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

Category 2 issues (21) are those issues for which the potential environmental significance must be determined on a plant specific basis. The remaining two issues, chronic effects of exposure to electromagnetic fields and environmental justice were not categorized. The results of the NRC review are summarized in Table 9.1 of NUREG-1437 (Reference 9.11) and have been codified in 10 CFR 51, Appendix B to Subpart A (Reference 9.14).

The conclusions presented in the GEIS with respect to the review of the 92 issues are applicable to the license renewal of commercial nuclear power reactors and are not necessarily applicable to the license renewal of research reactors. Therefore, each of the 92 issues listed in 10 CFR 51 was evaluated to determine if there was any potential impact due to the license renewal of MURR. No credit was taken in this review for any of the conclusions drawn by the NRC in the GEIS. However, the reviews performed by the NRC to reach their conclusions were used.

To ensure a consistent format, the results of the review of the 92 issues described in 10 CFR 51 are discussed as outlined in Supplement 1 to Regulatory Guide 4.2, "Preparation of Supplemental Environmental Reports for Applications to Renew Nuclear Power Plant Operating Licenses" (Reference 9.12). Section 4.1 contains the results of the review of the 21 Category 2 issues and the 2 issues not categorized in NUREG-1437. Section 4.2 contains the results of the review of the 69 Category 1 issues. The Category 1 issues are grouped by area of potential impact similar to the groupings used in Appendix B to 10 CFR 51.

Because most of the Category 1 issues are not applicable to continued operation of MURR, grouping the issues reduces the verbiage and facilitates review of the document.

In all cases, sufficient information is provided for those issues that are applicable to continued operation of MURR to support the finding of no significant environmental impact. Where an issue has been determined not to be applicable, sufficient information to support that determination is provided in this ER. The results of the review for all 92 issues are summarized in Table 1-1. In addition to providing a summary of the conclusions regarding each issue, this table provides a reference/guide to the section within the ER where each of the issues applicable to license renewal of MURR is discussed. The Category 2 issues, which are identified in Table 1-1, are discussed in Section 4.1.

The remaining items that are applicable to the license renewal of MURR, which are identified next to the headings in Table 1-1 are discussed in Section 4.2.

MURR's evaluation of each of the 92 issues has determined that a specific issue is either: 1) not applicable to continued operation, 2) has no significant potential to impact the environment, or 3) has no significant impact on the environment. A detailed discussion of the results of the environmental review is provided in Section 4.1 and 4.2.

In addition to the 92 issues, MURR has reviewed the information in the facility's Safety Analysis Report (SAR) for any new or significant information that might represent an adverse impact on the environment. The Missouri University, State of Missouri, and local agencies were contacted to determine if any new or significant information had been discovered that might cause the operation of MURR to adversely impact the environment. In addition, the latest information related to population, land use, and other socioeconomic factors were reviewed to determine if any of this information represents an adverse environmental impact related to the continued operation of MURR. Based on this review, MURR has determined that there is no new or significant information related to potential environmental impacts resulting from operation of MURR for the period of the license renewal term. In addition, MURR has determined that the 92 issues identified in the GEIS encompass the scope of issues addressed in this ER.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Table 1-1 provides a summary of the results of the evaluation of all 92 issues related to potential environmental impact of license renewal for nuclear power plants. These 92 issues are listed in 10 CFR 51, Table B-1 in Appendix B to Subpart A.

Issue	GEIS Category	Summary of Results
Surface Water Quality, Hydrology and Use (Section 4.2.1)		
Impacts on surface water quality	1	N/A. The facility does not discharge water to a body of surface water. Erosion control measures are in effect. No major refurbishment is planned.
Impacts on surface water use	1	N/A. The facility does not use surface water. No major refurbishment is planned.
Altered current patterns at Intake or Discharge Str.	1	N/A. The facility does not have an Intake or Discharge Structure.
Altered salinity gradients	1	N/A. The facility does not discharge water to a body of surface water.
Altered thermal stratification of lakes	1	N/A. The facility does not discharge water to a lake or pond.
Temperature effects on sediment transport capacity	1	N/A. The facility does not discharge water to a body of surface water.
Scouring due to discharge of cooling water	1	N/A. The facility does not discharge cooling water.
Eutrophication	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on aquatic life.
Discharge of Chlorine or other biocides	1	N/A. The facility does not discharge cooling water containing chlorine, corrosion inhibitors, or other biocides to a body of surface water.
Discharge of sanitary wastes or minor chemical spills	1	N/A. Sanitary waste is discharged to a sewage treatment facility. The mitigation of chemical spills is addressed by MURR's Laboratory Safety Manual.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Discharge of metals in waste water	1	N/A. The facility uses a cooling tower and does not directly discharge water to a body of surface water. All discharges are to the sanitary sewer system.
Water use conflicts (plants with once-through cooling systems)	1	N/A. The facility does not have a once-through cooling system.
Water use conflicts (plants w/cooling towers and makeup from small body of water)	2	The facility does not obtain makeup from any body of surface water. Water use is minimal compared to availability. (See Section 4.1.1)

Aquatic Ecology (Section 4.2.2)

Refurbishment	1	N/A. The facility does not discharge water to a body of surface water. No major refurbishment activities are currently planned.
Accumulation of contaminants in sediment	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Entrainment of phyto-plankton & zooplankton	1	N/A. The facility does not obtain water from a body of surface water. There is no impact on Aquatic Ecology.
Cold shock	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Thermal plume barrier to migrating fish	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Distribution of aquatic organisms	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Premature emergence of aquatic insects	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Gas supersaturation (gas bubble disease)	1	N/A. The facility does not discharge gasses to a body of surface water.
Low dissolved oxygen in the discharge	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Losses among organisms exposed to sub-lethal doses	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.
Stimulation of nuisance organisms	1	N/A. The facility does not discharge water to a body of surface water. There is no impact on Aquatic Ecology.

Aquatic Ecology (Once-through and cooling pond heat dissipation systems) (Section 4.2.2)

Entrainment of fish and shellfish in early life stages (refurbishment activities)	2	N/A. The facility does not use a once-through cooling system; nor does it use a cooling pond. (See Section 4.1.2)
Impingement of fish and shellfish (refurbishment activities)	2	N/A. The facility does not use a once-through cooling system; nor does it use a cooling pond. (See Section 4.1.3)
Heat shock (refurbishment activities)	2	N/A. The facility does not use a once-through cooling system; nor does it use a cooling pond. (See Section 4.1.4)
Entrainment of fish and shellfish in early life stages	1	N/A. The facility does not use a once-through cooling system; nor does it use a cooling pond.

TABLE 1-1
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Issue	GEIS Category	Summary of Results
Heat shock	1	N/A. The facility does not use a once-through cooling system; nor does it use a cooling pond.

Groundwater Use and Quality (Section 4.2.3)

Groundwater use and quality	1	The quantity of groundwater used by the facility is very small compared to that used by the entire University campus.
Groundwater use conflicts (plant use < 100 gpm)	1	N/A. Facility uses < 100 gpm. Water is obtained from an extensive aquifer. Facility's use is negligible.
Groundwater use conflicts (plant use > 100 gpm)	2	N/A. Facility uses < 100 gpm during normal operation. (See Section 4.1.5)
Groundwater use conflicts (cooling tower w/makeup from small stream)	2	N/A. Cooling tower make-up water is not obtained from small stream. (See Section 4.1.6)
Groundwater use conflicts (Plants with Ranney Wells)	2	N/A. The facility does not use Ranney Wells. (See Section 4.1.7)
Groundwater quality degradation (Plants with Ranney Wells)	1	N/A. The facility does not use Ranney Wells.
Groundwater quality degradation (saltwater intrusion)	1	N/A. The facility is not located near a body of saltwater. Saltwater is not used at the facility.
Groundwater quality degradation (cooling ponds in saltwater marshes)	1	N/A. The facility is not located near a salt marsh.
Groundwater quality degradation (cooling ponds at inland sites)	2	N/A. The facility does not have a cooling pond. (See Section 4.1.8)

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Terrestrial Resources (Section 4.2.4)		
Refurbishment impacts	2	The facility plans a building addition during the time of license renewal that is not directly related to operation of the reactor. Only maintenance and minor modification activities will be performed during the license renewal term. (See Section 4.1.9)
Cooling tower impacts on crops and ornamental vegetation	1	N/A. Given the location and small size of the cooling tower, its operation has a negligible impact on crops or ornamental vegetation in the area.
Cooling tower impacts on native plants	1	N/A. Given the location and small size of the cooling tower, its operation has a negligible impact on vegetation in the area.
Bird collisions with cooling towers	1	N/A. The cooling towers are relatively small. They do not have a strong updraft. Bird collisions do not occur.
Cooling pond impacts on terrestrial resources	1	N/A. The facility does not have a cooling pond.
Power line right-of-way management	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Bird collisions with power lines	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Impacts of electromagnetic fields on flora & fauna	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Floodplains & wetlands on power line right-of-way	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Threatened or Endangered Species (Section 4.2.5)		
Threatened or endangered species	2	Refer to Section 4.1.10.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Air Quality (Section 4.2.6)		
Air quality during refurbishment activities	2	No major refurbishment activities are planned during the license renewal term. (See Section 4.1.11)
Air quality effects of transmission lines	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Land Use (Section 4.2.7)		
Onsite land use	1	No additional use of land is expected during the license renewal term.
Power line right of way	1	N/A. The facility does not produce electricity. There are no power transmission lines.
Human Health (Section 4.2.8)		
Public radiation exposure during refurbishment	1	N/A. No major refurbishment activities are planned to support license renewal and only maintenance and modification activities are anticipated during the license renewal term.
Occupational radiation exposure - refurbishment	1	N/A. No major refurbishment activities are planned to support license renewal and only maintenance and modification activities are anticipated during the license renewal term.
Microbiological Organisms (Occupational Health)	1	Not a concern due to occupational health practices implemented at the facility.
Microbiological Organisms (Public Health)	2	See Section 4.1.12.
Noise	1	N/A. The facility is small and does not have a turbine. It makes very little noise.
Electromagnetic fields, acute effects	2	N/A. The facility does not generate electricity or electromagnetic fields. (See Section 4.1.13)

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Electromagnetic fields, chronic effects	No Category	N/A. The facility does not generate electricity or electromagnetic fields. (See Section 4.1.13)
Public radiation exposure (license renewal term)	1	Radiation dose to the general public is small and will remain small throughout the license renewal period.
Occupational radiation exposure - license renewal	1	Occupational radiation doses are very small. They are expected to remain very small.

Socioeconomics (Section 4.2.9)

Housing impacts	2	See Section 4.1.14.
Public services, safety, social services, tourism & recreation	1	This small and unobtrusive research reactor, located on a college campus, does not affect public services, tourism, or recreation.
Public services, public utilities	2	The water use at the facility is negligible and has little impact on the public water supply or public utilities. (See Section 4.1.15)
Public services, education (refurbishment activities)	2	N/A. No major refurbishment activities are planned during the license renewal term. Only minor modifications are planned. (See Section 4.1.16)
Public services, education (license renewal term)	1	The facility is a research reactor that has a positive impact on education.
Offsite land use (refurbishment)	2	N/A. No major refurbishment activities are planned during the license renewal term. Only minor modifications are planned. (See Section 4.1.17)
Offsite land use (license renewal term)	2	No population or tax revenue changes are expected during the license renewal term. (See Section 4.1.17)

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Public services (transportation)	2	No significant numbers of people are, or will be, employed at the site. (See Section 4.1.18)
Historic & archaeological resources	2	No major refurbishment activities are planned during the license renewal term. (See Section 4.1.19)
Aesthetic impacts (refurbishment)	1	N/A. No major refurbishment activities are planned during the license renewal term.
Aesthetic impacts (license renewal term)	1	Due to its small size, design, and location on a college campus, there is no aesthetic impact.
Aesthetic impacts (transmission lines)	1	N/A. The facility does not generate electricity and has no transmission lines.

Postulated Accidents (Section 4.2.10)

Design basis accidents	1	Due to the reactor's inherently safe design, the consequences of a design basis accident have a negligible environmental impact.
Severe accidents	2	The facility has analyzed the Maximum Hypothetical Accident. This analysis demonstrates that no adverse environmental impact would result. (See Section 4.1.20)

Uranium Fuel Cycle and Waste Management (Section 4.2.11)

Offsite radiological impacts - individual, not due to fuel or high-level waste disposal	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
Offsite radiological impacts - collective, not from fuel or high-level waste	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Offsite radiological impacts - fuel and high-level waste	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
Non-radiological impacts of uranium fuel cycle	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
Low-level waste storage and disposal	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
Mixed waste storage and disposal	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
On-site spent fuel	1	N/A. The facility does not permanently store spent fuel on-site. Spent fuel will not be permanently stored on-site during the license renewal term.
Non-radiological waste	1	Refer to Section 4.2.11 for a summary of the results of the environmental review.
Transportation	2	See Section 4.1.21.

Decommissioning (Section 4.2.12)

Radiation doses	1	Doses to the public have been shown to be significantly below established limits during facility operation. Occupational doses are not expected to increase during the license renewal term.
Waste management	1	The additional 20 years of operation would produce no additional solid waste to be disposed of during decommissioning. All waste is removed as it is generated.
Air quality	1	Operating the facility has no impact on air quality now or during the license renewal term.

TABLE 1-1
SUMMARY OF RESULTS OF THE REVIEW OF NEPA ISSUES

Issue	GEIS Category	Summary of Results
Water quality	1	N/A. Operation of the facility has no adverse impact on water quality now or during the license renewal term.
Ecological resources	1	Operation of the facility has no ecological impact now or during the license renewal term.
Socioeconomic impacts	1	Operation of the facility has minimal socioeconomic impacts now or during the license renewal term.

Environmental Justice (Section 4.1.22)

Environmental justice	No Category	See Section 4.1.22.

2.0 SITE AND ENVIRONMENTAL INTERFACES

2.1 Site Description

The Missouri University Research Reactor (MURR) is situated on a 7.5 acre lot in the central portion of the University Research Park, an 84-acre tract of land approximately one mile southwest of the Missouri University at Columbia (MU) main campus. The Research Park is an extension of the Missouri University campus and borders the campus to the South as shown in Figure 2.2. The site location latitude and longitude coordinates are 38° 55' 53" North Latitude, 92° 20' 31" West Longitude (Reference 9.1). The site location Universal Transverse Mercator (UTM) coordinates are Zone 15, 4,309,362 meters North and 557,037 meters East (Reference 9.1).

The University Research Park provides a buffer between the reactor and residences in the area. The Research Park consists of a number of research buildings that are occupied only part time and by a limited number of scientists and researchers.

The MU campus is situated in the southern portion of Columbia, Missouri. Columbia is the county seat and largest city in Boone County. Boone County is located in the central part of the state and consists of an area of approximately 683 square miles (1,769 square km) and is approximately 41 miles (66 km) in its greatest north-to-south length and 22 miles (35.4 km) in its greatest east-to-west width. The southwestern border of Boone County is formed by the Missouri River, and the southeastern border is formed almost entirely by one of its small tributaries (Cedar Creek).

The reactor facility is situated approximately 1.5 miles (2.4 km) south-by-southwest of downtown Columbia, Missouri. The City of Columbia currently (2006) has a population of approximately 91,885 residents (based on 2000 U.S. Census Bureau statistics and adjusted by an annual population growth of 1.4%). In addition, another 30,000 college students live in Columbia during the school year (Table 2-6). Approximately 100,192 people live within a 5-mile (8-km) radius of the reactor facility (Table 2-5) and an estimated 132,310 people will live within that area in 2026 (projected from the 2000 census statistics). This 5-mile radius encompasses nearly the entire city as well as parts of the outlying metropolitan area. The nearest permanent residence is located approximately 2,500 feet (762 m) north of the reactor facility near Stadium Boulevard (State Highway 740) on Brandon Road.

Table 2-1 provides the total population within 5 miles (8 kilometers) of the facility. The numbers are provided for each of 5 concentric rings (annuluses) around the facility.

Existing land uses within each concentric ring can generally be described as follows (Reference 9.1):

0 to 1 kilometer: There is very little residential development within 1 kilometer of the reactor facility site. Most of the land is owned by the Missouri University. Recreational areas include a golf course to the west and a park to the south. Also located within this area are three major University sports venues; Memorial Stadium/Faurot Field (62,000 seats), Mizzou Arena (15,061 seats) and Hearnes Center (13,300 seats).

1 to 2 kilometers: The major residential areas are located to the north, northwest, and south. A shopping center, business district, two hospitals, and a large portion of the MU's main campus are located within this area. With the exception of a small area to the southeast, there is no room for any substantial residential or nonresidential (industrial, commercial, or business) development.

2 to 4 kilometers: The major residential areas are located in the northern half and the southwest. A shopping center, business district, two hospitals, two colleges, three high schools, three middle/junior high schools, and nine elementary schools are located in this area. Recreational areas include two golf courses and eight parks. The downtown area of Columbia, which consists mainly of government offices and retail, commercial, and business uses, is located to the northeast. Development should continue within this area, probably to the south of the reactor facility.

4 to 6 kilometers: Most residential development is within the northern half. Three shopping centers, two hospitals, one middle/junior high school, three elementary schools, and an industrial park are located in this area. Recreational areas include two golf courses and five parks. Substantial amounts of land exist for residential or commercial development.

6 to 8 kilometers: The only substantial residential development is to the northeast. A shopping center, two middle/junior high schools, and four elementary schools are located in this area. Recreational areas include one park. Substantial amounts of land presently exist for residential or commercial development.

The land use pattern of the city is shaped by market forces and the available or proposed infrastructure (i.e., roadways, sewers, water, electricity, and fire and police protection). The City of Columbia tends to promote a mix of land uses instead of focusing on the separation of uses. However, based strictly upon the availability of land for development, most of the projected residential growth should occur within the four to eight kilometer (2.5 to 5 miles from the facility) rings (Reference 9.1).

TABLE 2-1
POPULATION DISTRIBUTION WITHIN 8 KILOMETERS OF THE REACTOR FACILITY (2006 Projected) [d]

Distance From Facility [a]	Area (sq. km)	Population [b]	Population [c]
0 to 1 kilometer	3.14	255	255
1 to 2 kilometers	9.42	16,060	16,315
2 to 4 kilometers	37.70	39,820	56,135
4 to 6 kilometers	62.83	29,506	85,641
6 to 8 kilometers	87.96	14,551	100,192
Total	201.06		100,192

[a] Represents the area surrounding the reactor facility as divided into a series of concentric rings.
[b] Population within each concentric ring.
[c] Cumulative population to a distance of 8 kilometers.
[d] Population based on 2000 U.S. Census Bureau statistics and adjusted by an annual population growth of 1.4%.

Table 2-2 provides the historical and the projected population growth for the City of Columbia. Population growth for the city is projected to be approximately 1.4% annually. This value was provided by the Chamber of Commerce and is based on economic development within the region. Student enrollment is difficult to project but should remain relatively constant.

TABLE 2-2
HISTORICAL AND PROJECTED POPULATION GROWTH FOR THE CITY OF COLUMBIA

Population	Year							
	1950	**1960**	**1970**	**1980**	**1990**	**2000**	**2006**	**2026**
Resident	25,335	36,650	58,557	62,061	69,101	84,531	91,885	121,340
Student [a]	10,909	13,191	24,184	27,228	29,496	30,000	30,000	30,000
Total	36,244	49,841	82,741	89,289	98,597	114,531	121,885	151,340

[a] Student enrollment includes the Missouri University, Stephens College, and Columbia College (Prior to 1970, Columbia College was named Christian College).

Due to the seasonal occupation of certain buildings, significant population variations do occur. Approximately 8,300 of the nearly 30,000 college students reside in residence halls or Greek houses. These buildings are located within 4 kilometers of the reactor facility and would only be occupied when school is in session. Memorial Stadium is located approximately 1 km northeast of the reactor facility and has a seating capacity of 62,000. The stadium is occupied five or six afternoons per year during football season for approximately four hours. The Hearnes or Mizzou arenas are, at most, occupied several times per week but are rarely occupied at the same time as Memorial Stadium.

Boone County's economy is based primarily on government (which includes the Missouri University), retail, and services with smaller contributions by such things as medical facilities (hospitals and clinics), insurance, agriculture, and manufacturing. The Missouri University at Columbia is the area's largest employer, with a total employment of 11,868, the majority of whom work on the University's main campus in Columbia, with the rest employed at various branch campuses throughout the state. MURR employs approximately 140 people to operate the reactor and conduct research. In addition, the MURR staff is often supplemented by visitors from the scientific and medical communities who participate in the research and development of radiopharmaceuticals.

All water used by MURR is obtained from wells owned and operated by the Missouri University. The volume of water used by MURR is a small percentage of the total capacity of these wells. If conditions such as equipment failure occur which require MURR to obtain water from the City of Columbia water supply system, the volume of water necessary to operate MURR represents a negligible drain on this system. The underground formations that supply water to the deep wells in the Columbia metropolitan area are generally referred to as the Ozark Aquifer.

MURR has a secondary coolant system that uses a mechanical draft cooling tower to dissipate the heat generated by the reactor core. This cooling system does not directly discharge water to a body of surface water.

2.2 Physiography

Boone County lies along the northern Ozark Border of the state. Crop production is confined primarily to valley bottoms and lower slopes. Corn, soybeans, and winter wheat, in general, are the most prevalent crops of the region. Livestock also has significant importance because much of the land is poorly adapted for row cropping.

The county contains a variety of topographic features, ranging from rugged maturely dissected hills to flat flood plains and flat uplands, and can be divided into four physiographic regions: the Centralia uplands, a flat upland plain 850 feet (259 m) above sea level; the Columbia dissected uplands; the Ashland hills; and the Missouri River flood plain, the latter being in the extreme southern tip of the County.

All of Boone County eventually drains into the Missouri River. The Missouri River flood plain varies in width, but along much of the southwestern part of the County, it is about 2 miles (3.2 km) wide. Perche Creek is the largest stream in the county, entering near the northwestern corner of the County and flowing southward across the western half. On the Missouri River flood plain, the creek meanders southeastward and parallels the Missouri river for about 5 miles before flowing into it near a location where the river approaches a steep bluff. The majority of the northern half of Boone County, including the City of Columbia and the reactor facility site, lies within the Perche Creek drainage basin. Principal tributaries of Perche Creek near MURR include the Hinkson, Grindstone, Flat Branch, and Hominy Creeks.

