NWMI

NORTHWEST MEDICAL ISOTOPES

Chapter 19.0 – Environmental Review

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0A
June 2015

Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, Oregon 97330

NORTHWEST MEDICAL ISOTOPES

Chapter 19.0 – Environmental Review

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0A
June 2015

Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, Oregon 97330

NORTHWEST MEDICAL ISOTOPES

Chapter 19.0 – Environmental Review

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0A
June 2015

Prepared by:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, Oregon 97330

This page intentionally left blank.

Chapter 19.0 – Environmental Review

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0A

Date Published:
June 29, 2015

***Document Number*:** **NWMI-2013-021**	***Revision Number*:** **0A**
***Title*:** **Chapter 19.0, Environmental Review Construction Permit Application for Radioisotope Production Facility**	
***Approved by*:** **Carolyn Haass**	***Signature*:** Carolyn C. Haass

This page intentionally left blank.

Rev	Date	Reason for Revision	Revised By
0	1/5/2015	Initial Report	Not required
0A	6/29/2015	Update due to maturation of design	C. Haass

This page intentionally left blank.

CONTENTS

APPENDICES

FIGURES

TABLES

TERMS

Acronyms and Abbreviations

^{41}Ar	argon-41
^{7}Be	beryllium-7
^{14}C	carbon-14
^{137}Cs	cesium-137
^{131}I	iodine-131
^{132}I	iodine-132
^{40}K	potassium-40
^{98}Mo	molybdenum-98
^{99}Mo	molybdenum-99
^{100}Mo	molybdenum-100
^{63}Ni	nickel-63
^{112}Pd	palladium-112
^{106}Rh	rhodium-106
^{99}Tc	technetium-99
^{99m}Tc	technetium-99m
^{132}Te	tellurium-132
^{235}U	uranium-235
^{237}U	uranium-237
^{238}U	uranium-238
^{133}Xe	xenon-133
ABC Laboratories	Analytical Bio-Chemistry Laboratories, Inc.
A.D.	Anno Domini
ADUN	acid-deficient uranyl nitrate
AECL	Atomic Energy of Canada, Ltd
AEGL	Acute Exposure Guideline Level
ALARA	as low as reasonably achievable
ANSTO	Australian Nuclear Science and Technology Organization
B.C.	Before Christ
BLM	Bureau of Land Management
BMP	best management practice
BRR	BEA Research Reactor
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAM	continuous air monitor
CATSO	Columbia Area Transportation Study Organization
CDBG	Community Development Block Grant
CEQ	Council on Environmental Quality
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CNSC	Canadian Nuclear Safety Commission
CO	carbon monoxide
CO_2	carbon dioxide
COLT	Columbia Terminal
CSR	Code of State Regulations
CWA	Clean Water Act
DBA	design basis accident
DEQ	Division of Environmental Quality
Discovery Ridge	Discovery Ridge Research Park

DOA	Department of Administration
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EF scale	enhanced Fujita tornado intensity scale
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ER	environmental review
ERPG	Emergency Response Planning Guideline
F scale	(original) Fujita tornado intensity scale
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FSAR	Final Safety Analysis Report
GCRA	Gans Creek Recreation Area
GHG	greenhouse gas
GIS	Geographical Information System
HAP	hazardous air pollutant
HEPA	high-efficiency particulate air
HEU	high-enriched uranium
HFR	High-Flux Reactor
HIC	high-integrity container
HVAC	heating, ventilation, and air conditioning
HWMC	Hazardous Waste Management Commission
ICP-MS	inductively coupled plasma mass spectrometry
IPaC	information, planning, and conservation
IRE	Institute of Radioelements
IRU	iodine retention unit
IX	ion exchange
Kr	krypton
LEU	low-enriched uranium
LLMW	low-level mixed waste
LLC	limited-liability company
LQG	large-quantity generator
LUST	leaking underground storage tank
Mallinckrodt	Mallinckrodt Pharmaceuticals, Inc.
MAR	material at risk
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MHA	maximum hypothetical accident
MHP	mobile home park
MIDUS	Medical Isotope Depleted Uranium Shielded
MMI	Modified Mercalli Intensity
MMRPC	Mid-Missouri Regional Planning Commission
MNRC	McClellan Nuclear Research Center
MoDOT	Missouri Department of Transportation
MOI	maximally exposed off-site individual
MU	University of Missouri
MURR	University of Missouri Research Reactor
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act

NESHAP	National Emission Standards for Hazardous Air Pollutants
NMSZ	New Madrid Seismic Zone
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRC	U.S. Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NRU	National Research Universal
NSR	new source review
NWMI	Northwest Medical Isotopes, LLC
O_3	ozone
OPAL	Open Pool Australian Lightwater
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OSTR	Oregon State University TRIGA Reactor
OSU	Oregon State University
PAC	Protective Action Criteria
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
PCCE	private common collector elimination
PM	particulate matter
PM-2.5	particulate matter, 2.5 micron
PM-10	particulate matter, 10 micron
PPE	personal protective equipment
PSAR	preliminary safety analysis report
PTE	potential to emit
QA	quality assurance
RADIL	Research and Diagnostic Laboratory
RCRA	Resource Conservation and Recovery Act
ROI	region of influence
RPF	radioisotope production facility
RSAC	Radiological Safety Analysis Code
SAFARI-1	South African Fundamental Reactor Installation 1
SHPO	State Historic Preservation Office
SHWF	State hazardous waste facility
SLA	street light addition
SMART	Simple Multi-Attribute Rating Technique
SO_2	sulfur dioxide
SO_x	sulfur oxides
SPCC	spill prevention, control, and countermeasure
SRS	Savannah River Site
SVOA	semivolatile organic analyte
SWPPP	stormwater pollution prevention plan
TDD	Transportation Development District
TDS	total dissolved solid
TEEL	Temporary Emergency Exposure Limit
Terracon	Terracon Consultants, Inc.

TLD	thermoluminescent dosimeter
TMDL	total maximum daily load
TPH	total petroleum hydrocarbon
U	uranium
UC Davis	University of California at Davis
Union Carbide	Union Carbide Nuclear Corporation
UO_2	uranium dioxide
U.S.	United States
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VKM	vehicle kilometer traveled
VMT	vehicle miles traveled
VOA	volatile organic analyte
VOC	volatile organic compound
WCS	Waste Control Specialists
WNA	World Nuclear Association
WWTP	wastewater treatment plant
Xe	xenon

Units

°C	degrees Celsius
°F	degrees Fahrenheit
μ	micron
μg	microgram
μS	microsiemens
b	barn
Ci	curie
cm	centimeter
cm^2	cubic centimeters
dB	decibel
dBa	A-weighted decibel
ft	feet
ft^2	square feet
ft^3	cubic feet
g	gram
gal	gallon
ha	hectare
hr	hour
in.	inch
kg	kilogram
km	kilometer
km^2	square kilometers
kn	knots
kV	kilovolt
kW	kilowatt
L	liter
lb	pound
m	meter
m^2	square meter

m^3	cubic meter
mCi	millicurie
mEq	milliequivalent
mg	milligram
Mgal	million gallons
mi	mile
mi^2	square mile
min	minute
mL	milliliter
ML	million liters
mmho	millimho
mR	milliroentgen
mrem	millirem
mSv	millisievert
MT	metric ton
MW	megawatt
MWD	megawatt days
NTU	nephelometric turbidity unit
oz	ounce
pCi	picocurie
ppb	parts per billion
ppm	parts per million
sec	second
Sv	sievert
t	tonne (metric)
wt%	weight percent
yd^3	cubic yard
yr	year

19.0 ENVIRONMENTAL REVIEW

19.1 INTRODUCTION

Licensing Background

Northwest Medical Isotopes, LLC (NWMI) is applying to the U.S. Nuclear Regulatory Commission (NRC) to obtain a license for a production facility under Title 10, *Code of Federal Regulations* (CFR) Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities." Embedded in the 10 CFR 50-licensed facility will be several activities subject to 10 CFR 70, "Domestic Licensing of Special Nuclear Material," to receive, possess, use, and transfer special nuclear material and 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," to process and transport molybdenum-99 (^{99}Mo) for medical applications.

NWMI intends to submit a single 10 CFR 50 license application for the radioisotope production facility (RPF) following the guidance in NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, that encompasses activities regulated under different NRC requirements (e.g., 10 CFR 70 and 10 CFR 30), in accordance with 10 CFR 50.31, "Combining Applications," and 10 CFR 50.32, "Elimination of Repetition."

The NRC has determined that a radioisotope separation and processing facility, which also conducts separation of special nuclear material, will be considered a production facility and as such, will be subject to licensing under 10 CFR 50. A significant portion of the NWMI RPF is focused on the disassembly of irradiated low-enriched uranium (LEU) targets, separation and purification of fission product ^{99}Mo, and the recycle of LEU that is licensed under 10 CFR 50. The RPF will also include the fabrication of LEU targets, which will be licensed under 10 CFR 70. These targets will be shipped to NWMI's network of research or test reactors for irradiation (considered a connected action) and returned to the RPF for processing. The LEU used for the production of the LEU target materials will be obtained from the U.S. Department of Energy (DOE) and from LEU reclaimed from processing the irradiated targets.

NWMI's licensing approach for the RPF defines the following unit processes and areas that fall under the following NRC regulations:

- 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities"
  - Irradiated LEU Target receipt (from network of university research or test reactors)
  - Irradiated LEU Target disassembly and dissolution
  - Mo recovery and purification
  - Uranium recovery and recycle
  - Waste management
  - Associated laboratory and support areas
- 10 CFR 70, "Domestic Licensing of Special Nuclear Material"
  - Receipt of fresh LEU (from DOE)
  - LEU target fabrication
  - Associated laboratory and support areas

Any byproduct materials produced or extracted in the RPF will be licensed under 10 CFR 30.

Introduction

In accordance with the provisions of 10 CFR 50 and supporting guidance, NWMI is providing this Applicant's Environmental Report – Construction Permit Stage (ER) in support of an application to construct and operate an RPF at Discovery Ridge Research Park (Discovery Ridge) in Columbia, Missouri. This ER is consistent with the content and organization of NRC-2011-0135, *Final Interim Staff Guidance Augmenting NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Parts 1 and 2, for Licensing Radioisotope Production Facilities and Homogeneous Reactors* (NRC, 2012a), Chapter 19.

The ER supports the regulatory review that is performed by the NRC under 10 CFR 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Review," which requires that environmental impacts from the project be evaluated and described in a concise, clear, and analytical manner. This document also provides information for the NRC to conducts its environmental review in accordance with 10 CFR 51, Subpart A, "National Environmental Policy Act – Regulations Implementing Section 102 (2)."

This ER addresses the National Environmental Policy Act (NEPA) (42 U.S.C. § 4321 et seq.) actions needed to support activities that will be provisions incorporated in the requested 10 CFR 50 license, including certain activities regulated under 10 CFR 70 and 10 CFR 30.

An overview of the assessment of the environmental effects of construction, operation, and decommissioning of the RPF on the site and surrounding areas is provided in the ER. The document is structured as follows:

- **Section 19.1** presents the purpose and need of the proposed action, and the regulatory provisions, permits, and required consultations.
- **Section 19.2** presents the proposed action. This section includes the proposed site location and layout; facility description; process description; operations and systems descriptions; water consumption and treatment; cooling and heat dissipating systems; waste systems, storage, and treatment; and transport of the radioactive and nonradioactive materials, and the schedule associated with the major phases of the project.
- **Section 19.3** presents the affected environment. This section describes existing conditions at the site of the proposed action and serves as the baseline to measure changes in the affected environment caused by the proposed action. Resources applicable to the scope of the action are presented and include land use, visual resources, air quality, meteorology, noise, geologic environment, water resources, ecological resources, historical and cultural resources, socioeconomics, and human health.
- **Section 19.4** presents the direct, indirect, and cumulative effects/impacts to the resources described in Section 19.2.1.3 associated with construction, operations, and decommissioning of the proposed action. Data and analyses presented in this section are commensurate with the importance of the impact, with less important material summarized, consolidated, or referenced. This section also discusses postulated accidents and environmental justice.
- **Section 19.4.13** presents the alternatives and associated costs and benefits. This section discusses the costs and benefits of each alternative and the proposed action, including a qualitative discussion of environmental impacts.
- **Section 19.6** presents the conclusions, which address the unavoidable adverse environmental impacts of the proposed action, the relationship between short-term uses and long-term productivity of the environment, and irreversible and irretrievable commitments of resources used to support the proposed action.
- **Section 19.7** provides a list of references cited within this chapter.

19.1.1 Purpose and Need for Action

NWMI has formed a team of United States (U.S.) universities and companies to cost-effectively address the need for a domestic ^{99}Mo supply. NWMI intends to provide approximately 50 percent of the ^{99}Mo demand in North America and has developed an approach, including manufacturing and processing, using a "total LEU solution" to be implemented by 2017.

As set forth in Section 19.2.1, the proposed action is the issuance of an NRC license under 10 CFR 50, with provisions for 10 CFR 70 and 10 CFR 30 that would authorize NWMI to construct and operate the RPF for the production of ^{99}Mo at a site located in Columbia, Missouri. Proposed RPF activities include:

- Receiving LEU from DOE
- Producing LEU target materials and fabrication of targets
- Packaging and shipping LEU targets to the university reactor network for irradiation
- Returning irradiated LEU targets for dissolution, recovery, and purification of ^{99}Mo
- Recovering and recycling LEU to minimize radioactive, mixed, and hazardous waste generation
- Treating/packaging wastes generated by RPF process steps to enable transport to a disposal site

For purposes of complying with NEPA requirements, two or more university research reactors are assumed to obtain a license amendment authorized by the NRC to irradiate LEU targets. The ER includes an evaluation of irradiating LEU targets in a reactor. For a specific university research reactor to irradiate LEU targets, an amendment to the university's 10 CFR 50 NRC license and an analysis of site-specific environmental impacts related to such an amendment would be required.

Figure 19-1 illustrates the NWMI's general ^{99}Mo process and distribution flow.

Figure 19-1. General Molybdenum-99 Process Flow and Distribution

The NWMI process to manufacture ^{99}Mo is approved by the U.S. Food and Drug Administration (FDA). No direct approvals from the FDA to manufacture ^{99}Mo for commercial use at the RPF will be needed. However, each pharmaceutical distributer of Technetium-99m (^{99m}Tc) generators desiring to purchase ^{99}Mo from NWMI may need to seek FDA approval of NWMI as a manufacturer of the^{99}Mo used in the manufacturer's ^{99m}Tc generators.

19.1.1.1 Background

^{99m}Tc is used for over 40 million nuclear medicine procedures annually. The characteristics of ^{99m}Tc allow high quality images with low radiation exposure to patients. ^{99m}Tc is very versatile for attaching to different chemical substances used to target different organs and diseases, as required by different diagnostic procedures. The two most widely used ^{99m}Tc-based procedures are for imaging blood flow to heart muscles (e.g., myocardial perfusion imaging) and mapping the spread of cancer to bones (e.g., skeletal metastases imaging).

The medical use of ^{99m}Tc has grown significantly since the early 1990s and is expected to have a moderate overall growth of 3–5 percent per year, with stronger growth in countries expanding healthcare programs (NAS, 2009).

Due to the short half-life of ^{99m}Tc of about 6 hours (hr), its parent isotope, ^{99}Mo, which has a 66-hr half-life, is the key supply chain product. ^{99}Mo is produced by bombarding uranium-235 (^{235}U) targets with neutrons from a nuclear reactor, with the resulting fission reaction producing ^{99}Mo and more than 250 other isotopes. After irradiation, targets are transferred to a processing facility and go through a number of extract and purification steps to produce ^{99}Mo. From the processing facility, the ^{99}Mo is shipped to radiopharmaceutical distributors (e.g., Lantheus Medical Imaging, Mallinckrodt Pharmaceuticals (Mallinckrodt), and GE Healthcare). The distributors then purify to FDA standards and package the ^{99}Mo in a radionuclide generator. This generator is called a ^{99m}Tc Generator Kit or "moly cow." The packaged kit is then shipped to nuclear pharmacies to be prepared for individual patient administration. Due to the short half-life, the ^{99}Mo must be efficiently processed and distributed.

The nuclear pharmacy uses the generator to facilitate the decay process from ^{99}Mo to ^{99m}Tc, extract the ^{99m}Tc doses, and bind the doses to compounds specific for an individual test needs. The ^{99m}Tc-compounded drug is then injected into the patient for various diagnostic-scanning purposes. This entire process usually takes place within six to nine days.

19.1.1.2 Molybedum-99 History

Beginning with the discovery of the ^{99m}Tc isotope by Emilio Segrè and Glenn Seaborg in 1938, the relationship between ^{99}Mo and ^{99m}Tc was clearly evident. As an observable fission product of ^{235}U in one of Segrè's later experiments, ^{99}Mo, having a half-life of about 66 hr, was observed emitting beta particles in its progression to a more stable state. In 1958, Walter Tucker and Margaret Green, two scientists under the direction of Powell Richards at the Brookhaven National Laboratory, hypothesized, based on their work with iodine-132 (^{132}I) and tellurium-132 (^{132}Te), that a "generator" could be developed using ^{99}Mo to produce ^{99m}Tc. In 1960, Richards became the first to suggest using ^{99m}Tc as a medical radionuclide tracer.

Benefitting from advancements in gamma camera technology, the production and medical use of ^{99m}Tc grew rapidly in the 1960s. Nuclear Consultants, Inc. and Union Carbide Nuclear Corporation (Union Carbide) began to manufacture commercial ^{99m}Tc generators. Mallinckrodt first undertook the production of ^{99}Mo using the research reactor at the University of Missouri Research Reactor (MURR); however, the size and flux capacity of the MURR reactor was insufficient to sustain a constant supply, and production of the isotope was stopped in the early 1980s. From 1968 to 1972, Union Carbide successfully developed a process using high-enriched uranium (HEU) targets at its Cintichem Facility in Tuxedo, New York, which permitted easy separation of the products of the fission process, thus, beginning domestic ^{99}Mo production in 1980.

Separating from Union Carbide, Cintichem Inc. became the sole producer of domestic ^{99}Mo during the 1980s. International production began in the same timeframe (e.g., Canada and Australia). A balance within the production-supply chain soon existed between the U.S., Canada, Netherlands, Belgium, and Australian production facilities, each having a share in the market and working collaboratively to help fill shortages created by a number of varying effects, including maintenance, inspection, and plant modifications.

In 1989, the Cintichem Facility had an underground leak of radioactive products that affected the surrounding environment. Due to this release, the surrounding community pressured the New York State government to have the Cintichem Facility cease production of ^{99}Mo. In May 1990, the Cintichem Facility closed and filed for decommissioning of its ^{99}Mo production facility, essentially shifting all production to Canada and Europe.

During the same timeframe, the use of ^{99m}Tc in diagnostic scanning continued to grow. In compliance with national regulatory agencies and the International Atomic Energy Agency recommendations, six reactor facilities sustain the HEU production supply:

- National Research Universal (NRU), Ontario, Canada
- High-Flux Reactor (HFR), Petten, Netherlands
- Belgian Reactor 2 (BR2), Mol, Belgium
- OSIRIS, near Paris, France
- MARIA, near Warsaw, Poland
- South African Fundamental Reactor Installation 1 (SAFARI-1), Pelindaba, South Africa

Two reactor facilities sustain the regional LEU production supply: Open Pool Australian Lightwater Reactor (OPAL, South Sydney, Australia) and RA-3 (Buenos Aires, Argentina). With a relatively constant supply and demand using all of the production facilities, the industry was able to produce the quantity of ^{99}Mo needed to fill generator orders from nuclear pharmacies all over the world. However, as these production facilities began to age, additional maintenance and facility improvements became inevitable, requiring temporary shutdowns for individual production facilities.

The first significant worldwide shortage came in November 2007, when the NRU reactor was shutdown for about month for routine maintenance. While the reactor was offline for repairs, the managing agency (Atomic Energy of Canada, Ltd [AECL]) decided to install an additional seismically qualified emergency power system for the two cooling pumps in the reactor, as required by the Canadian Nuclear Safety Commission (CNSC) operating license (amended in 2006). Instead of allowing for full inspections and testing of the new pumps, the Canadian House of Commons passed emergency legislation, without the consent of the CNSC, to restart NRU for commercial production with only one of the two seismic connections complete. With a 120-day grace period of operation issued by the Canadian House of Commons, NRU completed the second seismic connection in February 2008.

The most significant impact on ^{99}Mo production began in 2009, when the NRU reactor was shutdown during an unplanned shutdown of the HFR. In May 2009, a small heavy water leak was detected in the NRU reactor. While originally seen as a routine production stoppage, because of new regulations passed in January 2009, all operating reactors had to undergo intensive design reviews to comply with new safety standards to obtain a license renewal from the CNSC for commercial isotope production. Compliance with the new regulations consequently evolved from an anticipated 90-day renovation into a 17-month complete restructuring and redesign of the reactor and facility. With two-fifths of the world's ^{99}Mo supply facilities rendered inoperative for that period, production shifted to the Netherlands and other ^{99}Mo production sites.

As with the Canadian plant, the plant in the Netherlands faced renewal of its license in May 2010. With the supply of ^{99}Mo already depleted, the closing of the Dutch production plant placed a heavy strain on the worldwide production of ^{99}Mo. Nearly two-thirds of the production supply of ^{99}Mo for medical applications went offline for about six months. While the market did cope with the severe shortages by shifting production to other facilities and finding new ways to produce ^{99m}Tc through other isotope decay, the worldwide shortage exposed the large variability and fragility within the production process.

The National Research Council (NAS, 2009) documented the history of the development of the ^{99}Mo international isotope production industry and the U.S. role. This history is summarized in Figure 19-2. The report identified ^{99}Mo production before 2009.

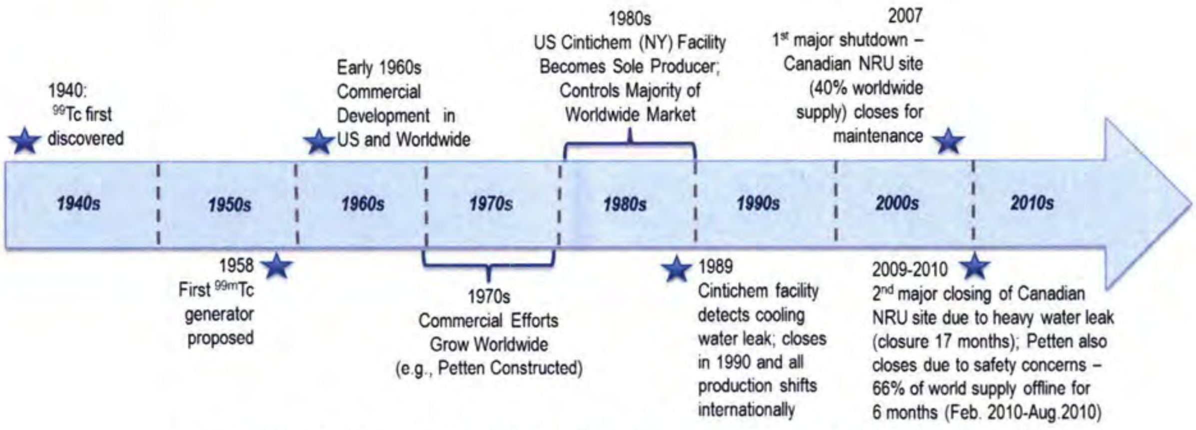


Figure 19-2. Historical Timeline of U.S. and Worldwide Molybdenum-99 Production Industry

19.1.1.3 Molybdenum Today

There are currently no domestic suppliers of ^{99}Mo. The U.S. supply chain structure includes six major reactors, four major processors, and two U.S. generator manufacturers. The irradiators, all using HEU targets, are spread across three continents and include: NRU in Canada (operating since 1957), owned by AECL; HFR in the Netherlands (operational since 1961), owned by the Institute of Energy of the Joint Research Center of the European Commission; OSIRIS owned by the French Atomic Energy Commission; BR-2 owned by the Belgian Nuclear Research Centre; MARIA owned by the Polish Institute of Atomic Energy; and SAFARI-1 owned by the Nuclear Energy Corporation of South Africa. Only the OPAL reactor in Australia, owned by Australian Nuclear Science and Technology Organization, and the RA-3 reactor in Argentina, owned by INVAP S.E., currently produce ^{99}Mo from LEU.

The HEU processors include Nordion Inc. in Canada, National Institute of Radioelements (IRE) in Belgium, Mallinckrodt (previously known as Covidien) in the Netherlands, and NTP Radioisotopes SOC Ltd, a subsidiary of the South African Nuclear Energy Corporation. The LEU processors include the Australian Nuclear Science and Technology Organization (ANSTO) and INVAP S.E. The current U.S. radiopharmaceutical distributors manufacture the ^{99m}Tc generator kits and distribute them to hospitals and clinics. ANSTO is the only LEU ^{99}Mo producer that provides ^{99}Mo in very small quantities to the U.S. through Lantheus Medical Imaging.

The entire reactor network is currently operating at or near capacity. Any unscheduled maintenance or other production disruption immediately translates into a supply disruption. Reliance on such a limited and aging resource results in an extremely delicate supply chain, the vulnerability of which was highlighted late in 2009 when an extended shutdown of the NRU reactor led to a critical ^{99}Mo shortage in North America, and the shutdown of the HFR reactor in August 2008 and November 2013 to the present has caused ^{99}Mo shortages in North America and Europe.

An estimated 40–50 kilograms (kg) (107–134 pounds [lb]) of HEU are used per year for the production of ^{99}Mo worldwide. In the past several years, nuclear non-proliferation and security concerns have led to increased worldwide pressure to mandate migration of HEU targets towards LEU targets by 2016. Conversion from HEU to LEU targets is both expensive and technically challenging for current producers of ^{99}Mo. This LEU mandate further exacerbates the risk of assured ^{99}Mo supply. Only the OPAL reactor in Australia currently produces ^{99}Mo from LEU. NWMI proposes to replace foreign HEU reactor irradiation with a domestic network of university reactors using LEU targets and a domestic processing facility for the extraction and purification of ^{99}Mo.

Figure 19-3 presents an overview of the worldwide nuclear reactors and radioisotope production facilities that currently produce ^{99}Mo.

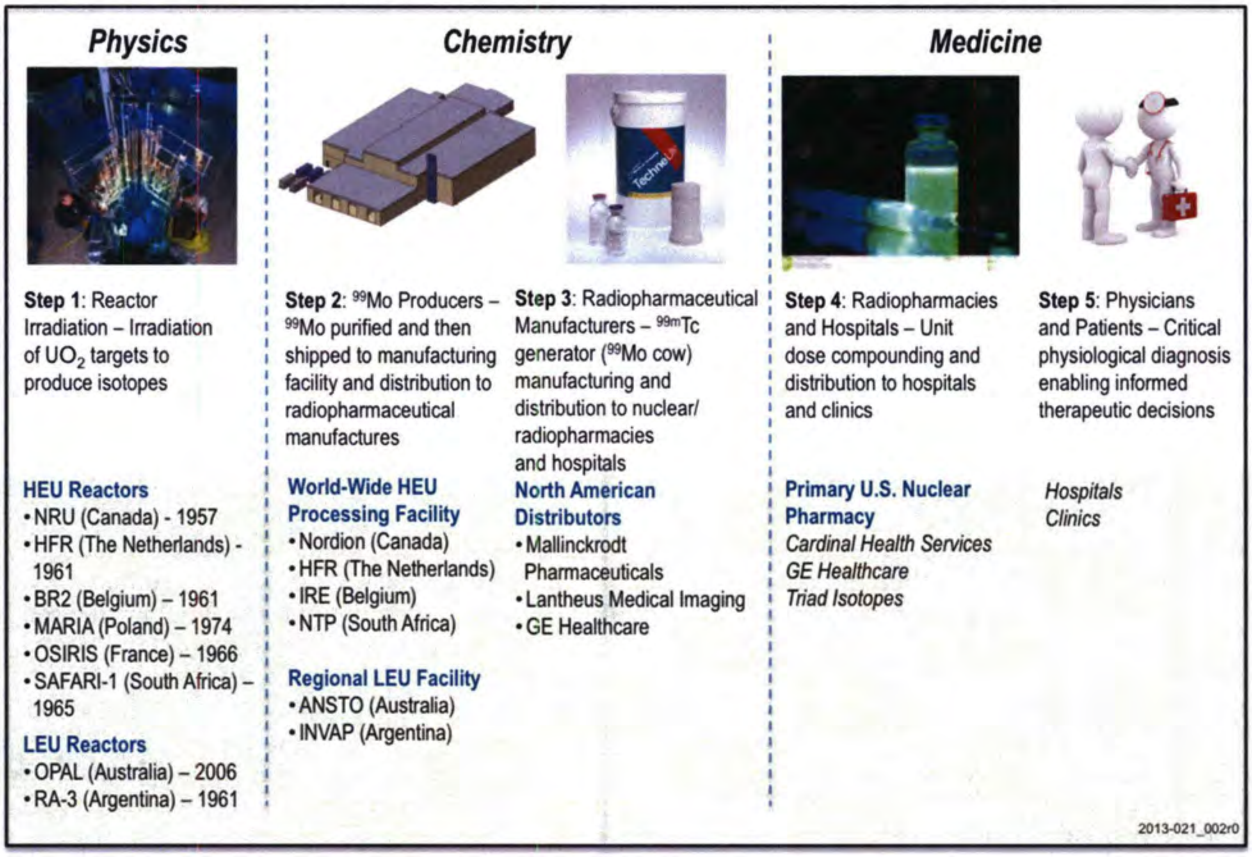


Figure 19-3. Overview of Current Molybdenum-99 Worldwide Process

19.1.2 Regulatory Provisions, Permits and Required Consultations

In addition to NRC licensing and regulatory requirements, a variety of Federal, State, and local environmental requirements apply to the RPF. Some require construction and operating permits or approvals, and others require facility compliance demonstrations. The following sections summarize the environmental requirements applicable to the RPF by the various regulatory agencies. Permits, approvals, and consultations necessary for RPF construction and operation are identified in Section 19.1.2.7 and Section 19.1.3.

19.1.2.1 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) has primary authority for implementing the environmental requirements discussed in the following sections. The state of Missouri is delegated the authority to issue permits on behalf of EPA, and to administer and enforce many of the requirements applicable to the RPF, except for requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA) (42 U.S.C. Chapter 116 § 11001–11050).

19.1.2.1.1 Clean Air Act

The Clean Air Act of 1970 (42 U.S.C. § 7401 et seq.) establishes regulations to ensure air quality and authorizes individual states to issue and manage air quality permits. The Act requires (1) National Ambient Air Quality Standards (NAAQS) to protect the public health, (2) national standards of performance for new or modified stationary sources of atmospheric pollutants, (3) evaluation of specific emission increases for prevention of significant deterioration in air quality, and (4) standards for the releases of hazardous air pollutants, including radionuclides. Implementing regulations include the following:

- 40 CFR 50, "National Primary and Secondary Ambient Air Quality Standards"
- 40 CFR 60, "Standards of Performance for New Stationary Sources"
- 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants" (NESHAP)
- 40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories"

19.1.2.1.2 Clean Water Act

The Clean Water Act of 1972 (CWA) (33 U.S.C. § 1251 et seq.) requires states to set water quality standards for bodies of water within their boundaries, and directs EPA to regulate stormwater and wastewater discharges per the National Pollutant Discharge Elimination System (NPDES) permitting program. The EPA issues discharge permits under the requirements of 40 CFR 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." The permit program controls water pollution by regulating point source discharges of pollutants into U.S. surface waters.