2.3 Major Highways

The City of Columbia is at the crossroads of two major highways: Interstate Highway 70 (I-70), and U.S. Highway 63. I-70 extends east-to-west across the United States from Baltimore, Maryland to an intersection with I-15 in Utah. This highway crosses the middle of Boone County and provides connections between St. Louis and Kansas City. U.S. Highway 63 extends north and south across the mid-length of the county, connecting with Jefferson City to the south and with U.S. Highway 24 at Moberly to the North.

The reactor facility is located on Research Park Drive approximately 3.5 miles (5.6 km) southwest of the I-70/U.S. Highway 63 intersection. In addition to these two main highways, there are numerous state highways, state routes, and secondary roads making most sections of Boone County easily accessible. Figure 2.1 presents a map of Boone County, Missouri that identifies the location of MURR with respect to major highways, rivers, and municipalities in the vicinity of the facility.

TABLE 2-3
MAJOR LAND TRANSPORTATION ROUTES WITHIN 5 MILES OF THE REACTOR FACILITY

Highway Name	Location From Reactor Facility		
	Miles	Kilometers	Direction
Interstate Highway 70 (I-70)	2.5	4.0	N
State Highway 763	2.3	3.7	N
U.S. Highway 63	2.4	3.9	E
State Highway 740	0.4	0.6	N
State Highway 163	0.2	0.3	E

2.4 Operational Boundaries

There are three defined areas surrounding the facility which involve the normal operation, safety, and emergency actions associated with the reactor facility: the area within the operations boundary; the area within the site boundary; and the Emergency Planning Zone (EPZ).

The operations boundary is a restricted access area and consists of the outer walls of the Research Reactor Facility (laboratory and reactor containment buildings). In addition, the adjacent cooling tower building is contained within the restricted access area. The operations boundary is within the site boundary.

The site boundary consists of the following: Stadium Boulevard; Providence Road (Route K); the MU Recreation Trail; and the former Missouri-Kansas-Texas (MKT) Railroad bed. The area within these boundaries is owned and controlled by the Missouri University and may be frequented by people unacquainted with the operation of the reactor.

An Emergency Planning Zone (EPZ) has been established for which emergency plans have been developed to ensure that prompt and effective actions can be taken to protect the public in the event of an accident. The EPZ for MURR is the area bounded by a 150-meter radius from the reactor facility ventilation exhaust stack and lies completely within the site boundary (Reference 9.1). Figure 2.2 shows the configuration and the main features within the MURR EPZ.

2.5 Climatology

2.5.1 General

Central Missouri's location within the North American continent places it in the Humid Continental – Warm Summer climatic zone. This type of climate has a characteristic long, warm summer with moderate relative humidity. The winters are cool to cold and mark a period of lower precipitation than during the remainder of the year. Columbia, Missouri, with its interior continental location, experiences moderately cold winters and warm summers that are often humid. The official weather station for Columbia is located at the Columbia Regional Airport, elevation 880 feet (268 m) above sea level, approximately 10 miles (16km) southeast of the reactor facility.

2.5.2 Temperature

The lowest temperature recorded occurred in December 1989 with a temperature of -20.0° F, while the warmest daily high temperature was 111°F, occurring in July 1980. The normal and extreme temperatures for the City of Columbia are shown in Table 2-1.

TABLE 2-1
NORMAL AND EXTREME TEMPERATURES FOR COLUMBIA, MISSOURI

Temperature (°F)							
Normal				Extreme			
Month	Daily Max.	Daily Min.	Monthly	Record High	Year	Record Low	Year
Jan	36.5	19.3	29.6	74	1989	-19	1982
Feb	43.0	24.4	33.2	82	1972	-15	1979
Mar	54.0	33.6	43.3	85	1986	-5	1978
Apr	65.6	44.0	54.9	90	1987	19	1975
May	74.1	53.4	64.4	92	1998	29	1976
Jun	82.8	62.2	73.4	103	1988	40	1993
Jul	88.3	67.0	77.9	111	1980	48	1975
Aug	86.9	65.0	76.4	110	1984	42	1986
Sept	78.9	56.6	68.7	101	1971	29	2003
Oct	67.2	45.3	57.5	93	1981	22	1993
Nov	52.9	34.5	44.1	83	1978	0	1991
Dec	41.3	24.2	33.2	76	1991	-20	1989
Year	64.3	44.1	54.7	111	1980	-20	1989

Data obtained by 2004 National Climate Data Center (NCDC) Local Climatological Data, Asheville, North Carolina.

2.5.3 Precipitation

In Columbia, Missouri, the late spring and early summer months produce more frequent and larger amounts of rain than the other months of the year. By late summer smaller amounts of rain fall and rains occur less frequently, so by mid August, the moisture in the top 2 feet of soil is often depleted. The average annual precipitation in Columbia is 40.28 inches per year. The maximum twenty four hour total for the 30 year period was 5.95 inches, which occurred in July 1989. The normal and extreme precipitation totals for the City of Columbia are shown in Table 2-2.

TABLE 2-2
NORMAL AND EXREME PRECIPITATION FOR COLUMBIA, MISSOURI

Precipitation (inches)							
Normal		Extreme					
Month	Monthly Avg.	Record Max.	Year	Record Min.	Year	24 hour Max.	Year
Jan	1.73	4.78	1995	0.05	1986	2.06	2001
Feb	2.20	6.18	1985	0.11	1991	2.88	1985
Mar	3.21	10.09	1973	0.78	1971	4.03	1990
Apr	4.16	11.69	1994	0.89	2000	4.50	1996
May	4.87	12.31	1995	1.43	1998	5.73	1995
Jun	4.02	10.28	1985	0.35	1980	3.87	1995
Jul	3.80	12.14	1981	0.24	1976	5.95	1989
Aug	3.75	9.10	2000	0.21	1976	5.43	1993
Sept	3.42	12.06	1993	0.45	1979	3.81	1986
Oct	3.18	7.28	1998	1.03	1992	4.94	1998
Nov	3.47	10.42	1985	0.42	1989	2.97	1983
Dec	2.47	6.96	1982	0.48	1996	2.88	1982
Year	40.28	12.31	May-95	0.05	Jan-86	5.95	Jul-89

Data obtained by 2004 National Climate Data Center (NCDC) Local Climatological Data, Asheville, North Carolina.

2.5.4 Humidity

The mean relative humidity for the Columbia area is 72%. The lowest value occurs in April (66%) while the highest occurs in December (75%). The monthly and average annual relative humidity during the 30-year reporting period for 6:00 a.m., noon, 6:00 p.m., and midnight are shown in Table 2-3.

TABLE 2-3
RELATIVE HUMIDITIES FOR COLUMBIA, MISSOURI

Relative Humidity (%)													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Normal	74	72	67	66	72	73	72	73	72	70	72	75	72
Hour 06 LST	80	81	79	79	86	87	88	89	88	85	82	82	84
Hour 12 LST	67	64	58	56	61	60	58	57	58	57	63	69	61
Hour 18 LST	70	66	58	55	61	62	60	61	64	62	68	71	63
Hour 24 LST	76	76	72	71	80	83	83	83	81	77	77	78	78

Data obtained by 2004 National Climate Data Center (NCDC) Local Climatological Data, Asheville, North Carolina. LST = Local Sidereal Time.

2.5.5 Winds

The wind data for Columbia is given in Table 2-4. The maximum 2-minute and 5-second wind speeds are based on a 9-year period of record.

TABLE 2-4
WIND DATA FOR COLUMBIA, MISSOURI

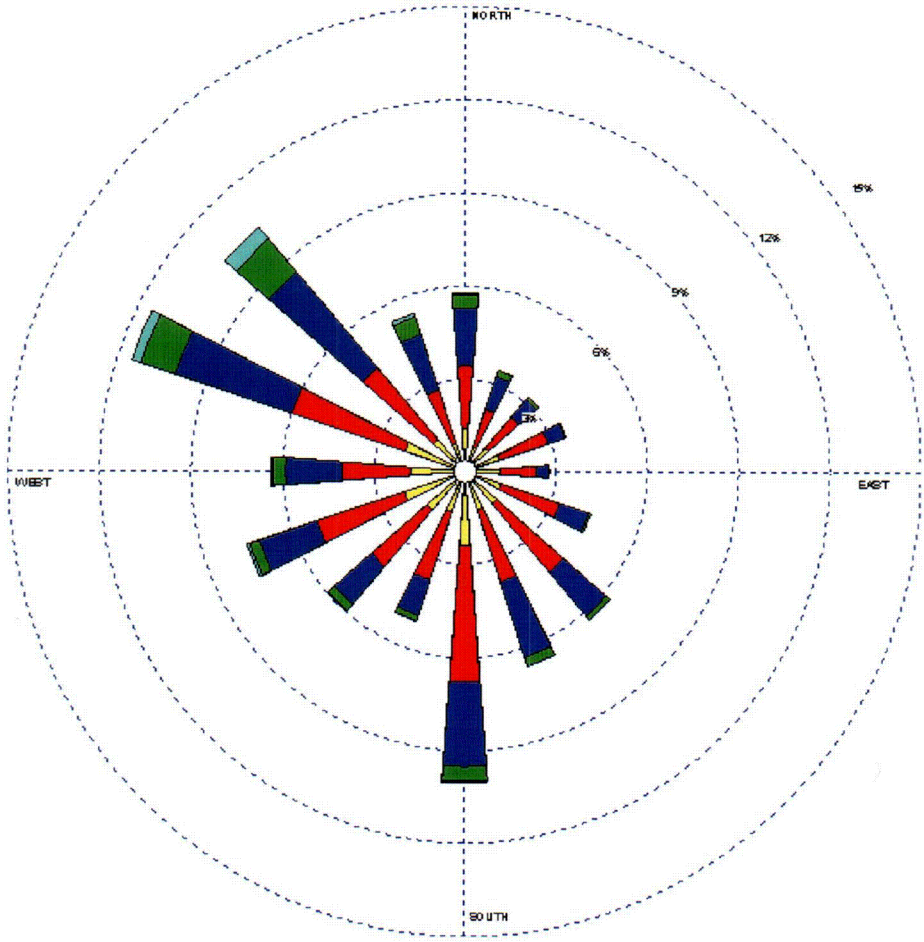
Wind							
		Maximum 2-Minute			**Maximum 5-Seconds**		
Month	**Speed (mph)**	**Speed (mph)**	**Dir (degs)**	**Year**	**Speed (mph)**	**Dir (degs)**	**Year**
Jan	10.8	41	230	1996	49	220	1996
Feb	10.6	41	160	2001	51	160	2001
Mar	11.6	41	220	2004	49	220	2004
Apr	11.4	54	250	2002	68	250	2001
May	9.2	39	310	2000	48	310	2003
Jun	8.5	44	220	1998	52	170	1998
Jul	8.0	44	290	2003	55	270	2003
Aug	7.7	59	180	2003	81	180	2003
Sept	8.5	38	190	2003	46	190	2003
Oct	9.3	47	210	1996	59	210	1996
Nov	10.5	45	20	1998	53	10	1998
Dec	10.6	37	200	1997	45	200	1997
Year	9.7	59	180	Aug-03	81	250	Aug-03

Data obtained by 2004 National Climate Data Center (NCDC) Local Climatological Data, Asheville, North Carolina.

The following monthly wind roses were obtained at the weather station located at Columbia Regional Airport. The wind roses clearly show a prevailing southerly wind direction with some instances, depending on the season, in which the winds will generally blow from the northwest.

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	Sara West	10/29/2002	USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 5.09 m/s	CALM WINDS 1.63%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Jan 1 - Jan 31 Midnight - 11 PM	

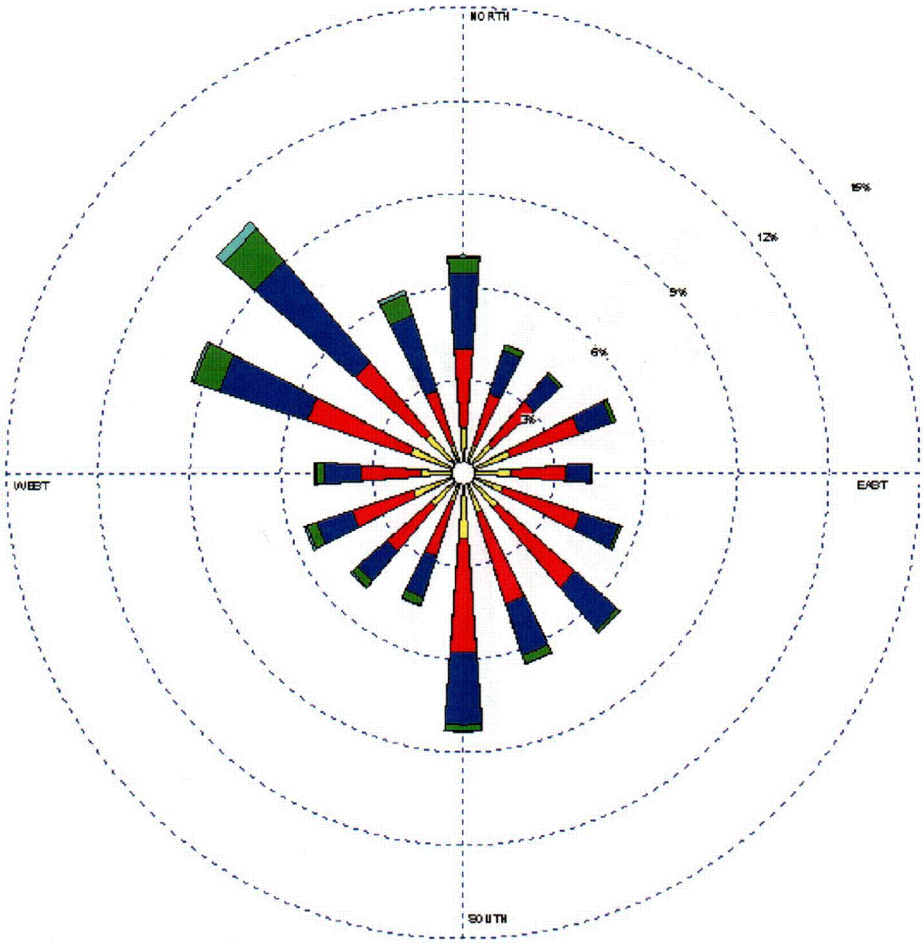
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com

Month of January

C-01

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s): > 11.06; 8.49 - 11.06; 5.40 - 8.49; 3.34 - 5.40; 1.80 - 3.34; 0.51 - 1.80	MODELER: Sara West	DATE: 10/29/2002	COMPANY NAME: USDA-ARS
	DISPLAY: Wind Speed	UNIT: m/s	COMMENTS
	AVG. WIND SPEED: 5.03 m/s	CALM WINDS: 1.58%	
	ORIENTATION: Direction (blowing from)	PLOT YEAR-DATE-TIME: 1961 Feb 1 - Feb 29 Midnight - 11 PM	

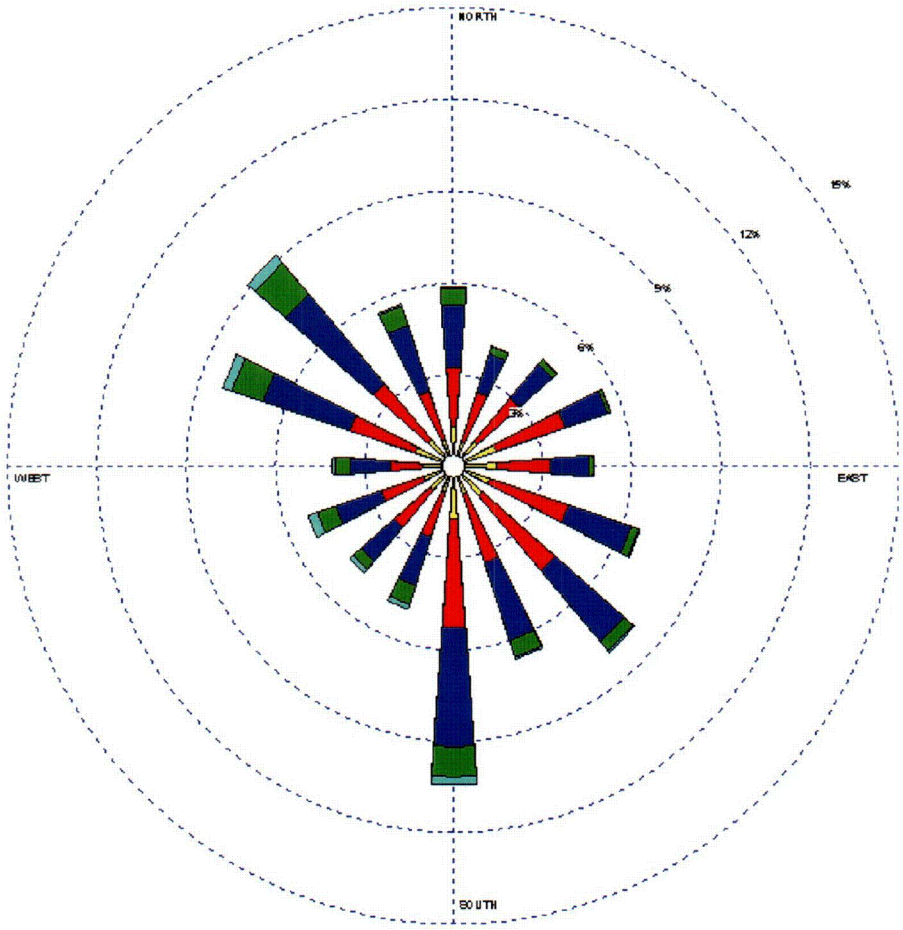
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environmental.com

Month of February

C-02

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	Sara West	10/29/2002	USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 5.54 m/s	CALM WINDS 1.54%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Mar 1 - Mar 31 Midnight - 11 PM	

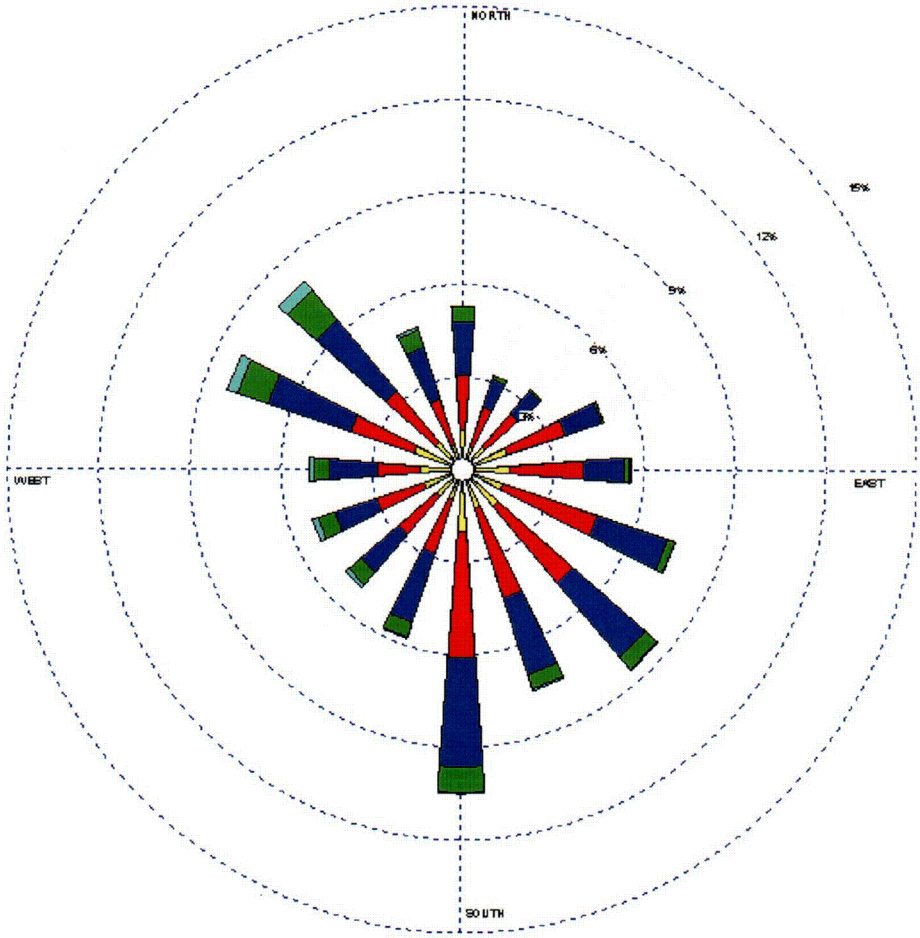
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com

Month of March

C-03

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY	UNIT	COMMENTS
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	AVG. WIND SPEED	CALM WINDS	
1.80 - 3.34	5.36 m/s	1.30%	
0.51 - 1.80	ORIENTATION	PLOT YEAR-DATE-TIME	
	Direction (blowing from)	1961 Apr 1 - Apr 30 Midnight - 11 PM	

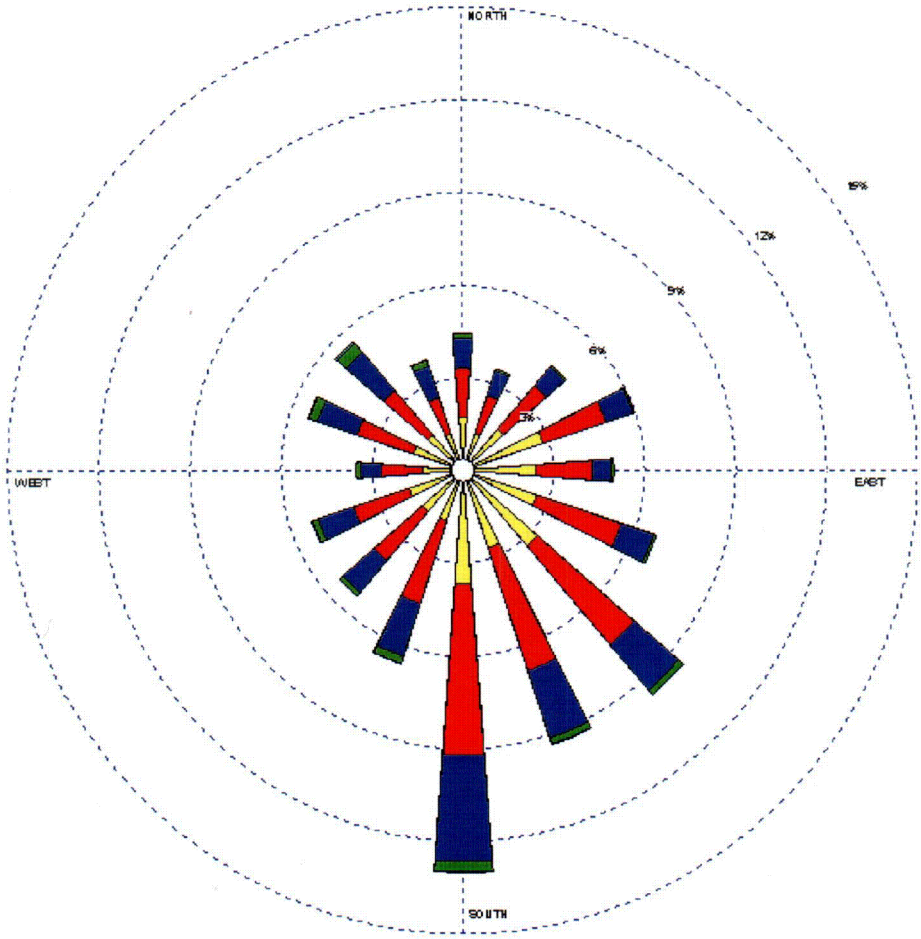
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environmental.com

Month of April

C-04

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO

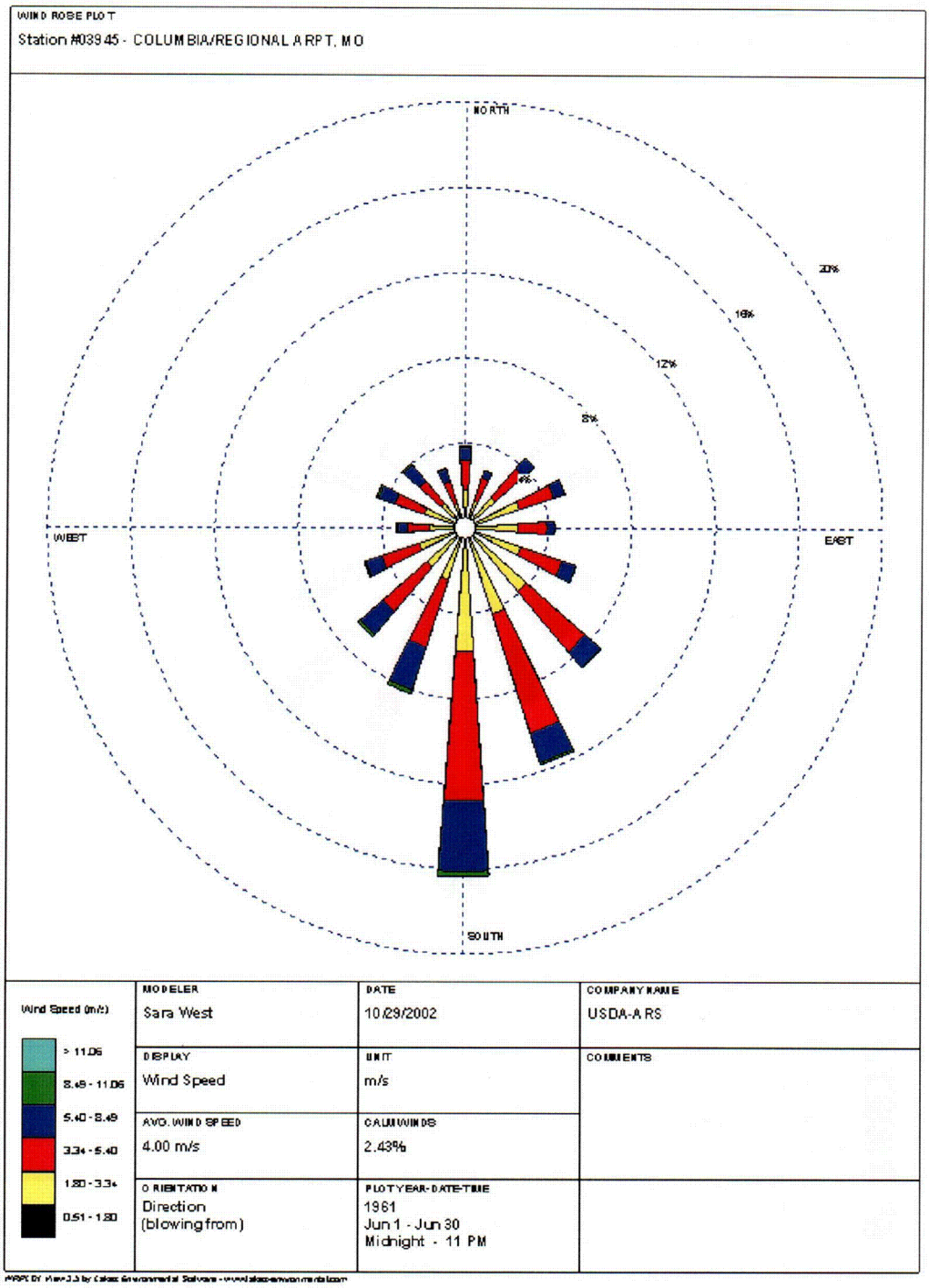


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	Sara West	10/29/2002	USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 4.43 m/s	CALM WINDS 2.43%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 May 1 - May 31 Midnight - 11 PM	

WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environmental.com

Month of May

L-05

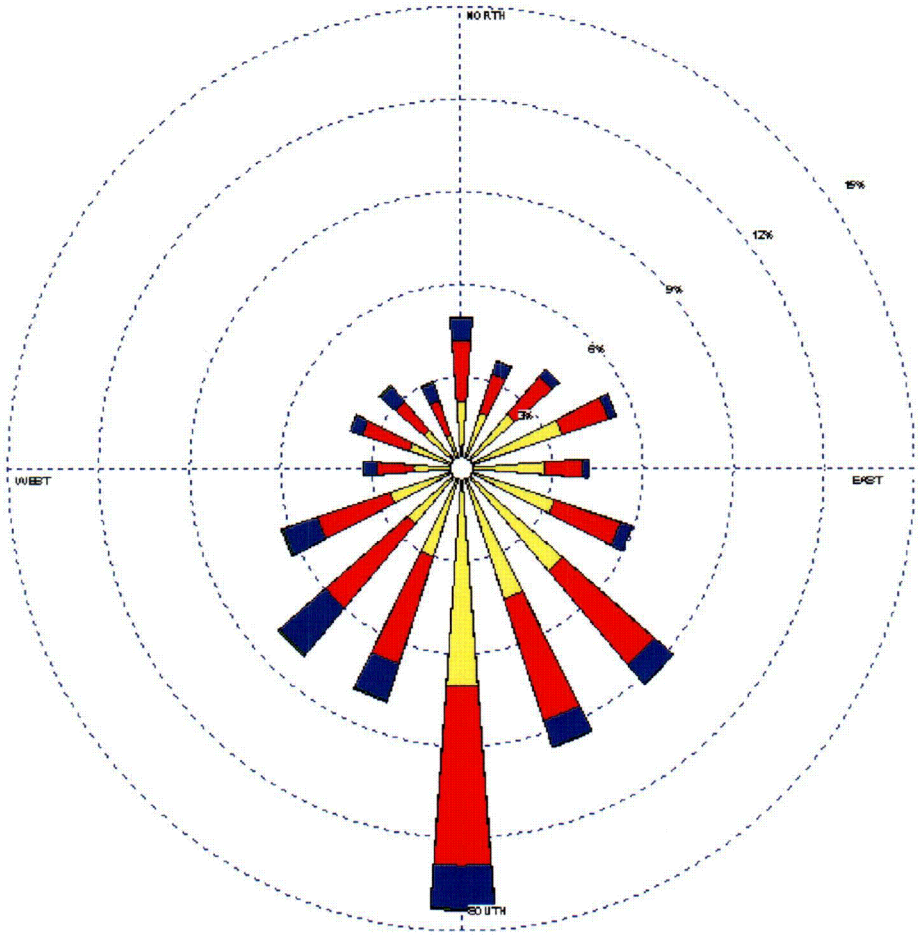


Month of June

C-06

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	Sara West	10/29/2002	USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 3.76 m/s	CALM WINDS 2.27%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Jul 1 - Jul 31 Midnight - 11 PM	

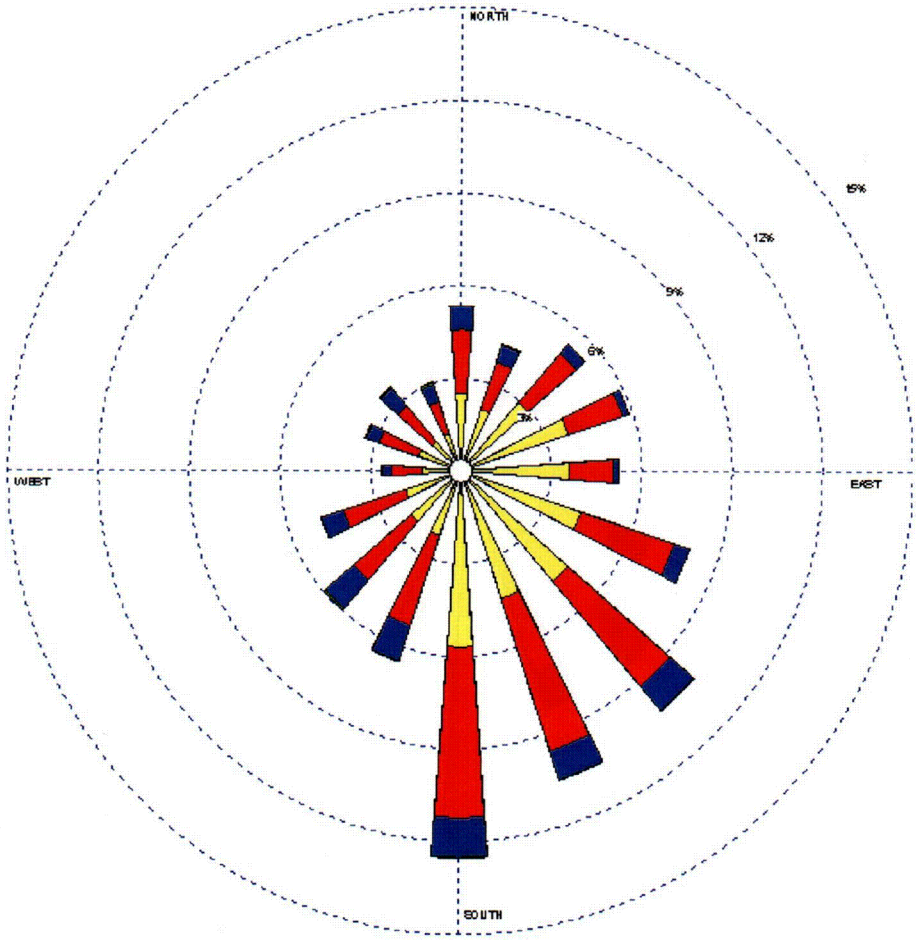
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com

Month of July

1.07

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY	UNIT	COMMENTS
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	AVG. WIND SPEED	CALM WINDS	
1.80 - 3.34	3.73 m/s	2.48%	
0.51 - 1.80	ORIENTATION	PLOT YEAR-DATE-TIME	
	Direction (blowing from)	1961 Aug 1 - Aug 31 Midnight - 11 PM	

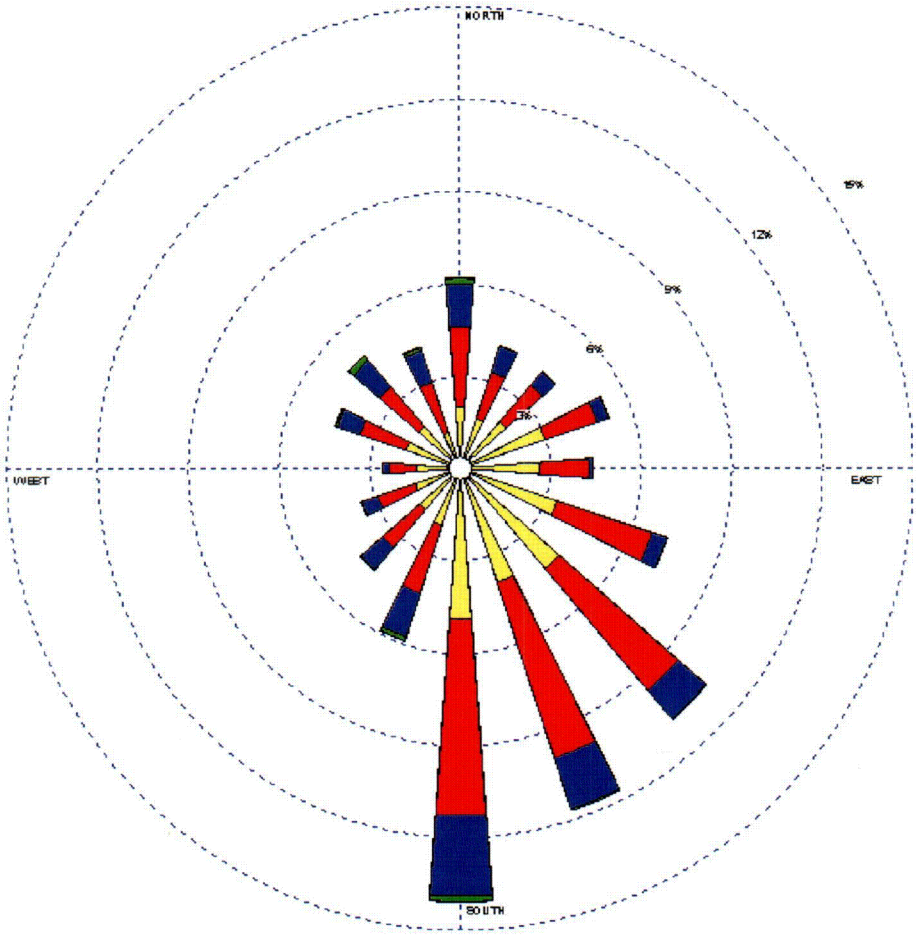
WRPLOT View 3.3 by Lakes Environmental Software - www.lakesenvironmental.com

Month of August

C-08

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY	UNIT	COMMENTS
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	AVG. WIND SPEED	CALM WINDS	
1.80 - 3.34	4.01 m/s	2.18%	
0.51 - 1.80	ORIENTATION	PLOT YEAR-DATE-TIME	
	Direction (blowing from)	1961 Sep 1 - Sep 30 Midnight - 11 PM	

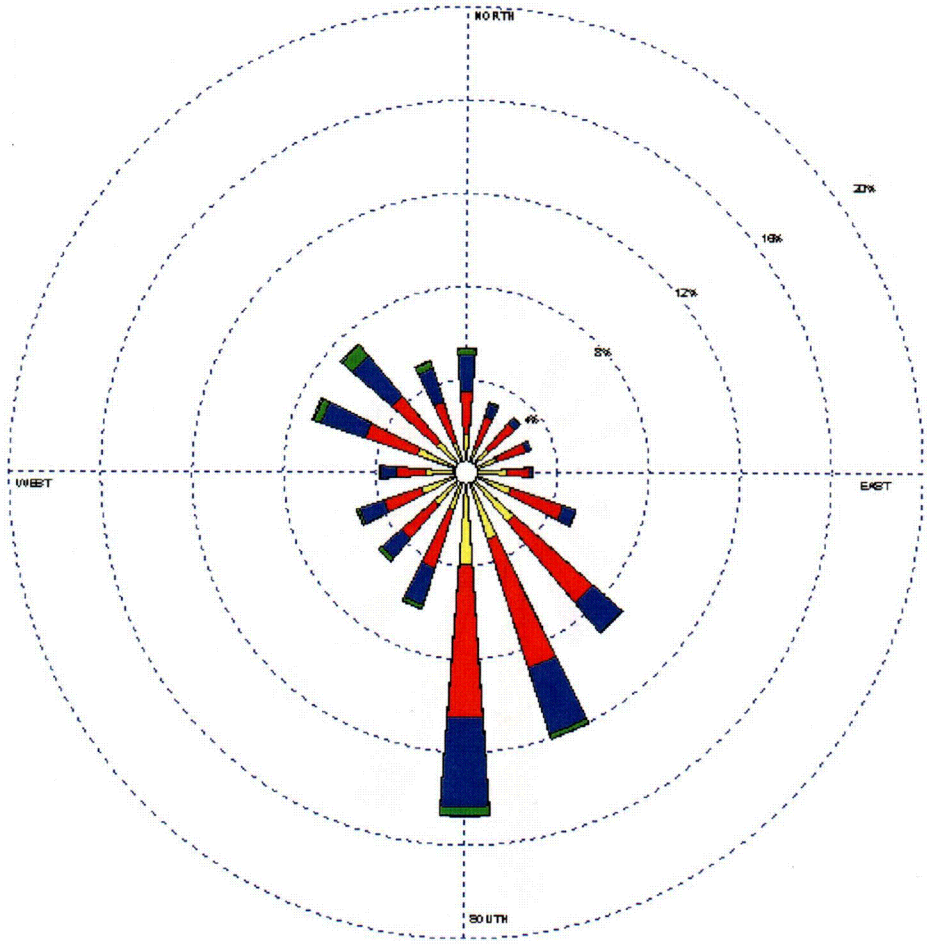
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com/wrplotview

Month of September

c-09

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	Sara West	10/29/2002	USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 4.48 m/s	CALM WINDS 1.77%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Oct 1 - Oct 31 Midnight - 11 PM	

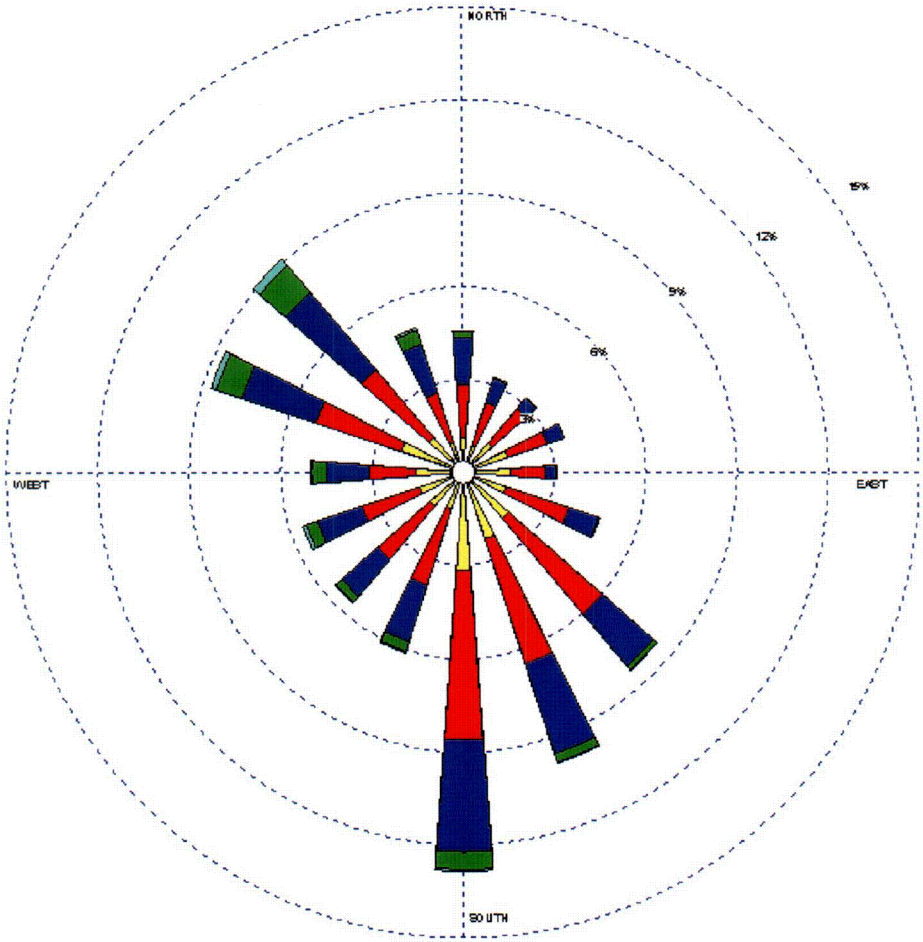
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com/wrplot.htm

Month of October

C-10

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY	UNIT	COMMENTS
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	AVG. WIND SPEED	CALM WINDS	
1.80 - 3.34	4.90 m/s	1.54%	
0.51 - 1.80	ORIENTATION	PLOT YEAR-DATE-TIME	
	Direction (blowing from)	1961 Nov 1 - Nov 30 Midnight - 11 PM	