The NPDES construction stormwater program applies to sites with land disturbance of 0.4 hectares (ha) (1 acre) or more, including smaller sites in a larger common plan of development or sale. The NPDES industrial program applies to 10 categories of industrial activities conducted at facilities. Applicants may apply for either individual or a general NPDES permits. Individual permits are specifically tailored to the individual facility, and general permits cover multiple facilities with a specific category of discharges (e.g., stormwater discharges). NPDES permits specify the control technology applicable to each pollutant, the effluent limitations, and the deadline for compliance.

Wastewater generated from any facility or structure must be disposed through wastewater treatment and disposal systems. Facilities that discharge to a municipal or publically owned treatment works do not have NPDES permits but must meet pretreatment regulations. The pretreatment regulations require industrial users to obtain permits or authorizations and to use pollutant control mechanisms prior to discharging to the publically owned treatment works.

19.1.2.1.3 Safe Drinking Water Act

The Safe Drinking Water Act (42 U.S.C. § 300[f] et seq.) was enacted in 1974 to establish minimum national standards for public water supply systems. This Act authorizes EPA to set national standards for drinking water; provides guidance, assistance, and public information about drinking water; collects drinking water data; and oversees State drinking water programs. Primary and secondary drinking water regulations and regulations applicable to drinking water systems are identified in 40 CFR 141 and 142, "National Primary Drinking Water Regulations Implementation," and 40 CFR 143, "National Secondary Drinking Water Regulations." The EPA and states work together to ensure that these standards are met.

19.1.2.1.4 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act of 1976 (RCRA) (42 U.S.C. § 6901 et seq.) requires EPA to define and identify hazardous waste; establish standards for transportation, treatment, storage, and disposal; and require permits for persons engaged in hazardous waste activities. RCRA regulations are found in 40 CFR 260, "Hazardous Waste Management System: General," through 40 CFR 282, "Approved Underground Storage Tank Programs."

"Mixed waste" is hazardous waste containing radioactive material. This waste is regulated by RCRA and the Atomic Energy Act (42 U.S.C. § 2011 et seq.). In 40 CFR 266, "Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities," EPA conditionally exempts low-level mixed waste (LLMW) from the definition of hazardous waste in 40 CFR 261.3, "Definition of Hazardous Waste." The conditional exemption applies to (1) waste generated under a single NRC license that meets certain conditions for management, and (2) stored and treated tanks or containers meeting substantive RCRA requirements. LLMW that meets the applicable treatment standards in 40 CFR 268, "Land Disposal Restrictions," may also be exempt from RCRA transportation and disposal requirements.

19.1.2.1.5 Emergency Planning and Community Right-to-Know Act

The EPCRA establishes the requirements for Federal, State, and local governments; Indian Tribes; and industry regarding emergency planning and community right-to-know reporting on hazardous and toxic chemicals. The EPCRA is implemented by:

- 40 CFR 355, "Emergency Planning and Notification"
- 40 CFR 370, "Hazardous Chemical Reporting: Community Right-To-Know"
- 40 CFR 372, "Toxic Chemical Release Reporting: Community Right-To-Know"
- 40 CFR 373, "Reporting Hazardous Substance Activity When Selling or Transferring Federal Real Property"

EPCRA requires a submission of: (1) a list of hazardous chemicals present at the facility in excess of 10,000 lb for which material safety data sheets are required, (2) an Emergency and Hazardous Chemical Inventory Form (Tier II Form) identifying the inventory of hazardous chemicals present during the preceding year, and (3) notification to the State Emergency Response Commission and the local Emergency Planning Committee of any accidental releases of hazardous chemicals in excess of reportable quantities. The list of hazardous chemicals and the Tier II Form are submitted to regional fire departments. Facilities also must submit a toxic chemical release report to the EPA and the resident state if toxic chemicals are used at the facility in excess of established threshold amounts.

19.1.2.2 U.S. Department of Transportation

The Hazardous Materials Transportation Act of 1975 (49 U.S.C. §§ 5101–5127) regulates transportation of hazardous material in and between states. States may regulate the transportation of hazardous materials as long as the State requirements are consistent with the Act or U.S. Department of Transportation (DOT) regulations. DOT regulations of interest to this action include the following:

- 49 CFR 107, "Hazardous Materials Program Procedures," Subpart G, "Registration and fee to DOT as a person who offers or transports hazardous materials"
- 49 CFR 171, "General Information, Regulations, and Definitions"
- 49 CFR 172, "Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements and Security Plans"

- 49 CFR 173, "Shippers – General Requirements for Shipments and Packages"
- 49 CFR 175, "Carriage by Aircraft"
- 49 CFR 177, "Carriage by Public Highway"

19.1.2.3 U.S. Army Corps of Engineers

Both the EPA and U.S. Army Corps of Engineers jointly administer Section 404 of the CWA, which requires permits for the discharge of dredged or fill material into waters of the U.S. The requirements for Section 404 permits are identified in 40 CFR Subpart 230.404(b)(1), "Guidelines for Specification of Disposal Sites for Dredged or Fill Material." States are responsible for issuing Section 401 certifications for NPDES and Section 404 permits that certify the permitted activity complies with all applicable State water quality standards, limitations, and restrictions.

19.1.2.4 Occupational Safety and Health Administration

The Occupational Safety and Health Act of 1970 (29 U.S.C. §§ 657–658) is designed to increase the safety of workers in the workplace. The Act stipulates that the U.S. Department of Labor is expected to recognize the dangers that may exist in workplaces and establishes employee safety and health standards. The Occupational Safety and Health Administration (OSHA) regulates mitigation requirements and mandates proper training and equipment for workers as established in 29 CFR 1910, "Occupational Safety and Health Standards."

19.1.2.5 Missouri State Agencies

Several programs responsible for protection and management of the environment and public health in Missouri are applicable to the proposed RPF. These programs are managed by the Missouri Department of Natural Resources (MDNR), the Department of Health and Senior Services, and the Department of Conservation.

The proposed facility site is located at the Discovery Ridge on property owned by the University of Missouri (MU) System headquartered in Columbia, Missouri. Discovery Ridge is being developed under the guidance of the *Discovery Ridge Master Plan and Protective Covenants* (MU, 2009). Consolidated Public Water Supply District #1 has extended drinking water services to the site and sewer lines. The Master Plan requires tenant compliance with the Discovery Ridge Master Storm Water Management Plan that is developed on a project-by-project basis and is based on regional accepted practices for stormwater management, including MDNR regulations (MDNR, 2012a). General environmental requirements and permits for new facilities are discussed in the following sections. Integration with the existing services or plans of Discovery Ridge is discussed, as applicable.

19.1.2.5.1 Missouri Department of Natural Resources

The Division of Environmental Quality (DEQ), within the MDNR, includes the Air Pollution Control Program, Water Protection Branch, Hazardous Waste Program, Public Drinking Water Branch, and State Historic Preservation Office. The following sections summarize these programs.

19.1.2.5.1.1 Air Pollution Control Program

The Air Conservation Commission administers the air quality standards and requirements within the Code of State Regulations (CSR), specifically 10 CSR Division 10, "Air Conservation Commission."

Construction permits – Construction permits are also called new source review permits and are issued by the Air Conservation Commission. Construction permits allow for construction and operation of an air emission source and are required prior to commencing construction of an air emission source. All new installations built with the potential to emit (PTE) a regulated air pollutant in an amount equal to or greater than the *de minimis* (threshold) level are required to obtain a construction permit.

A construction permit is not required if potential emissions of the entire installation are less than regulatory *de minimis* levels or potential emissions of the proposed project are below the insignificance levels. Permit exemptions are detailed in 10 CSR 10-6.061, "Construction Permit Exemptions."

The regulated air pollutants, *de minimis* emissions levels, and insignificance levels for determining exemptions and new source review thresholds are listed in Table 19-1 and Table 19-2.

Table 19-1. *De Minimis* Emission Levels of 10 CSR 10-6.020(3)(A)

Air contaminant	Emission rate		Air contaminant	Emission rate	
	(t/yr)	(ton/yr)		(t/yr)	(ton/yr)
Carbon monoxide (CO)	90.71	100	Asbestos	0.0064	0.007
Nitrogen dioxide (NO_2)	36.28	40	Fluorides	2.72	3
Particulate matter	22.67	25	Sulfur acid mist	6.35	7
Particulate matter, 10 micron (PM-10)	13.6	15	Vinyl chloride	0.91	1
Sulfur dioxide (SO_2)	36.28	40	Hydrogen sulfide	9.07	10
Ozone (to be measured as VOCs)	36.28	40	Total reduced sulfur (including hydrogen sulfide)	9.07	10
Lead	0.544	0.6	Reduced sulfur compounds (including hydrogen sulfide)	9.07	10
Mercury	0.090	0.1	Hazardous air pollutant (each)	9.07	10
Beryllium	0.00036	0.0004	Sum of hazardous air pollutants	22.67	25

Source: 10 CSR 10-6.020, "Definitions and Common Reference Tables," *Missouri Code of State Regulations*, as amended.

VOC = volatile organic compound.

Table 19-2. Emission Levels of Common Air Pollutants

Pollutant	Insignificant levels		Regulatory *de minimis* levels		Major source thresholds – operating permits/NSR names sources		Major source thresholds – NSR non-name sources	
	(kg/hr)	(lb/hr)	(t/yr)	(ton/yr)	(t/yr)	(ton/yr)	(t/yr)	(ton/yr)
PM-10	0.45	1.00	13.6	15	90.7	100	226.8	250
SO_x	1.25	2.75	36.29	40	90.7	100	226.8	250
NO_x	1.25	2.75	36.29	40	90.7	100	226.8	250
VOC	1.25	2.75	36.29	40	90.7	100	226.8	250
CO	3.12	6.88	90.7	100	90.7	100	226.8	250
HAPs	[a]0.23	[a]0.5	9.07/22.67	10/25	9.07/22.67	10/25	226.8	10/25

[a] Or the hazardous emission threshold as established in Subsection (12)(J) of 10 CSR 10-6.060, "Construction Permits Required," whichever is less.

CO = carbon monoxide.
HAP = hazardous air pollutant.
NO_x = nitrogen oxides.
NSR = new source review.
PM-10 = particulate matter, 10 μ.
SO_x = sulfur oxides.
VOC = volatile organic compound.

The PTE of the RPF project will be calculated based on the maximum design capacity of the equipment, assuming continuous operation (24 hr/day, 365 days/year). In the Construction Permit Application, the RPF may request emission limits that, if accepted by the Missouri Air Pollution Control Program, will become part of the constraints in the construction permit. The proposed limits could change the type of RPF construction permit issued and the operating permit status.

Operating permits – Operating permits are issued by the Air Pollution Control Program in accordance with Title V of the 1990 Clean Air Act amendments and implementing regulations in 40 CFR 70, "State Operating Permit Programs." All sources with a PTE-regulated air pollutant above *de minimis* levels are required to obtain an operating permit. There are three classes of operating permits in Missouri:

- ***40 CFR 70 operating permit*** – This is required for installations with potential emissions exceeding 91.7 tonne per year (t/yr) (100 tons per year [tons/yr]) of any criteria pollutant, (9.07 t/yr) 10 tons/yr of any single hazardous air pollutant (HAP), or 22.7 t/yr (25 tons/yr) of combined HAPs; or if the EPA Administrator requires a 40 CFR 70 permit as part of a Federal rulemaking. These emissions levels are calculated after control devices and are called the major source threshold.
- ***Intermediate (or synthetic minor) operating permit*** – These permits may be obtained by installations with a PTE above the major source threshold that request a voluntary limit on operations to keep emissions below the major source threshold. Conditions could include absolute emissions limits, recordkeeping of operating hour limits, or production limits.
- ***Basic State operating permit*** – This permit is required if the PTE is between *de minimis* and major levels. All incinerators must obtain an operating permit, regardless of the level of emissions.

Sources of nonradioactive criteria air pollutants or HAPs from RPF construction may include fugitive dust and vehicle emissions (on-road and off-road vehicles). Vehicle emissions are also a source of greenhouse gases (GHG). Operation of the RPF may generate criteria air pollutants, HAPs, and GHGs from diesel-fired boilers, electric diesel generators, and facility chemical usage.

The NRC implements the primary radiation protection standards for RPF air emissions. Radioactive air emissions will be addressed in the license application and subject to the dose limits and requirements of 10 CFR 20, "Standards for Protection Against Radiation."

19.1.2.5.1.2 Water Protection Branch

The MDNR Clean Water Commission administers water quality standards and requirements in 10 CSR Division 20, "Clean Water Commission." The Clean Water Commission issues construction and operating permits as required in 10 CSR 20-6.010, "Construction and Operating Permits," to persons who build, erect, alter, replace, operate, use, or maintain existing point sources, or intend these actions for a proposed point source, water contaminant sources, or wastewater treatment facilities. These permits enforce the Missouri Clean Water Law and regulations and administer the NPDES program. Nonpoint source discharges and service connections to wastewater sewer systems are exempt from permitting requirements.

The proposed lot for the RPF at Discovery Ridge is approximately 3.0 ha (7.4 acres). An NPDES construction stormwater management permit is required for disturbances of greater than 0.4 ha (1 acre) of land. The RPF would either operate under a Missouri General Operating Permit MO-R10A000 for land disturbance on new sites or conform to the criteria and standards of the Discovery Ridge Master Storm Water Management Plan under a stormwater management permit issued to the site.

The Clean Water Commission issues a 401 Water Quality Certification to any facility requiring a Federal Section 404 (of the CWA) permit. This includes facilities that place material or fill into the jurisdictional waters of the U.S. The Section 401 certification is verification by the state of Missouri that the project would not violate water quality standards. The construction, operation, and decommissioning of the RPF is not anticipated to need a Federal Section 404 permit or Section 401 certification from the Commission.

Under 10 CSR 20-6.010, facilities that discharge wastes into a sewerage system are not required to obtain an NPDES permit if the owner of the sewerage system has a valid NPDES permit. The RPF would not discharge process wastewater into the Discovery Park sewer system. Sanitary wastewater would be discharged in accordance with Boone County sewer regulations.

19.1.2.5.1.3 Hazardous Waste Program

The Hazardous Waste Management Commission (HWMC) administers the hazardous waste standards and requirements in 10 CSR Division 25, "Hazardous Waste Management Commission."

The HWMC regulates hazardous waste and administers a permitting program for owners and operators of treatment, storage, and disposal facilities. 10 CSR Division 25 hazardous waste management rules incorporate by reference, unless otherwise modified, the Federal hazardous waste management regulations. The effective date for rules for mixed radioactive and hazardous wastes in Missouri was March 12, 1993.

Under 10 CSR 25-7.270, "Missouri Administered Permit Programs: The Hazardous Waste Permit Program," a permit is required for the treatment, storage (generated onsite and stored beyond the timeframes allowed without a permit pursuant to 10 CSR 25-5.262, "Standards Applicable to Generators of Hazardous Waste") or disposal of hazardous waste. Resource recovery of hazardous waste is regulated by 10 CSR 25-9.020, "Hazardous Waste Recovery Processes," and an owner or operator of a facility that uses, reuses, or recycles hazardous waste must be certified under 10 CSR 25-9, "Resource Recovery," or permitted under 10 CSR 25-7, "Rules Applicable to Owners/Operators of Hazardous Waste Facilities." A permit is not required for an elementary neutralization unit or a wastewater treatment unit that receives hazardous waste generated onsite and demonstrates compliance with the requirements of 10 CSR 25-7.270(2)(A)3 to the satisfaction of the HWMC.

The RPF would generate hazardous, universal, and mixed waste (hazardous waste containing radioactive material) from facility processes. The waste may exhibit hazardous characteristics (e.g., corrosivity or toxicity) and contain spent regulated solvents. Waste would generally be managed under requirements of 10 CSR 25-5.262 and 10 CSR 25-16.273, "Standards for Universal Waste Management." Treatment, including elementary neutralization or resource recovery of solvents, may occur without a permit, subject to certification and demonstrations required under 10 CSR 25-9 and 10 CSR 25-7.270(2)(A)(3).

LLMW generated by the RPF would be managed to meet the storage and treatment conditional exemption in 10 CSR 25-7.266, "Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities" (incorporating 40 CFR 266, Subpart N, "Conditional Exemption for Low-Level Mixed Waste Storage, Treatment, Transportation, and Disposal"). The RPF mixed waste would be exempt from the definition of hazardous waste in 10 CSR 25-3.260, "Definitions, Modifications to Incorporations, and Confidential Business Information," as the waste would be generated under a single NRC license, stored, and treated in a tank or container, and managed according to conditions that include the following:

- NWMI would notify MDNR, in writing and by certified delivery, to claim a conditional exemption for LLMW stored in the facility.

- LLMW would be stored and treated in tanks or containers in compliance with the license requirements that apply to the proper storage of LLMW (not including those requirements that relate solely to recordkeeping).
- LLMW would be stored and treated in tanks or containers in compliance with chemical compatibility requirements.
- Inventory of the stored conditionally exempt LLMW would be conducted at least annually and be inspected at least quarterly for compliance with 10 CSR 25-7.
- Facility personnel who manage stored conditionally exempt LLMW would be certified and trained in a manner to ensure that the conditionally exempt waste is safely managed; this includes training in chemical waste management and hazardous materials incident response that meets the personnel training standards.
- An emergency plan would be maintained and provided to all local agencies that may respond to a fire, explosion, or release of hazardous waste or hazardous constituents.

19.1.2.5.1.4 Public Drinking Water Branch

The Safe Drinking Water Commission administers the public drinking water standards and requirements in 10 CSR Division 60, "Safe Drinking Water Commission." The mission of the Public Drinking Water Program is to provide safe and adequate public drinking water supplies for residents of and transients in the state. Drinking water for the RPF would be provided through service connections in accordance with the Columbia Code of Ordinance requirements (City of Columbia, 2013a).

19.1.2.5.1.5 Department of Health and Senior Services

The Department of Health and Human Services administers a radiation control program under the requirements of 19 CSR 20-10, "Protection Against Ionizing Radiation." Exemptions to the regulations are identified in 19 CSR 20-10.020, "Exemptions from Requirements of this Chapter," and include use of radioactive sources licensed by the NRC to installations in Missouri. Radioactive sources, as applicable to the RPF, would be managed under requirements of the NRC license and excluded from Missouri regulation.

19.1.2.5.1.6 Department of Conservation

The Department of Conservation is charged with the protection and management of Missouri fish, forest, and wildlife resources. Conservation requirements are identified in 3 CSR Division 10, "Department of Conservation." The department maintains two references relating to the status of listed plants and animals in Missouri: *The Missouri Species and Communities of Conservation Concern Checklist* (State of Missouri, 2014), and Wildlife Code of Missouri (3 CSR 10-4.110, "General Prohibition; Applications," and 3 CSR 10-9.110[1][B], "General Prohibition; Applications"). The Conservation Concern Checklist is used mostly for planning and communication purposes.

All birds, fish, crayfish, mussels, amphibians, reptiles, mammals, or other forms of wildlife, including other invertebrates listed in the checklist, are protected by the Wildlife Code. Collection or harvest of these species during RPF construction, operation, or decommissioning would only be performed according to applicable permits as prescribed in Chapter 5 of the Wildlife Code.

19.1.2.6 Local Governments

The RPF would be located in Columbia, Missouri, in Boone County. The following sections summarize how local jurisdictions implement environmental requirements for land disturbances, stormwater management, sewer discharges, and drinking water connections.

19.1.2.6.1 Boone County

The Boone County Resource Management Department centralizes the engineering, planning, and inspection services provided by the county. County requirements address stormwater management, stream buffers, floodplain regulations, driveway location, road design, subdivision requirements, and building construction. Boone County requires a land disturbance permit prior to land-clearing activities equal to or greater than 0.4 ha (1 acre) or within close proximity to an environmentally sensitive area. If not covered under Discovery Ridge land disturbances permits, NWMI would request a land disturbance permit through the Resource Management Department. The department also offers an electronic stormwater pollution prevention plan (SWPPP) for land disturbance projects disturbing 0.4 ha (1 acre) or more. The SWPPP template would guide NWMI through the SWPPP development process to help ensure that the SWPPP addresses all the necessary elements stated in the Missouri State General Permit and Boone County regulations (Boone County, 2013a).

The Boone County Regional Sewer District provides wastewater management services to Discovery Ridge. The NWMI facility must comply with the applicable requirements of Chapter 2 of the Sanitary Sewer Use Regulations, including Section 2.12, "Unlawful Dischargers," establishing pollutant limits and pretreatment requirements, and Section 2.17.2, "Operating, Inspection, and Monitoring," which is for industrial users (Boone County, 2013b).

The Missouri State Legislature (Missouri Revised Statutes, Chapter 64.850, "County commission may prescribe zoning regulations") delegated the responsibility to local governmental units to adopt floodplain management regulations designed to protect health, safety, and general welfare. This ordinance applies to all lands within the jurisdiction of Boone County, identified as numbered and unnumbered A, AE, AO, and AH zones on Panel 29019CIND0A of the Flood Insurance Rate Map for Boone County (Boone County, 2011). A floodplain development permit must be acquired for all proposed construction or other development, including the placement of manufactured homes, in those zones. The RPF site is not located within any of these zones.

19.1.2.6.2 City of Columbia

Potable water connections – The Columbia Water Treatment Plant is owned and operated by the City of Columbia and the Water and Light Department. The system supplies water to approximately 45,500 customers. The water system has approximately 46,250 service connections, and the average daily consumption is 47.69 million liters (ML)/day (12.6 million gallons per day ([Mgal/day]). The Columbia Water Treatment Plant is in compliance with all State and Federal drinking water regulations. The plant is in the Northeast Regional Office district of the MDNR. Requests for drinking water connections would be made in accordance with Code of Ordinances, Chapter 27, "Utilities for the City of Columbia" (City of Columbia, 2013a). Code of Ordinances, Chapter 6, "Buildings and Building Regulations" (City of Columbia, 2013b), adopts the 2009 Edition of the International Building Code (IBC, 2009) by reference with amendment, and would be the building standard for the RPF.

Stormwater regulation – The City of Columbia and Boone County adopted stormwater regulations in response to requirements mandated by EPA as part of implementing Phase II of the CWA (MDNR, 2012a). These regulations were adopted by the city in 2007 and the county in 2010. Two components are within each set of regulations: Stormwater Management Standards, and Stream Buffer Standards.

Stormwater management – The adopted city and county regulations address the water quantity and water quantity that leaves a development site. The regulations specify that the volume of post-development runoff cannot exceed that of a site's predevelopment state. Therefore, many new developments require significant on-site detention and filtration facilities. Previous regulations allowed stormwater to be discharged directly into the creeks (MDNR, 2012a). Under the city stormwater regulations, subdivisions preliminarily platted prior to September 2007 are exempt from the new regulations (City of Columbia, 2013a).

The goal of the new city regulations is to mitigate flooding, erosion, pollution of streams, and personal property damage caused by development activities.

Stream buffers – A major component of the City of Columbia and Boone County stormwater regulations is the stream buffering requirement. Stream buffers are natural vegetation areas that serve as boundaries between disturbed land and local waterways. The buffers act as filtration systems for stormwater runoff entering creeks and protect aquatic habitat. Stream buffers also stabilize stream banks, mitigate flooding, and preserve natural areas that serve as vital habitat and corridors. Stream buffers are measured from the ordinary high-water mark and vary in width depending on stream type. The three regulated stream types identified in the city and county regulations are shown in Table 19-3.

Table 19-3. Required Stream Buffer Width, Identified by Stream Type

Stream type	Description	Total buffer width, each side	
		(m)	(ft)
1	Perennial	31	100
2	Intermittent	15.2	50
3	Ephemeral	9.2	30

Stream buffers were expanded to include slopes greater than 15 percent that are adjacent to outer buffers. City and county regulations include a 61 meter (m) (200-foot [ft]) buffer from karst features (e.g., sinkholes). The inner half of stream buffers must be left as undisturbed natural vegetation. In Columbia, but not in Boone County, accessory structures (e.g., sheds) may be built within the outer half of these buffers. Trails and maintained lawns may be situated within the outer buffer.

Landscaping regulations – Landscaping and screening standards exist as part of the city zoning ordinance. These provisions are intended to accomplish the following:

- Establish healthy environmental conditions by providing shade, air purification, oxygen regeneration, groundwater recharge, stormwater runoff retardation, erosion control, and noise, glare, and heat abatement
- Provide visual buffering from streets, to buffer potentially incompatible land uses and to generally enhance the quality and appearance of a development site
- Encourage the preservation of existing trees and vegetation
- Supplement the land disturbance permit requirements

The landscaping standards apply to all new development and new parking lots exceeding a minimum threshold size. There are several exclusions to the landscaping requirements, which are explained in the zoning ordinance (City of Columbia, 1998).

Tree preservation regulations – While City of Columbia requires tree preservation, Boone County has no specific tree preservation ordinance. However, with the recent adoption of the county stream buffer regulations, there exists an opportunity to implement the first ongoing regulation that would have a direct effect on tree preservation.

According to the MDNR, tree preservation has been most effective on unsubdivided parcels greater than 0.4 ha (1 acre) inside the city limits. This is the result of the city requirement that a tree survey be conducted to determine what climax forest exists on a site prior to land-clearing activities.

19.1.2.7 Permit and Approval Status

A final determination of permits and approvals applicable to the RPF would be made with appropriate regulatory interface. Consultations will ensure that applications or certifications are prepared and submitted in accordance with requirements, and approved in a timely manner. Permits and approvals necessary for RPF construction and operation are identified in Table 19-4.

Table 19-4. Regulatory Compliance Status (4 pages)

Agency	[a]Regulatory authority	Permit or approval	Activity covered	Status
Federal				
U.S Nuclear Regulatory Commission	Atomic Energy Act 10 CFR 50.50	Construction Permit	RPF construction	Addressed in Construction Permit Application
	10 CFR 50.57	Operating License	RPF operation	To be addressed in operation license application
	10 CFR 30	By-Product Material License	Production, possession, and transfer of radioactive by-product material	To be addressed in license application
	10 CFR 70	Special Nuclear Materials License	Receipt, possession, use, and transfer of special nuclear material	To be addressed in license application
	National Environmental Policy Act 10 CFR 51	Environmental assessment or environmental impact statement	Site approval for RPF construction and operation	Addressed in this Construction Permit Application
U.S. Army Corp of Engineers	Clean Water Act 33 CFR 323	Dredge and Fill Permit (Section 404)	Discharges of dredged or fill material into U.S. waters	Not required
U.S. Environmental Protection Agency	Resource Conservation and Recovery Act 40 CFR 262	Notification of RCRA Subtitle C activity	EPA identification number for generation of hazardous waste	Notification to be submitted 60 days prior to construction
	Clean Water Act 40 CFR 112, Subpart D, Appendix F	[b]SPCC plans for construction and operation	Storage of oil during construction and operation	SPCC plans to be submitted 30 days prior to construction
U.S. Department of Transportation	Hazardous Materials Transportation Act 49 CFR 107	Certificate of Registration	Transport of hazardous materials	Registration to be filed no later than June 30 of the calendar year or prior to offering hazardous materials for transport

Table 19-4. Regulatory Compliance Status (4 pages)

Agency	[a]Regulatory authority	Permit or approval	Activity covered	Status
State				
Missouri Department of Natural Resources	Federal Clean Air Act Missouri Revised Statute Chapter 643 10 CSR Division 10	Construction Permit	Construction of an air emissions source	Not required
		Part 70 Operating Permit	Operation of an air pollution emission source that has potential emissions exceeding 100 tons/yr of criterion pollutants	Not required
		Intermediate Operating Permit	Operation of an air pollution emission source that has the potential to emit is above major threshold, but a voluntary limits of operation is requested	Not required
		Basic State Operating Permit	Operation of an air pollution emission source that has the potential to emit is between *de minimis* and major levels	Not required
	Clean Water Act Missouri Revised Statute Chapters 640 and 644 10 CSR Division 20	NPDES Construction Stormwater Permit	Land disturbance and discharge of stormwater from the construction site	Applications for general permits (Forms E and G) to be submitted 30 days prior to construction
		NPDES Industrial Stormwater Permit	Discharge of stormwater from the industrial site during operations	Permit to be submitted one year prior to operation
		Section 401 Water Quality Certification	Certifies that the Section 404 permitted activity complies with all applicable State water quality standards, limitations, and restrictions	Not required

Table 19-4. Regulatory Compliance Status (4 pages)

Agency	[a]Regulatory authority	Permit or approval	Activity covered	Status
Missouri Department of Natural Resources (continued)	Resource Conservation and Recovery Act Missouri Revised Statute Chapter 260 10 CSR Division 25	Notification of Regulated Activity	Obtain Missouri identification number for generation of hazardous waste	Registration to be filed 90 days prior to generating hazardous waste
		Certified Resource Recovery Facility Application	Reuse, reclamation, or recycling 1,000 kg (2,204.6 lb) or more of site-generated hazardous waste in a month	Application to be submitted 90 days prior to operations
		Notification to MDNR of Conditional Exemption	Notify MDNR in writing and by certified delivery of the claim of a conditional exemption for LLMW stored and treated in the facility	Notification to be submitted 90 days prior to operations
		Hazardous Waste Permit	Treatment, storage or disposal of hazardous waste	Not required
Missouri Department of Health and Senior Services	Atomic Energy Act Missouri Revised Statute Chapter 192 19 CSR Division 20	Registration of sources of ionizing radiation	Protection against ionizing radiation	Radioactive sources will be managed under the NRC license and are excluded from Missouri regulation
Boone County				
Boone County Resource Management Department	Clean Water Act Missouri Revised Statute, Chapter 64 Boone County Stormwater Ordinance	Stormwater Discharge Permit	Stormwater management	Application to be submitted 30 days prior to construction
		Land Disturbance Permit	Activity disturbing 0.4 ha (1 acre) or more of land or disturbing 278.7 m^2 (3,000 ft^2) in environmentally sensitive areas	Application to be submitted 30 days prior to construction
	Missouri Revised Statute, Chapter 64 Boone County Zoning Regulations	Application for Commercial Building Permit	Construction of a commercial building	Application to be submitted 30 days prior to construction
Boone County Regional Sewer District	Clean Water Act Missouri Revised Statute Chapter 250 Chapter 2 of Boone County Sanitary Sewer Use Regulations	Sanitary sewer connection approval	Building connection to District wastewater treatment works	Required information to be submitted 30 days prior to construction

Table 19-4. Regulatory Compliance Status (4 pages)

Agency	[a]Regulatory authority	Permit or approval	Activity covered	Status
City of Columbia				
City of Columbia	Clean Water Act 10 CSR Division 60 Part II City of Columbia Code of Ordinances Chapter 27	Application for utility service	Allows RPF to connect to Columbia Water Treatment Plant	Application to be submitted 30 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 6, Article II	Building Permit	Approval of building code and standards, including site plan	Application to be submitted 60 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 6, Article III	Electrical plan approval	Electrical Code	Information to be submitted 60 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 6, Article IV	Plumbing plan approval	Plumbing Code	Information to be submitted 60 days prior to construction
	Part II Code of Ordinances Chapter 6, Article V	HVAC plan approval	Mechanical Code	Information to be submitted 60 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 6	Certificate of Occupancy	Facilities meeting Building Code	Information to be submitted upon completion of construction
	Part II City of Columbia Code of Ordinances Chapter 27, Article II	Fire Prevention Plan Approval	Fire Code	Information to be submitted 60 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 12A, Article II	Land Disturbances Permit	Land disturbance activity, including construction on any site that results in a disturbed area of 1 acre or more.	Application to be submitted 30 days prior to construction
	Part II City of Columbia Code of Ordinances Chapter 12A, Article V	Stormwater Management Plan Approval	Approval required prior to approval for Land Disturbance Permit	Information to be submitted 45 days prior to construction

[a] Full references are provided in Section 19.7.

[b] Only required when oil is stored in a tank or shell with a capacity over 1,320 gallons (gal), and the oil could reasonably reach navigable water.