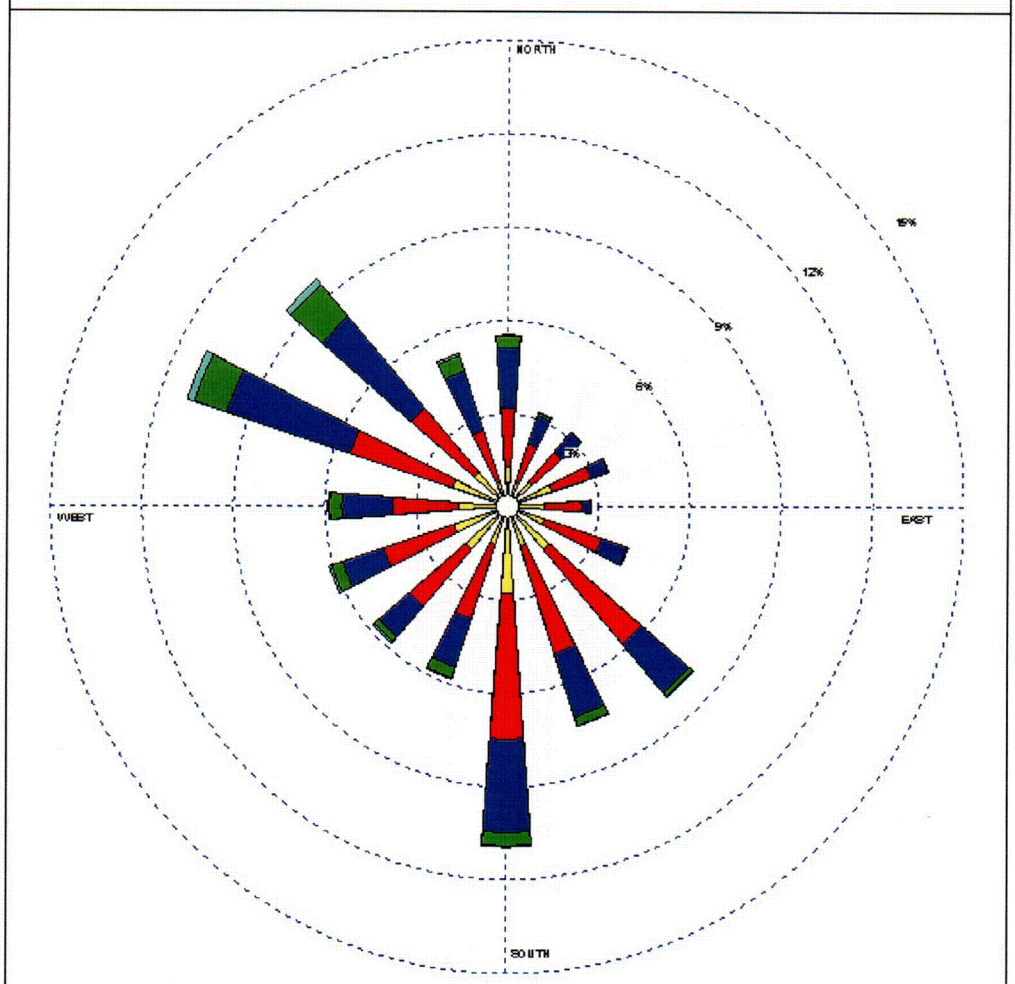
WRPLOT View 3.3 by Lakes Environmental Software - www.lakes-environ.com/data.com

Month of November

C-11

WIND ROSE PLOT

Station #03945 - COLUMBIA/REGIONAL ARPT, MO



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY	UNIT	COMMENTS
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	AVG. WIND SPEED	CALM WINDS	
1.80 - 3.34	5.01 m/s	1.48%	
0.51 - 1.80	ORIENTATION	PLOT YEAR-DATE-TIME	
	Direction (blowing from)	1961 Dec 1 - Dec 31 Midnight - 11 PM	

WRPLOT View 3.3 by Class Environmental Software - www.class-software.com/class.com

Month of December

C-12

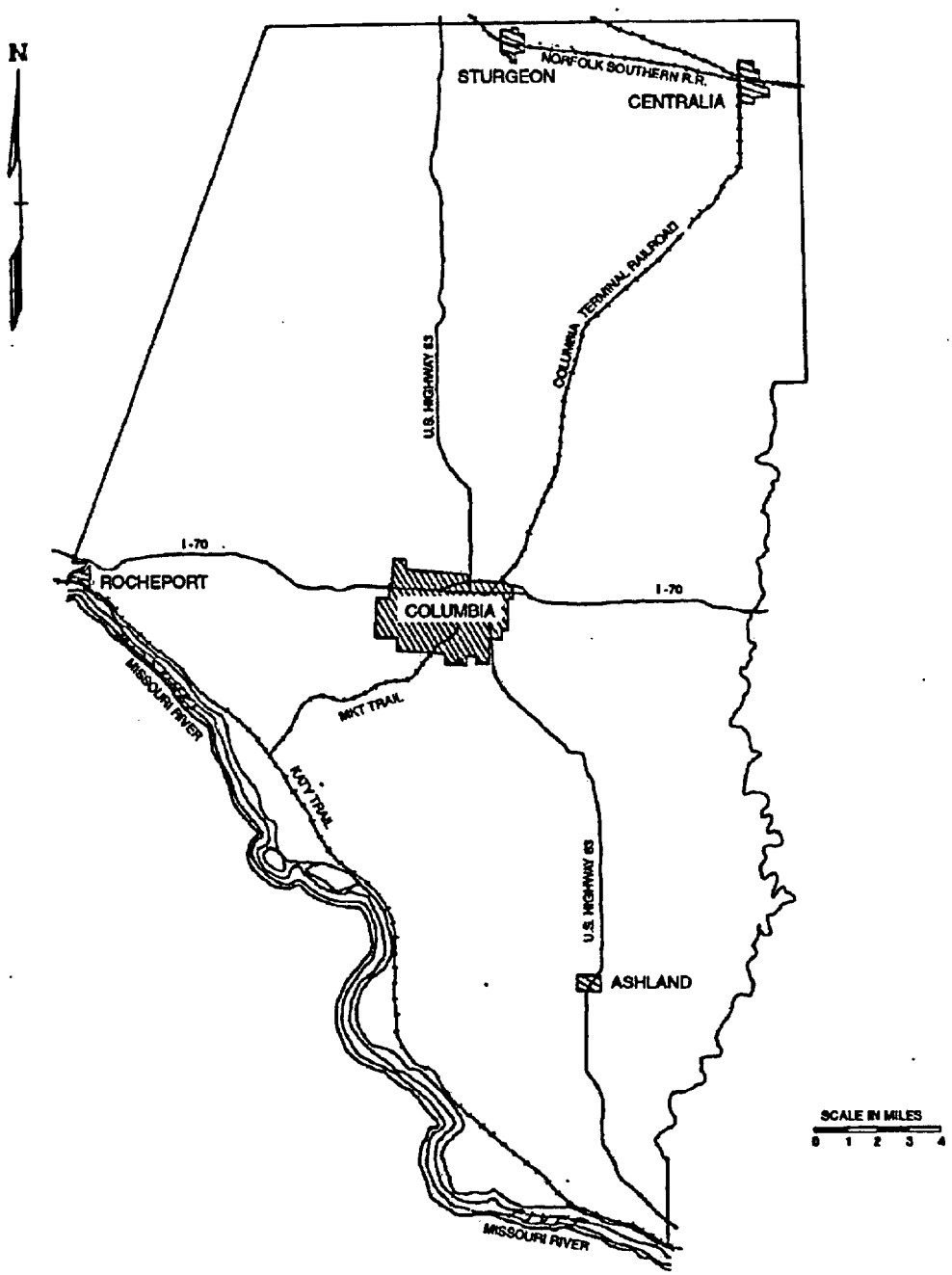


FIGURE 2.1

LOCATION OF MAJOR CITIES, RAILROADS, AND HIGHWAYS IN BOONE COUNTY, MISSOURI

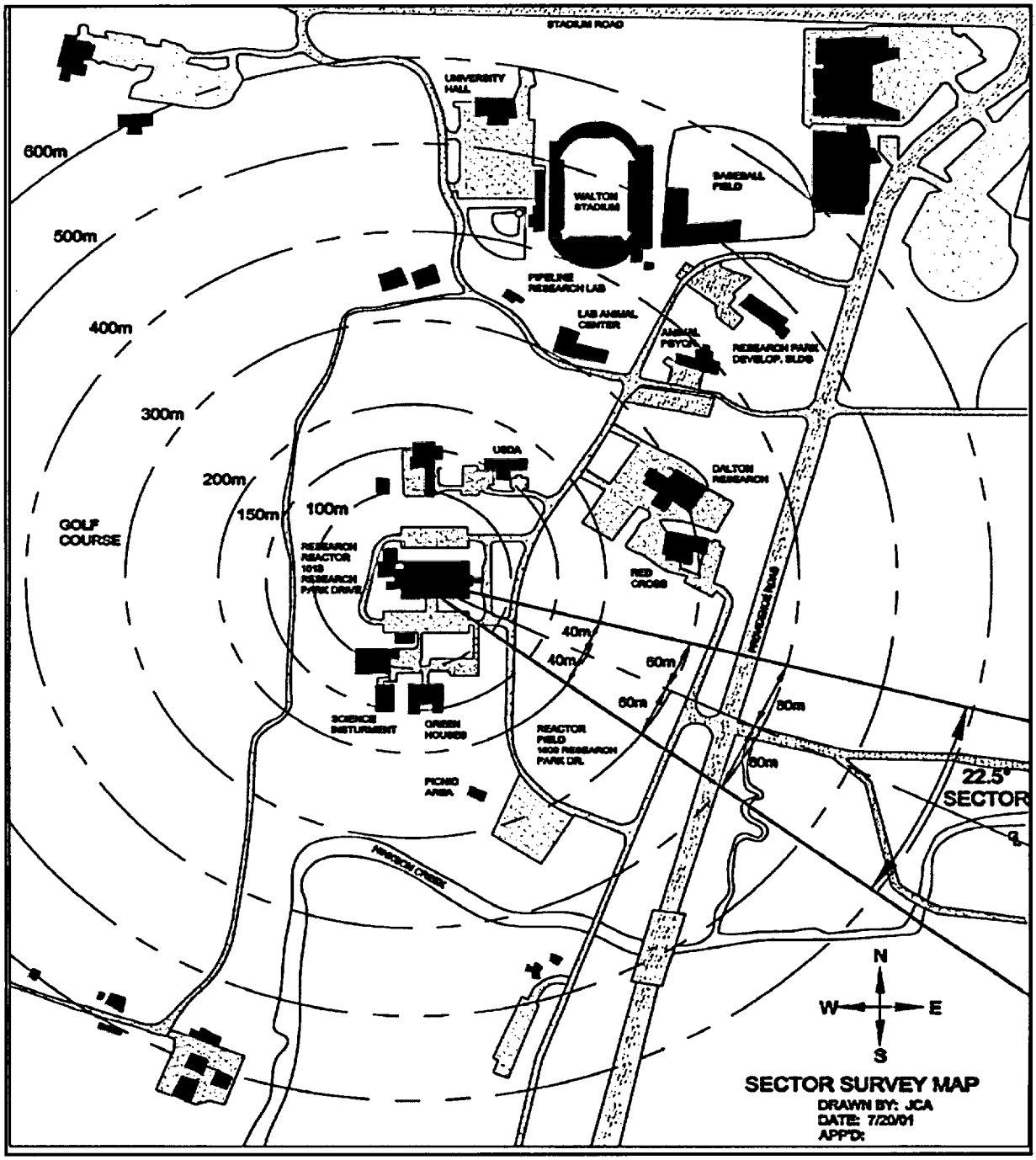


FIGURE 2.2

MURR EMERGENCY PLANNING ZONE

3.0 PROPOSED ACTION

The Missouri University requests that the expiration of Facility Operating License No. R-103 be extended for an additional twenty (20) years. The license was originally issued as a Construction Permit (CP) on November 21, 1961 and will expire on October 11, 2006.

3.1 General Reactor Information

MURR is a pressurized, beryllium reflected, light-water moderated and cooled heterogeneous design reactor. The reactor is fueled with high-enriched, aluminum-clad, plate-type fuel and has a maximum steady-state power level of 10 Megawatts thermal [MW (t)].

3.1.1 Reactor and Containment Systems

MURR is an open pool-type nuclear reactor, which is light-water moderated and cooled. A unique design feature provides an experimental position (flux trap) through the center of the core. A flux trap-type reactor is characterized by a thin fuel region adjacent to a good moderator that thermalizes the neutrons and causes the thermal neutron flux to peak in a region (center test hole) accessible for experiments. A relatively high neutron flux is provided for beamport experiments as well. The reactor is designed to operate at a maximum power of 10 MW with forced cooling, or up to 50 kW in the natural-convection cooling mode.

The reactor core assembly is located eccentrically within a cylindrically shaped pool, approximately 10 feet in diameter and 30 feet deep. The reactor fuel is covered by approximately 23.5 feet of shielding water during reactor operation. The pool liner is surrounded by and anchored to a reinforced concrete edifice (biological shield). The biological shield is a massive bulk structure varying in thickness from 3 to 7.5 feet, with the smaller dimension at the top.

The reactor core consists of three major regions: fuel, control blade, and reflector. The fuel region has a fixed geometry consisting of eight (8) fuel elements having identical dimensions placed vertically around an annulus within the reactor pressure vessel. Each assembly is comprised of 24 circumferential plates containing uranium enriched to approximately 93% in the isotope U-235 as the fuel material.

The control blade region is an annular gap between the pressure vessel and the inner reflector. Five control blades operate vertically within the gap, controlling reactor power by varying neutron reflection. The control blades are attached to drive mechanisms by means of a support and guide extension. The drive mechanisms, mounted on the upper bridge over the reactor pool surface, consist of a motor and a reduction gear drive assembly.

The reflector region consists of two concentric right circular annuluses surrounding the control blade region. The inner reflector annulus is a 2.71-inch thick solid ring of beryllium metal. The outer reflector annulus consists of vertical elements of graphite canned in aluminum, having a total thickness of 8.89 inches. The graphite elements are designed to accept the source ends of four (4) radial and two (2) radial-tangential neutron beamtubes.

The reflector region, the control blade region, and the center test hole are cooled by pool water that is drawn through these regions and circulated though the pool coolant system. The reactor containment building is a five level, poured concrete building with 12-inch thick reinforced exterior walls configured to form the shape of a cube, with each side being approximately 60 feet long. All horizontal and vertical seams created in the pouring are sealed with a polyvinylchloride (PVC) plastic waterstop of the dumbbell type. The outside surfaces of the concrete walls are finished with removable aluminum sheeting. Centered on the exterior of each wall are two pilaster support columns closed at the back to form a tower. Located within each tower is the support equipment necessary for the operation of the reactor facility. The pilaster support columns, comprising the sidewalls of the towers, are built into the main building structure to achieve structural strength.

The containment system is designed to completely isolate the reactor containment building, thereby preventing or mitigating an uncontrolled release of radioactive materials to the environment during an accident. Redundancy is incorporated into the system to ensure no single component or circuit failure will render any portion of the containment system inoperative. Isolation of the reactor containment building can be automatically initiated by radiation detectors located on the reactor pool upper bridge and in the containment building exhaust plenum. Containment isolation can also be manually actuated by switches in the reactor control room or the facility lobby. Operation of the facility lobby switch also causes the facility evacuation horns to sound.

The reactor containment building is designed to hold a peak internal overpressure of 2.0 psig with a leakage rate over a 24-hour period not exceeding 10% of the contained volume. However, no credible accident has been identified which can result in a significant overpressure condition within the containment building.

3.1.2 Cooling and Auxiliary Water Systems

MURR has three separate coolant systems: Primary, Pool, and Secondary. The primary and pool coolant systems are designed for the following three modes of operation:

1) At power levels of up to 50 kW with the primary coolant system open to the reactor pool, the reactor pressure vessel head removed, the flanged port open, and the pool water level at the elevation of either the upper or lower reactor bridge. This mode is used for core flux calibrations following the loading of a new core, or after a fuel rearrangement.

2) At power levels of up to 5 MW with the primary coolant system pressurized and at a flow rate of 1,875 gpm, and a pool loop flow rate of approximately 600 gpm. This mode uses only half the design heat exchange and pumping capacity available.

3) At power levels of up to 10 MW with the primary coolant system pressurized and at a flow rate of 3,750 gpm, and a pool loop flow rate of approximately 1,100 gpm. This mode is used when all heat exchange and pumping capacity is available.

The primary coolant system consists of: the reactor pressure vessel, two main circulating pumps, two heat exchangers, two automatic isolation valves, a pressurizer, a closed in-pool convective cooling system (decay heat removal system), an in-pool invert loop and anti-siphon system, a fuel element failure monitoring system, a bypass loop for water clean-up, and associated piping and valves. All metal surfaces in contact with the primary or pool coolant are either aluminum or stainless steel, except where noted.

The primary coolant circulation pumps are horizontal, centrifugal, single-stage pumps that are direct connected to the driving unit through flexible couplings. The pumps and driving unit are mounted on a common base. One pump will provide approximately 1,875 gpm to the reactor, and two pumps will supply 3,750 gpm with sufficient discharge head to overcome system pressure drop losses.

The primary coolant heat exchangers are tube-type, water-to-water shell, with removable tube bundles. The tubes, and all materials in contact with the primary coolant, are made of stainless steel. The primary coolant flow makes two passes through the tube side of the heat exchanger with a velocity of no greater than 7 feet/second. At a maximum of 1,600 gpm of secondary water flow and an inlet water temperature at 87 °F, one heat exchanger is capable of removing 17×10^6 BTU/h of heat from 1,800 gpm of primary coolant and returning it at 140 °F. Two heat exchangers are installed for design power operation.

The pool coolant system consists of two main circulating pumps, a heat exchanger, an automatic isolation valve, a reflector plenum natural convection valve, a hold-up tank, a return diffuser, a bypass loop for water clean-up, and associated valves and piping. The system is designed to transfer 3.6×10^6 BTU/h at a flow rate of 1,200 gpm. This allows for reactor operation at a maximum thermal power of 10 MW.

The pool coolant is circulated by horizontal, centrifugal, single-stage pumps that are directly connected to the driving unit through flexible couplings. The pumps are designed to overcome system pressure drops at variable flow rates to a maximum flow of 1,075 gpm with one pump operating and 1,325 gpm when both pumps are operating.

The pool coolant heat exchanger is a water-to-water plate-type with all surfaces in contact with pool water constructed of stainless steel. This heat exchanger is designed to remove 3.6×10^6 BTU/h of heat from 1,200 gpm of pool coolant and return it at 99°F with a secondary flow rate and inlet temperature of 500 gpm and 87°F, respectively. One heat exchanger is installed for operating at a maximum thermal power level of 10 MW.

The heat from the primary and pool coolant systems is transferred to the secondary coolant system by means of the heat exchangers. The heat is then dissipated to the atmosphere through a cooling tower. The secondary coolant system also provides a heat sink for the laboratory building air-conditioning system.

The secondary coolant system consists of four circulation pumps, a pool coolant heat exchanger, two primary coolant heat exchangers, two automatic temperature control valves, a water treatment system, temperature and flow instrumentation, a cooling tower, radiation monitoring instrumentation, and associated piping and valves.

The secondary coolant circulation pumps are horizontal, centrifugal, single-stage pumps that are direct connected to 150-HP variable speed drive units through flexible couplings. Three pumps are installed in a parallel configuration with each pump capable of supplying approximately 2,200 gpm to the secondary coolant system. One pump is typically required for 5 MW operation and two pumps are normally required for 10 MW operation. A fourth pump, with a capacity of 700 gpm, is dedicated to the laboratory building air-conditioning system.

The secondary water flow makes a single pass on the shell side of the primary coolant system heat exchangers and on the opposite plate side of the pool coolant in the pool coolant system heat exchanger.

The demineralized water supply system provides primary grade water for daily reactor and facility operations. This system consists of three principle components: a water treatment system; demineralized water storage for reactor make-up; and demineralized water storage for general use throughout the facility.

The water treatment system consists of a water conditioning unit, an activated charcoal filter, cartridge type pre-filters, a reverse osmosis (RO) unit, a mixed bed resin column, and associated piping and valves. The effluent from this system will contain no greater than 0.1 ppm total hardness at a conductivity of less than 2.0 μmho. The demineralized water can then be directed to the water storage systems for the facility or the reactor plant.

Two lined carbon steel tanks, each having a capacity of 7,000 gallons, provide storage of demineralized make-up water for both the primary and pool coolant systems. These tanks are located in the south tower of the reactor containment building, external to the containment structure.

A 2-inch line connects one tank to the suction of the primary coolant charging pump. Demineralized make-up water is added automatically to the primary coolant system by the primary coolant charging pump as required by system demand. Make-up water is added to the reactor pool during normal operation through the pool skimmer system. Demineralized water from the other tank is gravity fed to the skimmer system via a 1¼-inch line and into the reactor pool. A 4-inch line to the pool coolant system is also provided to maintain pool water level when the reactor is secured. The two tanks may be cross-connected to provide a total capacity of 14,000 gallons for reactor pool water level lowering operations.

Three water storage tanks, each with a capacity of 420 gallons, supply demineralized water for general use throughout the reactor facility. The tanks are constructed of 304 stainless steel and are connected in parallel, resulting in a total capacity of 1,260 gallons. A pressurization tank and pump ensure that sufficient demineralized water pressure is maintained at all service locations.

3.1.3 Radioactive Waste Treatment Processes

Gaseous Releases - Gaseous releases are exhausted to the atmosphere of through the facility ventilation and air treatment system. Air exiting the facility through the exhaust stack is continuously monitored for airborne radioactivity. Radioactive gases are diluted to minimum concentrations by the mixing of potentially contaminated air with uncontaminated air.

The maximum rate of discharge through the facility ventilation exhaust stack is specified in the Technical Specifications. The limits established in the Technical Specifications ensure that exposure to the general public resulting from the radioactivity released to the environment will not exceed the limits of 10 CFR 20 (Reference 9.15).

Solid Waste - Receptacles lined with polyethylene bags, or in other ways made acceptable for the disposal of radioactive waste, are located in laboratories and other work areas that create solid radioactive waste. The solid waste is placed in these receptacles and then collected on a routine basis and stored on the below grade level of the laboratory building until a sufficient volume has accumulated to be packaged in sealed containers (typically metal drums). Appropriate radiation monitoring equipment is used in identifying and segregating the solid radioactive waste. All items and materials initially categorized as radioactive waste are monitored a second time before packaging for disposal to confirm data needed for waste shipment records, and to provide a final opportunity for decontamination/reclamation of an item. The containers are then processed and prepared for shipment by the MURR Health Physics Group in accordance with Department of Transportation (DOT) regulations. All applicable regulations with respect to radiation and contamination levels are met prior to shipment of any low-level solid waste. The containers are shipped directly to a waste processing site for final disposal or transferred to an authorized radioactive waste broker or brokerage service. Solid waste is not permanently stored on the MURR site.

In general, MURR does not produce significant amounts of mixed waste during operation of the facility or during the performance of any experiment or test. Therefore, disposal of mixed waste is not a concern during the license renewal term. Hazardous waste is transferred to the hazardous waste storage facility run by the Missouri University as described in Section 3.1.5.

Liquid Waste - All potentially contaminated liquids either drain or are pumped to a liquid waste retention system located on the below grade level of the laboratory building. The liquid waste retention system consists of four tanks (three with a capacity of approximately 5,000 gallons and one with a capacity of 550 gallons), three transfer pumps, three filter banks, and associated piping and valves. Liquid waste is retained or chemically treated until an analysis indicates activity levels are less than the limits for disposal specified in 10 CFR 20 (Reference 9.15), and is then released into the Missouri University, Columbia sanitary sewer system. It is standard practice to hold all liquid waste as long as practical to minimize the total activity released to the environment. However, no liquid waste is permanently stored at MURR.

The MU's sanitary sewer system discharges directly into the City of Columbia's sanitary sewer system. The Columbia Regional Wastewater Treatment Plant is located in the southwest section of the city, approximately 3.7 miles (6 km) west of MURR. This is an activated sludge/anaerobic digester treatment facility with a design flow capacity of 20.6 million gallons per day (design population equivalent of 174,058 people). After processing, the effluent from the treatment facility is diverted to a series of constructed wetlands that serve as polishing units to further purify the discharge. The effluent is then directed from these "polishing" wetlands to a final wetlands area maintained by the Missouri Department of Conservation known as Eagle Bluffs, located adjacent to the Missouri River, approximately 5 miles (8 km) south of the wastewater treatment plant.

3.1.4 Transportation of Radioactive Materials

Solid waste is packaged in sealed containers (typically metal drums). The containers are then processed and prepared for shipment by the Health Physics Group according to DOT regulations.

Normally, the transfer of solid radioactive waste is to an authorized solid waste broker or brokerage service. However, the facility may opt to ship solid radioactive waste directly to a waste disposal site without the use of a broker. The individual responsible for making the waste shipment must have documented training meeting the requirements of 49 CFR Chapter I, Part 172, Subpart H.

Irradiated fuel does not leave the reactor pool until it is loaded into an NRC approved cask for shipment. A spent fuel element is not loaded into a shipping cask until a predetermined cooling period has elapsed after the element is last removed from the reactor core. Cooling times are based on a thermal analysis of the decay heat generated by a spent fuel element and by the storage requirements at the Department of Energy (DOE) site. The thermal analysis is included in a separate SAR prepared for each cask prior to shipment.

The Certificate of Compliance for the shipping cask specifically identifies the required minimum cooling time determined from the thermal analysis. The shipping cask containing the spent irradiated fuel is decontaminated prior to release for shipment and all shipments are performed in accordance with applicable NRC and DOT regulations.

3.1.5 Non-Radioactive Waste Systems

Any non-radioactive hazardous waste possessed by MURR is transferred for processing to the Missouri University Environmental Health and Safety Department. This department maintains a non-radioactive hazardous waste collection and processing facility administered by the university and subject to inspection by the Missouri Department of Natural Resources (MDNR). Hazardous materials that are transferred to the hazardous waste storage facility are disposed of in a manner that complies with regulations specified by the Environmental Protection Agency (EPA). See Section 5.0 of this Environmental Report for further discussion.

The secondary coolant system water quality is maintained using four commercial products containing hazardous materials. These products are the same or similar to those used in the air conditioning cooling towers of industrial facilities or large office buildings. These chemicals include two biocides, a corrosion inhibitor, and sulfuric acid for pH control. The volume of water treatment chemicals used annually is about 105 gallons of the biocides, 700 gallons of corrosion inhibitor, and 4,000 gallons of sulfuric acid. These materials are stored and used in accordance with EPA requirements.

3.2 Maintenance, Inspection, and Refueling Activities

Routine maintenance performed on facility systems and components is necessary for safe and reliable operation of the reactor. Some of the maintenance activities conducted at MURR include inspection, testing, and surveillance to maintain the current licensing basis and ensure compliance with environmental and occupational safety requirements. The results of these activities are recorded, retained and trended. Certain activities can be conducted while the facility is operating and others require that the reactor be shut down.

The MURR Technical Specifications contain the surveillance requirements for the following key systems: containment system, cooling systems, control blade system, reactor instrumentation, fuel elements and auxiliary systems. These surveillance requirements contain acceptance criteria that must be met to assure proper operation of the respective systems. There are Limiting Conditions for Operation (LCOs) associated with failure to meet the acceptance criteria.

Since September 1, 1977, MURR has operated 24 hours a day, 6½ days per week (averaging approximately 150 hours per week). The weekly half-day shutdown is required for refueling the reactor and changing samples in the flux trap. These refueling opportunities are also used for performing any required corrective or preventive maintenance activities. This operating schedule equates to operating at full power [10 MW (t)] for 90% of all available hours in the year. MURR plans to continue to operate on this schedule.

New unirradiated fuel is obtained from the DOE and arrives at the facility in DOT approved shipping containers. The new fuel is removed from the shipping containers by hand and placed in a storage vault. Following each refueling sequence, a verification is performed to ensure that the fuel elements are fully seated, and a visual inspection of the core is performed to verify that no debris is present. These steps are completed prior to bolting the reactor pressure vessel cover in place.

The DOE maintains title to all nuclear fuel used at MURR and is obligated by contract to take possession of the fuel for storage after its use in the reactor. Transfer of spent fuel from in-pool storage locations to the cask is performed manually with the cask underwater and resting on the shelf behind the weir. The 15-ton capacity overhead rectilinear crane is used to lower and remove the cask from the reactor pool. The cask is decontaminated prior to release for shipment.

No changes in this process are anticipated during the license renewal term. No irradiated spent fuel will be permanently stored at MURR either in the reactor pool or in an independent spent fuel storage facility (ISFSI). All irradiated fuel will continue to be shipped to the DOE on a routine basis.

3.3 Refurbishment

There are no new major construction activities or modifications to the facility that are required to support the license renewal request. In addition, the only modifications and refurbishment activities anticipated during the license renewal term are small upgrades and enhancements associated with equipment and facility maintenance.

3.4 Programs and Activities Related to Aging

The staff at MURR addresses potential degradation due to the effects of aging through regular visual inspections and equipment surveillance. Any effects of aging that might affect the performance of equipment or components are identified through routine surveillance programs and systems operational tests. Each week, when the reactor is shut down for refueling, any required corrective and preventive maintenance is performed. Equipment and other components are replaced as required to ensure functionality.

The design of the MURR includes a cylindrical sleeve beryllium reflector located around the section of the outer pressure vessel that contains the reactor core. The radiation heating of the beryllium causes thermal stresses when the reactor is operating. Based on operating experience, the beryllium reflector is replaced approximately every 26,000 MWD of reactor operation to preclude cracking. A new beryllium reflector was installed in 2006.

During a beryllium reflector change-out, the MURR staff takes the opportunity to inspect the reactor pressure vessel. With the control blades and beryllium reflector removed, the full length of the outer pressure vessel can be visually inspected. This inspection has been performed during each beryllium reflector replacement and a visual recording was made of the pressure vessel surfaces during the previous three beryllium change-outs. Based on the results of these inspections, the pressure vessel was determined to be in excellent condition.

In addition to the surveillance requirements and regular inspection activities, MURR has other ongoing efforts to monitor component condition. The primary and pool coolant systems are constructed of aluminum 6061-T6 components with the exception of the pool liner, which is aluminum 5052 or 5086. Both the primary and pool coolant systems contain an ion exchange column for demineralization and conductivity monitors. The demineralization systems, in addition to maintaining a low conductivity, maintain the pH in a range of 5 to 6. Aluminum 6061's aqueous corrosion resistance is high, especially in slightly acidified water in the pH range of 4.5 to 7.0. Water samples are taken weekly from the primary and pool coolant systems and are analyzed for pH to minimize corrosion and degradation of aluminum piping and components.

During the months of April and June 2000, a video-recorded inspection of the pool liner was performed by an independent contractor. Because corrosion is most likely to occur at the welds and adjacent areas of the aluminum pool liner, the inspection of the liner focused on welds and the aluminum plate and components around the welds. During the inspection, particular emphasis was placed on searching for evidence of a number of potential corrosion mechanisms and forms of liner distress, including cracks, deformations (including bulges), buckling, and tears (at anchorages or attachments). This inspection was performed after 34 years of reactor operation and no evidence of any of these corrosion mechanisms or signs of liner distress was observed on the inspected welds and plates. No changes to operating conditions or procedures that have the potential to impact the pool liner are anticipated during the period of the license renewal term.

3.5 Employment

MURR employs approximately 140 people on its full-time staff. In addition, there are often various researchers and scientists working at MURR on a temporary basis performing experiments and receiving training in operation of the reactor. No significant increase in permanent staff or in the number of visiting scientists or engineers is expected during the license renewal term.

In addition, there are no major modifications or refurbishment activities planned to support the license renewal or for the period of the license renewal term. Therefore, there will be no requirement for a significant contractor workforce on site to complete modifications or upgrades during the license renewal term directly related to the reactor facility itself. There will be however, a building constructed next to the existing reactor and laboratory building that will be used for additional laboratory and office space and will contain a cyclotron for the production of medical and research-related isotopes.

4.0 ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION

The following sections presents the results of the evaluations performed for each of the 92 environmental issues that could be potentially impacted by the license renewal of a nuclear power plant. The issues discussed in Section 4.1 are those issues identified in NUREG-1437 as Category 2 issues and the issues not categorized in NUREG-1437. The issues discussed in Section 4.2 are the Category 1 issues listed in NUREG-1437. The format used to discuss the issues is similar to the format recommended in Supplement 1 to Regulatory Guide 4.2, "Preparation of Supplemental Environmental Reports for Applications to Renew Nuclear Power Plant Operating Licenses." (Reference 9.12)

4.1 Assessment of NUREG-1437 Category 2 and Unclassified Issues

4.1.1 Water Use Conflicts

There are no potential water use conflicts caused by the continued operation of MURR for an additional 20 years. MURR uses a secondary coolant system that requires approximately 50 gpm of makeup water to compensate for the evaporative losses from the cooling tower. The water used for makeup is obtained from 5 wells that are owned, operated, and maintained by the Missouri University at Columbia. These wells have the capacity to produce a total of 4,700 gpm of water.

In addition, the University can obtain water from the City of Columbia water system if equipment is out of service or if there is a failure in the system. The City of Columbia water supply has sufficient capacity to pump 24 million gallons of water per day, or 16,667 gpm, from a alluvial wellfield located near the Missouri River. This system is supplemented by 4 deep wells owned by the City of Columbia that are maintained in a standby status. These wells have the capacity to produce a flow of 700 to 1,200 gpm.

The alluvial wellfield used by the City is located in the McBaine Bottom of the Missouri River flood plain approximately 12 miles southwest of Columbia. The alluvial aquifer is replenished by direct rainfall infiltration and by the Missouri River. The Missouri River's average flow rate is more than 45 billion gallons of water per day in the vicinity of Columbia (United States Geological Service, 1990).

MURR has a closed-loop primary coolant system that is used to cool the reactor. This system discharges heat to the secondary coolant system. Heat is removed from the secondary coolant system by dissipation to the atmosphere through a cooling tower. The dissipation of heat to the atmosphere results in a loss of water inventory that is restored by the secondary coolant make-up water system.

Make-up water can be supplied to the reactor pool at a rate of approximately 1,000 gpm during an emergency condition to keep water level in the reactor pool above the irradiated fuel that is stored in the pool. This make-up water is provided by the fire protection system. The fire protection system is supplied by the Missouri University water supply system. In case of equipment failure, or other unforeseen event, the fire protection system can alternatively be supplied by the City of Columbia water system. The City of Columbia water system is supplemented by four deep wells that are not normally in use. These standby wells can supply a total of 2,800 to 4,800 gpm. The capacity of the standby wells is significantly more than the maximum amount of water required by MURR, even during an emergency situation.

During normal facility operation, MURR uses approximately 50 gpm for make-up to the secondary coolant system. In addition, approximately 25 gpm of potable water is used for activities associated with operation of the reactor such as, sanitary use and service water supply. The total flow rate of approximately 75 gpm is extremely small compared to the capacity of the Missouri University and the City of Columbia water supply systems. MURR's normal and emergency water consumption rate has no significant impact on these supply systems. In case of emergency, the water supply system has the capability of providing an almost limitless quantity of water for cooling the reactor without any impact on the rest of the Missouri University or the City of Columbia.

Therefore, there is no potential for water use conflicts due to the continued operation of MURR during the license renewal term.

4.1.2 Entrainment of Fish and Shellfish

Potential environmental impacts due to entrainment of fish and shellfish are not applicable to the present or continued operation of MURR. Adverse impacts are caused by entrainment on screens or filters at plant intakes for cooling water. This issue is only applicable to nuclear power plants that have a once-through cooling system or a cooling pond. MURR has a secondary coolant system that uses a mechanical draft cooling tower. The facility does not have a once-through cooling system or a cooling pond. As such, it does not have an intake structure. All water is obtained from deep wells located in an underground aquifer that contains no fish or shellfish. Therefore, entrainment of fish or shellfish is not possible. This issue is not a concern applicable to the present or continued operation of MURR.

4.1.3 Impingement of Fish and Shellfish

Impingement of fish and shellfish is not a concern for the present or continued operation of MURR for the reasons that entrapment of fish and shellfish is not a concern as described in Section 4.1.2 above. MURR does not use water obtained from a body of surface water containing fish or shellfish.

4.1.4 Heat Shock

MURR does not discharge heated water to a body of surface water. MURR uses a secondary coolant system that dissipates heat through evaporative losses to the atmosphere through a mechanical draft cooling tower. Thus, there is no potential for heat shock to impact aquatic ecology.

4.1.5 Groundwater Use Conflicts for Potable and Service Water

Plants that use more than 100 gpm taken from groundwater have a potential impact if the groundwater source is limited. MURR uses a total of approximately 38 million gallons of water per year (Reference 9.6). This is equal to approximately 72 gpm. The majority of this volume, approximately 50 gpm (28 million gallons per year), is used to provide makeup to the secondary coolant system. The balance of approximately 20 gpm is used as potable water. Given the capacity of the aquifer and the pumping capacity of the wells used to obtain water as described in Section 4.1.1, the volume of water used by MURR is negligible.

Therefore, there are no potential groundwater use conflicts resulting from water usage, either for secondary coolant make-up or potable water use. MURR's total water usage is less than 100 gpm during normal plant operation. No changes or modifications are anticipated during the license renewal term that will increase water usage at MURR.

4.1.6 Groundwater Use Conflicts - Cooling Towers with Small Makeup Source

MURR uses a mechanical draft cooling tower to remove heat from the secondary coolant system. This tower dissipates heat to the atmosphere along with small quantities of water. The total usage by the cooling tower is negligible compared to the capacity of the aquifer and the wells used to supply make-up water to the facility. Therefore, there are no potential groundwater use conflicts resulting from the present or continued operation of MURR.

4.1.7 Groundwater Use Conflicts - Use of Ranney Wells

This issue is not applicable to MURR because the facility does not use radial collector (Ranney) wells as part of its operation.

4.1.8 Degradation of Ground Water Quality

MURR draws ground water from wells owned and maintained by Missouri University. This water is used only for makeup to the secondary coolant system that dissipates heat and water vapor to the air and for potable water use. The facility does not have a cooling pond and does not discharge water to a body of surface or ground water.

Liquid waste produced by the facility is discharged to the sanitary sewer system, which flows to the Columbia Regional Wastewater Treatment Plant. The waste treatment plant is designed to process the waste from a city with a population of 174,058 people and has a design flow capacity of 20.6 million gallons of water per day (14,306 gpm). The effluent from the sewage treatment plant is directed to "polishing" wetlands and then to final wetlands from where it migrates to the Missouri River. The volume of water discharged by MURR daily constitutes a negligible percentage of the volume of water processed by the treatment plant each day. In addition, the volume of water released by the sewage treatment plant represents an insignificant increase in Missouri River's flow. Therefore, the present or continued operation of MURR has no impact on ground water quality.

4.1.9 Impacts of Refurbishment on Terrestrial Resources

There are no plans for significant refurbishment activities or modifications to MURR related to license renewal and only minor upgrades are anticipated during the license renewal term. No major construction activities related to license renewal are planned. In addition, the only modifications or refurbishment activities anticipated during the license renewal term are minor enhancements related to facility maintenance. Therefore, there is no potential impact on terrestrial resources related to the present or continued operation of MURR.

4.1.10 Threatened or Endangered Species

The State of Missouri has determined that there are no threatened or endangered "listed species" on the facility site (Reference 9.6). There are no plans for major refurbishment activities associated with license renewal and the facility has no plans to expand the facility site except for the previously mentioned cyclotron, laboratory and office building. Thus, there is no impact on threatened or endangered species on the facility site due to the present or continued operation of MURR.

While there are no threatened or endangered species on the facility site, there are two species of concern in the surrounding area. The Trout-Perch and the Topeka Shiner are both found in Hinkson Creek in an area near the facility site. The Hinkson Creek, which drains the MURR site, is a major tributary of Perche Creek, the principal stream of the Boone County drainage basin. The Perche Creek enters the county from the northwest and then flows south and then southeasterly before entering the Missouri River approximately 8.5 miles (13.7 km) from the reactor facility. To preserve the Trout-Perch and the Topeka Shiner, the Hinkson and its tributaries should be protected from soil erosion, water pollution and instream activities that modify or diminish aquatic habitats.

No activities associated with license renewal that would contribute to soil erosion are anticipated. There are no plans to pave additional areas or portions of the facility site. Therefore, no increase in water run-off is expected during the license renewal term. The facility does not now and does not plan in the future to conduct any instream activities associated with the Hinkson Creek.

MURR uses a secondary coolant system that does not discharge water to the ground or directly to a body of surface water. Approximately 50 gpm of non-radioactive water is evaporated to the atmosphere from the cooling tower. This loss is made up entirely from well water. The operation of the cooling tower will remain unchanged during the license renewal term.

In addition, the facility uses approximately 25 gpm for potable use. This water is discharged through the sanitary sewer effluent line. This release has no impact on threatened or endangered species because the amount of waste discharged by MURR is not significant and because the effluent from the treatment plant is released to the Missouri River, and not to the Perche Creek or its tributaries.

No increase in the volume of liquid effluent discharged by the facility to the sanitary sewer system during the license renewal term is anticipated.

There are no activities planned that will change the characteristic of the rainwater runoff or result in any other discharges to the Perche Creek or its tributaries. No changes to facility operations are planned that would increase the volume of water discharged by the facility. Thus, there is no impact on threatened or endangered species caused by the continued operation of MURR during the license renewal term.

4.1.11 Air Quality During Refurbishment

MURR has no plans for major refurbishment or modification activities associated with license renewal. All anticipated construction activities to be performed during the license renewal term are related to the new cyclotron facility, existing facility maintenance or minor upgrades to equipment. The cyclotron building project is projected to last approximately nine months from beginning to end of construction. These modifications will be accomplished with minimal increase in work staff or equipment on site. Therefore, air quality concerns related to dust, construction equipment, or the additional automobiles associated with a large workforce are not a major issue.

The employees of MURR makeup a small fraction of the total number of workers employed at the Missouri University. Thus, the work force at MURR creates an insignificant increase in auto emissions compared to the remainder of the University staff or the City of Columbia as a whole. There will be no increase in the size of the MURR staff during any anticipated refurbishment activities or during the license renewal term. Thus, there is no adverse impact on the environment due to the operation of MURR and no impact on air quality resulting from the license renewal of MURR.

4.1.12 Impact on Public Health of Microbiological Organisms

MURR does not use a once-through cooling water system and does not have a cooling pond. Water is discharged from the facility into the sanitary sewer system. Non-contaminated water is evaporated into the atmosphere as a result of the cooling tower's operation. The amount of water lost to the atmosphere is equivalent to the losses experienced by the cooling towers of industrial sites, large office buildings, or large residential buildings.

In addition to losses through the cooling tower, facility service water and potable water are discharged by the facility through the sanitary sewer system. This liquid waste is processed through the Columbia Regional Wastewater Treatment Plant and makes up a negligible portion of the water released by the treatment plant. Additionally, the water released by the treatment plant is discharged to polishing beds and then to the Missouri River. The amount of water released by the treatment plant is insignificant compared to the total average flow of 45 billion gallons of water per day carried by the Missouri River.

The secondary coolant system water quality is maintained using four commercial products containing hazardous chemical compounds that are commonly used in the air conditioning cooling towers of large office buildings. These chemical compounds include two biocides, a corrosion inhibitor, and sulfuric acid for pH control.

Approximately 100 gallons of one and 5 gallons of the other biocide, 700 gallons of the corrosion inhibitor, and 4,000 gallons of sulfuric acid are used annually in the secondary coolant water. The secondary coolant system is essentially a recirculation loop, so much of the water and the chemical compounds are retained in the system. However, the chemically treated water enters the environment through evaporation at the cooling tower and through the blow down line that is routed to the sanitary sewer. These chemical compounds have been approved for use. Their use does not represent a significant environmental impact.

Therefore, there is no potential impact on public health due to the growth of microbiological organisms in the water released from the facility (or the chemicals used to control the growth of microbiological organisms) during MURR's present or continued operation.

4.1.13 Electromagnetic Fields - Acute and Chronic Effects

MURR does not generate electricity and has no transmission lines. Because this issue concerns transmission lines built to connect the facility to an existing transmission and distribution system, it is not applicable to MURR.

The only power lines onsite are those that provide electricity to the facility from the off-site power grid. These power lines are maintained by University staff and by the local electric utility company. Facility personnel are protected from the potential harmful effects of electromagnetic fields through adherence to safe work practices established by the Occupational Safety and Health Administration (OSHA). Therefore, there is no potential for acute or chronic effects from the presence of electromagnetic fields caused by the present or continued operation of MURR.

4.1.14 Housing Impacts

There are two aspects of potential impact on housing that must be assessed, impacts during refurbishment and impacts during the license renewal term. With respect to housing impacts during refurbishment, MURR is planning no major refurbishment activities related to license renewal. Any modifications performed during the license renewal term that are required to maintain the facility and upgrade equipment will be accomplished with the existing work force and/or with a very limited number of contracted workers. Because the size of the work force will not be increased, there will be no significant impact on the housing market.

In addition, with respect to the license renewal term, there are no plans to significantly increase the size of the permanent staff at MURR during the license renewal term. If there are any unexpected increases in staff, they will be a small percentage of the increase in staff that will occur at the Missouri University, Columbia as a whole. The size of MURR's staff will continue to makeup a small percentage of the University's total student, faculty, and employee population. As such, there are no potential impacts on housing due to the present or continued operation of MURR.