CFR = Code of Federal Regulations.
CSR = Code of State Regulations.
EPA = U.S. Environmental Protection Agency.
HVAC = heating, ventilation, and air conditioning.
LLMW = low-level mixed waste.
MDNR = Missouri Department of Natural Resources.
NPDES = National Pollutant Discharge Elimination System.
NRC = U.S. Nuclear Regulatory Commission.
RCRA = Resource Conservation and Recovery Act.
RPF = radioisotope production facility.
SPCC = spill prevention, control, and countermeasure.
U.S. = United States.

19.1.3 Consultation and Coordination

Table 19-5 lists the consultations required for construction and operation of the proposed RPF. The table provides the following information for each consultation, as applicable, including the name of the responsible regulatory agency; applicable law, ordinance, or regulation; required consultation; summary of any surveys required to complete the consultation; and status.

Table 19-5. Consultation Required for Construction and Operation Status (2 pages)

Agency	[a]Regulatory authority	Required consultation	Surveys required	[b]Status
Federal				
USFWS	Endangered Species Act (16 U.S.C. § 1531 et seq.)	Consultation regarding potential to adversely impact protected species; concurrence with no appropriate mitigation measures	None	Consultation letter was submitted to the USFWS on July 14, 2014. Received response July 21, 2014 requesting that an IPaC form be prepared. Based on the analysis, the project area was determined to not include any designated critical habitat or suitable habitat for candidate or proposed species. No further action was required.
State of Missouri				
Missouri State Historic Preservation Office	National Historic Preservation Act (16 U.S.C. § 470 et seq., Section 106)	Consultation regarding potential to adversely impact historic resources; concurrence with no appropriate mitigation measures		Letter submitting the Cultural Resources Investigation to the Missouri State Historic Preservation Office, October 7, 2013. A response was received October 10, 2013; no additional action is required (Appendix B).
Missouri Department of Conservation	Rules of Department of Conservation (3 CSR 10)	None	None	Consultation letter was submitted to the MDC on July 14, 2014. No response has been received.
Native American Tribes				
Osage Nation	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act (25 U.S.C. § 3001 et seq.)	Consultation regarding protection of traditional Native American religious and cultural resources	None	Consultation letter was submitted to the Osage Nation on July 14, 2014. No response has been received.

Table 19-5. Consultation Required for Construction and Operation Status (2 pages)

Agency	[a]Regulatory authority	Required consultation	Surveys required	[b]Status
Iowa Tribe of Oklahoma	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act	Consultation regarding protection of traditional Native American religious and cultural resources	None	Consultation letter was submitted to the Iowa Tribe of Oklahoma on July 14, 2014. No response has been received.
Kaw Nation	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act	Consultation regarding protection of traditional Native American religious and cultural resources	None	Consultation letter was submitted to the Kaw Nation on July 14, 2014. No response has been received.
Miami Tribe of Oklahoma	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act	Consultation regarding protection of traditional Native American religious and cultural resources	None	Consultation letter was submitted to the Miami Tribe of Oklahoma on July 14, 2014. No response has been received.
Omaha Tribe	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act	Consultation regarding protection of traditional Native American religious and cultural resources	None	Consultation letter was submitted to the Omaha Tribe on July 14, 2014. No response has been received.
Yankton Sioux Tribe of South Dakota	• National Environmental Policy Act • National Historic Preservation Act • Native American Graves Protection and Repatriation Act	Consultation regarding protection of traditional Native American religious and cultural resources.	None	Consultation letter was submitted to the Yankton Sioux Tribe of South Dakota on July 14, 2014. No response has been received.

[a] Full references are provided in Section 19.7.

[b] Unless noted otherwise, copies of the consultation letters submitted/received are provided in Appendix A.

CSR = Code of State Regulations.
IPaC = information, planning, and conservation.
MDC = Missouri Department of Conservation.
U.S.C. = United States Code.
USFWS = U.S. Fish and Wildlife Service.

19.2 PROPOSED ACTION

As described in Section 19.2.1, the proposed action requires authorization by the NRC for NWMI to construct and later operate the proposed RPF at Discovery Ridge to commercially produce ^{99}Mo using LEU. Section 19.2.1 also describes actions that are connected to the proposed action. Connected actions fall within the scope of the actions evaluated in an environmental impact statement (40 CFR 1508.25, "Scope").

19.2.1 Description of Proposed Action and Connected Actions

The proposed action is the issuance of an NRC Construction Permit and Operating License under 10 CFR 50 and provisions of 10 CFR 70 and 10 CFR 30 that would authorize NWMI to construct and operate a ^{99}Mo RPF at a site located in Columbia, Missouri. Proposed RPF activities include:

- Receiving LEU from DOE
- Producing LEU target materials and fabrication of targets
- Packaging and shipping LEU targets to the university reactor network for irradiation
- Returning irradiated LEU targets for dissolution, recovery, and purification of ^{99}Mo
- Recovering and recycling LEU to minimize radioactive, mixed, and hazardous waste generation
- Treating/packaging wastes generated by RPF process steps to enable transport to a disposal site

The RPF is being designed to have a nominal operational processing capability of one batch per week of up to 12 targets from MURR for up to 52 weeks per year and approximately 30 targets from the Oregon State University (OSU) TRIGA[1] Reactor (OSTR) or a third university reactor for eight weeks per year per reactor. The impacts analyzed for this ER were based on the bounding scenario of MURR operating 52 weeks per year, with both the OSTR and third reactor operating eight weeks per year, for a total of 68 batches of irradiated LEU targets processed at the RPF annually.

For the proposed RPF to fulfill its function, other "connected actions" would also occur. The RPF connected action is the use of a network of university research reactors for the irradiation of LEU targets. The ER evaluates transport of the unirradiated LEU targets to each university research reactor, irradiation of the LEU targets at each reactor, and transport of the irradiated LEU targets back to the RPF. License amendments associated with university research reactors irradiating LEU targets would be completed by each reactor organization and would be separate from this proposed action.

NWMI has currently identified two university research reactors to be part of the irradiation network: MURR and OSTR.reactor will be added to the network that is similar to OSTR. An analysis to recommend the third university reactor is currently underway. The university reactors being considered include [Proprietary Information]. NWMI has bounded the decision for the third reactor by the university reactor that is the [Proprietary Information].

The primary activities to be completed during construction, pre-operation, operation, and decommissioning are described below.

Construction – During the construction phase of the RPF, the following types of construction activities would be completed, including land clearing, set up of equipment laydown areas, utility installation, buildings, parking lots, and roads.

Pre-Operations – Prior to commercial operations, the RPF would go through a commissioning phase to ensure that the facility functions as designed and meets all NRC license and State and local requirements. The commissioning process comprises the integrated application of a set of engineering techniques and procedures to check, inspect, and test every operational component of the project, from individual functions (e.g., instruments and equipment), to complex modules, subsystems, and systems.

[1] TRIGA (Training, Research, Isotopes, General Atomics) is a registered trademark of General Atomics, San Diego, California.

Operations – The RPF would have the operations capacity to produce 50 percent of the U.S. ^{99}Mo demand. ^{99}Mo produced from the proposed NWMI RPF would indistinguishable from ^{99}Mo from the existing fleet of nuclear reactors and would not require redesign of the ^{99}Mo generator technology in the U.S. supply chain.

Decommissioning – The process of closing and securing a nuclear facility would provide adequate protection from radiation exposure and to isolate radioactive contamination from the environment. Activities include surveillance, maintenance, decontamination, and/or dismantlement. These actions are taken at the end of the life of a facility to retire it from service, with adequate regard for the health and safety of workers and the public and protection of the environment.

19.2.1.1 Schedule

The schedule for proposed RPF construction, operation, and decommissioning is as follows:

- Start date of site preparation/construction: First quarter 2016
- End date of construction: First quarter 2017
- Start date of facility startup and cold commissioning (pre-operational): Second quarter 2017
- Date of hot commissioning and commercial operations: Third quarter 2017
- Date of decommissioning: 2047

19.2.1.2 Affected Land

During construction the total affected land would 3.0 ha (7.4 acres) or 100 percent of the site. The entire site (3.0 ha [7.4 acres]) would be permanently affected as a result of operational activities.

19.2.1.3 Personnel, Materials, and Equipment Required During Project Phases

All work completed prior to receiving the Construction Permit Application for the proposed RPF would be completed in accordance with 10 CFR 50.10(a)(2), "License Required; Limited Work Authorization." Table 19-6 provides an estimate of the resources required during each of the major facility phases (construction, pre-operation, operation, and decommissioning) of the proposed action.

Table 19-6. Resources Required During Radioisotope Production Facility Phases

Resource	Construction	Pre-operation	Operation	Decommissioning
Average workforce	38	21	98	15
Peak workforce	82	98	98	28
Delivery trucks (per week)	20	2	4	1
Offsite radioactive materials and waste shipments (per week)	1	0.5	10	20
Fuel (diesel), L/month (gal/month)	[a]1,647 (435)	[b]189 (50)	[b]189 (50)	1,647 (435)
Low enriched uranium kg/year (lb/year)	0	[c][Proprietary Information]	[Proprietary Information]	0

[a] The majority of the diesel fuel is consumed during the first three months of construction.
[b] Diesel fuel is used for backup generator.
[c] LEU needed for hot commissioning and initial RPF startup.
[d] LEU needed in Operation [Proprietary Information] for addition of second university reactor.
[e] LEU needed in Operation [Proprietary Information] for addition of third university reactor.

Materials consumed during the construction phase are shown in Table 19-7.

Table 19-7. Estimated Materials Consumed During Construction Phase

Material	Amount		Material	Amount	
Concrete	3,257 m^3	4,260 yd^3	Asphalt	245 m^3	320 yd^3
Structural steel	363 t	400 tons	Stone granular material	1,300 m^3	1,700 yd^3
Miscellaneous steel	45 t	50 tons	Roofing	4,645 m^2	50,000 ft^2
Steel liner	127 t	140 tons	Precast concrete	435 t	480 tons

19.2.1.4 Applicant for the Proposed Action

NWMI is an Oregon limited-liability company (LLC). The company was formed solely to provide ^{99}Mo to the medical industry. NWMI's owners are listed in Table 19-8.

Table 19-8. Northwest Medical Isotopes Ownership Summary

Company	State/structure	Membership interests
Samaritan Health Services, Inc.	Oregon, not-for-profit corporation	[Proprietary Information]
CAC IsoMed, LLC	Washington, limited-liability company	[Proprietary Information]
Orion Ventures, LLC	Oregon, limited-liability company	[Proprietary Information]
Oregon State University	Oregon, institute of higher education	[Proprietary Information]
Talents Venture Fund	Delaware, limited-liability company	[Proprietary Information]
Dignity Health	California, not-for-profit corporation	[Proprietary Information]
[a]Other		[Proprietary Information]
Total		**100%**

[a] Membership interests are less than 2 percent.

19.2.2 Radioisotope Production Facility Site Location and Layout

19.2.2.1 Site Location

The proposed 3.0 ha (7.4-acre) RPF site is situated within Discovery Ridge, north of Discovery Ridge Drive. Discovery Ridge is located in the City of Columbia, Boone County, Missouri. The site is situated in central Missouri, approximately 201 kilometer (km) (125 miles [mi]) east of Kansas City and 201 km (125 mi) west of St. Louis. The site is 7.2 km (4.5 mi) south of U.S. Interstate 70, just north of U.S. Highway 63 (Figure 19-4). The Missouri River lies 15.3 km (9.5 mi) west of the site. The site is located 5.6 km (3.5 mi) southeast of the main MU campus.

The approximate center of the RPF is longitude 92° 16' 34.63" and latitude 38° 54' 3.31" (NAD 83, 1983). Figure 19-5 illustrates the 8 km (5-mi) radius from the center of the facility and shows highways, rivers, and other local bodies of water.

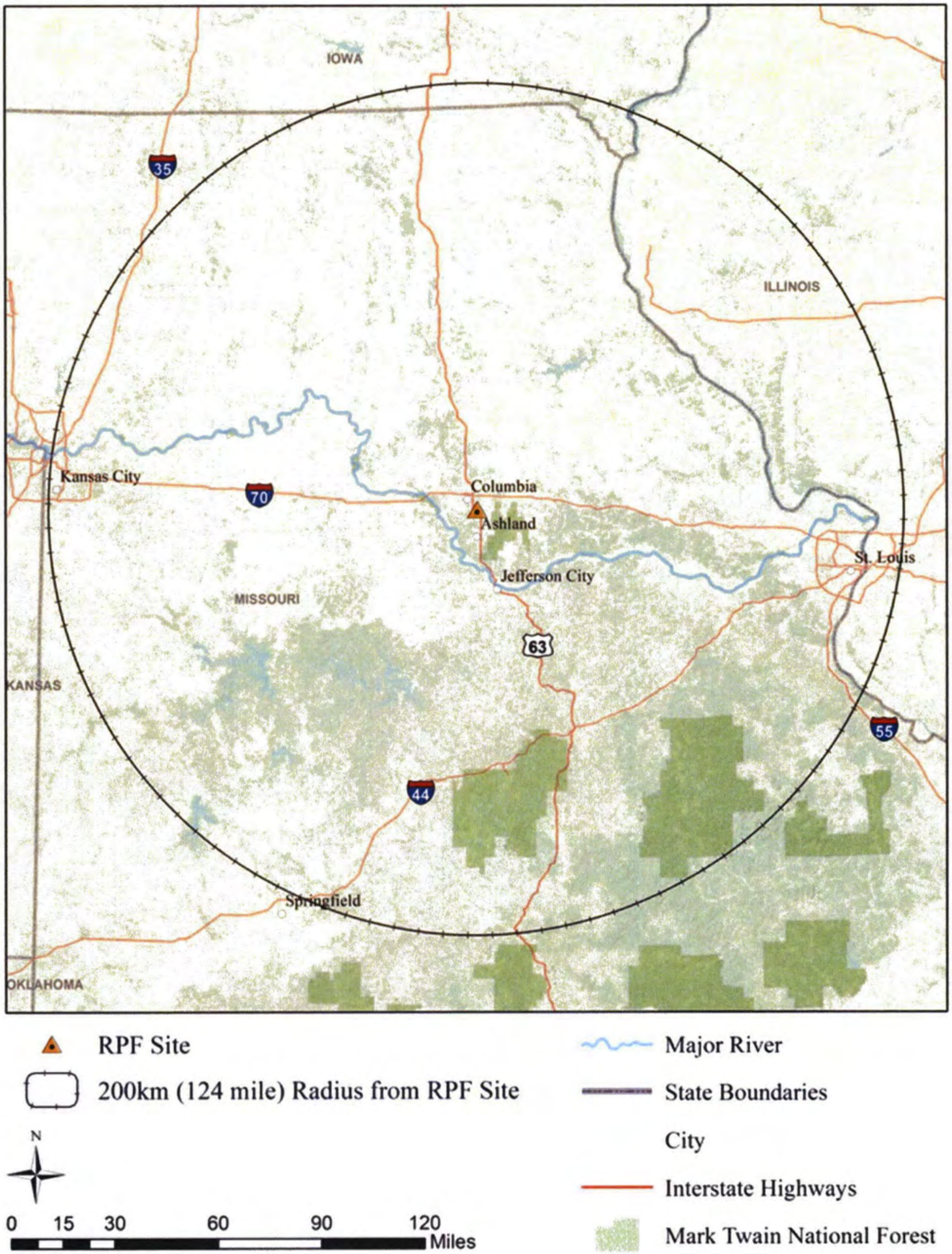


Figure 19-4. 200 km (124-mi) Radius with Cities and Roads

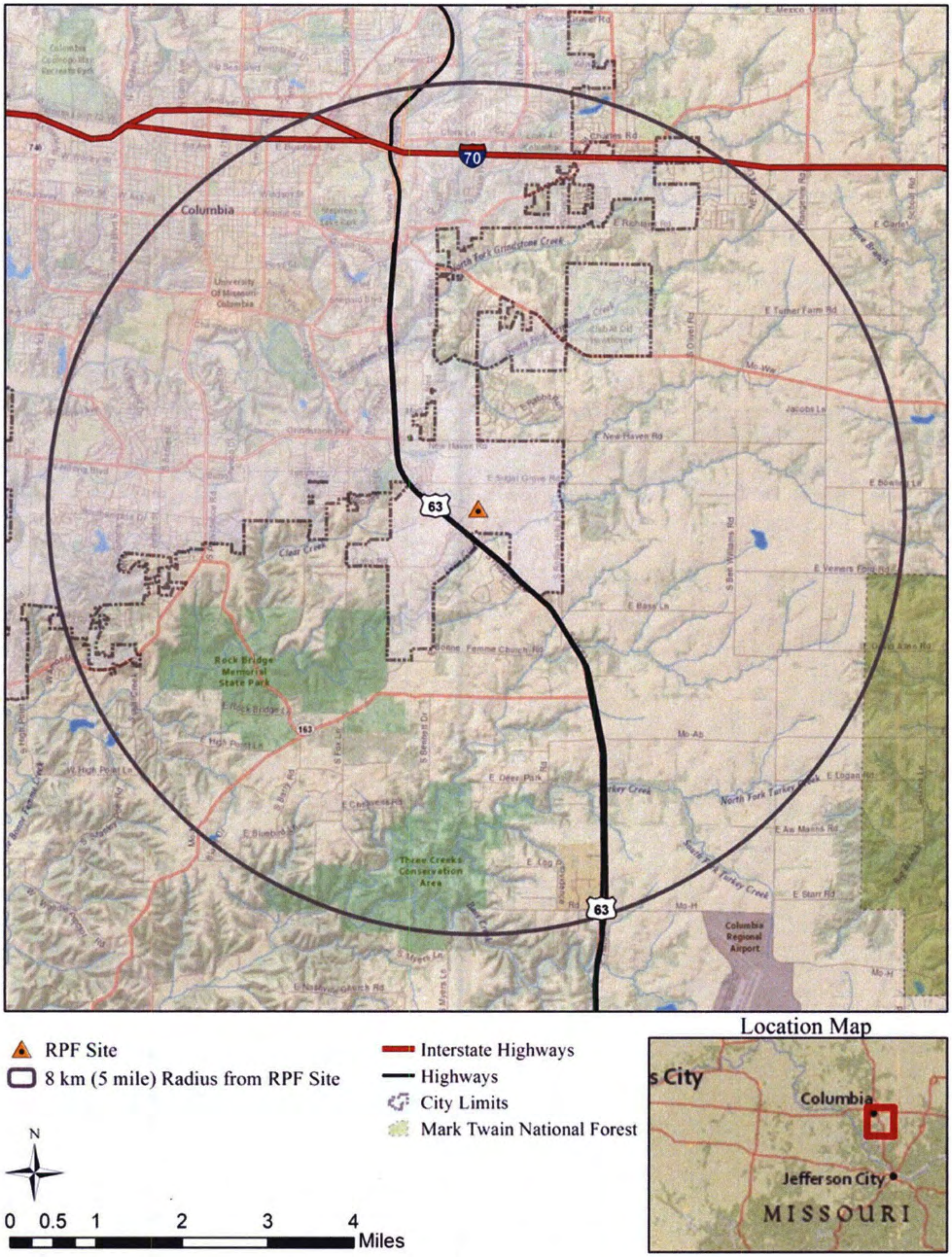


Figure 19-5. Illustration of 8 km (5-mi) Radius from the Center of the Facility

19.2.2.1.1 Population

The 2010 Census reported that Columbia had a population of 108,500, which increased by 20.1 percent over the 10 preceding years (USCB, 2010a/b). Ashland is located approximately 14.5 km (9 mi) south of the proposed RPF site and had a 2010 Census population of 3,707, which increased 50 percent over the 10 preceding years. The population of Columbia resides primarily north-northwest of the proposed site. The 2010 Census Boone County population was 162,642 (USCB, 2010a/b). In the fall of 2012, MU had a population of approximately 34,748 students (MU, 2013).

19.2.2.1.1.1 Sensitive Populations

Table 19-9 provides a list of the sensitive populations (e.g., schools, daycares, retirement homes) within a 5-mi radius of the proposed RPF site. The list was developed using multiple sources and surveys. Google Earth was used to determine the distances from the site.

Table 19-9. Sensitive Populations (2 pages)

Facility	Distance		General direction	Facility	Distance		General direction
	km	mi			km	mi	
Resident							
Nearest full-time resident	0.43	0.27	South	Sunset Mobile Home Park	0.93	0.58	Northwest
Full-time resident	0.58	0.36	Northwest	High Hill Courts Mobile Home	1.99	1.24	Southeast
Public Schools							
New Haven Elementary School	1.6	1.0	Northwest	Benton Elementary School	7.2	4.5	Northwest
Rock Bridge High School	5.25	3.26	West	Hickman High School	8.52	5.3	Northwest
Mill Creek Elementary School	8.55	5.31	West	Lee Elementary School	6.90	4.22	Northwest
Rock Bridge Elementary School	5.12	3.18	West	Field Elementary School	7.96	4.95	Northwest
Gentry Middle School	6.1	3.8	West	Jefferson Junior High School	7.82	4.86	Northwest
Cedar Ridge Elementary School	4.08	2.54	North	Grant Elementary School	7.85	4.88	Northwest
Shepard Boulevard Elementary School	4.55	2.83	Northwest	Douglas High School	7.82	4.86	Northwest
Colleges/Universities							
University of Missouri-Columbia	6.1	3.8	Northwest	Bryan University -Columbia	2.22	1.38	Northwest
Western Governors University Missouri	2.16	1.34	Northwest	Steven's College	6.92	4.3	Northwest
William Woods University	2.33	1.45	Northwest				
Private							
Christian Chapel Academy	5.13	3.19	North	Windsor Street Montessori	6.63	4.12	Northwest
Little Miracles Preschool	2.8	1.74	North	Fr. Tolton Catholic High School	1.42	0.88	Southwest
Children's House Montessori	6.36	3.95	Northwest	Islamic School of Columbia	7.26	4.51	Northwest

Table 19-9. Sensitive Populations (2 pages)

Facility	Distance km	Distance mi	General direction	Facility	Distance km	Distance mi	General direction
Child Care/Preschools							
Rock Bridge Child Development	5.5	3.4	West	Community Nursery School-Green Meadows Preschool	7.2	4.5	Northwest
Green Meadows Preschool	6.92	4.3	West	Tiger Tots Child Development Center	7.43	4.62	Northwest
Country Day School	3.14	1.95	Southeast	End of the Rainbow	3.69	2.29	Northwest
Luke's Child Care and Preschool	3.62	2.25	North	Academy of Early Childhood Learning	5.46	3.39	North
Apple School	5.1	3.2	West	Sylvan Learning Center	5.52	3.43	North
Down to Earth Preschool	5.8	3.6	West				
Retirement/Assisted Living Facilities							
Lenoir Woods Senior Living	1.46	0.91	Northwest	Columbia Manor Care Center	2.99	1.86	West
Tiger Place	2.54	1.58	Northwest	Boone Landing	5.97	3.71	North
Bluff Creek Terrace	2.53	1.57	Northwest				
Hospitals							
Providence Urgent Care	5.38	3.34	West	Green Meadows Pediatric and Adolescent Medicine	5.95	3.7	West
University Hospital Clinic	6.2	3.85	Northwest	University Physicians-Urgent Care	5.97	3.71	Northwest
Missouri Orthopedic Institute	5.83	3.62	Northwest	University of Columbia Hospital	6.13	3.81	Northwest
Harry S. Truman Memorial Veterans' Hospital	6.1	3.8	Northwest	Ellis Fischel Cancer Center	5.95	3.7	Northwest
Pediatric Plastic Surgery, University of Missouri Children's Hospital	6.16	3.83	Northwest	University of Missouri, Mohs & Dermatology Surgery Clinic	5.95	3.7	Northwest
Boone Hospital Center	6.39	3.97	Northwest	Children's Hospital	6.3	3.92	North

19.2.2.2 Site Layout

The RPF site is 3.0 ha (7.4-acre) and is located entirely on property owned by MU. Figure 19-6 shows a footprint of the major structures, site layout, fence line, and site boundary (Lot 15). The major structures include the RPF, Waste Staging and Shipping Building, and Diesel Generator Building. Additionally, the site has an Administration Building and Security Stations. These major facilities also receive, store/hold, or process chemicals, oil, diesel fuel, and other hazardous and radioactive materials. The site presently consists of grass fields and is primarily relatively flat surfaces at an elevation of 231 m (758 ft). Access to the site is provided from Discovery Drive and Discovery Parkway.

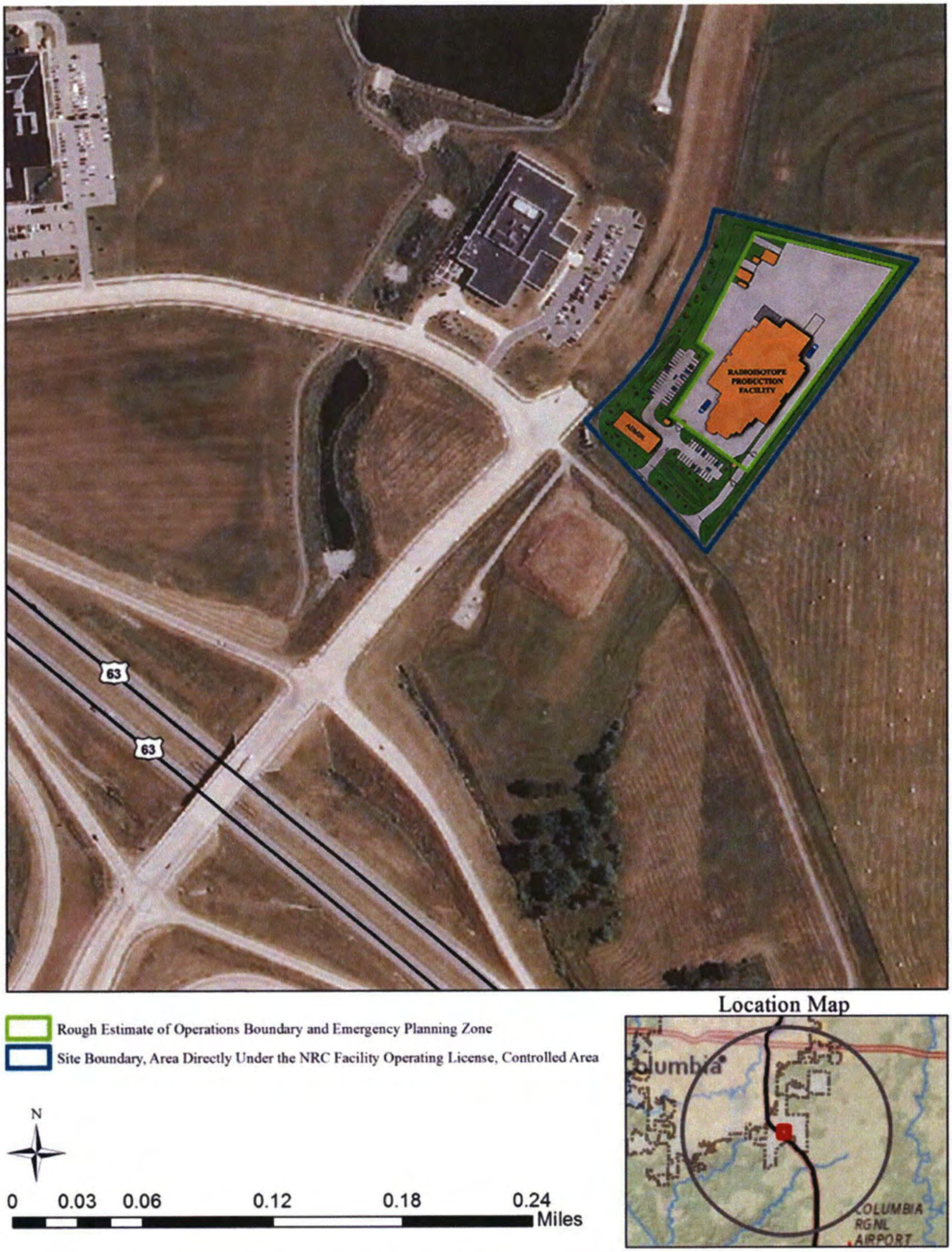


Figure 19-6. Radioisotope Production Facility Site Boundary

The RPF main building is approximately 106.7 m (350 ft) long and 56.4 m (185 ft) wide. The height above grade is 14 m (46 ft) for the mechanical/electrical bay roof, 19.8 m (65 ft) for the high bay roof, and 22.9 m (75 ft) for the facility stacks. The site is enclosed by perimeter fencing to satisfy safeguards and security and other regulatory requirements. The total fenced area includes paved roads laid out as appropriate for the turning radius of tractor/trailers used to transport the irradiated target shipping and waste handling casks.

19.2.2.3 Infrastructure Improvements

Discovery Ridge has the infrastructure (power, sewer, and water) required to support the proposed RPF. Sanitary sewer, electric power, municipal water, and natural gas are installed from the facility to the utility connections presently located at the southwest corner of the site.

19.2.2.4 Existing Infrastructure

The RPF site has no existing underground storage tanks, wells, pipelines, water supply, sewage, or stormwater systems.

19.2.2.5 Other Nearby Facilities/Buildings

Analytical Bio-Chemistry Laboratories – Analytical Bio-Chemistry Laboratories, Inc. (ABC Laboratories), is located approximately 0.48 km (0.3 mi) west of the proposed RPF within Discovery Ridge. ABC Laboratories is a contract research organization that delivers a broad array of product development and analytical testing services to the pharmaceutical, biotechnology, animal health, crop protection, and chemical industries. The facility is an 8,361 square meter (m^2) (90,000-square foot [ft^2]) facility that includes chemical and biochemical laboratories and associated systems and equipment. The facility is a RCRA large quantity generator-permitted facility.

Research and Diagnostic Laboratory Facility – The Research and Diagnostic Laboratory (RADIL) facility, located approximately 0.16 km (0.1 mi) northwest of the proposed RPF within Discovery Ridge. RADIL is owned by IDEXX Laboratories, Inc., who purchased the facility from the MU College of Veterinary Medicine. The 5,667 m^2 (61,000 ft^2) facility provides health monitoring and diagnostic testing services to bioresearch customers. The facility is a RCRA small quantity generator-permitted facility.

19.2.2.6 Monitoring Stations

The need for monitoring stations is discussed in the following sections:

- Air monitoring – Section 19.4.2.2
- Groundwater monitoring – Section 19.4.4.3
- Surface water monitoring – Section 19.4.4.3
- Meteorological monitoring – Section 19.4.2.2.5
- Ecological monitoring – Section 19.4.5.4
- Radiological monitoring – Section 19.4.8.4

19.2.3 Radioisotope Production Facility Description

The proposed RPF would support target fabrication, recovery and purification of the ^{99}Mo product from irradiated LEU targets that would be generated by irradiation in multiple university research reactors, and uranium recovery and recycle to produce ^{99}Mo. Figure 19-7 shows the proposed site layout, including the RPF, adjacent administration and support buildings, security buildings and associated security fence.

Figure 19-7. Radioisotope Production Facility Site Layout

Figure 19-8 is first level general layout of the RPF. Figure 19-9 and Figure 19-10 are preliminary layouts of the first level and second level, respectively, of the RPF. A mezzanine area above a portion of the process area would be for utility, ventilation and offgas equipment. The following sections provide a description of the major rooms included in the facility layout.

The first level (excluding the tank pit area) and second levels of the RPF are currently estimated to contain approximately 4,282 m^2 (46,088 ft^2) and 1,569 m^2 (16,884 ft^2) of floor space, respectively. The processing hot cell and waste management temporary storage floor space area is approximately 544 m^2 (5,857 ft^2). The maximum height of the building is 19.8 m (65 ft) with a maximum stack height of 22.9 m (75 ft). The depth of the processing hot cell belowgrade, without footers, is 4.6 m (15 ft) of enclosure height in rooms containing process equipment.