4.1.15 Public Utilities - Public Water Supply Availability

MURR uses a total of approximately 75 gpm during normal facility operation (50 gallons of makeup for the secondary coolant system and 25 gallons of potable water). Water for the facility is obtained from wells owned and operated by the Missouri University. These wells provide water to the Missouri University campus as well as MURR. This system is backed up by a connection to the City of Columbia water system that has the capacity to pump 16,667 gpm. The city water system is in turn backed up by four deep wells that can pump an additional 2,800 to 4,800 gpm. These wells are not normally used by the City. They are maintained in a standby mode in the event that they are needed.

Under normal operating conditions, MURR obtains all water from the wells owned and operated by the Missouri University. The volume of water used by MURR is a small percentage of the total capacity of these wells. If conditions such as equipment failure occur which require MURR to draw water from the City of Columbia water supply system, the volume of water necessary to operate MURR represents a negligible drain on the city's water supply system.

Even during a reactor emergency condition, when an additional 1,000 gpm would be required to keep the irradiated fuel adequately covered, water usage would be negligible compared to the capacity of the supply systems. The volume of water used by MURR during normal plant operation or emergency conditions could easily be supplied by the city's backup standby wells alone.

In addition, MURR plans no major modifications or refurbishment activities associated with license renewal or during the license renewal term that would require any significant use of water. Therefore, there is no impact on the public water supply availability due to the present or continued operation of MURR.

4.1.16 Education Impacts from Refurbishment

MURR does not plan any major refurbishment activities or modifications to the facility as part of the license renewal. In addition, MURR does not plan on any significant increase in the size of its staff during the license renewal term. All modifications or refurbishment type upgrades that are likely to be implemented during the license renewal term will be performed by the existing staff along with a limited number of contracted personnel. There will be no increase in the number of students entering the City of Columbia School System due to continued operation of the facility. Therefore, there is no impact on education caused by any refurbishment activities that might take place during the license renewal term.

4.1.17 Offsite Land Use

The staff at MURR consists of approximately 140 full-time employees. If additional personnel are required to meet specific needs, contracted personnel are hired on a temporary basis until the need is satisfied. Based on the 2000 census information, and adjusted by an annual population growth of 1.4%, the City of Columbia currently has a population of approximately 92,000 people and at least 105,000 people live within 7.5 miles of the facility. Thus, the total staff at MURR comprises less than 0.1% of the population within 7.5 miles of the facility. MURR does not plan on any major modifications or refurbishment activities as part of the license renewal process or during the license renewal term that would add any permanent staff. In addition, there are no plans to increase the permanent staff size that supports the routine operation of the facility. Because the number of people employed at MURR represents an insignificant percentage of the population in the area, there is no impact on housing or other off-site land use due to the present or continued operation of MURR.

In addition, because MURR is part of the Missouri University, the tax base and the amount of taxes received by the county and the state will remain essentially the same, whether or not MURR is operating. Given that the staff of MURR is such a small percentage of the total population in the vicinity of the facility, the amount of tax revenue obtained from property, income and sales taxes due to the operation of MURR is negligible.

Thus, there is no significant impact on tax bases or revenues due to the continued operation of MURR and no resulting change in off-site land use that could occur due to the increased tax revenues generated by the facility or its employees.

4.1.18 Transportation

MURR is located within the city limits of Columbia, Missouri. The area is served by two major highways; Interstate 70 and US Highway 63. Interstate 70 is a major East-West route across the United States that connects St. Louis and Kansas City. This highway carries approximately 72,530 vehicles a day at present. It is projected to carry more than 109,410 vehicles by the year 2026.

US highway 63 is a major North-South route that connects Columbia, Missouri and Memphis, Tennessee. This highway carries approximately 44,300 vehicles per day at present. It is projected to carry over 68,930 vehicles a day by the year 2026. MURR has approximately 140 employees. There are no plans for any major refurbishment activities related to license renewal and only minor modifications or refurbishment during the license renewal term. The number of vehicles used by the facility staff represents a very small percentage of the total number of vehicles used in the area daily. As such, there is no significant impact on transportation in the area due to the present or continued operation of MURR.

4.1.19 Historic and Archaeological Resources

MURR is situated on a 7.5-acre lot in the central portion of the University Research Park, an 84-acre tract of land approximately one mile southwest of the Missouri University at Columbia (MU) main campus. In addition to MURR, there are several low occupancy research buildings situated within the University Research Park.

These buildings were constructed recently and are not listed in the National Historic Register. The Missouri University staff has performed an assessment of the potential impact on historic properties in accordance with Section 106 of the Historical Preservation Act of 1966, as amended, and in accordance with the provisions of 36 CFR 800, Protection of Historic and Cultural Properties. There are no buildings, or sites of historical or archaeological importance, located on the facility site. There is insignificant impact to historical properties as stated in the draft NRC environmental assessment (Reference 9.7) related to the MURR request for a construction permit recapture license amendment filed on December 27, 2000 (Reference 9.2).

In addition, MURR is not planning any major refurbishment activities to support the license renewal of the facility. Only minor refurbishment activities or modifications related to facility and equipment maintenance are anticipated during the license renewal term. None of these refurbishment activities or modifications will involve construction activities that could disturb previously undisturbed land. Therefore, there is no potential for an impact on historical or archaeological resources due to the continued operation of MURR.

4.1.20 Severe Accident Mitigation Alternatives

NUREG-1537 (Reference 9.10) identifies nine postulated accident events or categories that are applicable to research reactors.. The consequences of each of these nine postulated accident events or categories must be evaluated to determine the potential environmental impacts. They are as follows:

- Maximum Hypothetical Accident
- Insertion of Excess Reactivity
- Loss of Primary Coolant
- Loss of Primary Coolant Flow
- Mishandling or Malfunction of Fuel
- Experiment Malfunction
- Loss of Electrical Power
- External Events
- Mishandling or Malfunction of Equipment

Each of the above postulated accident events or categories have been evaluated and the results of the evaluation are presented in Chapter 13 of the MURR SAR. Based on the results presented in Chapter13, the Maximum Hypothetical Accident (MHA) leads to consequences worse than any other postulated accident. The MHA assumes that the number-1 fuel plate in each of four (4) 775-gram U-235 fuel elements has melted. These four plates represent the peak power region of the reactor core.

The MHA's radiation source term is comprised of Iodine and Noble Gas isotopes, including I-131, I-132, I-133, I-134 I-135, Kr-85, Kr-85m, Kr-87, Kr-88, Kr-89, Kr-90, Xe-133, Xe-135, Xe-135m, Xe-137, Xe-138, and Xe-139. Detailed calculations that use the conservative assumptions outlined in the SAR demonstrate that the maximum radiation dose that would be received by an individual inside the containment building are:

Committed Dose Equivalent (CDE)	=	7.5 millirem (thyroid)
Committed Effective Dose Equivalent (CEDE)	=	0.23 millirem (thyroid)
Deep Dose Equivalent (DDE Radioiodines)	=	0.052 mrem
Deep Dose Equivalent (DDE Nobel Gases)	=	132 millirem (whole body)
Total Effective Dose Equivalent (TEDE)	=	132.28 millirem (whole body)

The above doses are applicable to an occupational worker who remains in the containment building for 10 minutes. Most occupants would be evacuated from containment in less than two minutes and would receive a TEDE of only about 5 millirem.

Further analysis of the MHA was performed to determine the potential impact on members of the general public. To complete this analysis, MURR calculated the maximum dose to the general public using conservative assumptions regarding release rate and atmospheric conditions. The radiation source term used in this analysis is comprised of all radioiodines and noble gases assumed to leak into the containment building. The results of this analysis demonstrate that the maximum exposure to any member of the public is 0.03 mrem. This maximum exposure is well below established limits. 10 CFR 20.1101(d) and 20.1301 specify the allowable radiation exposure limits for members of the general public from facilities such as research reactors.

The MURR reactor building is constructed of twelve-inch thick reinforced concrete walls. The reactor is located below grade and is surrounded by a reinforced concrete biological shield wall that varies in thickness from 3.0 to 7.5 feet. This construction provides substantial protection from external events and significant radiation shielding to individuals located outside the containment. The only pathway for radiation to be released to the containment building is from primary coolant system leakage. A conservative primary coolant system leak rate is assumed and used in the MHA. Most of the fission products released during an accident will be retained within the primary coolant system where fission products will be removed by the demineralizer.

In addition to the MHA, MURR has evaluated each of the other eight (8) postulated accident events or categories and has determined that their resultant radiation exposures are enveloped by the MHA. MURR has investigated external events that could lead to potential damage to the reactor. The results of this investigation conclude that there are no natural or manmade external events that could cause fuel element damage that approaches the level of damage postulated in the MHA.

Thus, MURR has addressed the worst-case postulated accident and evaluated the resulting dose to personnel inside the containment at the initiation of the event and to the general public as well. MURR has determined that there are no credible accidents that could lead to core damage more extensive than postulated in the MHA.

The MHA core damage results in radiation exposures to personnel located in the containment building and to the general public that are substantially less than the limits established in 10 CFR 20.1201 and 20.1101(d) / 20.1301, respectively. As such, the continued operation of MURR does not adversely impact public health and safety.

4.1.21 Transportation and Storage of Radiological Waste

Spent fuel generated during operation of MURR is stored in the reactor pool that is located within the containment building until it is ready for shipment to a disposal site maintained by the DOE. Irradiated fuel remains in the reactor pool until it is loaded into an NRC approved cask for shipment. Transfer of irradiated fuel from in-pool storage locations to the cask is performed with the cask underwater and resting on the floor behind the weir area wall. The entire transfer activity is performed under water. The cask is decontaminated prior to release for shipment.

A spent fuel element is not loaded into a shipping cask until a predetermined cooling period has elapsed since the element was last removed from the reactor core. Cooling times are based on a thermal analysis of the decay heat generated by a spent fuel element and the storage requirements established by the DOE site. The thermal analysis is included in a separate SAR for each cask. The Certificate of Compliance for the shipping cask identifies the required minimum cooling time determined from the results of the thermal analysis. Due to the small quantity of fuel shipped in each cask, and the elapsed time after removal from the reactor, there are no credible accidents associated with the shipment of spent fuel that could potentially impact the environment. No changes to the existing process for handling, storing, and shipping spent nuclear fuel are anticipated during the license renewal term.

The Nuclear Waste Policy Act of 1982, Section 302(b)(1)(B) states that the NRC may require, as a precondition to renewing an operating license for a research reactor under Section 104 of the Atomic Energy Act of 1954, as amended (the Act), that the applicant shall have entered into an agreement with the DOE for the disposal of high-level radioactive wastes and spent nuclear fuel. The DOE supplies fuel to MURR through a fuel assistance program. This program provides the necessary funds to purchase nuclear fuel. The DOE has informed the NRC that universities and other government agencies that operate non-power reactors have entered into contracts with DOE. These contracts require that the DOE retain title to the fuel and that the DOE is obligated to take the spent (i.e., irradiated) fuel for storage or reprocessing. The Curators of the Missouri University have entered into such a contract with the DOE. As such, the applicable requirements of the Nuclear Waste Policy Act of 1982 are satisfied. (Reference 9.1)

MURR currently stores spent fuel onsite only until the criteria for shipment are satisfied and a cask can be prepared for shipment to DOE facilities. There are no environmental impacts from this short-term storage of irradiated fuel due to the shielding provided by the water in the reactor pool and the concrete walls of the biological shield and containment structure, in conjunction with the distance to the nearest residence. There are no plans to change this mode of operation or to permanently store spent irradiated fuel on the MURR site during the period of the license renewal term. As a result, there is no environmental impact due to storage of spent fuel at MURR.

With respect to the shipment of other radioactive materials, written procedures provide guidance regarding the segregation and preparation of radioactive waste prior to its transfer to the Health Physics Group for disposal. Safe disposal may be accomplished by any one of the following methods: 1) storage for decay and ultimate disposal as ordinary trash, 2) release of limited and strictly controlled quantities into the sanitary sewage system, 3) transfer to another of the Missouri University licenses for storage, incineration, or processing for other disposal, or 4) packaging for subsequent shipment to a commercial Low Level Radioactive Waste processing or disposal facility.

Solid radioactive waste is generated by reactor maintenance activities, the manufacturing of products, and research activities performed in the laboratories. Section 11.1.1.3 of the SAR summarizes the sources of solid waste produced by MURR.

Solid waste is placed in receptacles and then collected on a routine basis and stored on the below grade level of the laboratory building until a sufficient volume has accumulated to be packaged in sealed containers (typically metal drums). All material initially categorized as radioactive waste is monitored a second time before packaging for disposal to confirm the data required for waste shipment records, and to provide a final opportunity for decontamination and reclamation of an item. This helps reduce the volume of waste by eliminating the disposal of material that can be reused. The waste containers are then processed and prepared for shipment by the Health Physics Group in accordance with DOT regulations. The containers are shipped directly to a waste-processing site for final disposal or transferred to an authorized radioactive waste broker or brokerage service.

Normally, solid radioactive waste is shipped to an authorized solid waste broker or brokerage service. However, the facility may opt to ship solid radioactive waste directly to a waste disposal site without the use of a broker. The individual responsible for making the waste shipment must have documented training that meets the requirements of Title 49, Chapter I of the Code of Federal Regulations, Part 172, Subpart H.

The policy of MURR management is to keep the volume of waste materials generated to a minimum. Operations are continually assessed for the purpose of identifying opportunities or technological improvements that will reduce or eliminate the generation of radioactive waste. It is also the policy of MURR that no radioactive waste, including irradiated spent fuel, be permanently stored at the facility.

MURR does not permanently store any radioactive waste at the facility. Material is only stored until requirements for shipping are met and a package can be prepared for shipment. All shipments are conducted in accordance with NRC/DOT regulations and all material is shipped to disposal sites that are licensed and that comply with NRC or Agreement State regulations. No changes in procedures or operations are expected during the license renewal term. Therefore, there is no impact on the environment due to storage and shipment of radiological waste by MURR during the license renewal term.

4.1.22 Environmental Justice

Environmental justice refers to a Federal policy under which Federal actions should not result in disproportionately high and adverse environmental impacts on low-income or minority populations. A minority population is defined to exist if the percentage of minorities within the census blocks exceeds the percentage of minorities in the entire State by 10 percent, or if the percentage of minorities within the census block is at least 50 percent. Executive Order 12898 [59 FR 7629] directs Federal executive agencies to consider environmental justice under NEPA, and the Council on Environmental Quality (CEQ) has provided guidance for addressing environmental justice under NEPA (CEQ 1997).

Although it is not subject to the executive order, the Commission has voluntarily committed to undertake environmental justice reviews. Specific guidance regarding environmental justice reviews is provided in Attachment 4 to NRR (Office of Nuclear Reactor Regulation) Office Letter No. 906, Revision 1: *Procedural Guidance for Preparing Environmental Assessments and Considering Environmental Issues* (NRC 1996b).

The scope of the review should include an analysis of impacts on low-income and minority populations, the location and significance of any environmental impacts during operations on those populations that are particularly sensitive, and any additional information pertaining to mitigation. Documentation of this review should be of sufficient detail to permit subsequent staff assessment and evaluation of specific impacts. In particular, the review should determine whether these specific impacts are likely to be disproportionately high and adverse, and to assess the significance of such impacts. Specifically, the impact of facility operation on minorities and low-income individuals that reside within the vicinity of the facility should be evaluated with respect to the applicable environmental issues.

MURR is situated on a 7.5-acre lot located in the central portion of the University Research Park, an 84-acre tract of land approximately one mile southwest of the Missouri University at Columbia (MU) campus and is bordered by the campus to the North. The campus is situated in the southern portion and within the city limits of Columbia; a city that currently has a population of approximately 92,000 people. Columbia is the county seat and largest city in Boone County, Missouri. The University Research Park consists of low occupancy research buildings and classrooms.

MURR discharges all liquid waste effluents to the sanitary sewer system. In addition, MURR does not obtain water from a surface water source. Thus, there are no adverse impacts with respect to water use conflicts. Furthermore, MURR does not generate electricity. Therefore, there are no adverse impacts related to electromagnetic fields or electric transmission lines.

The maximum radiation dose that could potentially be received by any individual member of the public, and the collective dose to the public as a whole, is well below established limits. As such, there is no adverse impact due to radiation releases or accidents.

The only source of water that could promote the growth of microbial organisms is contained in the cooling tower basin. Biocides are successfully used to limit the growth of microbiological organisms that could adversely affect the public's health and safety. Because the growth of microbiological organisms is adequately controlled, there is no adverse impact due to the potential growth of microbial organisms.

The facility does not discharge liquid waste effluents directly to a body of surface water. All liquid effluent discharges are to the sanitary sewer system. The quantities of liquid released to the sanitary sewer system represent a negligible percentage of the system's total flow. In addition, all gaseous releases are at the top of the stack and these releases are below the radioactivity limits specified in the applicable Federal regulations and reactor technical specifications. The release of these gaseous effluents has a negligible impact at distances greater than one mile from the facility.

The cooling tower is typical of cooling towers located at other industrial facilities or large office buildings. The cooling tower has no impact on the environment outside the University Research Park. There are no permanent residences located in the University Research Park. While the plume of water vapor from the cooling tower is sometimes visible from the local community, it is no more obtrusive than plumes from cooling towers located at other facilities in the area.

The MURR staff has not identified any geographic areas where there is a potential for adverse impact on the environment due to continued operation of the facility for the period of the license renewal term. In addition, there are no anticipated major refurbishment activities associated with the license renewal or during the license renewal term that will have any adverse impact on the environment.

MURR is located in a research park near a major university. As with most large universities, much of the housing in the vicinity consists of apartments for students and housing for personnel employed by the University. As such, the area surrounding the facility is no more heavily populated by minority or low-income households than the other portions of Boone County or the City of Columbia. The area immediately surrounding the facility is typical of areas around the remaining portions of the University. The percentage of minorities or low-income individuals living within the vicinity of the facility is less than in the surrounding communities. Therefore, the present or continued operation of MURR has no impact on the environmental justice of the surrounding community.

Furthermore, NRC guidance provided in NRR Office Letter No. 906 makes it clear that if no significant impacts are anticipated from the proposed action, then, "...no member of the public will be substantially affected" and, as a consequence, "...there can be no disproportionate high and adverse effects or impacts on any member of the public including minority or low income populations." MURR concludes that license renewal would have no significant impact and that no member of the public would be substantially affected. As a consequence, there would be no disproportionately high and adverse impacts on any member of the public, including minority and low-income populations. In light of this conclusion, a qualitative review of potential impact on environmental justice is adequate and no mitigation measures are required.

4.2 Assessment of NUREG-1437 Category 1 Issues

4.2.1 Surface Water Quality, Hydrology and Use

The MURR reactor is cooled by a secondary coolant water system that uses a mechanical draft cooling tower to remove heat from the reactor. The only continuous discharge of water is due to evaporative losses from the cooling tower. Makeup water is obtained from wells owned, operated, and maintained by the Missouri University.

The total water usage by the facility, including makeup to the secondary coolant system and potable water use, is approximately 75 gpm. Approximately 50 gpm is released into the atmosphere through evaporation at the cooling tower. The balance of approximately 25 gpm is discharged to the sanitary sewer system of the City of Columbia, a city with a current population of approximately 92,000 people. The amount of water discharged by MURR to the sanitary sewer system is a negligible percentage of the total volume of water processed by the sewage treatment plant. After treatment at the Columbia Regional Wastewater Treatment Plant, the processed water eventually flows to the Missouri River. The volume of wastewater effluent released by MURR has no impact on the water quality, hydrology, or use of the Missouri River.

Surface rainwater runoff from MURR is relatively small compared to the surface runoff from the Missouri University campus. Runoff from MURR is directed to the storm drainage system along with runoff from the rest of the University. Thus, the present or continued operation of MURR has no impact on surface water quality, hydrology, or use. The issues related to this topic are not applicable to MURR.

4.2.2 Aquatic Ecology

MURR does not obtain water from, or discharge water to, a body of surface water. All water used at the facility is pumped from wells owned and maintained by the Missouri University. The volume of water used by the facility is a small percentage of the total volume of water used by the University. The volume of water used by the facility represents a very small percentage of the total production capacity of the wells operated by the University. All water discharged by the facility is released either to the atmosphere by evaporative losses at the cooling tower or to the City of Columbia sanitary sewer system.

Biocides are used in the secondary coolant water to eliminate or limit the growth of nuisance microbiological organisms at the cooling tower. The presence of such organisms is monitored and adjustments or mitigating measures are taken as necessary. The measures used at MURR to control the growth of nuisance microbiological organisms in the cooling tower are comparable to those used at large office buildings and industrial complexes that have cooling towers. The volume of liquid effluent released to the sanitary sewer system represents a negligible percentage of the total volume of wastewater treated by the sewage treatment plant.

Because no water is obtained from a body of surface water, there is no possibility of entrainment or entrapment of plankton, fish, shellfish, or other organisms. Also, because no water containing chemical or radioactive contaminates is directly discharged to a body of surface water, there is no impact on aquatic ecology due to heat, cold, contaminants, gas supersaturation, or low dissolved oxygen resulting from the discharge. As such, there is no impact on the aquatic ecology associated with the present or continued operation of MURR. The issues related to this topic are not applicable to MURR.

4.2.3 Ground Water Use and Quality

MURR uses less than 100 gpm for makeup to the secondary coolant system and for potable water use. All water is obtained from wells owned and operated by the Missouri University. These wells are capable of producing a total of 4,700 gpm. Thus, the amount used by MURR represents an extremely small percentage of the capacity of the Missouri University water supply system.

In emergency situations, the facility can obtain water directly from the City of Columbia domestic water supply system. During reactor emergency conditions, total water usage would be on the order of 1,000 gpm. This water consumption rate is expected to last only for short periods. Furthermore, the volume of water used by MURR is extremely small compared to the capacity of 16,667 gpm that can be supplied by the City of Columbia water supply system. The 16,667 gpm capacity of the City of Columbia water supply system does not include the capacity of the city's standby wells.

The alluvial wells operated by the City of Columbia draw water from the McBaine Bottom flood plain located approximately 12 miles southwest of Columbia. This alluvial wellfield is replenished by direct rainfall and the Missouri River, which has an average flow rate of approximately 45 billion gallons of water per day. The volume of water obtained from this aquifer by MURR is negligible.