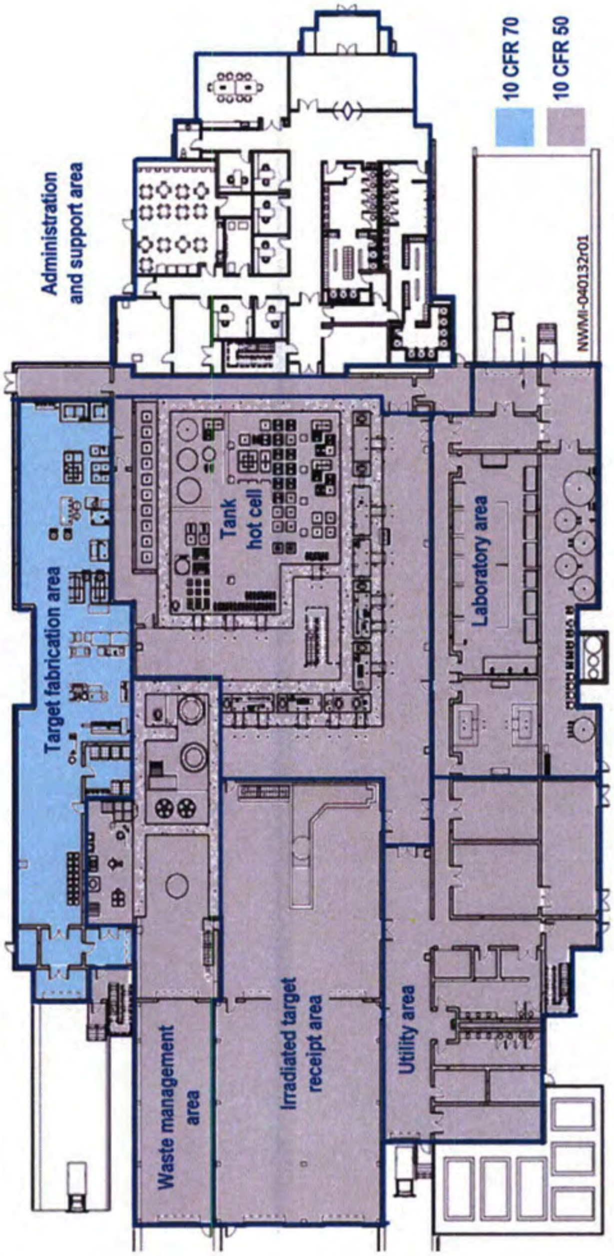


Figure 19-8. General Layout of the Radioisotope Production Facility

[Proprietary Information]

Figure 19-9. Preliminary Layout of the Radioisotope Production Facility First Level Floor Plan

[Proprietary Information]

Figure 19-10. Preliminary Layout of the Radioisotope Production Facility Second Level Floor Plan

Figure 19-11 illustrates the hot cell details for target disassembly dissolution, Mo recovery and purification, uranium recovery and recycle, and waste management.

[Proprietary Information]

Figure 19-11. Radioisotope Production Facility Hot Cell Details

19.2.3.1 Process Description

A flow diagram of the primary process to be performed by the proposed RPF is provided in Figure 19-12.

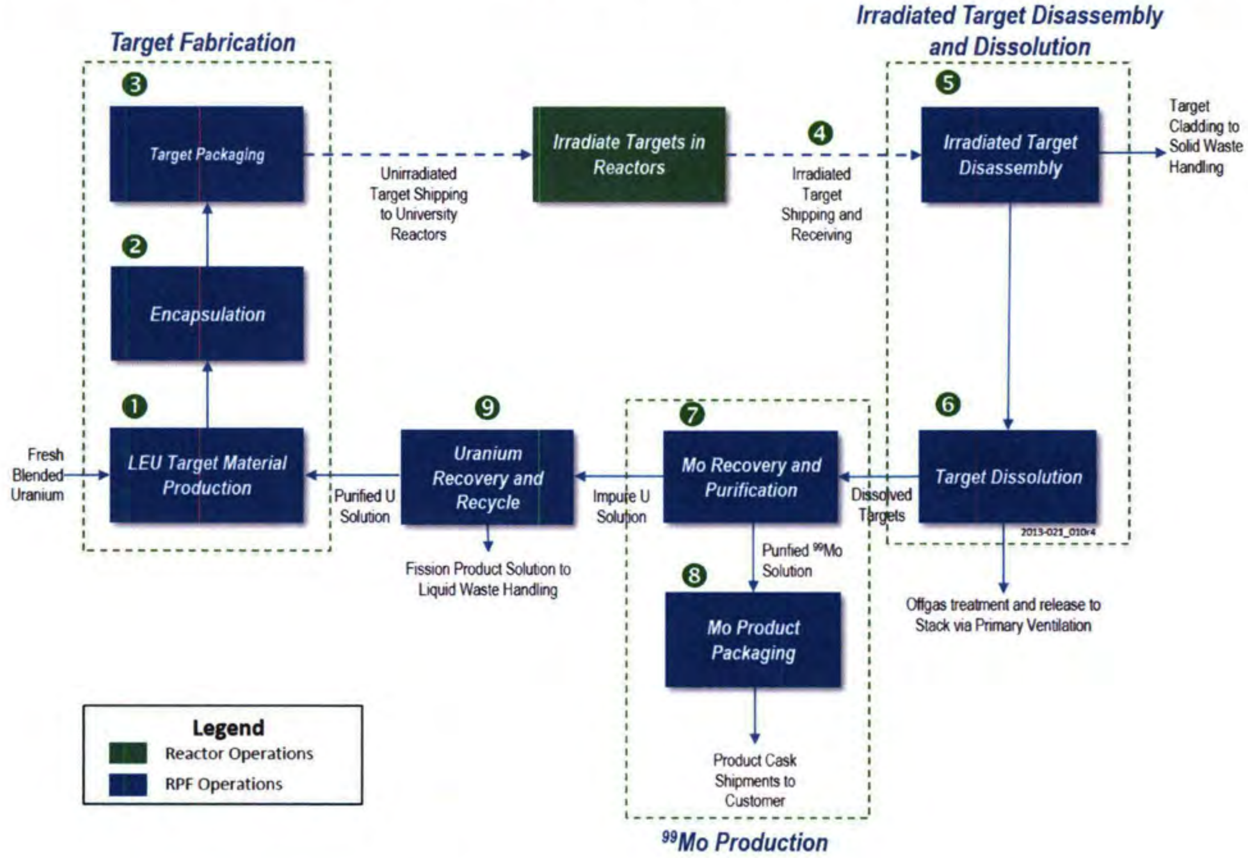


Figure 19-12. Radioisotope Production Facility Block Flow Diagram

RPF operations include the following general process steps (which correspond with the above figure).

❶ LEU target material is fabricated using a combination of fresh LEU and recycled uranium.

❷ Target material is encapsulated using metal cladding to contain the LEU and fission products produced during irradiation.

❸ Fabricated targets are packaged and shipped to university reactors for irradiation.

❹ After irradiation, targets are shipped back to the RPF.

❺ Irradiated targets are disassembled and metal cladding is removed.

❻ Targets are then dissolved into a solution for processing.

❼ Dissolved LEU solution is processed to recover and purify ^{99}Mo.

❽ Purified ^{99}Mo is packaged in certified shipping containers and shipped to a radiopharmaceutical distributor.

❾ LEU solution is treated to recover uranium and remove trace contaminants and is recycled back to Step 1 to be made into new targets via the target fabrication system.

All process wastes that contain unwanted isotopes are converted to a disposal form by the waste handling system, where the wastes are placed in casks for shipment to a disposal site. Offgases are captured and treated through appropriate treatment systems and then released through a stack.

19.2.3.1.1 Target Fabrication Summary (Steps ➊, ➋, and ➌)

The target fabrication process converts fresh and recycled uranium into LEU target material, which is then loaded into target hardware for shipping to the reactors for irradiation. The material being processed in the target fabrication area requires no shielding; the equipment is contact-handled.

LEU target material production (Step ➊) – LEU target material is produced using an internal gelation process. The material is produced from a combination of recycled uranyl nitrate, fresh uranium metal, and uranium compounds recycled from various points in the target fabrication system. The recycled uranyl nitrate is converted to acid-deficient uranyl nitrate (ADUN) using a solvent extraction process, which selectively removes nitrate ions from the solution. The resulting ADUN is mixed with the uranyl nitrate produced by dissolution of fresh uranium. This ADUN is evaporated to achieve the desired uranium concentration, and is then chilled before mixing with urea and hydroxymethyltetramine (HMTA) to form the gelation broth. This broth is injected into a column of heated silicone oil. At the base of the column, the LEU target material is filtered from the oil and washed with a solvent, ammonium hydroxide and water. The target material is then reduced in a stream of dilute hydrogen within a furnace. The LEU target material is sampled and analyzed to ensure that it meets quality requirements before routing to the target fabrication system.

Encapsulation (Step ➋) – LEU target material is loaded into the target hardware. This hardware is prefabricated and cleaned before entering the facility. The targets are filled with LEU target materials and helium cover gas. Once the targets have been loaded and welded, they undergo inspection and quality assurance (QA) checks, including leak testing. Targets that pass the QA checks are shipped to the university reactors for irradiation. Targets that fail the QA checks are disassembled. The LEU target material is recycled, and the hardware is cleaned and disposed of as nonradioactive scrap.

Target packaging and shipment (Step ➌) – Assembled targets are loaded into shipping casks for transport to the university reactors. Transport will be via ground transportation.

19.2.3.1.2 Irradiated Target Receipt, Disassembly, and Dissolution Summary (Steps ➍, ➎, and ➏)

Target receipt and disassembly (Steps ➍ and ➎) – The irradiated targets are received in shielded shipping casks. The irradiated LEU targets are moved into the hot cell via a below-grade tunnel to the hot cell access point that mates up with either the shipping cask or a transfer cask. The targets are disassembled by puncturing the target, collecting any fission product gases, severing the target in half, and transferring the irradiated LEU target material into a transfer container. The spent target are inspected and disposed of as solid waste.

Target dissolution (Step ➏) – The target dissolution process is operated in a "batch" fashion, with the irradiated LEU target material transferred into a dissolver. The LEU material is dissolved in hot nitric acid. The offgas containing the fission product gases goes through a series of cleanup columns. The nitrogen oxides (NO_x) is removed by a reflux condenser and several NO_x absorbers, the fission product gases (noble and iodine) are captured on absorbers, and the remaining gas is filtered and discharged into the process ventilation header. The dissolver solution is diluted, cooled, filtered, and pumped to the ^{99}Mo system feed tank. Only one of the two dissolvers is planned to be actively dissolving LEU target material at a time.

19.2.3.1.3 Molybdenum-99 Product Recovery and Purification System (Steps ❼ and ❽)

The dissolver solution from the target dissolution operation is processed to purify the ^{99}Mo. The uranium-containing solutions from the ^{99}Mo ion exchange (IX) columns are transferred to the uranium recovery system. The remaining waste solutions are sent to low- or high-dose waste storage tanks.

Mo recovery and purification (Step ❼) – The dissolver solution from the target dissolution operation is pumped through the first IX column (Mo recovery). The ^{99}Mo and trace components are absorbed onto the media. The uranium and most of the fission products and other contaminates flow through the column and are sent to the lag storage tanks in the uranium recovery and recycle system. The ^{99}Mo is eluted from the first column and purify in the second and third IX columns. The product purification process primarily consists of a series of chemical adjustments and IX columns to remove unwanted isotopes from the ^{99}Mo product solution.

^{99}Mo product packaging and shipping (Step ❽) – Product solution is sampled to verify compliance with acceptance criteria after a final chemical adjustment. The product solution in small vials is then placed into shipping containers that are sequentially loaded into shipping casks. The casks are removed from the hot cell, surveyed, and manifested for transport to the customer. ^{99}Mo product is transported via air or ground transportation depending on which radiopharmaceutical distributor is receiving the shipment.

19.2.3.1.4 Uranium Recovery and Recycle Summary (Step ❾)

The uranium process system consists of solution storage vessels, IX columns, and concentrators for uranium recovery and recycle. The lag storage tanks minimize upstream processing delays and provide several weeks of decay time before the material is processed through the system.

First cycle uranium recovery – The LEU stream from the first cycle molybdenum IX column is held in lag storage tanks to allow selected radionuclides to decay. The solution is then diluted and pumped through the first IX columns to separate the bulk of the fission product contaminants from the uranium. The waste is sampled and sent to the high-dose liquid waste accumulation tank. The uranium is eluated from the IX columns, and a concentrator/condenser is used to control the volume of the uranium interim product. The condensate is send to the low-dose liquid waste accumulation tank.

Second cycle uranium recycle – The interim uranium product solution is processed through a second stage IX column to remove trace contaminates. The waste is sampled and sent to the high-dose liquid waste accumulation tank. The uranium is eluated from the IX columns, and a concentrator/condenser is used to control the volume of the recycled uranium product. The condensate is sent to the low-dose liquid waste accumulation tank. The final uranium product solution is sampled to confirm that it meets the recycle specification.

Product uranium lag storage – This subsystem consists of a series of solution storage vessels. The vessels allow the time necessary for uranium-237 (^{237}U) to decay to contact-handled levels in the uranium product solutions. The decayed uranium product is returned to target fabrication.

19.2.3.1.5 Waste Management System Description

The waste management system is divided into three subsystems: (1) the liquid waste system, (2) the solid waste system, and (3) specialty waste systems.

Liquid waste system – The liquid waste disposal system consists of storage tanks for accumulating waste liquids and adjusting the waste composition. Liquid waste is split into high-dose and low-dose streams by concentration. The high-dose fraction is further concentrated, adjusted, and mixed with adsorbent material. A portion of the low-dose fraction is expected to be suitable for recycle to selected systems as process water. Water that is not recycled is adjusted and then mixed with an adsorbent material. Both solidified streams are held for decay and shipped to a disposal facility.

Solid waste system – The solid waste disposal system consists of an area for collection, size reduction, and staging of solid wastes. The solids are placed in a waste drum and encapsulated by adding a cement material to fill voids remaining within the drum. The solidified waste is held for decay and shipped to a disposal facility.

Specialty waste system – A specialty waste disposal system is based on addressing small quantities of unique wastes generated. The goal is to reuse as much of the material as possible. Examples of these processes may include organic and non-organic reclamation processes and silicone oil waste accumulation. These waste streams are containerized, stabilized, as appropriate, and shipped offsite for treatment and disposal.

19.2.3.1.6 Process Offgas Systems

The process offgas subsystem is connected directly to the process vessels and maintains a negative pressure within the vessels. Process vessel ventilation systems include a set of subsystems that are specialized to the equipment that the subsystems support. These systems merge together at the process offgas filter train.

Dissolver offgas subsystem – The dissolver offgas subsystem is connected directly to the process vessels associated with the irradiated target dissolution process. There are two primary features of this system: (1) recover NO_x from the nitric acid dissolution of irradiated targets, and (2) capture fission product gases released from the irradiated targets. This subsystem is installed in the remote hot cell.

Iodine potential offgas subsystem – The iodine potential offgas subsystem is connected directly to process vessels or equipment that contain tellurium isotopes that decay and form iodine isotopes. Within this subsystem, an iodine capture system is included to ensure that any iodine evolving from the process is captured on the treatment media. After iodine treatment, the subsystem merges with the other process ventilation subsystems.

LEU target/target fabrication offgas subsystem – The microsphere/target offgas subsystem is connected directly to the process vessels and equipment that are associated with the wet portion of the microsphere/target fabrication process. Filtration is required for this subsystem prior to merging with the other process ventilation subsystems. There are controls/design features in place to maintain the reducing gas within flammability limits.

19.2.3.2 Facility Areas

19.2.3.2.1 Irradiated Target Receipt Bay

The irradiated target receipt bay is used to receive irradiated fuel elements in shipping casks loaded on semi-truck trailers. The traveling bridge crane is used to transfer a shipping cask from the trailer onto a transfer cart for transfer to the hot cells. The shipping cask/transfer cart is transferred from the receipt bay airspace through a doorway into the hot cell operating gallery. The cask is introduced to a shielded transfer port in the hot cell, where the cask is remotely opened and targets are removed and staged within the hot cell for disassembly.

19.2.3.2.2 Remote Hot Cells

Irradiated target processing is performed using equipment that is located in shielded hot cells to protect operating personnel from doses generated by radioactive materials. The hot cells provide remote operation and maintenance capabilities with features such as (1) shielding windows and in-cell and through-wall manipulators for equipment operation and maintenance, (2) access via cover blocks and bridge crane to support remote maintenance activities, and (3) equipment (e.g., pumps and valves) that remotely operated from outside the hot cell.

The hot cells and associated ventilation equipment also provide containment and confinement for the potential release of radioactive materials from a process vessel during maintenance activities or off-normal operating conditions. The hot cell area will have a criticality favorable floor/sump geometry configuration and high-efficiency particulate air (HEPA) filters on the ventilation inlets and outlets. The hot cell is divided up into the following areas:

- LEU target disassembly and dissolution area
- Mo recovery and purification area
- Uranium recovery and recycle area
- Operating gallery area
- Maintenance areas
- Remote support systems areas

Low-Enriched Uranium Target Disassembly and Dissolution Area

The disassembly area has a feature that mates with the shielded cask and enables the target basket with irradiated LEU targets to be placed in the hot cell. Two disassembly stations are currently envisioned as semi-automated devices that pick one target at a time from the shipping basket, puncture and delid the target, and pour target material into a transfer container. The spent target is inspected to ensure that it is empty, passed through to the waste management area, and disposed of as solid waste. The area also contains the dissolver vessels, dissolver offgas treatment equipment, and fission gas capture columns. The disassembly stations are supported with leaded windows and/or cameras and master-slave manipulators.

Molybdenum-99 Recovery and Purification Area

Cells are included in the remote hot cell to house equipment associated with the Mo recovery and purification system. The cells include a series of small IX columns with containers, peristaltic pumps, and collection tanks. Operations and maintenance of the process are performed by the through-wall manipulators. An egress point is included for load-in and load-out of the ^{99}Mo shipping cask. This area of the hot cell will have design features that support FDA requirements.

Uranium Recovery and Recycle Area

Equipment associated with the LEU recovery and recycle system is also located within the remote hot cell area. This equipment will be much larger than the small Mo recovery and purification equipment, and use a large portion of the remote hot cell. The process equipment includes a series of IX columns; lag storage, feed, and product tanks to support operation of IX columns; and concentrator systems. The process equipment is skid-mounted, which enables remote replacement and ensures critically safe spacing between skids.

Operating Gallery Area

The operating gallery is situated adjacent to the hot cell. The operating gallery is an area used by personnel to physically operate remote wall-mounted manipulators. Local control stations are provided in the operating gallery to support process operations. The operating gallery width is sufficient to allow removal of a wall-mounted manipulator for maintenance or repair. After removal from the wall, a manipulator is transported via a cart system to the maintenance area where actual repairs are performed.

Maintenance Areas

Two maintenance areas are used for facility equipment maintenance: the maintenance shop and the manipulator repair room.

Remote Support Systems

Remotely operated equipment is used to perform the core operations of processing irradiated targets, recovering ^{99}Mo for shipment to customers, and recycling LEU for fabrication into targets for future irradiation. These operations are backed by remotely operated support systems, including the main crane and manipulator arms. These two systems provide the ability to keep the process in operation for years.

Along with the manipulator arms, the main crane provides the heavy-lifting capacity needed to lift the hot cell cover blocks, remove nonfunctional items from the remote hot cell, and bring in replacement components. An additional crane is provided for remote operations and lifting waste packages in the waste management area.

19.2.3.2.3 Target Fabrication Area

The target fabrication area contains equipment associated with the LEU target material and target fabrication systems. Material processed by the system is unirradiated LEU, obtained as feed from DOE, and LEU recycled from processing irradiated targets. Recycled LEU is purified in the remote hot cell and transferred as a solution to the microsphere fabrication vessels. Verification measurements are performed on the purified recycled LEU solutions prior to transfer into the fabrication area to confirm that the recycled LEU material satisfies criteria that allow processing in the unshielded process enclosures.

The microsphere/target fabrication area includes the following sub-areas:

- **Target fabrication wet area** – The wet area contains the process equipment for conversion of uranium compounds to LEU target material. Most of the equipment processes aqueous solutions of uranium. The equipment includes concentrators, dissolvers, liquid-liquid contactors, lag storage and blending tanks, columns for forming and washing LEU target materials, a filter system, furnace boat loading and transfer systems, and furnaces for drying and reducing the LEU target material. The LEU target material is manually transferred from the wet area to the dry area.
- **Target fabrication dry area** – The dry area is used to encapsulate LEU target material in the target hardware. Activities performed in this area are primarily receipt and inspection of target hardware components, loading LEU target material into the target, filling the target with helium, and seal welding the targets.
- **Target fabrication QA/laboratory area** – This area is used to perform the various tests and inspections for monitoring and QA of the target fabrication processes. Tests are performed on liquid solutions, LEU target material, and assembled targets.
- **Storage areas** – These are secure rooms within the target fabrication area that store materials used by the above processes. These rooms contain storage racks that segregate raw and in-process materials from the final product.

19.2.3.2.4 Waste Management Area

The waste management area includes shielded enclosures for tanks collecting liquid waste and containers used to stage solid wastes generated by the process systems. Portions of the waste management system that are dedicated for high-dose liquid waste are included in the remote hot cell. There are three shielded areas in the waste management area: (1) the high-integrity container (HIC) vault, where filled waste containers are held for several months to allow short-lived radioisotopes to decay to lower doses, (2) the hot cell solid waste export area, where equipment and empty targets are passed out of the hot cell, and (3) the solidification cell, where liquid waste is processed/mixed with materials to prepare waste packages for disposal.

The solid waste is moved to the waste loading area, where the waste is loaded into a shipping cask (typically already on a truck trailer) to be transported to a disposal site. The waste management area is serviced by a bridge crane.

19.2.3.2.5 Mechanical/Electrical Rooms

The mechanical/electrical rooms are located on the second floor on both sides of the hot cell. The mechanical/electrical rooms house electrical systems, motor control centers, pumps, boilers, air compressors, and ventilation supply equipment. The heating, ventilation, and air-conditioning (HVAC) chillers are located outside of the facility, in the same area as the process water chillers. The mechanical room over the laboratory/chemical make-up areas houses the exhaust fans and filter trains.

19.2.3.2.6 Process Offgas Room

The process offgas room is connected directly to the process vessel and process offgas subsystems to treat the stream and maintain negative pressure within the vessels. The process offgas room contains absorbers, filters trains, and fans. Process offgas is discharged from the primary building exhaust system.

19.2.3.2.7 Laboratory and Research and Development Hot Cell

An analytical laboratory and research and development hot cell area support the production of the ^{99}Mo product and recycle of uranium. Samples from the process are collected, transported to the laboratory, and prepared in the laboratory hot cell.

Other laboratory features include the following:

- Hoods and/or gloveboxes to complete sample preparation, waste handling, and standards preparations
- Rooms with specialty instruments, including an inductively coupled plasma mass spectrometry (ICP-MS)—a gamma spectroscopy system, an alpha spectroscopy system, a liquid scintillation system, and a beta-counting system
- Chemical and laboratory supplies storage
- Bench-top systems (e.g., balances, pH meters, ion-chromatography)

19.2.3.2.8 Chemical Make-up and Gas Storage Room

The chemical make-up room includes tanks supplying aqueous chemicals to the process systems, flammable material storage cabinets used to segregate incompatible materials, and storage of chemical solids used in the process systems. The gas distribution room serves as a location for storage of small quantity gases (stored in gas cylinders) and distribution manifolds. Large quantities of gases are stored outside of the RPF in appropriate storage tanks or trailers. These areas are designed to segregate incompatible chemicals.

19.2.3.2.9 Raw Materials and Molybdenum-99 Product Shipping and Receiving Areas

Two separate access points are proposed to move process materials into and out of the facility and ship ^{99}Mo product to the radiopharmaceutical distributors. Both access points are truck bays that interface with process areas near the chemical make-up room. The ^{99}Mo product bay functions as an airlock as part of the confinement ventilation control strategy for exporting the casks transported by a cargo vehicle. The second access point next to the ^{99}Mo product area is a shipping/receiving room and loading dock for the movement of smaller packages using handcarts or forklift. This area is the planned location for the receipt of chemicals and will have a pad/berm for spill protection and collection.

19.2.3.2.10 Support Staff Areas

The support staff areas are an annex to the RPF and include various areas supporting the process. The support staff areas include a shift office, health physics office, break room, support offices/workroom, change rooms/bathrooms, storage areas, and personnel airlock.

19.2.3.2.11 Control Room

The control room houses the process control system for operating and monitoring the facility. The control room door into the facility is equipped with controlled access. The control console has two or three operator interface stations or human-machine interfaces (one being a dedicated engineering interface), a master programmable logic controller or distributed controller, and all related and necessary cabinetry and subcomponents (e.g., power supplies and uninterruptable power supply). This control system is supported by a data highway of sensing instrument signals in the facility process areas that are gathered throughout the facility by an Ethernet communication-based interface backbone and brought into the control room and onto the console displays.

Dedicated controllers and human-machine monitoring interfaces or stations for other equipment systems are also in the control room. A control panel for all facility on-site and off-site (if required) communications (e.g., telephone, intercom) will potentially be located in the control room.

19.2.3.2.12 General Ventilation System

The facility ventilation system maintains a series of cascading pressure zones to draw air from the cleanest areas of the facility to the most contaminated areas. Zone IV is a clean zone and is independent of the other ventilation zones. Zone IV will be slightly positively pressurized with respect to the atmosphere. Zone III is the cleanest of the potentially contaminated areas, with each subsequent zone being more contaminated and having lower pressures. Table 19-10 defines the ventilation zone applicable to major spaces. Figure 19-13 graphically presents the ventilation zone for the first level of the RPF.

A common supply air system provides 100 percent outdoor air to all Zone III areas and some Zone II areas that require make-up air in addition to that cascaded from Zone III. Three separate exhaust systems maintain zone pressure differentials and containment: (1) the Zone I exhaust system services the hot cell, waste loading areas, target fabrication enclosures, and process offgas subsystems in Zone I; (2) the Zone II/III exhaust system services exhaust flow needs from Zone II and Zone III in excess of flow cascaded to interior zones; and (3) a laboratory exhaust system services fume hoods in the laboratory area.

Table 19-10. Facility Areas and Respective Confinement Zones

Area	Zone
Hot cells (production)	I
Tank hot cell	I
Solid waste treatment hot cell	I
High-dose waste solidification hot cell	I
Uranium decay and accountability hot cell	I
HIC vault	I
Analytical laboratory gloveboxes	I
R&D hot cell laboratory hot cells	I
Target fabrication room and enclosures	II
Utility room	II
Analytical laboratory room and hoods	II
R&D hot cell laboratory room and hoods	II
Waste loading hot cell	II
Maintenance gallery	II
Manipulator maintenance room	II
Exhaust filter room	II
Airlocks[a]	II, III
Irradiated target basket receipt bay	III
Waste loading truck bay	III
Operating gallery and corridor	III
Electrical/mechanical supply room	III
Chemical supply room	III
Corridors	III
Decontamination room	III
Loading docks	IV
Waste management loading bay	IV
Irradiated target receipt truck bay	IV
Maintenance room	IV
Support staff areas	IV

[a] Confinement zone of airlocks will be dependent on the two adjacent zones being connected.
HIC = high-integrity container.
R&D = research and development.

[Proprietary Information]

Figure 19-13. First-Level Confinement of the Radioisotope Production Facility

The supply air is conditioned using filters, heater coils, and cooling coils to meet the requirements of each space. Abatement technologies (primarily HEPA filtration and activated carbon) are used to ensure that air exhausted to the atmosphere meets NESHAP and applicable State law. A stack monitoring system is employed to demonstrate compliance with the stated regulatory requirements for exhaust.

The systems and components of the main ventilation system are described in the following subsections.

Supply Air Subsystem

The supply air system provides filtered and conditioned air to all Zone III spaces and some Zone II spaces at a ventilation rate of 100 percent outside air. The three supply air handling units are sized at 50 percent capacity each, for redundancy. Two of the three units will be operating, while the third is on standby. Each unit consists of an outdoor air louver, filters, a cooling coil, a heating coil, a heat recovery coil, isolation dampers, and a fan.

Variable-speed fans are modulated to control the pressure in the common air plenum. The heating and cooling coils in each air-handling unit are controlled based on a common supply air temperature sensor. Reheat coils are provided in the supply ducts to each space, as required, to further condition the supply air, based on space temperature thermostats.

Exhaust Air Subsystems

Four exhaust air subsystems are provided: Zone I exhaust, Zone II/III exhaust, laboratory exhaust, and process offgas exhaust. Each exhaust system is provided with two 100 percent capacity exhaust fans and filter trains for complete redundancy on all exhaust subsystems. This redundancy is important to ensure confinement ventilation pressure differentials are maintained at all times. Each exhaust filter train consists of prefilters, two stages of HEPA filters, carbon adsorbers, and isolation dampers. Exhaust ducts upstream of the filter trains are round to minimize areas where contamination can accumulate, and are sized to minimize particulate settling in the duct. Each exhaust system has a separate stack, with the exception of the process offgas subsystem, which merges with the Zone I exhaust stream. A stack monitoring system is provided on each stack to demonstrate compliance with applicable State law.

Zone I Exhaust Subsystem

The Zone I exhaust system serves the hot cell, HIC loading area, and solid waste loading area. This exhaust system maintains Zone I spaces at negative pressure with respect to atmosphere. The disassembly station is maintained at a slightly lower pressure due to the increased likelihood of contamination in that area. All make-up air to Zone I spaces are cascaded from Zone II spaces. Space temperature control is not provided for Zone I spaces unless thermal loads are expected to cause temperatures to exceed equipment operating ranges without additional cooling. HEPA filters are included on both the inlet and outlet ducts to Zone I. The outlet HEPA filters minimize the spread of contamination from the hot cell into the ductwork leading to the exhaust filter train. The inlet HEPA filters prevent contamination spread in case of an upset condition that results in positive pressurization of Zone I spaces with respect to Zone II spaces. The process offgas subsystem enters the Zone I exhaust subsystem just upstream of the filter train.

Zone II/III Exhaust Subsystem

The Zone II/III exhaust system serves the Zone II spaces and those Zone III spaces that do not provide cascaded air flow into Zone II. This exhaust system maintains Zone II spaces at negative pressure and Zone III spaces at a less negative pressure with respect to atmosphere. Make-up air to Zone II spaces is either cascaded from Zone III spaces or supplied from the supply air subsystem to meet additional space conditioning needs. All make-up air to Zone III spaces is provided from the supply air subsystem.

Laboratory Exhaust Subsystem

The laboratory exhaust system provides fume hood and glovebox exhaust capability. This essentially is a Zone I system, but is separate from the main Zone I exhaust system to accommodate the large flow fluctuations from changing fume hood positions. These highly variable flow conditions are controlled better through a separate exhaust system. This exhaust system minimizes the potential pressure perturbations and control difficulties that could result from including the fume hoods on the main Zone I exhaust system. Make-up air for increased fume hood exhaust flow is supplied from the common supply air system.

Cleanroom Subsystem

The cleanroom subsystem is designed to provide filtered and conditioned air at an exchange rate to meet the standards of an ISO 14644-1, "Cleanrooms and Associated Controlled Environments—Part 1: Classification of Air Cleanliness," Class 8 cleanroom. The cleanroom is maintained at a slightly positive pressure relative to its surroundings to ensure that unfiltered air does not infiltrate the cleanroom. Air inside the cleanroom is continually recirculated through a dedicated filtration system to remove internally generated contaminants. Air would be 100 percent recirculated, with the only air exchange with the surroundings of the cleanroom occurring through exfiltration and make-up air entering on the suction side of the fan. The cleanroom air handling unit and filters are located inside the hot cell and, therefore, must be remotely maintainable. Periodic cleanroom certification testing also needs to be performed remotely with permanently installed instrumentation.

19.2.3.2.13 Other Radioisotope Production Facility Support Buildings

External waste management storage and shipping building – The waste management building is approximately 111.5 m^2 (1,200 ft^2) and will provide additional waste storage and shipping preparation for radioactive waste prior to disposal.

Diesel generator building – The diesel generator building houses the RPF backup generator, which is used for temporary operation and safe shutdown of the RPF if required. The diesel fuel tank is stored aboveground next to the building, with an approximate volume of 3,785 liters (L) (1,000 gallons [gal]).

Security buildings – The RPF will have to two security buildings, one for personnel access and one for shipping and receiving of materials and waste. NWMI will establish, implement, and maintain its authorization program in accordance with NRC requirements.

19.2.4 Water Consumption and Treatment

19.2.4.1 Water Consumption

The water supply source for the proposed RPF is the municipal water system. Connection to this system will comply with applicable State or local requirements. Required ancillary equipment (e.g., pressure regulators, backflow preventers) is installed as required by local ordinances.

The demineralized water system supplies demineralized water to the process for water addition, flushing, and chemical dilution. The demineralized water system can also potentially provide make-up water to the steam boilers. Wash water is used to washdown the tractor/trailers.

Final flow rates and process needs are determined on completion of performance testing (e.g., fire protection systems). Additional pumps and regulators may be installed to meet the performance needs of the systems. Where appropriate, water recycle or reuse systems are employed. Lavatory and office supply water systems are provided. These systems are designed and installed in accordance with local code.

The RPF water flow rates and consumption data is summarized in Table 19-11. The chilled water and steam systems are closed-loop systems and require water during startup, with minimal make-up water requirements during operation.

Table 19-11. Radioisotope Production Facility Water Flow Rates and Consumption Information

Activity	[a]Annual demineralized water		Annual wash water	
	L	gal	L	gal
Target fabrication	25,000	6,600	–	–
Target disassembly and dissolution	1,500	400	–	–
Mo recovery and purification system	–	–	–	–
Uranium recovery and recycle system	500,410	132,200	–	–
Waste management	–	–	–	–
Laboratory facilities	2,000	530	–	–
Faculty support	2,000	530	360,000	95,100
Total	**530,910**	**140,260**	**360,000**	**95,100**
[b]Average daily use	2,042	539	1,385	366

[a] These numbers do not account for planned process recycle.

[b] Assumes 260 days of operation per year.

19.2.4.2 Water Sources Independent of Municipal or Commercial Supply

The RPF will not use water sources independent of the municipal or commercial supply.

19.2.4.3 Water Treatment

Potable water is provided through the public utility system and will require no additional treatment. Contaminated process wastewater storage and treatment systems are addressed in Section 19.2.7.3.

19.2.5 Cooling and Heating Dissipating Systems

19.2.5.1 Cooling Water Systems

The process chilled water system provides cooling for the process equipment. Cooling is required for condensing offgas from the concentrators and for cooling the process stream. Chilled water is delivered to cooling jackets in a closed loop system. Redundancy is provided for components that present a single-point failure risk in the process chilled water system to ensure that cooling remains available for continued production.

Air-cooled chillers are located outside of the RPF. These chillers are expected to be typical commercial HVAC chillers. Redundancy for cooling capacity is provided by sizing each of the three chillers at 50 percent of the design cooling capacity. Chilled water is circulated from the chillers to an intermediate heat exchanger in the secondary loop. The primary loop then circulates and distributes chilled water from the heat exchanger to the various process loads in a closed loop. The chilled water pumps are typical centrifugal pumps used in HVAC systems.

The intermediate heat exchanger is provided to minimize the risk of contamination spread outside of the facility in case of a process system leak into the chilled water system. To further minimize this risk, pressure differentials are maintained to ensure that flow is from lower contaminated systems into higher contaminated systems. The primary loop is maintained at a higher pressure than the process equipment, and the secondary loop is maintained at a higher pressure than the primary loop.

Some process cooling loads (e.g., the fission gas-trap and target fabrication equipment) require lower supply temperatures (e.g., below 0 degrees Celsius [°C]). These loads are served by standalone process chillers.

The RPF is designed to have zero liquid discharge from the radiologically controlled area (i.e., no liquid would be released from the facility).

19.2.5.2 Heating Systems

Process steam is used to provide heating for process equipment. Heating is required for the concentrators and process stream. The steam from the boilers flows to an intermediate heat exchanger in the secondary loop. The primary loop then circulates and distributes steam from the heat exchanger to the various process loads in a closed loop. The steam is assumed to be supplied to the heating jacket, condensed, and returned to the intermediate heat exchanger in a closed loop system. Redundancy is provided for components that present a single-point failure risk in the process steam system to ensure that heating remains available for continued production. Three electric boilers are located in the mechanical room of the facility. The boilers are assumed to be standard, commercially available, packaged high-pressure steam boilers. Each boiler is sized at 50 percent of the design capacity to provide redundancy for heating.

19.2.5.3 Heat Dissipation Systems

The RPF has no additional heat dissipation systems, besides the process chilled water system described in Section 19.2.5.1.

19.2.6 Auxiliary Systems

The compressed air system supplies instrument-quality (dry and oil-free) air to power air-actuated valves and dampers and for instruments that require compressed air (e.g., bubbler tube-level indicators). The compressed air system can also provide process air, although these loads are undefined.

The system is assumed to consist of a packaged air compressor system, with the compressor mounted on the receiver tank with associated filters, coolers, and pressure relief. A separate modular, heatless desiccant-type air dryer is provided. Process air can be taken directly from the air receiver, prior to drying and further filtering.

The HVAC chillers are located outside the facility, in the same area as the process chilled water chillers. The hot water boilers are located in the mechanical room. Pumps and supporting distribution system equipment for both systems are located in the mechanical room.

19.2.7 Waste Systems

The waste management area includes shielded enclosures for tanks collecting liquid waste and containers used to stage solid wastes generated by the other process systems. Liquid waste is mixed with a sorbent (or solidification agent) material in a HIC that is stored and eventually loaded into a shielded waste transport cask. The solid waste is size-reduced, placed in a drum, and encapsulated by adding a cement material. The drum is then closed and loaded into a shielded waste transport cask.

There is no solid or liquid waste disposal at the RPF site. Air effluents are discussed in Section 19.4.2.1.

19.2.7.1 Process System Liquid Wastes

Where practicable, liquid wastes are condensed and/or treated or recycled to reduce the environmental impacts associated with disposal. The liquid waste streams generated during the processing operations are handled with the aqueous waste-handling system discussed in Section 19.2.7.3.1. The individual liquid wastes generated during processing are summarized in Table 19-12.

Table 19-12. Liquid Waste Produced Annually from the Radioisotope Production Facility

Process	Annual waste	
	L	gal
[a]Target fabrication	45,000	11,890
[a]Target disassembly and dissolution	1,500	396
[a]Mo recovery and purification system	5,800	1,532
[a]Uranium recovery/recycle system	~1,120,000	295,873
Waste management	[b]	[b]
Laboratory facilities	2,000	530
Facility support	2,000	530

[a] Annual waste transferred to waste processes for concentration and solidification. These numbers do not account for planned process recycle.

[b] Wastes processed do not produce liquid waste other than small quantities of specialty wastes.

19.2.7.2 Process System Solid Waste

Where practicable, solid wastes are condensed and/or packaged to reduce the environmental impacts associated with disposal. The individual solid waste streams generated during the processes are summarized in Table 19-13.

Table 19-13. Solid Waste Produced at the Radioisotope Production Facility

Process	Components	Annual waste
Target fabrication	[a]NA	NA
[b]Target disassembly and dissolution	Target cladding materials from disassembly	1,100 L (290 gal)
[b]Mo recovery and purification	Exchange resins and other solid waste	20 L (5 gal)
[a]Uranium recovery and recycle	Exchange resin and media	~1,350 L (~360 gal)
[c]Waste management	Solid wastes encapsulated in cement	8,000 L (2,113 gal)
	High-dose solidified liquids	200,000 L (52,834 gal)
	Low-dose solidified liquids	150,000 L (39,625 gal)
Laboratory facilities	Municipal waste (e.g., chemicals) Potentially contaminated laboratory waste (e.g., sample vials and containers)	4,000 L (1,056 gal)
Facility support	Municipal waste (e.g., paper)	26,000 L (6,868 gal)
	Potentially contaminated waste (e.g., decontamination materials, PPE)	40,000 L (10,566 gal)

[a] Solid waste generated during target fabrication is anticipated to be decontaminated and free-released.

[b] Transferred to waste processing system for final disposition.

[c] The waste quantities current bounding estimates. Optimization of waste processing should reduce the volume of liquid waste generation.

NA = not applicable. PPE = personal protective equipment.

19.2.7.3 Waste Handling Process Systems

Solid and liquid waste generated by the other system operations discussed in Section 19.2.3.1.5 is processed by the waste handling process system. The waste handling process consists of three major subsystems:

- Liquid waste handling and disposal
- Solid waste handling and disposal
- Specialty waste handling and disposal

19.2.7.3.1 Liquid Waste Handling and Disposal System

The liquid waste handling system includes two subsystems: high-dose liquid waste solidification, and low-dose liquid waste solidification.

- **High-dose liquid waste solidification** – Accumulation tanks provide the needed handling capacity to match the volume of wastewater generated by the upstream processes. Caustic solution is added as needed to neutralize the excess acidity. The liquid is forwarded to a package concentrator in which water is evaporated from the high-dose liquid, condensed, and directed to a condensate holding tank. The concentrated high-dose liquid is directed to a concentrate holding tank.

  From the concentrate tank, the high-dose liquid is metered into a specialty inline mixer that melds together the high-dose liquid and a powder solidification agent (sorbent or solidification agent). A vibratory motor ensures that the mixture falls from the inline mixer into a HIC. With time, the mixture solidifies. The filled HIC is moved via remote equipment to one of several decay stations where the waste is held for several months. During that time, the short-lived radioisotopes in the waste that cause the container to register a very high dose rate decay to much lower levels. Afterward, the HIC is moved into a transport cask on a trailer. Cask operational steps are completed prior to shipment offsite for disposal.

- **Low-dose liquid waste solidification** – Accumulation tanks provide the needed handling capacity to match the volume of wastewater generated by the upstream processes. Condensates are held in a storage/recycling tank that provides make-up water to the LEU recovery process. Excess condensate, along with all the other low-dose liquid, is forwarded to a staging tank. In this heated tank, the liquid is held at elevated temperatures, and high rates of ventilation air pass through the tank. The heated tank contents, plus the high ventilation, cause a significant amount of the water to evaporate from the low-dose liquid.

  The excess low-dose liquid is then metered into a specialty inline mixer that melds the liquid and a powder solidification agent together. A vibratory motor ensures that the mixture falls from the inline mixer into a waste container. With time, the mixture will solidify. The waste container is then shipped for disposal offsite.

19.2.7.3.2 Solid Waste Handling and Disposal System

The solid waste disposal system includes areas for collection, size reduction, and staging of solid wastes. The solids are placed in a 208 L (55-gal) waste drum and encapsulated by adding a cement material to fill voids remaining within the drum. The drum is then loaded in a cask for transfer to a disposal site. The radioactive solid wastes have been identified and include:

- Hardware from target disassembly
- Resins and exchange media from the Mo recovery and purification process
- Resins from the uranium recovery and recycle process

- Low-dose solid waste from the hot cell and support areas
- Slightly contaminated hardware (low levels of LEU) from the target fabrication area
- Instruments, connectors, jumpers, and other hardware

Solid waste encapsulation – High-dose solid wastes are remotely moved in the hot cell to a staging area in the waste handling facility area. Size-reduction and handling tools are envisioned to place the wastes into a disposal container. Nominally of 454 L (120-gal) capacity, the container holds four weeks of wastes generated from the process. When practicable, the accumulated wastes are encapsulated with a fluid cement. The material solidifies and provides the needed stabilization to meet disposal criteria. The filled container is remotely moved to a transport cask via a shielded loading cask. The appropriate cask operational steps are completed prior to shipment for disposal offsite.

Support system waste – Spent filters containing suspended solids from dissolver solutions are disposed as solid waste. The number of filters to be disposed has not been determined, but is expected to be no more than one per batch of targets. Empty target hardware containing trace contamination is disposed as solid waste.

19.2.7.3.3 Specialty Waste Handling and Disposal System

A specialty waste disposal system addresses small quantities of unique wastes generated by other processes. A reclamation process is included to recycle trichloroethylene from waste liquid. Specialty wastes are assumed to be shipped offsite for treatment and disposal. These wastes include:

- Used silicone oil
- Solvent waste
- Facility maintenance fluids (e.g., paints, lubricants)
- Spent batteries, spent fluorescent lighting tubes, and others
- Personal protective equipment (PPE) waste
- Laboratory waste for expired chemicals and expired radioactive sources

19.2.7.4 Construction Waste

During construction, efforts are made to minimize the environmental impact. Erosion, sedimentation, dust, smoke, noise, unsightly landscape, and waste disposal are controlled to practical levels and applicable regulatory limits. The wastes generated during site preparation and construction are varied, depending on the activities in progress. The bulk of the waste consists of nonhazardous materials such as packing materials, paper, and scrap lumber. These wastes are transported offsite to an approved landfill. These wastes that are generated are handled by approved methods and shipped offsite to approved disposal sites.

Best management practices (BMP) are used during construction to minimize the possibility of spills of hazardous substances, minimize environmental impacts of any spills, and ensure prompt and appropriate remediation.

19.2.7.5 Recycling and Reclamation

With a continued focus on managing economic and environmental cost and impacts, proposed RPF processes involve recycling throughout each step. The following subsections summarize the systems designated for specific recycling efforts. Paper, plastic, and other administrative supplies are also recycled as appropriate.

Solvent recovery – Forming of the LEU target material requires use of a common solvent (trichloroethylene). Used solvent falls under the F-code type of waste disposal, making the solvent a potentially costly disposal and treatment path. Because most solvents are not spent after their use, the solvent could be recovered for reuse to minimize the final waste volume that is sent offsite for treatment and disposal. Standard industrial units are available for solvent reclamation. The used solvent from the process is loaded into the unit and vaporized, and then condensed to yield reclaimed solvent ready for reuse. The residue is contained in a concentrated solvent heel that is sent offsite for treatment and disposal.

Uranium – A major portion of hot cell operations is to recover and recycle uranium. This approach significantly reduces the amount of waste that has to be disposed. Section 19.2.3.1.4 discusses the recovery and recycle of uranium. The target fabrication process also recycles the uranium scrap generated during processing.

Process water – The waste management system segregates and recycles process condensates to be used back in the processes as make-up and flush water. The recycle will reduce the low level waste generated by about 50 percent.

19.2.7.5.1 Direct Radiation Sources Stored Onsite the Radioisotope Production Facility

Direct radiation sources stored onsite – The waste listed in Table 19-14 is stored onsite for a period of time to allow decay before the waste is shipped offsite. The frequency of shipments for each type of waste is also provided in Table 19-14.

19.2.7.5.2 Direct Radiation Sources Stored at Nearby Operating Facilities

Facilities that handle and store radioactive materials in the area of the RPF are discussed in Section 19.2.2.5 and 19.3.8.2.2.

19.2.7.5.3 Pollution Prevention and Waste Minimization Program

Pollution prevention and waste minimization activities promote practices that maximize beneficial effects and minimize harmful effects on the surrounding environment. These activities include efforts to prevent pollution by minimizing the kinds and amounts of waste generated. The RPF will have a pollution prevention and waste minimization program that includes the following:

- Employee training and education
- Waste minimization and recycling programs for various phases (e.g., construction, operations)
- Recognition of employees for improved environmental conditions
- Responsibilities and requirements to consider in day-to-day activities

Pollution prevention involves source reduction, or preventing pollution at its source, before it is generated. Source reduction includes any practice that reduces the quantity and/or toxicity of pollutants entering a waste stream prior to recycling, treatment, or disposal. Examples include equipment or technology modifications, substitution of less toxic raw materials, and improvements in work practices, maintenance, worker training, and inventory control.

Waste minimization refers to the use of source reduction and/or environmentally sound recycling methods prior to energy recovery, treatment, or disposal of wastes. Waste minimization does not include waste treatment (i.e., any process designed to change the physical, chemical, or biological composition of waste streams).

19.2.8 Storage, Treatment, and Transportation of Radioactive and Nonradioactive Materials, including Fuel, Waste, Radioisotopes, and Any Other Materials

19.2.8.1 Storage and Treatment

Storage, handling, and treatment of materials, product, and wastes are performed in a time-sensitive manner, in assigned areas, and using approved waste management, security, health and safety, and shielding procedures. This approach ensures that appropriate volume reduction is achieved, while minimizing the risk of exposure to the worker, public, or the environment.

19.2.8.1.1 Storage of Chemicals and Supplies

A chemical management plan, product handling plan, or radioactive materials management plan is developed to ensure that:

- Noncompatible chemicals are separated
- Flammable chemicals/items are stored in a flameproof cabinet, as applicable
- Oxidizers are stored separate from flammable chemicals and reducers
- Radioactive sources or supplies are stored in locked cabinets/areas such that any potential exposure is kept as low as reasonably achievable (ALARA)
- New feed and recycled LEU is stored in an appropriate configuration and in a locked storage area until needed in the process

19.2.8.1.2 Treatment and Temporary Storage of Waste Onsite

Treatment and temporary storage of radioactive and mixed wastes are performed predominantly onsite within the RPF.

- Liquid waste that is not recycled/reused is eventually concentrated and mixed with sorbent material in the waste management area.
- High-dose material, solidified (if necessary) and encapsulated, is held in a shielded enclosure in the RFP, interim-stored for radioactive decay to meet shipping and disposal requirements, and then loaded into a cask and shipped to a disposal site.
- Low-dose stream, mixed with sorbent, is placed in drums, moved to the external waste management building for staging, and then shipped to a disposal site.
- Solid waste is typically size-reduced as necessary, placed in containers, encapsulated, moved to the external waste management building for staging, and then shipped to a disposal site.
- Target fabrication solvent reclamation area allows reuse of key materials. Any spent solvent is treated and packaged for shipment to a treatment and disposal facility.
- Other industrial or commercial wastes (e.g., chemicals, paper products) will be managed in an environmentally and economically responsible manner. Recycling programs are used as needed.

19.2.8.1.3 Capacity of Onsite Radioisotope Production Facility Materials Storage

Materials needed for LEU target fabrication (e.g., solvents, silicon oil, cladding) are received and stored. Finished LEU targets are interim-stored until shipped to a university reactor system for irradiation.

Because of the short half-life of ^{99}Mo, there is almost no accumulation of ^{99}Mo product. The ^{99}Mo product is shipped out twice per week. Chemicals and process supplies are stored according to the chemical management plan or facility procedures to ensure the lowest risk of exposure/contamination or accidental release.

19.2.8.2 Transportation of Material

The transport of radioactive materials and waste and other hazardous materials associated with the RPF must comply with applicable NRC and DOT regulations. DOT specifies the requirements for marking, labeling, placarding, providing emergency response information, and training hazardous material transport personnel in 49 CFR 172. Specific packaging requirements for radioactive materials are provided in 49 CFR 173, Subpart I, "Class 7 (Radioactive) Materials." These requirements invoke the NRC packaging requirements for radioactive material per 10 CFR 71, "Packaging and Transportation of Radioactive Material." The DOT requirements for truck transportation of radioactive and other hazardous materials are specified in 49 CFR 177 and 49 CFR 397, "Transportation of Hazardous Materials; Driving and Parking Rules." Requirements affecting the shipment of ^{99}Mo are specified in 49 CFR 175 and are the responsibility of the air carrier chosen to transport the ^{99}Mo product.

19.2.8.2.1 Packaging Systems

The majority of the radioactive components being shipped to and from the RPF require special container systems to ensure that protection of the public and the environment is achieved. Each of these containers is designed to meet certain NRC and DOT standards. Although the irradiated targets are not identified as a spent nuclear fuel shipment, NWMI will also use the guidance provided in NUREG-0561, *Physical Protection of Shipments of Irradiated Reactor Fuel.*

The primary radioactive materials and wastes that require a specialty container or cask are as follows:

- **Fresh LEU** – Fresh LEU will be shipped from the DOE Y-12 Program Office in Oak Ridge, Tennessee to the NWMI RPF using an ES-3100 Package (Certificate of Compliance No. 9315) (NRC, 2005). The DOE Y-12 Program Office routinely uses the package, which is currently licensed for the NWMI feed materials. DOE has a dedicated QA program for package use and maintenance, and all procedures are in a mature state.

  The ES-3100 package is a cylindrical container that is approximately 110 centimeter (cm) (43 inches [in.]) in overall height and 49 cm (19 in.) in overall diameter, and has an outer drum assembly and an inner containment vessel. The containment vessel is placed inside the drum and surrounded by a cement-based borated neutron absorber, Catalog 277-4. The purpose of the ES-3100 is to transport bulk high enriched or LEU uranium in various forms.

- **Unirradiated targets** – Unirradiated targets will be shipped using the ES-3100 or similar package, as described above. Unirradiated targets will be shipped to the network of university research reactors.

- **Irradiated targets** – Irradiated targets will be received from the university reactors in a BEA Research Reactor cask or similar (Certificate of Compliance No. 9341) (INL, 2011). Within the cask, the irradiated targets are contained in basket structures that are specifically designed for NWMI's target and provide for optimum heat rejection and criticality control.

The BEA Research Reactor cask is a truck-mounted cask designed for the shipment of research reactor fuel. The cask fully loaded weighs approximately 14,515 kg (32,000 lb). The overall height of the package with impact limiters is 3.04 m (119.5 in.). The outer diameter of the body is 0.97 m (38 in.). The outer diameter of the impact limiters is 1.52 m (60 in.), and each weighs approximately 1,043 kg (2,300 lb). The cask body is shielded with 20.3 cm (8 in.) equivalency of lead. The inner cavity of the BEA Research Reactor cask is 0.46 m (16 in.) in diameter and 1.70 m (67 in.) in height.

The cask currently is designed to hold four different baskets for the different fuel families. NWMI will need to obtain a license amendment for transport of irradiated targets in the BEA Research Reactor cask.

- **^{99}Mo product** – The ^{99}Mo product will be placed into a Medical Isotope Depleted Uranium Shielded (MIDUS) Type B(U) container (Certificate of Compliance USA/9320/B(U)-96) (NRC, 2008a) or similar. The MIDUS container is currently used by U.S. and other radiopharmaceutical ^{99}Mo producers worldwide.
- **Radioactive waste** – High-dose radioactive waste will be loaded in HICs and shipped in a cask, such as the Model 10-160B cask (ES, 2012). This type of cask is a lead-shielded carbon steel cask with a double-lid, bolted closure and is top-loaded. The cask is shipped vertically, with removable top and bottom polyurethane foam-filled impact limiters. Low-dose radioactive waste will be loaded into 208 L (55-gal) waste drums.
- **Contact-handled waste** – Standard industrial waste drums or other appropriate containers will be used to dispose of contact-handled radioactive waste. Contact-handled waste is defined as waste that is less than 2 millisievert (mSv)/hr (200 millirem per hour [mrem/hr]) on contact and 0.1 mSv/hr (10 mrem/hr) at 1 m (3.3 ft). These containers must be handled according to the facility radioactive waste management plan to ensure that dose is kept ALARA. These waste containers generally do not require shielded casks or special shielding for transportation purposes.

19.2.8.2.2 Estimated Type and Quantity of Radioactive Materials and Wastes

The estimated type and quantity of radioactive materials and wastes, number of shipments, shipment type, distance, and destination are summarized in Table 19-14. These distances and times may vary depending on available shipping routes or weather conditions. The number of shipments per year may also vary depending on what reactor is used for irradiation.

Table 19-14. Summary of Radioactive Materials and Wastes Required or Generated at the Radioisotope Production Facility for Ongoing Operations

Description	Matrix	Qty/year	Package type	Number of shipments/year	To/from	Distance km (mi)
Fresh LEU Annually Initial need Operation [Proprietary Information] Operation [Proprietary Information] (U_3O_8 or metal)	Solid	[Proprietary Information] [c] [Proprietary Information] [d] [Proprietary Information] [e] [Proprietary Information]	ES-3100 cask	2 (operations annual average)	From DOE Y-12 (Oak Ridge, Tennessee)	953 (592)
Unirradiated LEU targets	Solid	[Proprietary Information]	[a]ES-3100 cask	26	To MURR	9.6 (6)
	Solid	[Proprietary Information]	[a]ES-3100 cask	8	To OSTR	3,320 (2,063)
	Solid	[Proprietary Information]	[a]ES-3100 cask	8	To third reactor	[Proprietary Information]
Irradiated LEU targets	Solid	[Proprietary Information]	[a]BRR cask	104	From MURR	9.6 (6)
	Solid	[Proprietary Information]	[a]BRR cask	16	From OSTR	3,320 (2,063)
	Solid	[Proprietary Information]	[a]BRR cask	16	From third reactor	[Proprietary Information]
^{99}Mo product	Liquid	48 L (12.7 gal)	[a]MIDUS cask	52	To Hazelwood, Missouri	181 (113)
	Liquid	48 L (12.7 gal)	[a]MIDUS cask	52	To Billerica, Massachusetts	[b]63 (39)
Spent LEU	Solid	[Proprietary Information]	ES-3100 cask	2	To SRS	1,345 (836)
Radioactive waste (high- and low-dose radioactive waste)	Solid	540,000 kg (1,190,500 lb)	[a]10-160B	200	To Waste Control Specialists (Andrews, TX)	1,469 (913)

[a] Package type identified can be changed to another similar package.
[b] Only includes road miles traveled.
[c] LEU needed for hot commissioning and initial RPF startup.
[d] LEU needed in Operation (Proprietary Information] for addition of second reactor.
[e] LEU needed in Operation [Proprietary Information] for addition of third reactor.

BRR = BEA Research Reactor.
DOE = U.S. Department of Energy.
LEU = low-enriched uranium.
MIDUS = Medical Isotope Depleted Uranium Shielded.
OSTR = Oregon State University TRIGA Reactor.
SRS = Savannah River Site.
MURR = University of Missouri Research Reactor.

19.3 AFFECTED ENVIRONMENT

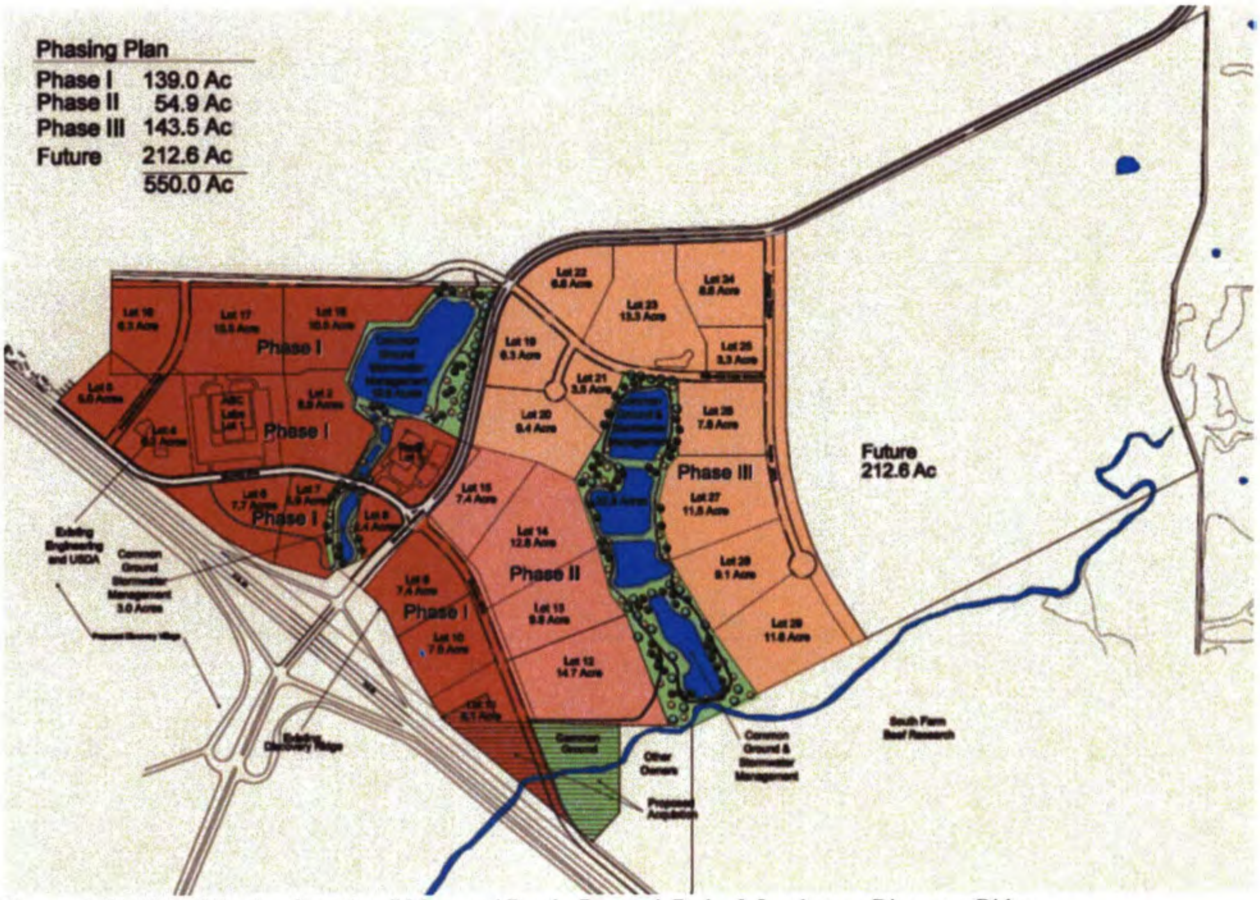
19.3.1 Land Use and Visual Resources

19.3.1.1 Land Use

This section characterizes land use associated with the proposed RPF. The facility is proposed to be sited at Discovery Ridge, located on property owned by MU. The university occupies a 505 ha (1,250-acre) campus and is located 4.8 km (3 mi) southeast of Discover Ridge, which is just south of downtown Columbia. Land uses are within an 8 km (5-mi) region of influence (ROI). The ROI is the geographic area associated with each resource that could potentially be affected by the proposed action. The land use for the site was analyzed using data from the National Land Cover Database (Fry et al., 2011).

19.3.1.1.1 Site – Description of the Proposed Property

The RPF would be located in Lot 15 of the Discover Ridge Phase II section. The Phase II area is 22.2 ha (54.9 acres) and, as shown in Figure 19-14, is bounded by the Phase III area to the north, Discovery Parkway and the Phase I section to the west/northwest, Discovery Drive to the south/southwest, Lot 14 and stormwater management areas to the east, and private property to the south.



Source: MU, 2011, "Phasing Overview," Maps and Roads, Research Parks & Incubators, Discovery Ridge, www.umsystem.edu/umrpi/discoveryridge/maps, University of Missouri, Columbia, Missouri, accessed July 2013.

Figure 19-14. Layout of Discovery Ridge Research Park Showing Lot 15, the Proposed Radioisotope Production Facility Site

Lot 15 is 3.0 ha (7.4 acres) and contains no existing structures (MU, 2011). Currently, the 46.1 ha (114-acre) research park is being developed under the guidance of the *Discovery Ridge Master Plan and Protective Covenants* (MU, 2009). Figure 19-6 shows the site boundaries and proposed structures. Dimensions of the RPF are approximately 106.7 x 56.4 m (350 x 185 ft) by 19.8 m (65 ft) in height abovegrade (maximum). The facility would occupy a rectangular area approximately 213 x 91 m (700 x 300 ft) at the outer perimeter and cover approximately 1.95 ha (4.8 acres) on Lot 15. The restricted area would be the area inside the fence surrounding the facility. The unrestricted area would be the area outside the fence surrounding the main building.