In addition, there are no major refurbishment or modification activities anticipated as a result of the license renewal. The only modification or refurbishment activities planned by MURR during the license renewal term are simple upgrades to enhance the facility's capability to conduct research.. None of these upgrades will require significant amounts of water during their installation and none will have any substantial impact on the amount of water used by the facility on a daily basis. Therefore, the present and continued operation of MURR has no impact on groundwater use or quality.

4.2.4 Terrestrial Resources

MURR plans no major refurbishment activities associated with the license renewal effort. Therefore, no additional land will be disturbed and there will be no impact on plant or animal habitats caused by construction activities. The previously mentioned cyclotron and laboratory building will be built on the site of an existing parking lot and adjacent grassy area. In addition, MURR does not generate electricity and there are no power lines maintained by the facility.

The power lines that provide electricity for facility operation are located underground and are the same lines used to provide power to the Missouri University. Thus, the present or continued operation of MURR has no impact on the environment caused by power line right-of-way maintenance, bird impact with power lines or electromagnetic fields. There is no impact on terrestrial resources caused by use of a cooling pond because MURR does have a cooling pond.

MURR uses a mechanical draft cooling tower to remove heat from the secondary coolant system. This cooling tower releases approximately 50 gpm of water into the atmosphere. This amount of water represents a negligible increase in the amount of water evaporated into the air from other terrestrial sources. There have been no adverse impacts on any terrestrial resources observed as a result of the operation of this cooling tower. Any icing, fogging, or increase in humidity is limited to areas immediately adjacent to the cooling tower. Historically, these conditions have not caused any observable effects. Salt drift is not an issue because the facility uses fresh water. The cooling tower is similar in size and capacity to cooling towers used at various industrial facilities and large office buildings.

Therefore, the present or continued operation of MURR has no impact on terrestrial resources, including native flora and fauna or domesticated animals or managed crops. Issues associated with power lines and cooling ponds are not applicable and issues related to operation of the cooling tower are not a concern due to its relatively small size.

4.2.5 Threatened or Endangered Species

The present or continued operation of MURR has no impact on any threatened or endangered species as described in Section 4.1.10. No major refurbishment activities associated with the license renewal effort or during the license renewal term are planned that would potentially disturb the environment of any threatened or endangered species.

4.2.6 Air Quality

MURR does not produce electricity and does not maintain any transmission lines. Power lines that supply power to the facility are the same as those that supply power used by the Missouri University. Therefore, impacts on air quality due to the effects of transmission lines are not applicable to operation of MURR.

In addition, no major refurbishment activities associated with the license renewal effort are planned. Any modifications performed during the license renewal term will be minor in scope. These modifications will be performed by the existing staff; possibly supplemented by a small number of temporary contractors. The work force required to operate the facility and perform modifications represents a negligible percentage of the total number of people employed by the Missouri University. There will be no impact on the environment due to vehicle exhaust or other construction activities associated with these minor modifications. Thus, the continued operation of MURR has no impact on air quality.

4.2.7 Land Use

MURR does not generate electricity and does not own any transmission lines. Transmission lines that provide power to the facility are the same as those that provide power to the Missouri University. Thus, there is no impact on land use due to transmission line right-of-ways related to present or continued operation of MURR.

All land used by MURR is located in the University Research Park which is owned by the Missouri University. No additional land, either within the Research Park or on any other property, will be used by MURR during the license renewal term. No major modifications or refurbishment activities are anticipated that will require additional land use. Thus, continued operation of MURR has no impact on on-site land use.

4.2.8 Human Health

There are no major refurbishment activities planned that are associated with the license renewal of MURR. The only modifications that are anticipated during the license renewal term are minor upgrades that are associated with facility maintenance activities. Thus, there is no impact on human health due to refurbishment associated with the license renewal. MURR does not generate or transmit electricity. Therefore, there is no impact on human health due to acute or chronic effects of electromagnetic fields.

MURR does not directly discharge water to a body of surface water. Therefore, the operation of MURR does not promote or stimulate the growth of any microbiological organisms. Normal industrial health and hygienic practices will ensure that there are no occupational health issues related to the limited microbiological growth that occurs at the cooling tower.

In addition, the license renewal of MURR will not impact human health with respect radiation exposure. The facility is operated in a manner that maintains radioactive releases at a minimum and well below the limits prescribed by law. The ventilation system at MURR is designed to ensure that there are no unplanned or unmonitored gaseous effluent releases to the atmosphere. MURR's ventilation system is designed to perform the following radiological control functions:

- Maintain the reactor containment building at a slightly negative pressure with respect to the surrounding laboratory building to minimize the spread of radioactive contamination.

- Provide the necessary air exchanges to ensure that concentrations of radioactive gases in the laboratory and reactor containment buildings are maintained at levels that are below the 10 CFR 20 limits for restricted areas.

- Ensure that maximum dilution of potentially contaminated air is attained; resulting in minimum concentrations of radioactive gases being released to the environment.

- Minimize the instantaneous release of Argon-41.

- Prevent uncontrolled release of radioactive materials to the environment in the event of an accident.

Air from the laboratory building is filtered prior to its release through the exhaust stack. Prior to release, the containment building air is mixed with exhaust air from the laboratory and other facility areas, thus assuring maximum dilution and minimum concentration of radioactive materials. The combined airflow from the laboratory building and containment building is monitored prior to release. The containment building exhaust duct is equipped with two fast-closing isolation valves that close to prevent release of air from the exhaust stack if the concentration of radioactive materials exceeds a predetermined maximum allowable level.

During normal facility operation, air from the laboratory building and containment building is exhausted through an exhaust stack. The top of the exhaust stack is approximately 70 feet above grade level of the containment building. Due to the negative relative pressure maintained inside the containment building, there are no other release points. The air is monitored prior to release to ensure that there is no possibility of exceeding established limits. In the event of an emergency, the ventilation system's exhaust is automatically isolated.

MURR has calculated the dose to the individual member of the public likely to receive the highest dose from air emissions of radioactive material to the environment to demonstrate compliance with 10 CFR 20.1101(d). This regulation provides "as low as is reasonably achievable" criteria for air emissions that must result in an individual member of the public receiving a total effective dose equivalent (TEDE) of less than 10 mrem per year from these air emissions. These values are well below the limit of 10 mrem per year for an individual most likely to receive the highest dose as established by 10 CFR 20.1101(d).

MURR has also measured and calculated the occupational doses received by MURR personnel and has determined that these doses are well below the limits established by 10 CFR 20, Subpart C and that they are "as low as reasonably achievable." No changes in reactor operation are planned for the license renewal term that would increase these occupational doses.

In addition, MURR has calculated the total dose received by the facility staff as well as the general public as a result of the Maximum Hypothetical Accident (MHA). The MHA is a bounding accident that envelops all design basis accidents that are postulated to occur at the facility. The MHA dose rates have been calculated using conservative assumptions regarding duration, dispersion, release point, and airflow. The results of the calculations are well below the limits specified in the Code of Federal Regulations for both facility staff and the general public. Results of the analysis of the radiological consequences resulting from the MHA are presented in Chapter 13 of the SAR.

An off-site dose calculation has been performed in support of the effort to renew MURR's operating license. This calculation assumes that the radioactive material concentration of all gaseous effluent releases is equal to the maximum concentration allowed by the MURR Technical Specifications. The results of the calculation identify that the maximum annual dose received by an individual located at a distance of 150 meters from the facility is 0.7 mrem, and the maximum annual dose received by an individual located at a distance of 760 meters from the facility is 4.2 mrem.

The normal radioactive material concentration of gaseous effluents released by MURR is approximately 70% of the maximum value allowed by MURR's Technical Specifications. As a result, an individual's anticipated normal annual dose at 150 meters and 760 meters is approximately 0.5 mrem and 3.0 mrem, respectively.

With regard to the total dose to the population as a whole, as stated in Section 2.1.3 of the MURR SAR, the population in the vicinity of MURR is expected to increase at a rate of approximately 1.4 percent per year for the period of the license renewal term. This rate of population increase will not appreciably change the current total dose estimates.

During normal facility operation and during accident conditions, all personnel within the containment building or any other areas where they could be exposed to measurable amounts of radiation are monitored. Personnel exposures are maintained at "as low as reasonably achievable" levels that are significantly less than the limits established in the Code of Federal Regulations. The facility's Health Physics Group is responsible for assuring that personnel radiation exposure is both monitored and minimized consistent with ALARA practices.

The reactor is located below grade level and is completely enclosed by a reinforced concrete structure. The design of the facility's shielding prevents direct radiation exposure to members of the general public. All potentially contaminated air released from the facility is monitored to ensure that the concentrations of radioactive material released is maintained within regulatory limits. The containment building air is mixed with filtered air from other areas of the facility and released through the facility ventilation exhaust stack. Given the extremely small amounts of gaseous effluent radioactive material that is released, there is no significant impact on public health due to the continued operation of MURR.

4.2.9 Socioeconomics

MURR is a small research reactor located on the campus of a large university in an area of moderate population density. There are approximately 140 personnel on staff at MURR and no significant increases in staff size are anticipated during the license renewal term. Given the total population of Boone County and the City of Columbia, there is no impact on housing, transportation, education, public utilities, social services, or land use, due to changes in the tax base.

No major refurbishment activities will be carried out by the facility as part of the license renewal effort and only small upgrades categorized as facility maintenance are anticipated during the license renewal term. Therefore, there is no impact on off-site land use related to refurbishment. In addition, because no additional permanent construction will occur outside of the existing facility structures, or on previously undisturbed land, there is no impact on any historic or archaeological resources in the vicinity of the facility.

MURR is a research reactor that is owned and operated by the Missouri University. It is used to perform experiments and research, and to produce isotopes. The reactor facility is also used by other universities that do not have their own research reactor.

With regard to aesthetics, MURR is a small facility whose design is compatible with other structures located in the Research Park and on the Missouri University campus. None of the structures are more than 50 feet tall with the exception of the exhaust stack; the top of which is 70 feet above grade level. No changes in appearance will be made during the license renewal term. In addition, MURR does not generate electricity and thus does not maintain any power transmission lines. Therefore, the continued operation of MURR has no impact on the aesthetics of the surrounding area.

No refurbishment activities except for minor upgrades related to facility maintenance will be performed during the license renewal term. Also, the facility is very small and employs only a relatively small number of personnel as compared to the total number of people that reside or work in the surrounding area. Therefore, the continued operation of MURR has no impact on the socioeconomics of Boone County or the City of Columbia.

4.2.10 Postulated Accidents

MURR has evaluated the radiation exposure to the general public and to staff and visitors at MURR due to consequences resulting from the Maximum Hypothetical Accident (MHA). The MHA represents the most severe accident that is postulated to occur at the facility. The results of this evaluation are described in the SAR and in Section 4.20 of this report. The results of the MHA demonstrate that maximum radiation doses to the general public, the facility staff, and visitors at the facility during this postulated accident would be significantly less than the limits specified in 10 CFR 20. The MHA doses are greater than the doses that result from all other design basis accidents.

The facility is designed to prevent or minimize potential releases of radioactive contamination and unacceptable levels of radiation even in the event of an MHA. During such a hypothetical accident, there would be no releases to the ground water and the amount of radioactive material released from the stack would be minimal and would not contaminate the ground surface or any bodies of water. In addition, even if the MHA were to occur, releases would be so small that there would be no significant societal or economic impact from the event. Any such impact remains unchanged relative to the potential impact of the facility's current operation.

Maximum radiation exposures received by the public, the staff, and visitors, during any postulated design basis or severe accident would be well below established limits. No changes to facility operation or design are anticipated during the license renewal term. Thus, the consequences of facility accidents remain unchanged during the license renewal term from those currently existing at the facility.

Therefore, the continued operation of the facility has no impact on the environment due to design basis or severe accidents. The maximum radiation dose to the public, even during the Maximum Hypothetical Accident, is below the limits established in10 CFR 20.1101(d).

4.2.11 Uranium Fuel Cycle and Waste Management

4.2.11.1 Nuclear Fuel

The fuel handling cycle consists of: 1) receiving new (i.e., unirradiated) fuel elements, 2) transferring the new fuel elements to the fuel storage vault, 3) transferring the new fuel elements from the storage vault to the reactor pool, 4) unloading irradiated fuel elements from the reactor into the in-pool storage locations, 5) loading new or previously irradiated (partially used) fuel elements from the in-pool storage locations into the reactor, and 6) transferring the spent fuel elements from the in-pool storage locations to the fuel transfer cask for shipment.

New fuel is obtained from the DOE and arrives at the facility in DOT approved shipping containers. The new fuel is removed from the shipping containers by hand and placed in a storage vault. The storage vault is equipped with special racks that allow storage of the fuel in a criticality safe geometry such that the calculated K_{eff} is less than 0.9. All new fuel elements are inspected before being placed in the reactor. During inspection, fuel elements are handled singly and are replaced to their proper storage location prior to inspecting a different element. The Special Nuclear Materials Custodian (Assistant Reactor Manager-Physics) ensures that a complete and accurate fuel inventory is maintained.

During all irradiated fuel handling activities, water in the reactor pool is maintained at a level to provide maximum shielding for the operators. The highest dose rate during fuel handling is approximately 25 mrem/h during the short interval of time when an element is passed into the weir area for storage, or when an element is raised to clear the top of the pressure vessel. Following each refueling sequence, a verification is performed to ensure that the fuel elements are fully seated, and a visual inspection of the core is performed to verify that no debris is present. These steps are completed prior to bolting the reactor pressure vessel head in place.

The DOE maintains title to all nuclear fuel used at MURR and is obligated by contract to take possession of the fuel for storage and/or reprocessing after its use in the reactor. Irradiated fuel does not leave the reactor pool until it is loaded into an NRC approved cask for shipment. Transfer of spent fuel from in-pool storage locations to the cask is performed manually; with the cask underwater and resting on the ledge behind the weir wall. The 15-ton capacity overhead rectilinear crane is used to lower and remove the cask from the reactor pool. The cask is decontaminated prior to release for shipment.

A spent fuel element is not loaded into a shipping cask until a predetermined cooling period has elapsed since the element was last removed from the reactor core. Cooling times are based on a thermal analysis of the decay heat generated by a spent fuel element and by the storage requirements established by the DOE site. The thermal analysis is included in a separate SAR for each cask. The shipping cask's "Certificate of Compliance" identifies the required minimum cooling time determined by the thermal analysis.

Prior to being irradiated, new fuel is not radioactive and can be handled without risk. Once the fuel is irradiated, it is stored in the reactor pool where it is protected from the environment until it is placed in a shipping container for shipment to the DOE. All transfers of spent fuel to the shipping casks occur under water and within the MURR containment structure. The shipping cask is certified for over-the-road use by DOE and is designed to withstand all credible accidents that could occur during shipment. Furthermore, this process is presently used to obtain and dispose of fuel for the reactor. No changes in this process are anticipated during the license renewal term. No irradiated spent fuel will be permanently stored at MURR either in the reactor pool or in an Independent Spent Fuel Storage Facility (ISFSI).

4.2.11.2 Radioactive Material & Waste

MURR has a comprehensive Radioactive Waste Management Program that supports operation of the reactor and the research activities conducted in the laboratories. All radioactive materials released from the facility through the Ventilation and Air Treatment System, the Radioactive Liquid Waste Retention and Disposal System, and the Solid Radioactive Waste Program are identified, analyzed, and disposed of in adherence with all applicable regulations and in a manner that protects the health and safety of the general public and the environment.

It is the policy of the reactor facility to keep the volume of waste materials being generated to the absolute minimum by the efficient use of experimental materials, by the use of proper techniques, and by any other means available.

The Radioactive Waste Management Program is periodically audited as part of the radiation protection program and other radiation safety programs (i.e., ALARA Program). The audit is performed by MURR management, or their authorized delegates, to verify the adequacy of the program and to ensure that it complies with applicable regulations. Radioactive waste management records, including radioactive material shipment and transfer records, are maintained by the Health Physics Group. All records are retained for the life of the facility.

Radioactive waste is generally considered to be any item or substance which is no longer of use to the facility and which contains, or is suspected of containing, radioactivity above the established natural background radioactivity. Reactor equipment or components are categorized as radioactive waste by the Reactor Operations or Health Physics staff, while standard consumable supplies such as plastic bags, gloves, absorbent material, contamination wipes, etc., become waste if detectable radioactivity above background is found to be present.

Written procedures provide guidance in the segregation and preparation of radioactive waste prior to its transfer to the Health Physics Group for disposal. Safe disposal may be accomplished by any one of the following methods: storage for decay and ultimate disposal as ordinary trash; disposal of limited and strictly controlled quantities into the sanitary sewage system; transfer to another of the Missouri University licenses for storage, incineration, or processing for other disposal; or packaging for subsequent shipment to a commercial waste facility.

Solid Waste

Solid radioactive waste, generally, is generated as a result of reactor maintenance activities, operations and by the various research activities conducted in the facilities laboratories. Solid waste is placed in receptacles lined with polyethylene bags or in other ways made acceptable for the disposal of radioactive waste. These receptacles are then collected on a routine basis and stored on the below grade level of the laboratory building until a sufficient volume has accumulated to be packaged in sealed containers (typically metal drums). Appropriate radiation monitoring equipment is used in identifying and segregating the solid radioactive waste. All items and materials initially categorized as radioactive waste are monitored a second time before packaging for disposal to confirm data needed for waste shipment records, and to provide a final opportunity for decontamination and/or reclamation of an item. All items are decontaminated prior to release and shipment where practical. This helps reduce the volume of waste by allowing items to be reused. The containers are then processed and prepared for shipment by the Health Physics Group according to DOT regulations. The containers are shipped directly to a waste disposal site for final disposal or transferred to an authorized radioactive waste broker or brokerage service for further processing. No solid radioactive waste is permanently stored at MURR. Table 4-1 provides a list of the volume of solid waste removed from the site from 1996 to 2005 and its radioactive content, in millicuries.

TABLE 4-1
VOLUME OF SOLID RADIOACTIVE WASTE
SHIPPED BY MURR (1996 to 2005)

Year	Volume (Cubic Feet)	Activity (mCi)
2005	730	829
2004	740	698
2003	478	465
2002	634.8	315,121
2001	1,094.4	5,584
2000	522.5	249
1999	565.0	281
1998	610.0	53
1997	420.0	404
1996	337.5	1,409

Mixed Waste

Mixed waste consists of a mixture of hazardous and radioactive materials. Mixed waste produced by MURR is transferred to the Missouri University Environmental Health and Safety Department for disposal. Mixed waste is disposed of in accordance with regulations imposed by the U.S. Environmental Protection Agency (EPA) and the Missouri Department of Natural Resources (DNR). The volume of waste produced varies depending on the nature of various active research projects being undertaken at MURR. However, MURR typically generates less than one liter per week of liquid mixed waste as a byproduct of radio-analytical processes performed in the research laboratories that use High Performance Liquid Chromatography.

MURR does not permanently store mixed waste at the facility. It is usually allowed to decay for a short time to allow the radioactive constituents to decay to background levels prior to being removed from the facility. In the case of longer lived isotopes the University's Environmental Health and Safety Department disposes of mixed waste as it is generated and does not permanently store mixed waste on campus.

Liquid Waste

All potentially radioactive liquid wastes either drain or are pumped to a liquid waste retention and disposal system located on the below grade level of the laboratory building. The liquid waste retention and disposal system consists of four tanks, three transfer pumps, three filter banks, and associated piping and valves.

Liquid waste is retained or chemically treated until an analysis indicates that activity levels are less than the limits specified in 10 CFR 20 for release into the sanitary sewer system. The liquid wastewater effluent release point for the MURR site is the sanitary sewer effluent line. 10 CFR 20.2003 provide limits on liquid releases to the sewer system. In addition each isotope's specific limit, 10 CFR 20 also limits the total activity that can be annually released from MURR to the sanitary sewer. It is the policy of MURR to use some fraction, that is isotope dependant, of these total limits as an administrative limit. These limits ensure that the liquid waste is retained as long as practical to allow the activity to decay.

Chemical treatment consists of introducing a carrier solution that precipitates out the radionuclides. The precipitate can then be removed by filtration, or pumped to a different waste retention tank. In addition to having the activity levels measured, all liquid waste is circulated through a filter bank until no suspended solids of a visible size remain prior to release to the sanitary sewer. It is the policy of the reactor facility to hold all liquid waste as long as practical to minimize the total activity released to the environment.

Section 11.1.1.2 of the SAR describes the radioactive liquid sources associated with the operation of the reactor and its utilization programs. As indicated in the SAR, radioactive liquid waste generated in the laboratories is the most significant source in terms of volume. Because both primary and pool coolant is contained to the maximum extent practical by design, there are no routine releases of these liquids. However, certain maintenance operations, such as the transfer of resin from a demineralizer tank, result in small amounts of radioactivity (mainly tritium) being directed to the liquid waste retention system. The magnitude of liquid effluent radioactivity produced by the facility and released annually to the sanitary sewer system since 1996 is presented in Table 4-2.

TABLE 4-2
ANNUAL LIQUID EFFLUENT RADIOACTIVITY RELEASED TO THE SANITARY SEWER SYSTEM (1996 to 2005)

Year	Curies Released (^3H)	Curies Released (Total)
2005	0.0929	0.1069
2004	0.1029	0.2115
2003	0.0816	0.0871
2002	0.1763	0.1823
2001	0.1642	0.1738
2000	0.1199	0.1420
1999	0.1670	0.1740
1998	0.5901	0.5980
1997	0.1460	0.1510
1996	0.1487	0.1560

Gaseous Effluent

Although Argon-41 (^{41}Ar) and other radioactive gases are released from the facility through the ventilation system exhaust stack, this release is not considered to be waste in the same sense as the solid and liquid wastes previously described. Releases through the MURR exhaust stack are usually classified as an effluent, which is a routine part of the normal operation of the reactor. In MURR, as in many other non-power reactors, there are no radioactive waste off-gas collection systems. Exhaust air from both the laboratory and reactor containment buildings is combined in the facility ventilation exhaust plenum prior to being discharged to the atmosphere. Because air from these two buildings is never mixed until this point, potentially contaminated air from the containment building is diluted by being mixed with uncontaminated air from non-radioactive areas of the facility. This mixing results in minimum concentrations of radioactive gases being released to the environment. The rate of discharge of gaseous (mainly Argon-41) and particulate activity through the facility ventilation exhaust stack does not exceed the limits specified in the Technical Specifications. These limits ensure that exposure to the general public resulting from the radioactivity released by MURR will not exceed the limits of 10 CFR 20.