19.3.1.1.2 Major Population Centers and Infrastructure – Local Setting

The proposed site resides entirely within the Columbia city limits and is approximately 200 km (124 mi) south of St. Louis (population 319,294); 203 km (126 mi) east of Kansas City (population 459,787); and 45 km (28 mi) north of Jefferson City (population 43,088) (USCB, 2010a). The proposed site lies in Boone County (population 162,642) (USCB, 2010b).

19.3.1.1.3 Transportation Infrastructure

Section 19.3.7 provides a description of the regional air, road, and rail transportation systems.

The Missouri River is one of the largest river systems in the U.S. and the largest river in Boone County. The river originates in south central Montana and generally flows in an easterly and southeasterly direction before entering the Mississippi River in eastern Missouri, a length of about 4,345 km (2,700 mi). The river lies approximately 11.7 km (7.3 mi) to the west of the proposed RPF and forms the southwestern border of Boone County. The Missouri River is the only river system in Boone County large enough for commercial navigation; however, there are no ports that directly service Columbia (MU, 2006a).

19.3.1.1.4 Local Setting

Discovery Ridge lies at the crossroads of U.S. Highway 63 and Gans Road, which is near the MU main campus, U.S. Interstate 70, Columbia Regional Airport, University Hospital, Columbia Regional Hospital, downtown Columbia, and Jefferson City. Discovery Ridge, when fully developed, will occupy 223 ha (550 acres) and is bounded by East Sugar Grove Road to the north, South Rolling Hills Road to the east, U.S. Highway 63 to the south, and Sunset Mobile Home Park to the west. Perry Phillips Park (57 ha [140 acres] and a 16 ha [40-acre] lake) and the Frank G. Nifong Memorial Park (23 ha [58 acres]) are located nearby to the west. The MU Bradford Research and Extension Center (a 239 ha [591-acre] research farm) lies to the north of Discovery Ridge. Figure 19-5 shows the local setting for the proposed RPF site.

19.3.1.1.5 Regional Setting

The ROI is defined as the area within an 8 km (5-mi) radius of the proposed facility centerpoint (Figure 19-5). The ROI includes nearly half of Columbia and the entire MU area. The MU student population, when in full session, is approximately 34,658 (MU, 2013).

Existing land uses in a concentric ring pattern around the RPF can generally be described as follows (MU, 2006a):

- **0–1 km (0–0.6 mi)** – There is very little residential development within the immediate area of the proposed RPF. Most of the land is owned and operated by MU. Recreational areas include a golf course to the west and a park to the south. Three MU sports venues are located within this area: Memorial Stadium/Faurot Field, Mizzou Arena, and Hearnes Center.
- **1–2 km (0.6–1.3 mi)** – Residential areas are located north, northwest, and south of the proposed RPF site. A shopping center, business district, two hospitals, and a large portion of the MU 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.
- **2–4 km (1.3–2.5 mi)** – The major residential areas are located in the northern half of the ROI and to 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, comprised mainly of government offices and retail, commercial, and business uses, is located to the northeast. Development is expected to continue within this area, probably to the south of the proposed RPF.
- **4–6 km (2.5–3.7 mi)** – Most residential development is within the northern half of the ROI. 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 nonresidential development.
- **6–8 km (3.7–5 mi)** – The only substantial residential development is northeast of the proposed RPF site. 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 nonresidential development.

19.3.1.1.6 Land Use and Cover within the Regional Setting

There are 20,342 ha (50,265 acres) in the 8 km (5-mi) ROI surrounding the proposed RPF. According to the data from the U.S. Geological Survey (USGS) (Fry et al., 2011), approximately 25 percent of the land is developed (i.e., residential, commercial). Forest and pasture land are the next highest uses at 31 and 30 percent, respectively. Cultivated cropland follows next at 9 percent. The remaining land use types total less than 1 percent of each category and include barren land, evergreen forest, grassland/herbaceous, mixed forests, open water, scrub, and woody and emergent herbaceous wetlands.

Land use, as categorized by the USGS, is presented in Table 19-15. Figure 19-15 shows the distribution of these land uses within the ROI. Most developed lands lie to the northwest, while agricultural lands lie to the east and southeast. Deciduous forest is interspersed throughout the ROI.

Table 19-15. U.S. Geological Survey Land Use Categories for the 8 km (5-mi) Region of Influence Surrounding the Proposed Radioisotope Production Facility

Description	Hectares	Acres	Percent
Barren land	16.19	93.66	0.19
Cultivated crops	1,877.38	4,639.11	9.23
Deciduous forest	6,365.64	15,729.81	31.29
Developed, high intensity	368.85	911.45	1.81
Developed, low intensity	1,892.74	4,677.06	9.30
Developed, medium intensity	1,120.87	2,769.74	5.51
Developed, open space	1,666.96	4,119.15	8.19
Emergent herbaceous wetlands	0.955	2.36	0.00
Evergreen forest	216.30	534.48	1.06
Grassland/herbaceous	139.60	344.96	0.69
Mixed forests	189.75	468.87	0.93
Open water	140.20	346.44	0.69
Pasture/hay	6,134.34	15,158.25	30.16
Scrub	43.31	107.02	0.21
Woody wetlands	146.95	363.13	0.72
Total Acres	**20,320.035**	**50,265.48**	**100.00**

Source: Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham, 2011, "Completion of the 2006 National Land Cover Database for the Conterminous United States," Photogrammetric Engineering & Remote Sensing Journal, Volume 77(9):858-864, Bethesda, Maryland, 2001.

19.3.1.1.7 Special Land Uses

Special land uses within the ROI include public stewardship lands and prime farmlands (farmland is discussed in Section 19.3.1.1.10). There is no Federal land held in trust for American Indian tribes within the ROI. Approximately 7 percent (1427 ha [3,527 acres]) of the land is public stewardship lands (e.g., parks, conservation areas) that primarily lie southwest of the proposed RPF. There are no military reservations or Federally designated wild and scenic rivers, national parks, national forests, or coastal zone areas within the ROI. Figure 19-16 shows the location and extent of the special land uses.

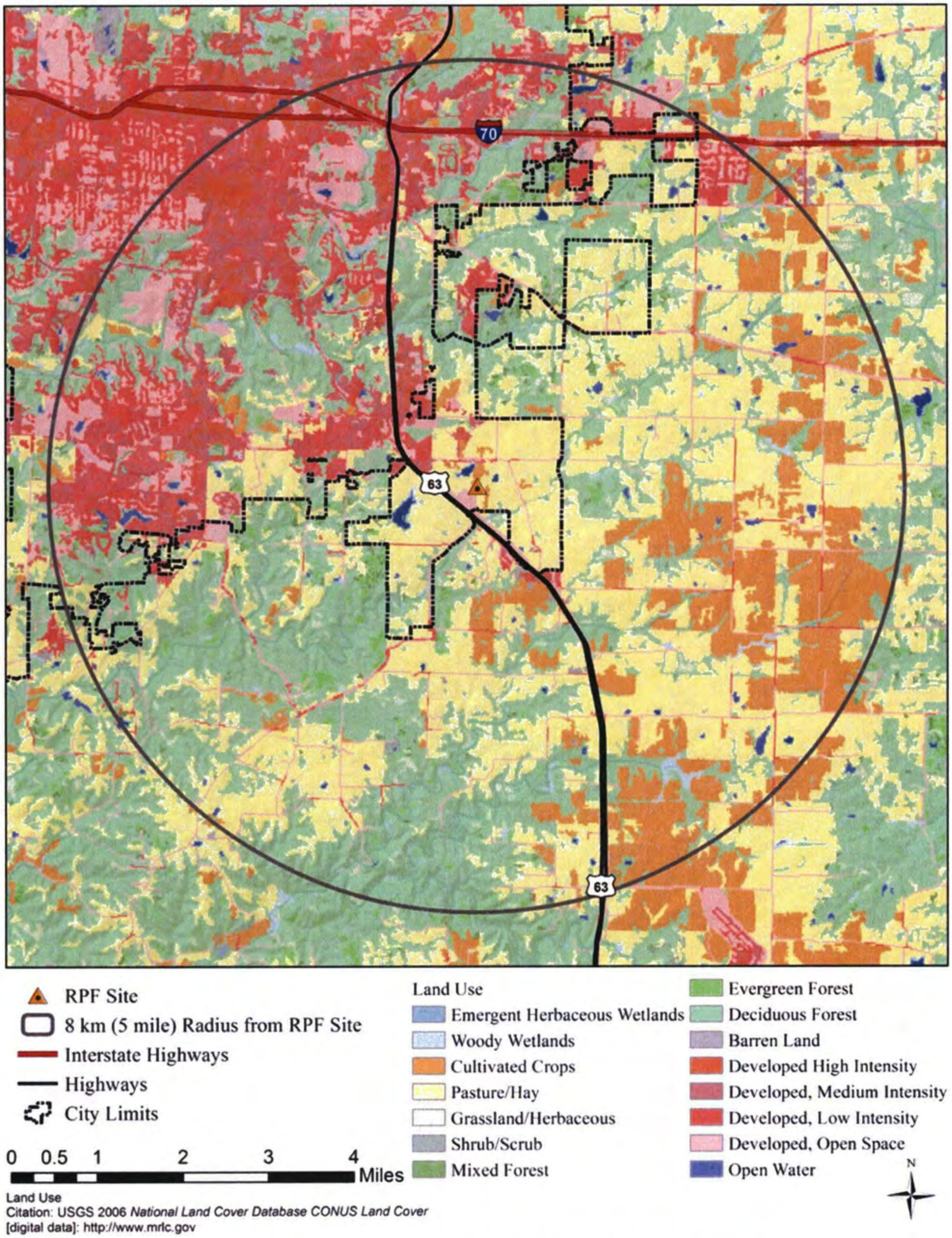


Figure 19-15. Land Use and Cover within the 8 km (5 mi) Region of Influence of the Proposed Radioisotope Production Facility Site

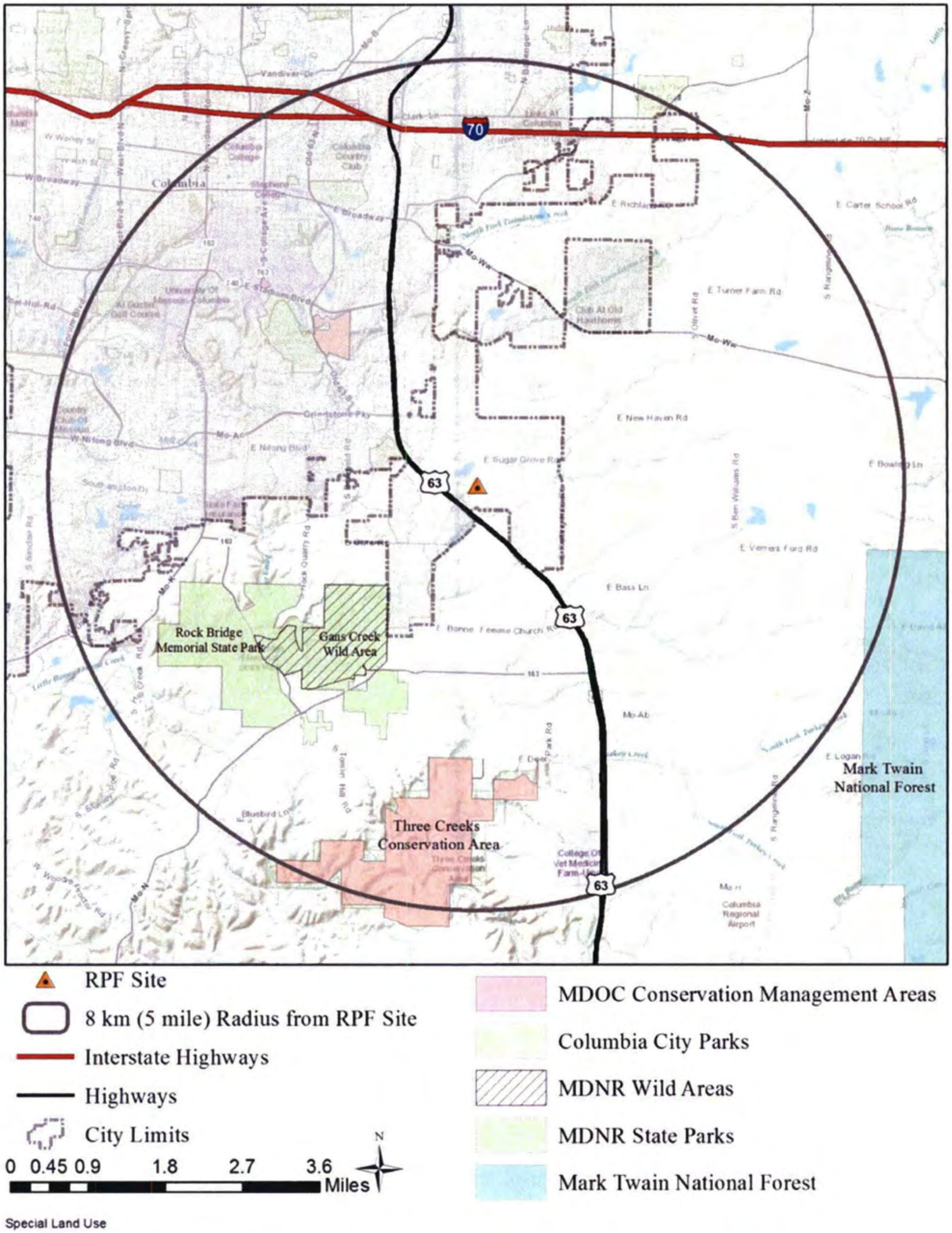


Figure 19-16. Special Land Use within the Region of Influence of the Proposed Radioisotope Production Facility Site

19.3.1.1.8 Applicable Land Use Plans and Guidance

Discovery Ridge was developed under Section 172.273 of the Missouri Revised Statutes, which provided that "the Curators of the University of Missouri may establish research, development, and office park projects in order to promote cooperative relationships and to provide for shared resources between private individuals, companies and corporations, and the University of Missouri, for the advancement of the University in carrying out its educational mission and such projects are declared to be in furtherance of the purposes of the University."

The *Discovery Ridge Master Plan and Protective Covenants* (MU, 2009) is the applicable land use guidance for the research park. Discovery Ridge is zoned commercial in the A-1 district (City of Columbia, 2012a), under the Section 29-18 provision, Board of Adjustment (City of Columbia, 2012b). The Columbia Code (Section 29-18) has height restriction for A-1 of 10.7 m (35 ft).

Missouri Revised Statute, Section 172.273, exempts university research parks, including Discovery Ridge, from local land development regulations. This allows MU to develop Discovery Ridge to its own master plan and to include non-agriculture-related structures with sizes in excess of the A-1 zoning requirements, provided MU gives Columbia courtesy review of the plan and design drawings and addresses the city's comments and concerns. The master plan and covenants for the development do not specify height restrictions.

"Columbia Imagined, The Plan for How We Live & Grow" is the current comprehensive plan for Columbia (City of Columbia, 2013c), and the *Boone County Master Plan* (Boone County, 1996) guides development of lands outside of city limits but within the county.

19.3.1.1.9 Future Development

Only a few tenants currently occupy Discovery Ridge. According to the master plan and covenants (MU, 2009), the future and growth of Discovery Ridge itself will be market-driven. Future tenants are expected to be businesses that are compatible and synergistic with the research programs at MU. Tenants obtain a ground lease from the university and construct their own facilities. Facilities are designed to conform to uniform building codes and design standards listed in the "Declaration of Covenants, Conditions, Restrictions, and Easements for Discovery Ridge" (MU, 2009). Expansion and/or property acquisition beyond the 223 ha (550 acres) currently defining Discovery Ridge is possible in the future and requires approval by the MU Board of Curators.

Nearby future development includes a city park and a large commercial and residential development that is planned for the west side of U.S. Highway 63, adjacent to the overpass that provides access to the Discovery Ridge Parkway. According to Columbia (2013c)," the city's planning staff is studying steering employment to developing office and industrial centers, which includes Discovery Ridge, in response to citizen goals and objectives offered through the city's comprehensive plan planning process. This approach is being considered as the city continues to study and identify anticipated future economic growth.

19.3.1.1.10 Agricultural Resources and Facilities

The principal agricultural products of Boone County, as estimated by the U.S. Department of Agriculture (USDA), are corn for grain, corn silage for greenchop, spring/winter wheat for grain, and oats and barley for grain (USDA, 2007). Livestock also has significant importance because much of the land is not suited for row crops.

Agriculture resources nearest to the RPF site are associated with MU and include the following:

- **South Farm** – A 588 ha (1,452-acre) complex that supports research, outreach, and teaching missions of animal science, plant science, veterinary science, biology, botany, and other disciplines. The farm is home to the Swine Research Complex, Beef Research and Teaching Farm, Turf Center, USDA Agricultural Research Service, and Horse Farm. The complex also supports research and demonstration projects in entomology, poultry, and maize genetics. The Missouri Foundation Seed Program uses South Farm to increase the sales of newly developed seed varieties to dealers. Hands-on teaching is provided to more than 1,500 students annually.
- **Jefferson Farm and Gardens** – A 27 ha (67-acre) educational facility that provides information on farming, gardening, and conservation.
- **Bradford Research and Extension Center** – A 239 ha (591-acre) research farm that provides land, equipment, and facilities to assist university and USDA scientists and extension personnel in performing research in crop, soils, entomology, pathology, turf, and other disciplines on more than 25,000 plots.

A number of privately owned farms also lie in the surrounding area.

19.3.1.1.11 Mineral Resources

According to the EPA Western Ecology Division's Ecoregions of Missouri (Chapman et al., 2002), the proposed RPF site is part of the Claypan Prairie Level IV ecoregion, which is located within the Central Irregular Plains Level III ecoregion.

Well-developed claypan soils on glacial till typify the Claypan Prairie ecoregion. This region has a more level, gently rolling topography than surrounding regions. Expansive cropland and pastureland, with an emphasis on livestock production, is common. The potential natural vegetation is tall grass prairie with less woodland than surrounding regions. Streams run generally west to east, draining into the Mississippi River, in contrast to the northwest-to-southeast drainage of ecoregions to the west.

The Claypan Prairie ecoregion was glaciated in the pre-Illinoian time period. The continental drift, largely derived from limestone and shale, is composed of clay with a high percentage of rock fragments. Groundwater tends to be saline, unlike the freshwater of ecoregions to the southeast. The mix of land-use activities includes mining operations of high-sulfur bituminous coal. Although, historically, mining was more widespread, a few new mines continue to open. The disturbance of these coal strata in southern Iowa, areas of northern and southwestern Missouri, and southeastern Kansas has degraded water quality and affected aquatic biota (Chapman et al., 2002).

19.3.1.2 Visual Resources

A viewshed is an area of land, water, sky and associated environmental elements that is visible to the human eye from a fixed vantage point. Viewsheds often contain relatively large expanses of natural areas such as watersheds, unfragmented habitat, and unobstructed views. Viewsheds typically are spaces that are readily visible from public areas such as from roadways, parks, or high-rise buildings. The beauty of these areas contributes to the short-term and long-term quality of life for the people and communities who experience them. In urban areas, appealing viewsheds attract people and businesses and are associated with higher property values.

Visual resource management is the identification of visual values and establishment of objectives for managing those values. NRC (2012a) identifies the Bureau of Land Management (BLM) Visual Resource Management System (BLM, 1986) as the method for rating the aesthetic/scenic quality of a proposed site.

The BLM process involves a scenic quality evaluation, sensitivity level analysis, and a delineation of distance zones. Based on these three factors, lands are categorized by their relative visual value, which provides the basis for considering these values and impacts during the planning process. The BLM process is considered the standard for visual resource management. In overview, the process involves the following steps:

- **Inventory** – An inventory provides written descriptions and photos of the views or open space of concern. The inventory may also include site information regarding distinguishing characteristics, parcel size, ownership, access points for best view, and potential threats to preservation.
- **Rating** – For each inventory item, a rating is assigned that considers such factors as scenic quality, sensitivity level, and distance zones. Based on the rating, lands are categorized into visual resource importance classes. The classifications typically range from most valued to least valued classes and assign value to the visual resource.
- **Protection level** – Levels provide the basis for considering visual values in the planning process. For example, during an environmental analysis, a project that is found to impact highly important visual resources might be redesigned, relocated, or resituated to lessen its impact.

The process of determining the affected environment for visual resources begins with a description of the visual setting and the regulatory requirements affecting the setting.

19.3.1.2.1 Description of the Visual Setting

Discovery Ridge is located on the edge of Columbia in a suburban/rural interface setting where farmland, parks, and natural areas are widespread and interspersed with residential dwellings, community and transportation infrastructure, and business establishments. Discovery Ridge is minimally developed at this time.

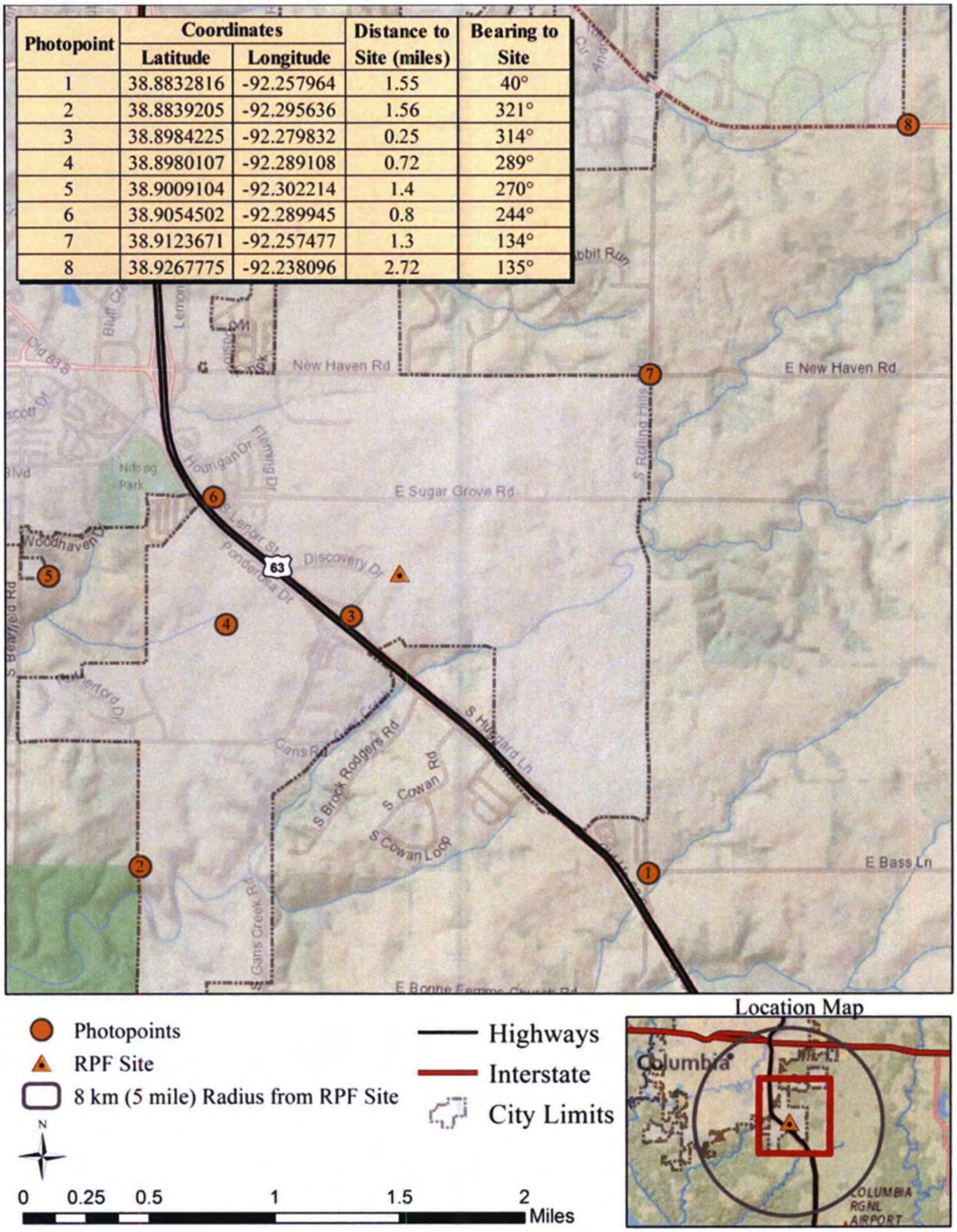
A Phase I environmental site assessment included a cursory visual reconnaissance and description of the area that included Lots 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18, and adjoining properties (Terracon, 2011a). The assessment describes the overall visual setting in which Lot 15 lies; the lot on which the proposed RPF would be located. All except Lot 5 are vacant; that lot is developed with a storage building. The ground is generally grass-covered, with portions of cultivated fields in the vicinity of Lot 16. The general topography slopes slightly to moderately downward toward the south and west (Terracon, 2011a). Table 19-16 presents information from the site assessment that describes the viewshed from Discovery Ridge boundaries.

Table 19-16. Discovery Ridge Viewshed

Direction	Objects discernible in the viewshed
North	Ed's Mobile Home Park and Sunset Mobile Home Park to the northwest, and farmland with University of Missouri storage buildings, farmland, and Sugar Grove Lane to the north and northeast
East	Farmland and buildings associated with the University of Missouri Beef Farm
South	Lenoir Street, a residential house, U.S. Highway 63, Ponderosa Drive, and farmland
West	Lenoir Street, U.S. Highway 63, Ponderosa Drive, and the Phillips Farm

Source: Terracon, 2011a, *Phase I Environmental Site Assessment Discovery Ridge Lots 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18*, Terracon Consultants, Inc., prepared for University of Missouri and Trabue, Hansen & Hinshaw, Inc., Terracon Project No. 09117701, March 23, 2011.

Photos were taken from the locations indicated on Figure 19-17 toward the proposed RPF in September 2013. Figure 19-18 through Figure 19-25 show the views. Most views are of undeveloped or minimally developed areas, with occasional trees, roads, power lines, and farmland.



Photopoint	Coordinates		Distance to Site (miles)	Bearing to Site
	Latitude	Longitude		
1	38.8832816	-92.257964	1.55	40°
2	38.8839205	-92.295636	1.56	321°
3	38.8984225	-92.279832	0.25	314°
4	38.8980107	-92.289108	0.72	289°
5	38.9009104	-92.302214	1.4	270°
6	38.9054502	-92.289945	0.8	244°
7	38.9123671	-92.257477	1.3	134°
8	38.9267775	-92.238096	2.72	135°

Figure 19-17. September 2013 Visual Reconnaissance Photo Locations

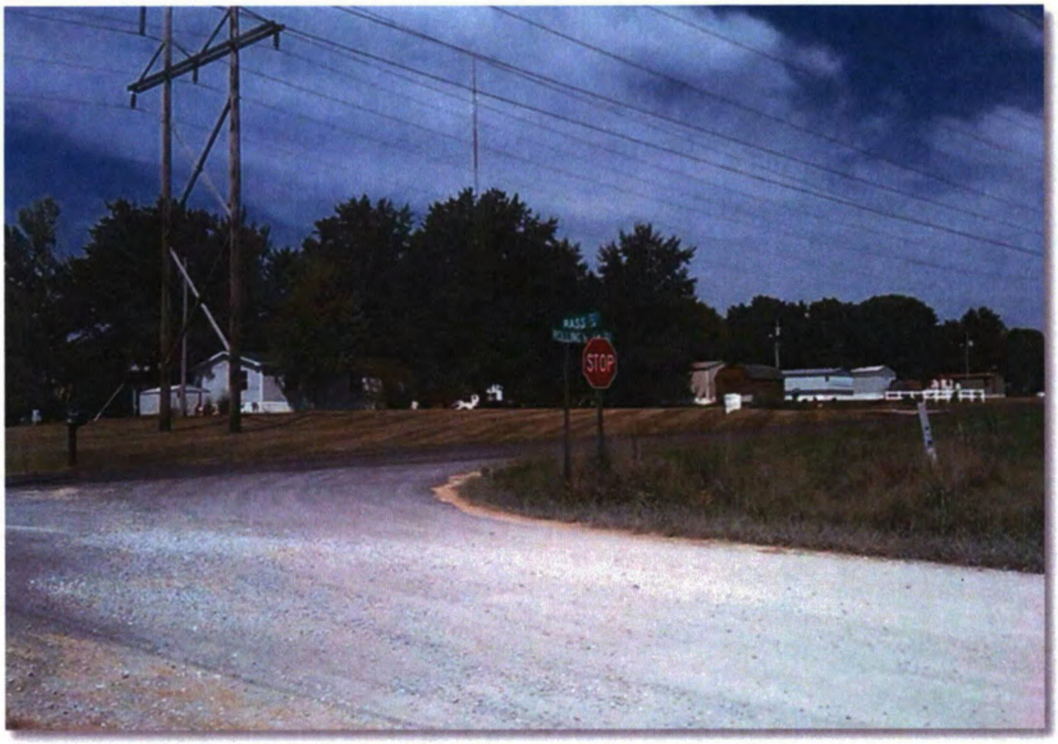


Figure 19-18. View of Proposed Radioisotope Production Facility Site from Intersection of Rolling Hills and Bass Roads, Photo Location #1

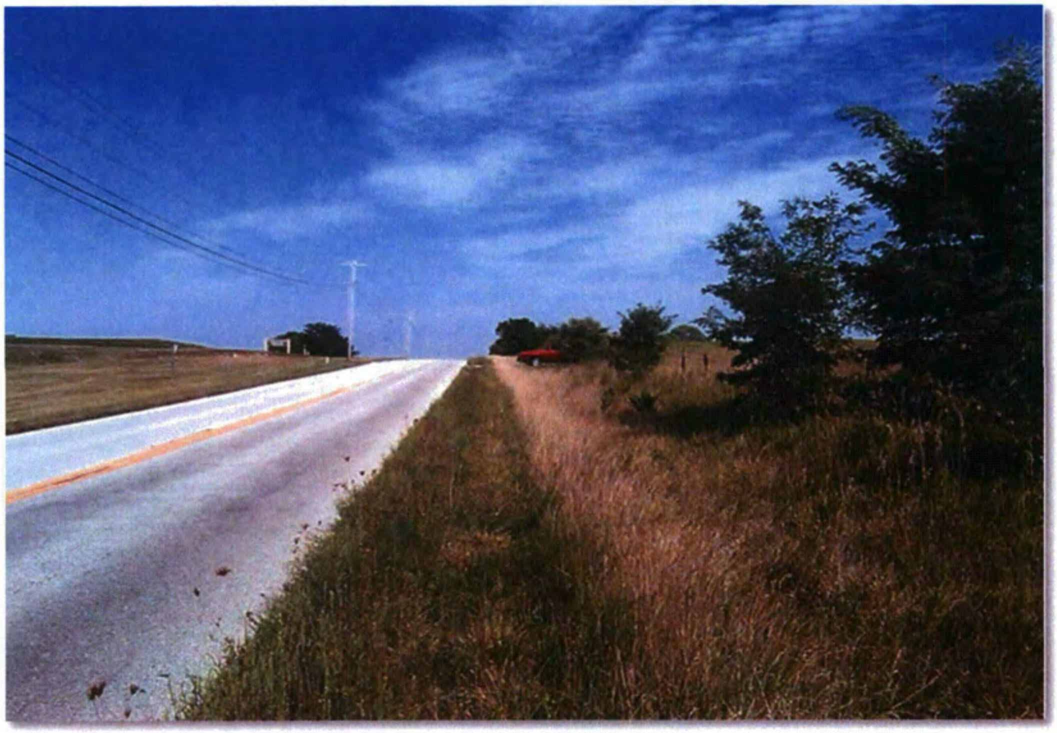


Figure 19-19. View of Proposed Radioisotope Production Facility Site from Gans Road, approximately 1.6 km (1 mi) North Photo Location #2

Figure 19-20. Direct View of Radioisotope Production Facility Site from Discovery Parkway near the Overpass, Photo Location #3

Figure 19-21. View of Radioisotope Production Facility Site from the North Edge of Perry Phillips Lake, Photo Location #4

Figure 19-22. View of Proposed Radioisotope Production Facility Site from Boys and Girls Town of Missouri, Photo Location #5

Figure 19-23. View of Proposed Radioisotope Production Facility Site from S. Lenoir and Roosevelt Avenue, Photo Location #6

Figure 19-24. View of Proposed Radioisotope Production Facility Site from Intersection of New Haven and Rolling Hills Roads, Photo Location #7

Figure 19-25. View of Proposed Radioisotope Production Facility Site from Route WW at Old Hawthorne, Photo Location #8

19.3.1.2.2 Tallest Structures

The tallest structural components of the RPF would be the three exhaust stacks, which extend 22.9 m (75 ft) high. The next highest portion of the building, the high bay, would be the second story above the process area, at 19.8 m (65 ft). The stacks would be visible from approximately 3.2 km (2 mi) away.

The scenic vistas of the nation's national parks and wilderness areas are protected under amendments of the Clean Air Act. Protected areas are known as Federal Class 1 areas. Congress declared the following as a national visibility goal for these areas:

> *The prevention of any future, and the remedying of any existing impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution.*
> (42 U.S.C. § 7491 Section 169A)

To address the problem of long-range transport of regional haze and to meet this goal, the EPA adopted regulations, known as the Regional Haze Rule (40 CFR 51, "Regional Haze Regulations"), to address visibility impairment caused by one or a small group of human-made sources generally located in close proximity to a specific Class I area. States are required to improve visibility in these areas incrementally over the next 60 years. The first milestone is to develop a regional haze plan to reduce causes of haze to make reasonable progress by 2018.

There are no Federal Class I areas, as defined by 40 CFR 81.416, "Identification of Mandatory Class I Federal Areas where Visibility is an Important Value, Missouri," within Boone County, Columbia, the ROI, or anywhere near the proposed RPF site. The site lies within the BLM Northeastern States Field Office planning district, which covers 20 states. The Milwaukee Field Office administers the nearest public land to the RPF site. Within that area, there are no BLM-managed acres that are classified as Class I. The RPF site also lies within the Forest Service Eastern Region. The Forest Service manages the only two Class I areas in the state. These Class I areas include the Hercules-Glades Wilderness Area, a 4,983.7 ha (12,315-acre) area approximately 352.4 km (219 mi) south of Columbia, and the Mingo Wilderness Area, a 3,237.5 ha (8,000-acre) area approximately 420 km (261 mi) southeast of Columbia.

19.3.1.2.3 Aesthetic and Scenic Quality Rating

The scenic quality of the proposed site was rated using the BLM Visual Resource Management System (BLM, 1986). The scenic quality classification is the rating of the visual appeal of the land designated for the site and is based on an evaluation of seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. Notes are taken at the observation points describing these characteristics and scored according to the criteria shown in Table 19-17. The RPF site scoring and photographs were used to determine the visual quality of the site. Scenic quality is classified as either A, B, or C, based on total score, with A being a high-quality visual classification and C being a low-quality visual rating. Table 19-18 shows the scoring and the final NWMI site determination as a C classification.

Table 19-17. Scenic Quality Inventory and Evaluation Chart

Key factors	Rating criteria and score		
Landform	High vertical relief as expressed in prominent cliffs, spires, or massive rock outcrops; or severe surface variation or highly eroded formations, including major badlands or dune systems; or detail features dominant and exceptionally striking and intriguing, such as glaciers Score: 5	Steep canyons, mesas, buttes, cinder cones, and drumlins; or interesting erosional patterns or variety in size and shape of landforms; or detail features that are interesting though not dominant or exceptional Score: 3	Low rolling hills, foothills, or flat valley bottoms; or few or no interesting features Score: 1
Vegetation	A variety of vegetative types as expressed in interesting forms, textures, and patterns Score: 5	Some variety of vegetation, but only one or two major types Score: 3	Little or no variety or contrast in vegetation Score: 1
Water	Clear and clean appearing, still, or cascading white water, any of which are a dominant factor in the landscape Score: 5	Flowing, or still, but not dominant in the landscape Score: 3	Absent or present, but not noticeable Score: 0
Color	Rich color combinations, variety, or vivid color; or pleasing contrasts in the soil, rock, vegetation, water, or snow fields Score: 5	Some intensity or variety in colors and contrast of the soil, rock, and vegetation, but not a dominant scenic element Score: 3	Subtle color variations, contrast, or interest; generally mute tones Score: 1
Influence of adjacent scenery	Adjacent scenery greatly enhances visual quality Score: 5	Adjacent scenery moderately enhances overall visual quality Score: 3	Adjacent scenery has little or no influence on overall visual quality Score: 0
Scarcity	One of a kind; or unusually memorable, or very rare within region; consistent chance for exceptional or wildflower viewing, etc. Score: 5+	Distinctive, though somewhat similar to others within the region Score: 3	Interesting within its setting, but fairly common within the region Score: 1
Cultural modifications	Modifications add favorably to visual variety while promoting visual harmony Score: 2	Modifications add little or no visual variety to the area and introduce no discordant elements Score: 0	Modifications add variety but are very discordant and promote strong disharmony Score: -4

Table 19-18. Scenic Quality Rating, by View

Scenic quality rating units	Landform	Vegetation	Water	Color	Adjacent scenery	Scarcity	Cultural modification	Total score	Scenic quality rating	Explanation
Direct view of the RPF site looking toward the northeast direction from Discovery Parkway										
Photo Loc. #3, Figure 19-20	1									Level to rolling topography, agriculture-related structures in the background
		1								Grass area, shrubs in foreground, trees in background
			0							None
				1						Little contrast in vegetation tones, mainly monochromatic
					0					Adjacent scenery is similar
						1				Common for the area
							0			Agriculture structures, utility pad
								4	C	A = 19 or more; B = 12–18; C = 11 or less
View toward the RPF site looking northeast from the North Edge of Perry Phillips Lake										
Photo Loc. #4, Figure 19-21	1									Level to rolling topography, agriculture-related structures and utility poles in the background
		1								Grass in foreground, dirt in background, trees in distance
			0							None
				1						Contrast in soil, rock, and vegetation; not unique
					0					Adjacent scenery is similar
						1				Common for the area
							0			Agriculture structures, power lines
								4	C	A = 19 or more; B = 12-18; C = 11 or less
View toward the RPF site looking southwest from intersection of New Haven and Rolling Hills Roads										
Photo Loc.#7, Figure 19-24	1									Level topography, farm field and trees in the background
		1								Pavement and grass in foreground, agriculture fields in background
			0							None
				1						Contrast in crop color is similar to contrast in grass area
					0					Adjacent scenery is similar
						1				Common for the area
							0			Pavement, power lines, signs
								4	C	A = 19 or more; B = 12-18; C = 11 or less

RPF = radioisotope production facility.

The sensitivity level, a measurement of the public concern for scenic quality, was also analyzed using six different indicators of public concern: types of users, amount of use, public interest, adjacent land uses, special areas, and other factors. The sensitivity level of the public concern for scenic quality is rated on a high (H), moderate (M), or low (L) scale. The site has an L sensitivity rating, as an area with low scenic values resulting from a low sensitivity to changes in visual quality by the type of users in the area, a low amount of use by viewers, low public interest in changes to the visual quality of the site, and a lack of special natural and wilderness areas.

19.3.2 Air Quality and Noise

19.3.2.1 General Regional Climate

Geomorphic, or physiographic, regions are broad-scale subdivisions of the nation that are based on terrain texture, rock type, geologic structure, and history. There are eight regions, subdivided into 25 provinces, and further subdivided to 85 sections within the U.S. (Fenneman, 1946). The characteristics and locations of these landforms influence local and regional climate and weather patterns.

The proposed RPF site lies at the southern edge of the Central Lowlands physiographic province, within a very few miles of the adjacent Ozark Plateau province, both of which lie within the larger Interior Plains physiographic region. The Central Lowlands includes most of the Corn Belt and lies within the heartland of America.

The proposed RPF location places the facility 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. Because of its geographical location far inland, the region is subject to significant seasonal and daily temperature variations. Air masses moving over the state during the year include cold continental polar air from Canada, warm and humid maritime tropical air from the Gulf of Mexico and the Caribbean Sea, and dry eastward flowing air masses from the Rocky Mountains located to the west. Prolonged periods of extreme hot or cold temperatures are unusual (MU, 2006b).

The general geostrophic airflow pattern and the prevailing jet stream track shuttle precipitation-producing mid-latitude cyclones (lows) across the state from west-to-east throughout the year. Consequently, precipitation events in all seasons move through from a westerly direction (MU, 2006b).

Spring, summer, and early fall precipitation occurs in the form of rain and thunderstorms. Severe thunderstorms typically occur during the period from mid- to late-spring through early summer. Hail may be expected as a product of these storms. Wind speeds of up to 97 km/hr (60 mi/hr) or more may be experienced once or twice a year during a severe thunderstorm (MU, 2006b). Winter precipitation is generally light to moderate and occurs in the form of rain or snow or a mixture of both with an occasional, though infrequent, thunderstorm. Occasional heavy snowfall episodes occur infrequently, and when they do occur, the accumulation does not last for any significant duration. Surface temperature conditions sometimes produce freezing rain or drizzle, although normally not more than a couple times each season.

The historical climate data within this section were obtained primarily from the National Oceanic and Atmospheric Administration (NOAA) High Plains Regional Climate Center historical climate data summaries for Columbia (NOAA, 2013a and 2013b). In addition, MU has a weather station at South Farm, less than 1.6 km (1 mi) away from the proposed site and approximately 6.4 km (4 mi) from Columbia. The weather station is used in conjunction with the MU agricultural program. The university makes the weather data available via its website. Simple searches may be performed and various averages can be obtained through this database.

Other sources were used as needed (e.g., Decker, 2013) to augment NOAA data, particularly to better understand the immediate area around the proposed site.

19.3.2.1.1 Temperature

Though temperatures reached a record high of 41.7°C (107 degrees Fahrenheit [°F]) in 2012, in general, temperatures rarely exceed 38°C (100°F) in the summer and rarely fall below -18°C (0°F) in the winter. The mean maximum temperatures in Columbia, collected from the reporting station at the Columbia Regional Airport (Station 231791) over a 43-year period, ranged from 2.8°C (37.2°F) in January to 31.4°C (88.5°F) in July. Daily temperatures during that period showed a wider variance, from -28.8°C (-20°F) in December to 44°C (111°F) in July. A summary of average and extreme temperature data for 1969 through 2012 is shown in Table 19-19.

Table 19-19. Columbia, Missouri, Average and Extreme Monthly Climate, Historic Temperature Summary, 1969–2012

Measurement		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average max. temperature	°C	2.9	6.1	12.7	18.9	23.6	28.5	31.4	30.7	26.0	19.6	12.0	5.1	18.1
	°F	37.2	43.0	54.9	66.1	74.4	83.3	88.5	87.3	78.8	67.2	53.6	41.2	64.6
Average min. temperature	°C	-6.8	-4.3	1.2	6.8	12.1	17.0	19.6	18.4	13.7	7.4	1.5	-4.3	6.8
	°F	19.7	24.2	34.2	44.3	53.7	62.6	67.2	65.2	56.7	45.3	34.7	24.2	44.3
Daily extreme high	°C	23.3	27.8	29.4	32.2	33.3	[a]89	43.9	43.3	38.3	34.4	28.3	24.4	43.9
	°F	74.0	82.0	85.0	90.0	92.0	[a]107	111.0	110.0	101.0	94.0	83.0	76.0	111.0
Daily extreme low	°C	-28.3	-26.1	-20.6	-7.2	-1.7	4.4	8.9	5.6	0.0	-5.6	-17.8	-28.9	-28.9
	°F	-19.0	-15.0	-5.0	19.0	29.0	40.0	48.0	42.0	32.0	22.0	0.0	-20.0	-20.0
Average mean	°C	-1.9	0.9	6.9	12.9	17.8	22.8	25.4	24.6	19.9	13.5	6.7	0.4	12.5
	°F	28.5	33.6	44.5	55.2	64.1	73.0	77.8	76.3	67.8	56.3	44.1	32.7	54.5

Source: WRCC, 2013a, "Period of Record General Climate Summary – Temperature, 1969 to 2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/cliGCStT.pl?mo1791, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

[a] Occurred during 2008–2012 time period.

Average temperature data for the Columbia, Missouri, weather station was reviewed for the most recent five years having data available (2008 to 2012). The lowest average temperature was -4.1°C (24.65°F), recorded in January 2010, and the highest average temperature was 29.5°C (85.06°F), recorded in July 2012. The five-year annual average temperature was 13.1°C (55.58°F).

A five-year temperature summary is presented in Table 19-20. The five-year average temperature for the same time period, reported at the South Farm weather station, was 12.3°C (54.2°F). The average minimum temperature was 6.9°C (44.5°F), and the average maximum temperature was 17.9°C (64.3°F) (MU, 2014).

Table 19-20. Columbia, Missouri, Five-Year Temperature Summary, 2008–2012

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2008	°C	-0.6	-0.9	6.1	11.6	17.1	23.3	24.7	22.8	19.0	16.0	2.4	-1.1	12.2
	°F	31.0	30.3	42.9	52.9	62.8	73.9	76.4	73.0	66.3	60.9	36.3	30.1	54.0
2009	°C	-3.1	2.4	8.1	11.7	17.9	23.3	22.5	21.9	18.6	10.2	9.8	-1.1	11.8
	°F	26.5	36.3	46.5	53.1	64.2	73.9	72.5	71.4	65.5	50.3	49.6	30.0	53.3
2010	°C	-4.1	-2.7	7.4	16.1	18.0	24.6	25.6	25.5	19.8	14.8	7.6	-1.6	12.6
	°F	24.7	27.1	45.3	60.9	64.4	76.2	78.0	77.9	67.6	58.6	45.7	29.1	54.6
2011	°C	-3.9	-0.1	6.6	14.0	16.9	24.0	27.5	24.9	17.6	14.2	8.9	3.1	12.8
	°F	24.9	31.9	43.9	57.2	62.5	75.1	81.6	76.7	63.7	57.5	48.1	37.5	55.0
2012	°C	1.7	4.3	14.9	15.0	21.6	25.0	29.5	25.8	19.6	12.0	7.7	7.5	16.1
	°F	35.0	39.7	58.8	59.0	70.9	77.1	85.1	78.5	67.3	53.6	45.8	45.5	61.0
Mean	°C	-2.0	0.6	8.6	13.7	18.3	24.0	25.9	24.2	18.9	12.8	8.5	-0.2	13.1
	°F	28.4	33.1	47.5	56.6	64.9	75.3	78.7	75.5	66.1	55.0	47.3	31.7	55.6

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

19.3.2.1.2 Precipitation

According to the historical data from Station 231791, precipitation in the Columbia area averages approximately 103.1 cm (40.6 in.) per year. Of that amount, the mean snowfall is 57.7 cm (22.7 in.) per year. The city has measurable amounts of precipitation 111 days per year. The maximum annual precipitation of 159 cm (62.49 in.) was measured in 1993, and the minimum annual precipitation of 60 cm (23.66 in.) was measured in 1980. On a monthly basis, rainfall amounts range from a high of 12.4 cm (4.89 in.) in May to a low of 4.62 cm (1.82 in.) in January (WRCC, 2013a).

According to the historical data from Station 231791, snow falls from November through April. During that period, a high of 16 cm (6.3 in.) was recorded in February 2011, and a low of 1.5 cm (0.6 in.) was recorded in 1980. A summary of average and extreme precipitation data for 1969 through 2012 is shown in Table 19-21.

Table 19-21. Columbia, Missouri, Average and Extreme Monthly Climate, Historic Precipitation Summary, 1969–2012

Measurement		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average total precipitation	cm	4.62	5.44	8.10	11.23	12.42	10.24	9.58	10.06	9.53	8.28	7.72	6.02	103.12
	in	1.82	2.14	3.19	4.42	4.89	4.03	3.77	3.96	3.75	3.26	3.04	2.37	40.60
High	cm	15.09	15.70	25.63	29.69	31.27	26.11	30.84	25.88	30.63	[a] 27.9	26.47	17.68	158.72
	in	5.94	6.18	10.09	11.69	12.31	10.28	12.14	10.19	12.06	[a] 10.99	10.42	6.96	62.49
Low	cm	0.13	0.28	1.98	2.26	[a] 3.33	0.89	0.61	0.53	1.14	[a] 0.91	1.07	1.22	60.10
	in	0.05	0.11	0.78	0.89	[a] 1.31	0.35	0.24	0.21	0.45	[a] 0.36	0.42	0.48	23.66
1-day max	cm	4.47	6.10	9.98	11.43	12.14	8.15	15.09	10.85	7.11	12.40	7.04	6.88	15.09
	in	1.76	2.40	3.93	4.50	4.78	3.21	5.94	4.27	2.80	4.88	2.77	2.71	5.94
Average total snowfall	cm	15.75	[a] 16.00	7.37	1.52	0.00	0.00	0.00	0.00	0.00	0.00	4.57	12.70	57.66
	in	6.20	[a] 6.3	2.90	0.60	0.00	0.00	0.00	0.00	0.00	0.00	1.80	5.00	22.70
High snowfall	cm	59.69	59.18	54.86	18.03	0.00	0.00	0.00	0.00	0.00	0.25	21.08	45.21	134.11
	in	23.50	23.30	21.60	7.10	0.00	0.00	0.00	0.00	0.00	0.10	8.30	17.80	52.80

Source: WRCC, 2013a, "Period of Record General Climate Summary – Temperature, 1969 to 2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/cliGCStT.pl?mo1791, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

[a] Occurred during 2008–2012 time period.

A recent five-year precipitation summary of the station data was obtained and reviewed. For each month during this time period, a portion of the data was missing, with the missing data ranging from approximately 15–30 percent of the total data. Precipitation data from the South Farm weather station was also reviewed. The averages shown on the site were different than the Columbia weather station by a factor of five. Thus, the Columbia weather station historical summary serves as the more complete picture of precipitation at the proposed RPF site.

19.3.2.1.3 Humidity

Average relative humidity data for the Columbia, Missouri, weather station was reviewed for 2008 to 2012. The lowest average relative humidity was 51.89 percent, recorded in August 2012, and the highest average relative humidity was 82.13 percent, recorded in September 2008. The five-year annual average was 69.18 percent. The five-year relative humidity data summary is shown in Table 19-22.

Table 19-22. Relative Humidity Data for Columbia, Missouri, 2008–2012

Year	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)	Annual (%)
2008	60.51	72.02	66.68	64.85	69.49	71.40	74.38	78.87	82.13	77.52	65.87	71.48	71.18
2009	64.95	63.73	63.28	66.52	68.42	73.66	74.46	76.90	75.92	76.62	68.08	72.33	70.41
2010	75.69	73.42	70.33	61.24	74.71	76.64	79.19	75.19	76.17	58.65	64.86	72.85	71.58
2011	71.86	71.51	71.26	64.73	74.61	72.69	76.29	75.19	70.82	59.46	71.92	74.84	71.27
2012	64.05	63.72	63.58	65.03	61.33	54.89	52.96	51.89	69.64	66.76	62.25	70.91	61.46
Mean	67.41	68.88	67.03	64.47	69.71	69.86	71.46	71.61	74.94	65.37	66.78	72.88	69.18

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

19.3.2.1.4 Wind

Extreme wind speeds are uncommon in central Missouri. When they do occur, they are usually caused by pressure gradients and temperature contrasts present in the mid-latitude cyclones that pass through the state. These cyclones may spawn storms that produce high winds from gust fronts, microbursts, and tornadoes. Non-storm-related extreme winds are rare. Occasionally, cold high-pressure air filling in behind a front causes high wind, especially in the winter when temperature contrasts are large.

Average wind speed data for the Columbia, Missouri, weather station was reviewed for 2008 to 2012. The lowest mean wind speed was 8.8 km/hr (5.47 mi/hr) in August 2008, and the highest was 19.1 km/hr (11.87 mi/hr) recorded in December 2008. The five-year annual average was 14.25 km/hr (8.86 mi/hr). The five-year mean wind speed data summary is shown in Table 19-23.

Table 19-23. Mean Wind Speed for Columbia, Missouri, from 2008–2012

Year	rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2008	(km/hr)	18.85	17.03	16.96	17.53	15.76	13.97	11.28	8.80	10.01	11.59	14.32	19.10	14.93
	(mi/hr)	11.71	10.58	10.54	10.89	9.79	8.68	7.01	5.47	6.22	7.20	8.90	11.87	9.28
2009	(km/hr)	15.24	17.96	18.31	17.99	12.38	12.47	10.32	11.91	10.40	14.58	14.71	17.03	14.44
	(mi/hr)	9.47	11.16	11.38	11.18	7.69	7.75	6.41	7.40	6.46	9.06	9.14	10.58	8.97
2010	(km/hr)	13.74	13.73	15.96	17.06	12.79	11.43	10.06	9.88	12.17	16.30	14.73	13.41	13.10
	(mi/hr)	8.54	8.53	9.92	10.60	7.95	7.10	6.25	6.14	7.56	10.13	9.15	8.33	8.14
2011	(km/hr)	13.63	16.87	17.08	18.49	15.14	14.45	10.09	10.38	11.89	13.66	18.88	14.15	14.56
	(mi/hr)	8.47	10.48	10.61	11.49	9.41	8.98	6.27	6.45	7.39	8.49	11.73	8.79	9.05
2012	(km/hr)	16.98	15.64	16.53	15.19	13.42	13.68	10.56	11.35	11.57	13.79	14.97	14.18	13.97
	(mi/hr)	10.55	9.72	10.27	9.44	8.34	8.50	6.56	7.05	7.19	8.57	9.30	8.81	8.68
Mean	(km/hr)	15.69	16.24	16.96	17.25	13.90	13.20	10.46	10.46	11.20	14.08	15.92	16.25	14.26
	(mi/hr)	9.75	10.09	10.54	10.72	8.64	8.20	6.50	6.50	6.96	8.75	9.89	10.10	8.86

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

Wind data from the South Farm weather station was also reviewed. The average shown on the site was different than the Columbia weather station by a factor of two. Thus, the Columbia weather station data provides a more comprehensive study of wind activity at the proposed site.

Two wind roses are presented to show the general historic wind flow patterns in the immediate area and the ROI. Figure 19-26 shows the wind pattern as measured at South Farm, located immediately north of the proposed RPF site. These data were collected by MU. Figure 19-27 shows the wind patterns recorded at the Columbia Remote Automatic Weather Station.

Both wind roses show that the prevailing surface wind direction is from the south. The South Farm wind rose shows a total average wind speed of 11.3 km/hr (7 mi/hr), while the Columbia wind rose shows a total average speed of 14.16 km/hr (8.8 mi/hr). Both wind roses show that the average frequency of higher speed winds falls into the 24–40 km/hr (15–25 mi/hr) range.

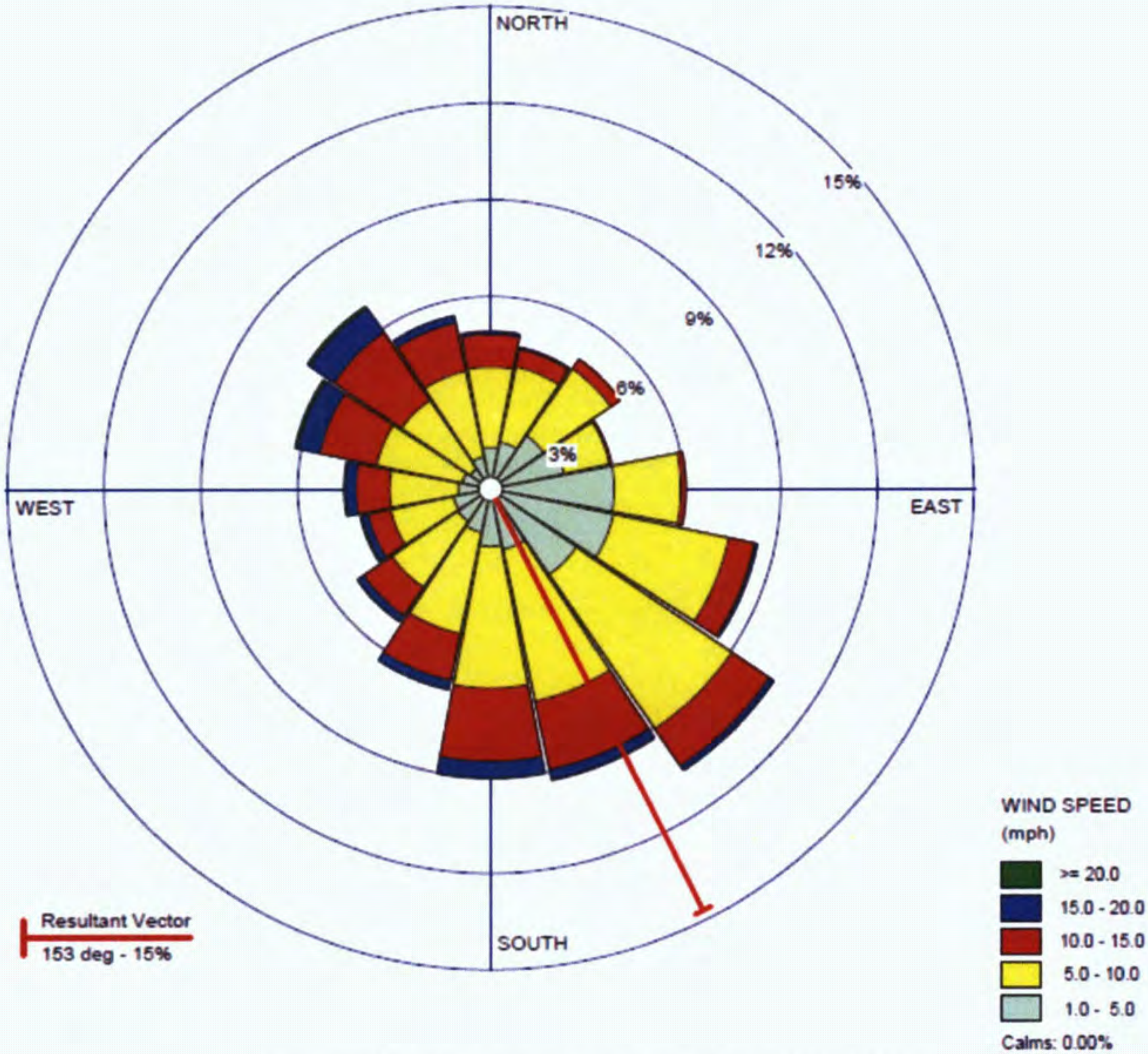


Figure 19-26. Wind Rose from South Farm, 2000–2010 (University of Missouri Agricultural Experiment Station)

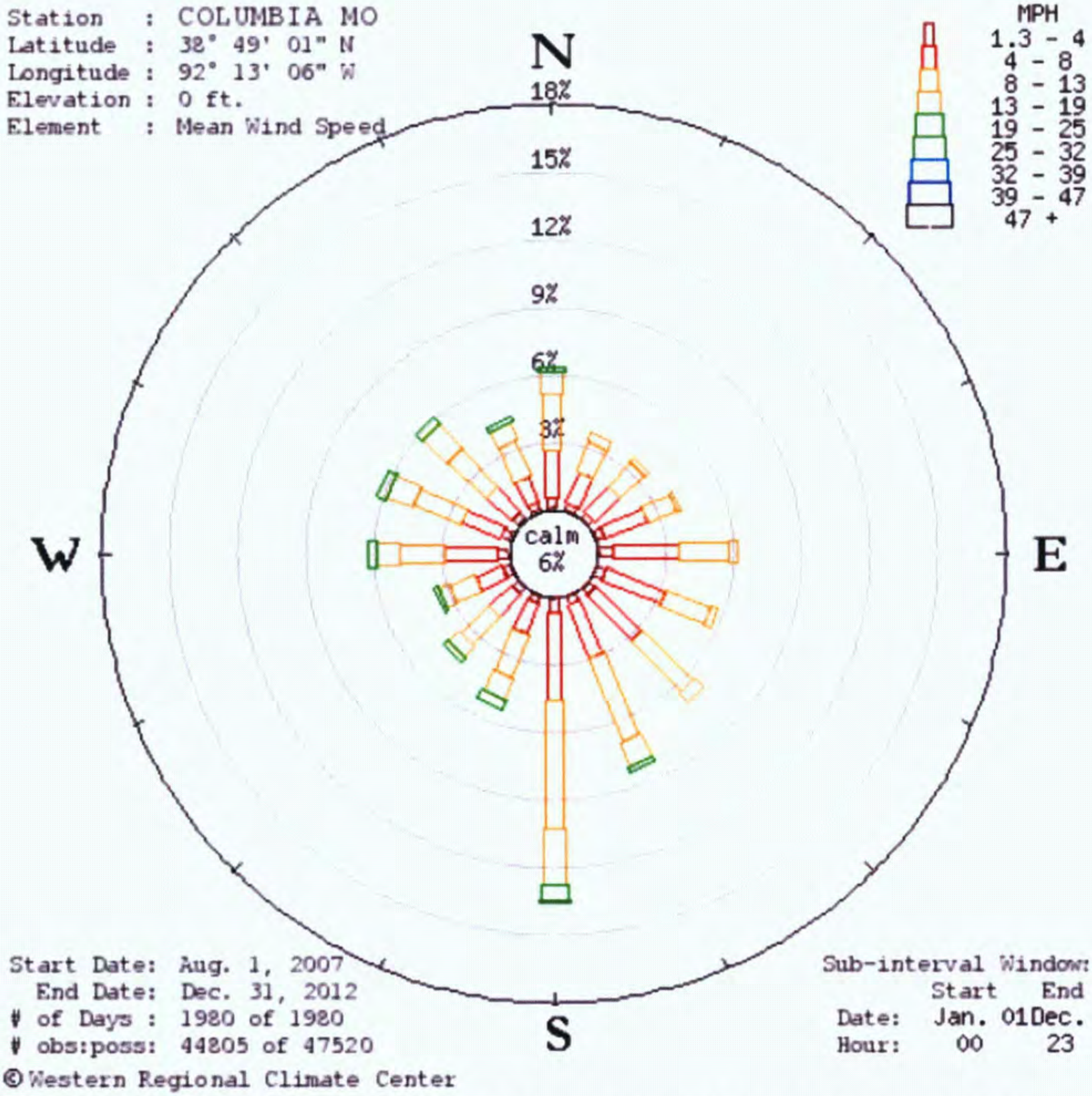


Figure 19-27. Wind Rose from Automatic Weather Station, Columbia, Missouri, 2007-2012 (Western Regional Climate Center)

19.3.2.1.5 Extreme Weather

The American heartland has the distinction of also being known as "tornado alley," a nonmeteorological term that references the area where 90 percent of tornadoes have occurred as a result of the mixing of cold, dry air from Canada and the Rocky Mountains with warm, moist air from the Gulf of Mexico and hot, dry air from the Sonoran Desert. This area exhibits considerable atmospheric instability, heavy precipitation, and many intense thunderstorms.

Tornados are extreme wind speed events that are classified according to the enhanced Fujita tornado intensity scale (EF scale). The scale matches wind speeds to the severity of damage caused by a tornado. The process involves determining the degree of damage according to a predefined damage scale of 28 indicators. The observed damage is associated with estimated wind speeds during the storm, and an EF scale number is assigned. Measuring tornadoes from EF-1 to EF-5, the scale uses more specific structural damage guidelines than the original Fujita tornado intensity scale (F scale), which was established in 1971. Table 19-24 shows the F and EF scales.