All air released from the MURR exhaust stack is continuously monitored prior to release. The radioactive concentrations released have been and continues to be well within the limits specified by 10 CFR 20. Because the ventilation system maintains the containment building at a slightly negative pressure relative to the outside environment, the exhaust stack is the only release point for radioactive gaseous effluents produced by the facility. The magnitude of gaseous effluent radioactivity released from the facility through the stack annually since 1996 is presented in Table 4-3.

TABLE 4-3
ANNUAL GASEOUS EFFLUENT RADIOACTIVITY RELEASED THROUGH THE STACK (1996 to 2005)

Year	Curies Released (Argon-41)	Curies Released (Total)
2005	1,240	1,252
2004	1,320	1,330
2003	1,250	1,260
2002	1,180	1,190
2001	1,180	1,190
2000	975	982
1999	1,130	1,137
1998	1,130	1,134
1997	861	870
1996	728	739

To provide additional assurance that the amount of radiation released by the facility has no impact on the environment around the facility, a total of 45 thermoluminescent dosimeters (TLDs) are placed at various distances and directions from the facility. These TLDs are monitored and the results averaged over a year's period of time. The average and maximum exposures measured at the location of the TLDs for the years 1996 to 2005 is presented in Table 4-4.

TABLE 4-4
AVERAGE AND MAXIMUM EXPOSURES MEASURED AT VARIOUS LOCATIONS SURROUNDING MURR (1996 to 2005)

Year	Average (mRem/yr) [a]	Maximum (mRem/yr) [b]
2005	<5	17
2004	< 5	16
2003	< 5	10
2002	< 5	17
2001	< 5	39
2000	< 5	19
1999	< 15	44
1998	< 5	52
1997	< 10	35
1996	< 10	35

[a] Represents the average of all monitored locations.

[b] Represents the single maximum reading of all monitored locations. In most cases the highest maximum reading is found on TLD's located near areas where shipments of radioactive materials are staged prior to acceptance by the carrier.

In addition, MURR has calculated the dose to the individual member of the public likely to receive the highest dose from air emission of radioactive material to the environment to demonstrate compliance with 10 CFR 20.1101(d). This regulation provides "as low as is reasonably achievable" criteria for air emissions that must result in an individual member of the public receiving a total effective dose equivalent (TEDE) of less than 10 mrem per year. The results of the calculation performed by MURR for the years 1996 to 2005 are presented in Table 4-5.

TABLE 4-5
CALCULATED TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE)
(1996 to 2005)

Year	Dose (mRem)
2005	1.0
2004	1.0
2003	1.0
2002	0.9
2001	0.9
2000	0.8
1999	0.9
1998	0.9
1997	0.7
1996	0.6

* Maximum dose expected to be received by an individual located in the vicinity of MURR.

These values are all 1 mrem or less, and are well below the limit of 10 mrem per year for the individual most likely to receive the highest dose, as established by 10 CFR 20.1101(d).

4.2.11.3 Offsite Radiological Impacts Not Associated with Spent Fuel

All gaseous and liquid wastes are monitored for radionuclides and radiation levels prior to release. No material is released until radiation levels are below the limits prescribed in 10 CFR 20. In addition, it is the policy of MURR to hold liquid wastes as long as practical to reduce the amount of radiation released to the environment. All gaseous waste is mixed with air from areas that are not potentially contaminated to dilute the effects of any radiation that may be released. Solid waste is held on site as long as practical to reduce the amount of radiation and is then shipped to storage locations in approved shipping containers.

Because the radiation levels of any waste produced by MURR and released to the environment are well below established limits, there is no significant impact on the environment. In addition, the maximum dose received by any one individual living in proximity to the site has been determined to be well below the limits established in 10 CFR 20.1101(d).

4.2.11.4 Offsite Radiological Impacts of Spent Fuel Disposal

The reactor core at MURR consists of eight identical fuel assemblies, each occupying a 45 degree segment of a cylindrical annulus. Each fuel assembly is comprised of 24 circumferential plates containing uranium enriched to approximately 93% in the isotope uranium-235 as the fuel material. A fuel assembly has an active fuel length of 24 inches. The overall length of a fuel assembly is 32.5 inches.

The DOE supplies fuel used by MURR. The DOE retains title to the fuel and is obligated to take possession of it once it can no longer be used in the reactor. Irradiated fuel is shipped only in shipping containers approved by the DOT. Fuel is held until a predetermined cooling period has elapsed since the element was last removed from the reactor core. Cooling times are based on a thermal analysis of the decay heat generated by a spent fuel element and by the storage requirements established by the DOE site. The thermal analysis is included as part of the SAR prepared for each cask prior to shipment.

Once the irradiated fuel is placed into the shipping cask and the cask has been decontaminated, it is shipped to a DOE facility for storage. Thus, there are no off-site radiological or non-radiological impacts associated with the storage of spent fuel. Furthermore, the shipping cask provides sufficient shielding and protection to eliminate concerns with respect to environmental impacts resulting from the shipment of spent fuel.

4.2.11.5 Non-Radiological Waste

MURR uses small quantities of typical laboratory chemicals such as acids, bases and organic liquids. These chemicals are purchased in one to four liter quantities. Typical transfers of hazardous material to the Missouri University Environmental Health & Safety waste storage facility consist of one to four liter quantities of hydrochloric acid, nitric acid, aqua regia and/or isopropyl alcohol. Hazardous materials are used in accordance with established procedures and controls, and in appropriate laboratory settings. After use, all such materials are disposed of in accordance with applicable regulations.

The Missouri University Environmental Health & Safety Department currently maintains a non-radioactive hazardous waste collection facility overseen by the Missouri Department of Natural Resources (MDNR). Unwanted, non-radioactive hazardous materials generated by MURR are transferred to this facility in accordance with University policies and procedures. The hazardous materials are then disposed of in compliance with regulations specified by the Environmental Protection Agency (EPA) and the MDNR. There are no non-radiological chemicals released from the facility that are unique to nuclear facilities or that have any significant environmental impact.

4.2.12 Decommissioning

Handling, transportation and disposal of radioactive waste is described in Sections 4.1.21 and 4.2.11 of this report. As discussed in these sections, MURR does not store any waste material or spent nuclear fuel on a long-term or permanent basis at the facility. Therefore, there will be no increase in the amount of solid or liquid waste, gaseous effluents, or spent fuel that will be stored onsite as a result of operating the facility for the additional period of the license renewal term. Thus, there would be no more radioactive waste generated during decommissioning after an additional 20 years than would be generated if the facility were decommissioned at the end of the current license term.
Doses to the public will continue to be well below 10 CFR 20 limits during the license renewal term because no changes to operation of the facility are anticipated. Occupational doses will increase only an insignificant amount due to buildup of long-lived radionuclides within the facility.

Due to the small size of the facility, a significant amount of construction activity will not be required to complete the decommissioning. Therefore, there will be no impact on air quality or water quality during decommissioning either at the end of the current license period or at the end of the license renewal term. Because no additional land will be disturbed and no materials will be released to the atmosphere, or to a body of surface water, there are no ecological impacts associated with decommissioning either at the end of the current license period or at the end of the license renewal term.

Also, because of its small size, decommissioning the facility would have little or no socioeconomic impacts. The increased work force required to complete the decommissioning would be an insignificant increase in the population in the area. Any impacts that did occur would be the same at the end of the license renewal term as at the end of the current license period.

5.0 NEW AND SIGNIFICANT INFORMATION

During the preparation of this request for license renewal, the information contained in the SAR has been reviewed and updated to reflect any changes to the facility. As part of the preparation of the ER, the information in the SAR was reviewed to determine if any new or significant information that might have an adverse impact on the environment had been discovered. In addition, the MU Environmental Health & Safety Department, and local and state agencies were contacted to determine if any new or significant information had been discovered that might cause the continued operation of MURR to have an adverse impact on the environment.

During this review, MURR has not discovered any new and significant information that would cause a change in the environmental impact if operation of the facility were to continue for the license renewal term. The projected increases in population in Boone County and the City of Missouri have been taken into account in determining any anticipated dose to the public due to normal facility operation and design basis and postulated severe accidents. Increases in highway and air traffic in the vicinity of the facility are projected to be small and to not fundamentally change the assessments documented in the SAR.

The projected increases in student body size at the Missouri University will have no direct effect because housing or other student facilities are not constructed within the University Research Park that immediately surrounds the facility. Any expected increases in population will not adversely impact the time or effort required to evacuate the area around the facility in the event of a radiological emergency.

There are no major refurbishment activities or modifications planned that are associated with the license renewal that will have any impact on conduct of operations of the facility. There will be little or no significant increase in levels of radiation or radioactive waste generated during normal facility operation or during severe accidents. There will be no change in water use or in the release of gaseous or liquid effluents to the environment.

Therefore, the MURR staff is not aware of any new or significant information that would cause the operation of the facility during the license renewal term to have any adverse impact on the environment.

5.1 Status of Compliance

As part of this license renewal request, MURR has conducted a review of all applicable local, State and Federal permits and licenses that support the extended period of operation as required by 10 CFR 51.45(d). This review has concluded that no additional permits or licenses are required and that no changes to existing permits or licenses are necessary. Furthermore, no new environmental licenses will be required by the Missouri University campus or MURR as a result of the license renewal of MURR.

MURR, as part of the Missouri University-Columbia campus, is covered by and subject to a variety of environmental permits. At the present time, there are two such applicable permits:

1. The campus has obtained from the Missouri Department of Natural Resources (DNR) a Part 70 Operating Permit Number OP1999-031, which places restrictions on air emissions from campus activities. This permit applies to the entire Columbia campus including MURR, but not including the University Power Plant, which has a separate permit. The MURR license renewal will not result in changes to this permit.

2. In the spring of 2001, the campus terminated its Part B permit, MOD 006326904, from the U.S. EPA and the Missouri DNR for storage of hazardous wastes for more than 90 days. The campus Part B permit had been amended to include the storage of seven (7) drums of mixed waste stored at MURR from a previous research project. This material has since been shipped of site and the modified Part B permit was terminated.

In addition to the above permit, the campus has an active program to ensure compliance with all environmental regulations and safety codes. As a State entity, the University is generally not subject to local zoning requirements. There are no regional planning authorities that have jurisdiction over MU. Although not subject to local zoning control, MU maintains good relations with the City of Columbia and adopts policies that are similar to those of local governmental jurisdictions.

MU requires all new construction and major renovation projects to be in compliance with current life safety and fire safety codes. This requirement will be applied to the license renewal of MURR. Construction activities are reviewed by architects and engineers employed by the University. In addition, a representative of the Environmental Health & Safety Department attends monthly meetings held by Campus Facilities Project Design & Construction Department. All proposed projects are reviewed at this monthly meeting. Each project is examined very closely to ensure compliance with applicable building codes, environmental regulations, and established safety practices.

MUC operates its own public drinking water system and maintains close contact with the City of Columbia's publicly owned treatment works (POTW). License renewal of MURR will not have a significant new impact on water usage or wastewater discharges to the POTW. MURR does not have nor need a National Pollutant Discharge Elimination System (NPDES) permit for discharge of process water or storm water. MU currently complies with EPA storm water regulations through a system coordinated by the University's Environmental Health & Safety Office.

MUC has a comprehensive environmental health and safety (EHS) program. The MU EHS program includes the safe use and disposal of radioactive, chemical, and biological materials. MURR has its own radiation safety program. There are a variety of mechanisms to coordinate radiation safety issues at MURR with those of the rest of the campus. A representative from MURR is a member of the Campus Radiation Safety Committee and an EHS representative is a member of the MURR Radiation Safety Committee. All users of hazardous materials, including those used at MURR, must be registered with EHS. No one may purchase hazardous materials without being registered. EHS is responsible for collection and management of unwanted hazardous materials. The EHS staff includes a full-time Biological Safety Professional, who addresses campus biosafety issues. The EHS program also addresses fire safety, life safety, industrial hygiene, environmental permits and compliance, and miscellaneous environmental health and safety issues.

MU has established the following committees consisting of faculty, staff, and students to ensure that environmental and safety concerns are adequately addressed:

- Campus Safety Committee
- Environmental Affairs Council
- Hazardous Materials Management Committee
- Institutional Biosafety Committee
- Radiation Safety Committee
- Recycling Committee

As part of this Status of Compliance this environmental report contains a run of the program COMPLY of the EPA that demonstrates that the Research Reactor is in compliance with the federal regulation established by the Clean Air Act. The following program's results are found on the Appendix of this report.

As a result of the review of information contained in the SAR, and based on discussions with representatives from MURR and from state and local agencies, there is no new or significant information that has any impact on potential environmental consequences associated with the license renewal of MURR. No issues beyond the 92 issues already identified in the GEIS and listed in Table 1-1 were identified during the license renewal environmental review.

6.0 SUMMARY OF LICENSE RENEWAL IMPACTS

The environmental impact of continued operation of MURR for the period of the license renewal term has been assessed as described in Section 4.0. The potential for environmental impact has been assessed with respect to all 92 issues listed in Appendix B of Subpart A of 10 CFR 51. In addition, research has been conducted as described in Section 5.0 to determine if there is any new and significant information available that would change the result of any previous analysis of the impact of continued operation.

Based on the reviews and assessments performed, the MURR staff has determined that the continued operation of the facility for the license renewal term has no adverse impact on the environment. Decommissioning the facility at the end of the license renewal term will not have any greater impact than decommissioning at the end of the current license term because there is no permanent storage of spent fuel or other radioactive waste at the facility. Furthermore, there are no major refurbishment activities required as part of the license renewal effort or during the license renewal term that could adversely impact the environment.

No mitigating actions of any kind other than those controls, practices, and procedures that are already in place are required to lessen or eliminate any potential impact on the environment. No additional structures, systems or components are required to provide additional protection to the environment.

7.0 ALTERNATIVES TO LICENSE RENEWAL

MURR's operating license will expire on October 11, 2006. This Environmental Report has been prepared to support a request for an extension of the operating license for an additional 20 years. That is, MURR is requesting an extension of the operating license until October 11, 2026. MURR had previously filed a request for an extension until October 11, 2006 to recapture the construction time required to build the facility. The original license expiration date was November 21, 2001. Therefore, there are two options applicable to the renewal of the facility's operating license for the requested 20-year period:

1. No license renewal. Under this "no action" alternative, the facility would cease to operate on October 11, 2006 and decommissioning would subsequently commence.

2. A renewal is granted until October 11, 2026 in response to the renewal application request filed by MURR in September 2006 (Reference 9.2). A denial or no action occurs on the request for a 20-year extension to the operating license is another possibility.

The environmental impact of each of these options is discussed in the following sections. It is assumed that the facility would be decommissioned after expiration of the operating license under both options. However, an extension of the operating license until October 11, 2026 has no environmental impact with respect to decommissioning, other than determining when those activities will commence (see Section 4.2.12). Because MURR is not a power reactor, the regional power grid will not be affected. Therefore, the primary impacts of each option will be related to human health and other socioeconomic factors.

7.1 No License Extension Granted (No Action Alternative)

There are currently only 27 operating research and training reactors in the United States. This represents a 50% decline since 1980 in the number of operating research reactors. United States Senate Bill (S. 242, "Department of Energy University Nuclear Science and Engineering Act") describes the decline in the number of University Research Reactors as a threat to the health of people in the United States and to national security. Because MURR is the largest University-owned research reactor in the United States, terminating operations at MURR would adversely impact a condition that is already a concern.

There are currently approximately 100 operating nuclear power plants in the United States and many more around the world. New reactors are currently being constructed in many locations, particularly in developing nations and in nations without an existing nuclear program. In addition, electric utilities within the United States are studying the potential for building and operating new advanced reactors to provide for power demand and to reduce the emission of greenhouse effect gases that increase global warming.

MURR provides vital research opportunities and training for nuclear physicists, health physicists, engineers, scientists, and members of the medical community. In addition to providing training and research capabilities for its staff and Missouri University students and faculty, MURR participates in a DOE program to provide the availability of university reactor facilities to non-reactor-owning colleges and universities. MURR also provides support to institutions with reactors that operate at power levels too low to adequately perform some experiments. Research conducted at MURR supports scientific advances in numerous fields of study including anthropology, archaeology, animal science, crystallography, geology, materials science, nuclear analysis development, physics, and biochemistry. If no extension is granted, a major educational and research resource will be lost.

In addition, MURR is presently the sole approved US provider of radioactive isotopes for use in at least three types of cancer therapies. Without continued operation of MURR, patients would not receive these therapies and would likely die sooner from the effects of the cancer. In addition, there are thousands of cancer patients who currently use the radioisotopes produced by MURR to relieve the debilitating pain caused by metastatic bone cancer. Without these isotopes, the patients would suffer intense pain that they do not presently experience.

In addition to the direct socioeconomic impacts, there would also be intangible impacts such as loss of educational diversity for the Missouri University relative to other major educational institutions within the Midwestern United States, a reduction in research grants to the University and impacts to the medical facilities near the University due to the absence of radioisotopes produced by the reactor. These impacts could eventually lead to a reduction in the number of doctors, scientists, and professors employed at Missouri University.

During decommissioning, impacts on water use and ecology in the vicinity of the reactor would be about the same as during operation. Radiological impacts to the public, though minimal during operation, would be further reduced during decommissioning. Radiation doses to workers at the facility would increase during the decommissioning operation. However, the radiation doses would be the same if decommissioning were to occur at the end of the license renewal term or upon expiration of the current license.

The production of spent fuel and high level radioactive waste would end once operation ceased and decommissioning began. However, approximately 6,000 to 9,000 cubic feet of waste would have to be disposed of during the decommissioning effort. With regard to aesthetics, there would be greater impact during decontamination and decommissioning (D&D), due to the construction and dismantlement activities that would be required. Finally, there would be a small increase in the number of workers at the facility in order to complete the D&D effort. All of these factors would be the same irrespective of when the decommissioning process began.

Once the decommissioning effort was completed, there would be no impact on water use or ecology. There would be no releases of liquid or gaseous effluent and no plume of water vapor from the cooling tower. Decommissioning would eliminate doses to facility workers as well as eliminate the minimal radioactive releases that occur during operation. In addition, no more radioactive waste or spent fuel would be generated.

With respect to aesthetics, there would likely be little change because only the contaminated components and structures would be removed. It is unlikely that the entire facility would be dismantled. Finally, there would be a small adverse economic impact due to the reduced work force after the completion of the D&D effort.

7.2 License Extension Granted to October 11, 2026

Under this alternative, the MURR would continue to operate until October 11, 2026. During these 20 years from October 2006 to October 2026, MURR would continue to conduct operations as described in the SAR and would continue to use the existing procedures, practices, systems and components. Impacts to the environment during this period would be similar to those incurred with the proposed twenty-year renewal period just discussed in this report.

8.0 EVALUATION OF ENVIRONMENTAL IMPACTS AGAINST ALTERNATIVE ACTIONS

As described in Section 4.0, there is no significant environmental impact related to the continued operation of MURR for the license renewal term. No major refurbishment activities or mitigating actions are required to support the license renewal effort and no major modifications to facility operations or procedures are planned. The only modifications anticipated are minor upgrades related to facility maintenance activities. The aforementioned cyclotron and laboratory building would be located on the research reactor site, but would not be directly related to the reactor itself. Because no spent fuel is permanently stored at MURR and all high and low level waste is shipped off-site for disposal, the extended period of operation will have minimal impacts on the decontamination and decommissioning (D&D) of the facility. There will be little or no change in environmental impact during the extended period of operation.

If the facility license is not extended and a shutdown is required, there would be a significant impact related to the loss of the research and training opportunities. In addition, cessation in the production of radioisotopes currently produced at MURR would have a negative impact on the health and quality of life of numerous cancer sufferers that use these isotopes for treatment and/or pain relief. The D&D effort would cause a slight increase in the impact of the facility on some aspects of the environment and a slight decrease in other aspects of the environment. After completion of the D&D, there would be a slight decrease in the impact of the facility on the environment. The changes would be approximately the same whether the D&D occurred at the end of the current license term or at a future date.

9.0 REFERENCES

9.1 Missouri University Research Reactor (MURR) Safety Analysis Report.

9.2 December 27, 2000 letter from MURR to the USNRC, "Application for amendment to Facility Operating License Number R-103 to extend the expiration date of the operating license from November 21, 2001 to October 11, 2006."

9.3 March 1, 2001 letter from the USNRC to MURR requesting additional information with regard to MURR's license extension request of December 27, 2000.

9.4 April 12, 2001 letter from MURR to the USNRC in response to the NRC request for additional information of March 1, 2001.

9.5 May 15, 2001 letter from the USNRC to MURR requesting additional information regarding MURR's license extension request of December 27, 2000.

9.6 June 6, 2001 letter from MURR to the USNRC in response to the NRC request for additional information of May 15, 2001.

9.7 June 25, 2001 letter from USNRC to MURR enclosing a copy of the predecisional Environmental Assessment and Finding of No Significant Impact related to the application for the license extension of MURR submitted on December 27, 2000.

9.8 July 26, 2001 letter from the USNRC to the State of Missouri Department of Natural Resources enclosing a copy of the NRC predecisional Environmental Assessment and Finding of No Significant Impact related to the application for the license extension of MURR submitted on December 27, 2000.

9.9 August 6, 2001 letter from the USNRC to MURR requesting additional information and providing additional guidance with respect to the application for the license extension of MURR submitted on December 27, 2000.

9.10 NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors."

9.11 NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants (GEIS)."

9.12 Supplement 1 to Regulatory Guide 4.2, "Preparation of Supplemental Environmental Reports for Applications to Renew Nuclear Power Plant Operating Licenses."

9.13 NUREG-1555, Supplement 1, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants."

9.14 Title 10, Code of Federal Regulations, Part 51 (10 CFR 51), "Environmental Effect of Renewing the Operating License of a Nuclear Power Plant," Appendix B to Subpart A.

9.15 Title 10, Code of Federal Regulations, Part 20 (10 CFR 20), "Standards for Protection Against Radiation."