Table 19-24. Fujita Scale and Enhanced Fujita Scales Used to Determine Tornado Intensity

F number	F scale				EF number	EF scale	
	Fastest 1/4-mi		3-sec gust			3-sec gust	
	(km/hr)	(mi/hr)	(km/hr)	(mi/hr)		(km/hr)	(mi/hr)
0	64 – 116	40 – 72	72 – 126	45 – 78	0	105 – 137	65 – 85
1	117 – 180	73 – 112	127 – 188	79 – 117	1	138 – 177	86 – 110
2	182 – 253	113 – 157	189 – 259	118 – 161	2	178 – 217	111 – 135
3	254 – 333	158 – 207	260 – 336	162 – 209	3	218 – 265	136 – 165
4	334 – 418	208 – 260	337 – 420	210 – 261	4	266 – 322	166 – 200
5	419 – 512	261 – 318	421 – 510	262 – 317	5	Over 322	Over 200

EF scale = enhanced Fujita tornado intensity scale.
F scale = Fujita tornado intensity scale.

According to compiled information from several extreme weather databases, including the U.S. Tornado and Weather Extremes database (1950 to 2010), a total of 625 tornado events that had a recorded magnitude of two or above were documented in Missouri (World, 2013). Of that total, 50 tornado events of the same magnitude were recorded within 80 km (50 mi) of Columbia. A listing of severe weather events is shown in Table 19-25. Columbia, in a ranking of 1,237 other Missouri cities, ranked 810 for tornados. The tornado index value is calculated based on historical tornado events data and is an indicator of the tornado level in a region. According to this ranking, 809 Missouri cities have a higher chance of tornado events than Columbia (World, 2013).

Table 19-25. Listing of Severe Weather Events from 1950 to 2010 within an 80 km (50-mi) Radius of the Radioisotope Production Facility Site

Event	Total	Event	Total
Blizzard	1	Ice storm	25
Cold	45	Strong wind	26
Dense fog	29	Thunderstorm winds	1,236
Drought	23	Wildfire	2
Flood	466	Winter storm	84
Hail	1,340	Winter weather	51
Heat	72	Other	86
Heavy snow	31	**Total all events:**	**3,517**

Source: World, 2013, "Natural Disasters & Extremes," www.usa.com/columbia-mo-natural-disasters-extremes.htm#TornadoIndex, World Media Group, LLC, Bedminster, New Jersey, accessed August 2013.

According to the NOAA National Climatic Data Center Storm Events Database (NOAA, 2013b), for the time period January 1996 to May 2013, there were 420 severe storm events (defined as an individual type of storm event) recorded in either Boone County or the Boone Zone. The most notable of the 420 events are summarized in Table 19-26.

Table 19-26. Summary of Notable Storm Events In and Near the Region of Influence, Recorded from 1996 to 2013

Event	Boone County	Boone Zone	Events	Notes
Blizzard		✓	1	51 cm (20 in.) of snow recorded
Extreme cold/wind chill		✓	1	Wind chill 29–40°C (20–40°F) below zero recorded
Excessive heat (heat wave)		✓	14	–
Flash flood	✓		50	10, Countywide 1, Central portion of Missouri 7, Columbia
Funnel cloud	✓		1	–
Hail	✓		220	Equal/greater than 1.9 cm (0.75 in.)
Heavy rain	✓		1	7.6–15.2 cm (3–6 in.) recorded
Heavy snow		✓	5	15.2–30.5 cm (6–12 in.) recorded
Ice storm		✓	4	0.64–1.27 cm (0.25–0.5 in.) recorded
Lightening			13	Strikes that resulted in damage/injury
Thunderstorm wind	✓		118	50–75 kn recorded
[a]Tornado	✓		6	Two F-0, one F-1, two F-2, one F-3 recorded
Winter storm		✓	25	--

Source: NOAA, 2013b, "Storm Events Database," www.ncdc.noaa.gov/stormevents, National Oceanic and Atmospheric Administration, Washington, D.C., accessed August 2013.

[a] As rated with the enhanced Fujita tornado intensity scale.

19.3.2.2 Air Quality

Missouri is located in EPA Region 7. The Missouri DEQ is the regulatory agency responsible to protect and enhance the quality of the Missouri environment and its citizens. The MDNR operates an extensive network of ambient air monitors to comply with the Clean Air Act and its amendments.

The ambient air quality monitoring network for Missouri consists of State and local air monitoring stations, special purpose monitoring stations, and national core monitoring consistent with requirements in 40 CFR 58.10, "Annual Monitoring Network Plan and Periodic Network Assessment."

The only MDNR air monitor in Boone County is located at Finger Lakes and monitors for ozone (O_3) from May to October each year. The MDNR continuous air monitors nearest to the proposed RPF site, also in similar urban locales, are at the following locations:

- **Mark Twain State Park** – In Stoutsville, Monroe County, approximately 103 km (64 mi) northeast of the RPF site. Monitors for sulfur dioxide (SO_2), O_3, and inhalable particulates PM-10 (particulate matter, 10 micron [μ]) and PM-2.5 (particulate matter, 2.5 μ).
- **El Dorado Springs** – In Cedar County, approximately 261 km (162 mi) southwest of the site. Monitors for nitrogen dioxide (NO_2), inhalable particulate PM-2.5, and O_3.

Both air monitoring locations are well outside of the ROI.

The EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants). These standards are known as NAAQS. Missouri DEQ monitors for CO, NO_2, O_3, total suspended particulate, inhalable particulates (PM-10 and PM-2.5), and lead (Pb). Other pollutants or compounds are measured as part of air toxics or particulate speciation sampling. Legal descriptions of the standards are available in the 6 CSR Division 10, "Air Quality Standards, Definitions, Sampling and Reference Methods and Air Pollution Control Regulation for the Entire State of Missouri." The NAAQS are summarized in Table 19-27.

Table 19-27. National Ambient Air Quality Standards Applicable in Missouri

Pollutant	Average time	NAAQS	Primary standard	Secondary standard
Carbon monoxide	1 hr	Not to be exceeded more than once per year	35 ppm	–
	8 hr	Not to be exceeded more than once per year	9 ppm	–
Lead	3 months	Rolling 3-month average	15 μg/m³	15 μg/m³
	Quarterly	Quarterly average	1.5 μg/m³	1.5 μg/m³
Nitrogen dioxide	1 hr	3-year average of the maximum daily 98th percentile 1-hr average	100 ppb	None
	Annual	Annual arithmetic mean	53 ppb	53 ppb
PM-10	24 hr	Not to be exceeded more than once per year on average over 3 years	150 μg/m³	150 μg/m³
PM-2.5	24 hr	98th percentile of the 24-hr values determined for each year; 3-year average of the 98th percentile values	35 μg/m³	35 μg/m³
	Annual	3-year average of the annual arithmetic mean	15 μg/m³	15 μg/m³
Ozone	8 hr	3-year average of the annual 4th highest daily maximum 8-hr average concentration	0.075 ppm	0.075 ppm
Sulfur dioxide	24 hr	NA	0.14 ppm	None
	1 yr	NA	0.03 ppm	None
	1 hr/3 yr	To attain the 1-hr/3-yr standard, the 3-yr average of the 99th percentile of the daily maximum 1-hr average at each monitor within an area must not exceed 75 ppb	75 ppb	None

Source: MDNR, 2013a, "National Ambient Air Quality Standards," dnr.mo.gov/env/esp/aqm/standard.htm, Missouri Department of Natural Resources, Division of Environmental Quality, Jefferson City, Missouri, accessed August 2013.

NA = not applicable. NAAQS = National Ambient Air Quality Standards.

Nonattainment means that a geographic area has not consistently met the clean air levels set by the EPA in the NAAQS. There are several nonattainment areas in Missouri; however, none of them are within Boone County, Columbia, the ROI, or anywhere near the proposed RPF site. Most nonattainment areas are located in St. Louis (201 km [125 mi] to the southeast) and in the nearby counties of Dent, Franklin, Iron, Jefferson, Reynolds, St. Charles, and St. Louis.

Maintenance areas are geographic areas that had a history of nonattainment, but are now consistently meeting the NAAQS. Maintenance areas have been redesignated by EPA from "nonattainment" to "attainment with a maintenance plan," or designated by the Environmental Quality Commission. There are no maintenance areas within Boone County, Columbia, the ROI, or anywhere near the proposed RPF site. The closest maintenance area (for Pb) is located in Bixby, Missouri (Iron County), 238 km (148 mi) to the southeast. Other maintenance areas are found in the cities of Herculaneum (Pb), St. Louis (CO), and Kansas City (O_3).

19.3.2.2.1 Greenhouse Gases

There are currently no programs or policies established or drafted related to operations at Discovery Ridge. NWMI will develop a comprehensive program to avoid and control GHG emissions associated with the RPF. This program will include elements such as:

- Developing a GHG emission inventory
- Investigating and implementing methods for avoiding or controlling the GHG emissions identified in the inventory
- Encouraging carpooling or other measures to minimize GHG emissions due to vehicle traffic during construction and operation of the RPF
- Conducting periodic audits of GHG control procedures
- Implementing corrective actions when necessary

19.3.2.3 Noise

Noise is generally defined as "unwanted sound." At high levels, noise can damage hearing, cause sleep deprivation, interfere with communication, and disrupt concentration. In the context of protecting the public health and welfare, noise implies adverse effects on people and the environment.

Sound is the result of a source inducing vibration in the air, creating sound waves. These waves radiate in all directions from the source and may be reflected and scattered or, like other wave actions, may turn corners. Sound waves are a fluctuation in the normal atmospheric pressure, which is measurable. This sound pressure level is the instantaneous difference between the actual pressure produced by a sound wave and the average or barometric pressure at a given point in space. The fundamental method of measuring sound is in decibel (dB) units. The most commonly used noise metric for measuring noise is A-weighted decibels (dBA).

The following sections discuss the baseline noise conditions within the ROI. The ROI for noise is the 8 km (5 mi) radius from the centerline of the RPF site.

19.3.2.3.1 Baseline Noise Conditions

As discussed in Section 19.3.1, the proposed RPF site is located on Lot 15 of the Discovery Ridge industrial park near the MU campus, and is currently an agricultural field. Existing noise sources in the area consist of agricultural equipment (e.g., tractors, forklifts), HVAC systems associated with existing buildings, and traffic noise from U.S. Highway 63 and the surrounding areas. The highest noise levels in the area originate from the intermittent operation of agricultural equipment associated with the MU School of Agriculture, and range from 80 to 100 dBA (Baker, 1997). When agricultural equipment is not running, noise levels are similar to that of a suburban community area, typically around 55 dBA (Berger et al., 2003).

Traffic-related noise sources include airports, railways, and highways. The Columbia Regional Airport is approximately 12 km (7.5 mi) from the proposed NWMI site, and the Columbia Terminal (COLT), a freight-only railway, is approximately 2.7 km (1.7 mi) from the proposed site (Terracon, 2006). Both the airport and railway are located a sufficient distance from the proposed RPF site to attenuate the noise associated with these locations to background levels. U.S. Highway 63 is approximately 0.4 km (0.25 mi) from the proposed site. Based on the most recent peak 1-hr traffic count summary from the Missouri Department of Transportation, the expected noise levels at the proposed RPF site resulting from traffic on U.S. Highway 63 range from 54 to 58 dBA (MoDOT, 2009).

Noise receptors include nearby residents, commercial workers at ABC Laboratories and RADIL, agricultural students and faculty present in the agricultural research areas, recreational users of the three sports venues in the area, site visitors, and domesticated and research wildlife.

19.3.2.3.2 Past Noise Studies

There are no known noise studies that have been performed in the audible range of the proposed RPF site.

19.3.2.3.3 Sound Level Standards

Permissible noise levels in Discovery Ridge are governed by both the *Discovery Ridge Master Plan and Protective Covenants* (MU, 2009) and the Columbia Code of Ordinances (City of Columbia, 2013d). Section 2.2 of the Covenants document specifies that buildings cannot be used for "excessive noise," and Section 3.3 requires that preliminary building plans specify the extent of noise that may be created by operation of the building (MU, 2009). Section 16-265 of the Ordinances states that site preparation and building construction cannot be performed outside the hours of 7:00 a.m. to 7:00 p.m. on weekdays and 9:00 a.m. to 5:00 p.m. on Saturdays without a special permit from the Director of Public Works. Sections 16-264 and 16-266 of the Ordinances prohibit the creation of "excessive noise" in connection with loading or unloading any vehicle, or in the vicinity of schools, hospitals, churches, and courts (City of Columbia, 2013d).

19.3.3 Geologic Environment

19.3.3.1 Regional Geology

This section provides summary descriptions of geomorphic provinces and their tectonic development. The glacial history responsible for surface topography features found today in Missouri is also described. The descriptions are based on a review of relevant, readily available published reports and maps and, where available, records and unpublished reports from Federal and State agencies. Information on the site conditions has been acquired from these same sources and from site-specific investigations, including geotechnical field studies.

19.3.3.1.1 Geomorphic Provinces

Missouri is divided into three geomorphic provinces:

- **Interior Plains Province** – Also referred to as the Central Lowland Province (northern Missouri, north of the Missouri River)
- **Interior Highlands** (central Missouri, south of the Missouri River)
- **Atlantic Plains** – Also referred to as the Coastal Plains Province (the "boot heel" or southeastern corner of Missouri)

The proposed RPF site is located north of the Missouri River within the Interior Plains Province. The Interior Plains are defined by the general texture of the surface terrain, rock type, and geologic structure. The province is characterized by moderately dissected, glaciated, flat-to-rolling plains that slope gently toward the Missouri and Mississippi River valleys. Local relief is 6.1–50.3 m (20–165 ft). Drainage is dendritic; current geomorphic processes are fluvial erosion, transport and deposition, and minor mass wasting. Elevations range from 183–457 m (600–1,500 ft) above mean sea level, with the proposed RPF site averaging 245 m (805 ft) above mean sea level (USGS, 2013a).

19.3.3.1.1.1 Interior Plains Province

The Interior Plains Province is a vast region spread across the stable core (craton) of North America. This area formed when several small continents collided and welded together over a billion years ago, during the Precambrian Era. Precambrian metamorphic and igneous rocks now form the basement of the Interior Plains and make up the stable core of North America. Throughout the Paleozoic and Mesozoic Eras, the low-lying Interior Plains remained relatively unaffected by mountain building and tectonic collisions in the western and eastern margins of the continent. During the Mesozoic Era, the majority of the North American continental interior was above sea level, with two notable exceptions. The first occurred during the Jurassic Era (208–144 million years ago), when rising seas flooded the low-lying areas of the continent, and most of the Interior Plains were eventually submerged beneath the shallow Sundance Sea. The second exception occurred during the Cretaceous Period, when record high sea levels flooded the continental interior with shallow seas. During this time, the Interior Plains continued to receive deposits from the eroding Rocky Mountains to the west and Appalachian and Ouachita-Ozark Mountains to the east and south throughout the most recent Cenozoic Era. The flatness of the Interior Plains is a reflection of the platform of mostly flat-lying marine and stream deposits laid down in the Mesozoic and Cenozoic Eras. The overlying sedimentary rocks are composed mostly of limestone, sandstone, and shales (USGS, 2013a).

19.3.3.1.1.2 Interior Highlands Province

The southern portion of Missouri, south of the Missouri River, is located within the Interior Highlands Province. The Interior Highlands includes the Ozark and Ouachita Mountains of southern Missouri, Arkansas, and eastern Oklahoma. The rocky outcrops that make up the core of the Interior Highlands are Paleozoic age carbonates and other sedimentary rocks that were originally deposited on the sea floor. In the Ouachita Mountains, these ancient marine rocks are now contorted by folds and faults. The ancient, eroded mountains of the Interior Highlands stand surrounded by nearly flat lying sedimentary rocks and deposits of the Interior and Atlantic Plains provinces.

The Interior Highlands consist of thick bedrock units of sandstone and shale, with lesser amounts of chert and novaculite (a fine-grained silica rock, like flint), deposited in a deep sea that covered the area from Late Cambrian through Early Pennsylvanian time. The area was then folded and faulted in such a manner that resistant beds of sandstone, chert, and novaculite now form long, sinuous mountain ridges that tower 152–457 m (500–1,500 ft) above adjacent valleys formed in easily eroded shale (USGS, 2013a).

19.3.3.1.1.3 Atlantic Plains Province

The Atlantic Plain Province is the flattest of all the provinces and stretches over 3,540 km (2,200 mi) from Cape Cod to the border of Mexico and southward another 1609 km (1,000 mi) to the Yucatan Peninsula. The Atlantic Plains slope gently seaward from the Interior Highlands in a series of terraces. The gentle sloping continues far into the Atlantic and Gulf of Mexico, forming the continental shelf.

Eroded sediments from the Interior Highlands were carried east and southward by streams and gradually covered the faulted continental margin, burying it under a wedge composed of layered sedimentary and volcanic debris thousands of feet thick. The sedimentary rock layers that lie beneath much of the coastal plain and fringing continental shelf remain nearly horizontal or tilt gently toward the sea (USGS, 2013b).

19.3.3.1.2 Glacial History

The MDNR describes the glacial history of the area as follows:

> *Recent studies of ice cores, stalagmites, and other temperature dating methods have concluded that there have been 30 sustained periods of frigid temperatures in the last 3 million years. Of the classical glacial periods, only two: pre-Illinoian (Nebraskan-Kansan) and Illinoian are now recognized as having left glacial deposits in the state of Missouri. The pre-Illinoian was the most severe. Amongst its legacy was the changing of the course of the Missouri River to its present location, the scouring and filling of Northern Missouri topography, and extensive outwash gravels left to the south of the present Missouri River. Although the Ozarks were not glaciated in the recent past, a cover of Pleistocene loess of varying thicknesses extends over all of the state except for the highest parts of the Ozark Mountains. Residuum, otherwise known as soil, clay, and rock fragments degrade from exposed and subsurface bedrock. Gravity and streams move this residuum, depositing it in sometimes graded layers* (MDNR, 2013b).

In Boone County, the glacial till averages over 43 m (140 ft) thick in the northeastern portion of the county, and the loess material reaches a maximum depth of 6.1 m (20 ft) along the Missouri River Bluffs (Boone County, 2013a).

19.3.3.1.3 Local Topography and Soils of Boone County

The topography of Boone County ranges from highly dissected hills to flat floodplains and nearly flat uplands. Elevations range from approximately 274 m (900 ft) above mean sea level along the northern boundary of Boone County to approximately 165 m (540 ft) above mean sea level in the southern tip of the county. Several areas of the county contain well-developed cave and sinkhole formations.

Ordovician to middle Pennsylvania age dolomite, limestone, sandstone, coal, and shale deposits are visible throughout Boone County in geologic outcrops and roadcuts. The Mississippian age Burlington Limestone is easily weathered by acidic groundwater and contains some unique natural resources of Boone County, including the most famous Devil's Ice Box cave system, located approximately 2.4 km (1.5 mi) southwest of the proposed RPF site. There are numerous caves in Boone County and 418 documented sinkholes (Boone County, 2013a).

Pennsylvanian age deposits are overlaid by glacial till and loess. The soils of Boone County are included in parts of two major land resource areas:

- **Central Claypan Area** – The Central Claypan Area soils were formed in glacial till and cover the northeastern and east-central portions of Boone County. Claypan soils display extreme variability within the soil profile and across the landscape; therefore, plant growth within these soils must contend with distinctively contrasting physical, chemical, and hydrologic properties at different soil depths. The depth to the claypan soils varies from approximately 10 cm (3.93 in.) on ridge tops up to 100 cm (39.4 in.) on back slopes. The soil horizons preceding the claypan are depleted of clay minerals, cations, and have a very low pH. The claypan horizon typically has an abrupt upper boundary with 100 percent more clay than the preceding horizon, and very low permeability.

- **Central Mississippi Valley Wooded Slopes** – This major land resource area consists of a dissected glacial till plain composed of rolling narrow ridge tops and hilly to steep ridge slopes. The small streams in this area have narrow valleys with steep gradients. The major rivers have nearly level broad floodplains, and the valley floors are tens of meters below the adjoining hilltops. Most of the soils within the central Mississippi Valley wooded slopes area are found in silty loess or glacial till, are moderately to fine-grained in texture with a mixed mineralogy, and are well-drained to moderately well-drained. These soils are typically observed on ridge tops and support forest flora (Boone County, 2013a).

19.3.3.2 Geology at the Proposed Site

The ROI for the geologic resource is defined as the 8 km (5 mi) radius surrounding the RPF site. The geologic units that underlie the proposed RPF site and/or properties within the ROI, from youngest to oldest, are as follows:

- Quaternary Age Holocene Series (Qal)
- Pennsylvanian Age Desmoinesian Series Marmaton Group (Pm)
- Pennsylvanian Age Desmoinesian Series Cherokee Group (Pc)
- Mississippian Age Osagean Series Burlington Formation (Mo)
- Mississippian Age Kinderhookian Series (Mk)
- Late to Early Devonian Age (D)
- Early Ordovician Age Ibexian Series (Ojc)

Figure 19-28 provides a map of the features within the ROI.

19.3.3.2.1 Quaternary Age Holocene Series (Qal)

The surface topography of the proposed RPF site and surrounding properties consists of Quaternary age bedrock overburden characterized by upland areas covered by a thin loess blanket and glacial drift. "Highly plastic clays that exhibit volume change with variations in moisture are commonly encountered near the ground surface" (Terracon, 2011b). The surface topography of the proposed RPF site and surrounding properties consists of upland areas covered by a thin loess blanket and glacial drift. Previous investigations of Discovery Ridge noted that "Highly plastic clays that exhibit volume change with variations in moisture are commonly encountered near the ground surface" (Terracon, 2011b).

Figure 19-29 depicts the Quaternary age bedrock overburden at the proposed RPF site as clay loam till (No. 27). Clay loam till is also depicted on all adjacent properties to the north, east, south, and west. Additional Quaternary age deposits located within an 8 km (5-mi) radius of the proposed RPF site include alluvium (No. 10), loess (No. 18), sandy clay (No. 40), and thin, cherty clay solution residuum (No. 41).

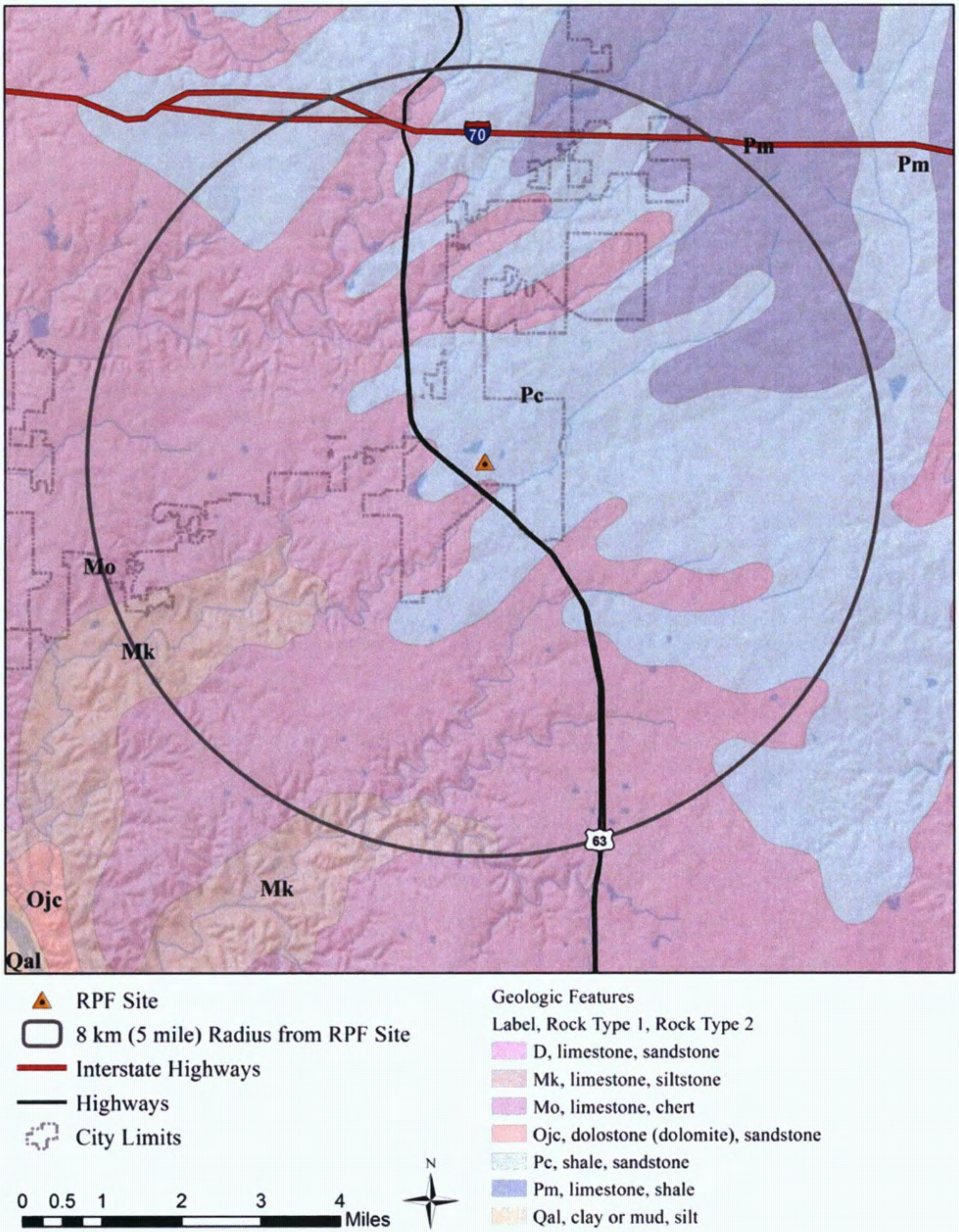
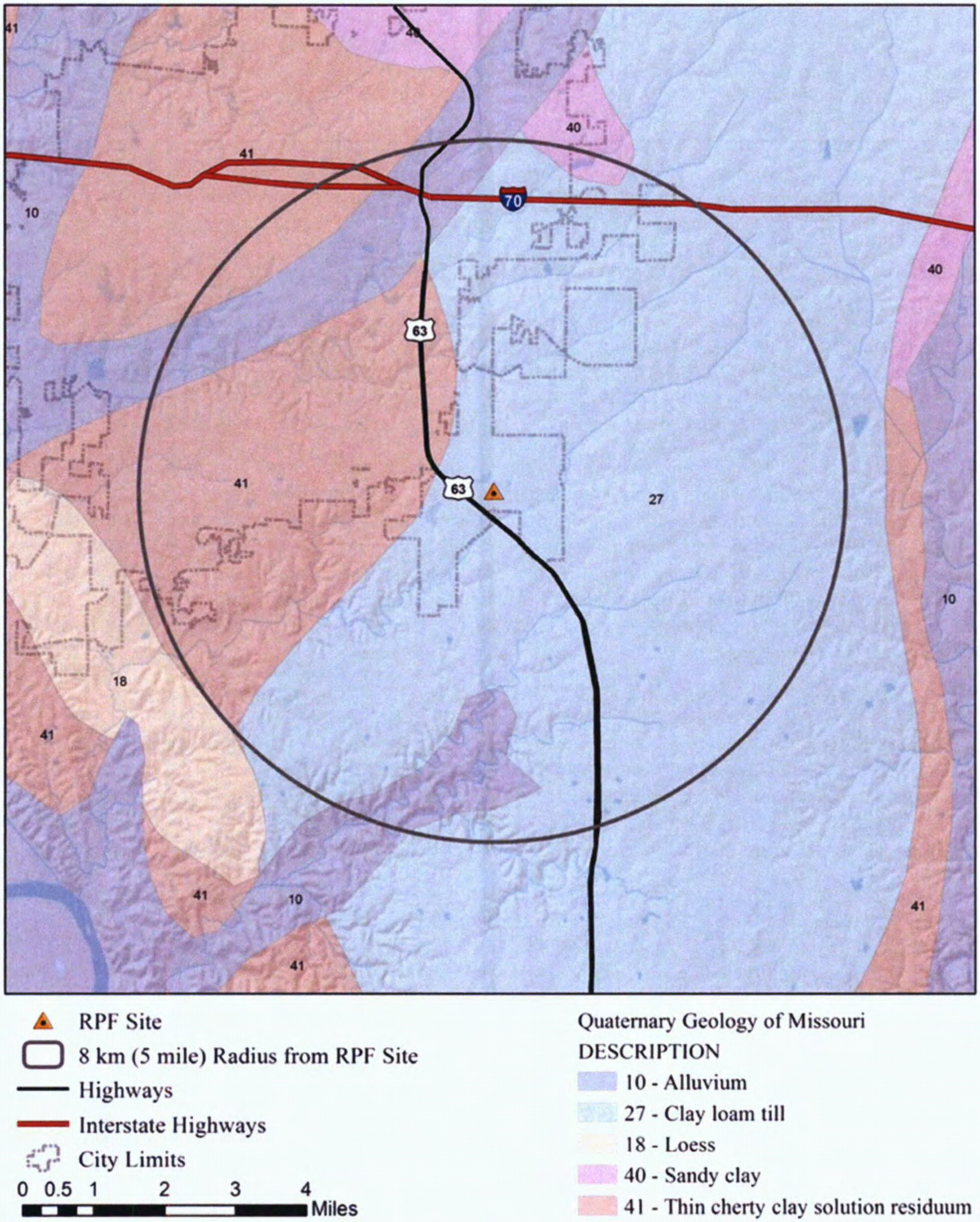


Figure 19-28. Geologic Features within an 8 km (5-mi) Radius of the Radioisotope Production Facility Site



USGS 1996. MO 1996 Quaternary Geology (SHP)
[digital data] ftp:msdis.missouri.edu/pub/Geological_Geophysical/MO_1996_Quaternary_Geology_shp.zip

Figure 19-29. Map of Missouri Quaternary Age Geology

The typical Quaternary age groundcover found in Boone County consists of alluvial (stream-deposited) clays, sand, and gravels (with a few poorly consolidated sandstones); glacial tills (sand and well-sorted gravels); and eolian (windblown) clays and loess (an extremely fine "rock flour," which forms solid masses) (MDNR, 2013c).

These glacial deposits mantle the upland areas and consist of a heterogeneous mixture of clay, sand, and pebbles of diverse rock types. The deposits vary greatly in thickness and are as much as 42.7 m (140 ft) thick in the northern portion of Boone County. This material is relatively impermeable and supplies very little water to wells (MU, 2006a).

19.3.3.2.2 Pennsylvanian Age Desmoinesian Series Marmaton Group (Pm) and Cherokee Group (Pc)

Pennsylvanian age strata (both Marmaton and Cherokee Groups) consists largely of clay and shale with minor accounts of coal and thin, impure limestone beds. The total thickness may be as much as 33.5 m (110 ft). These beds produce only small quantities of water and are not used in this area as a source of supply. The water found in this unit is usually high in iron and sulfur content (MU, 2006a).

Limestone and shale beds are generally thin and very widespread lateral units. Pennsylvanian deposits are quite extensive across Missouri, and they usually form thin to medium-bedded layers of distinctive composition, called cyclothems. A cyclothem results when a sea transgresses and regresses very rapidly along a coastal area, and in a repeating pattern. Often, this pattern consists of a sandstone (beach), silty shale or siltstone (tidal), freshwater limestone (lagoon), underclay (terrestrial), coal (terrestrial swampy forest), shale (near shore tidal), limestone (shallow marine), and black shale (deep marine). This sequence can then repeat itself as the sea first regresses from the land, and then transgresses again (MDNR, 2013c).

19.3.3.2.3 Mississippian Age Osagean Series Burlington Formation (Mo)

The Mississippian age Burlington Formation stratum is the most extensively studied Mississippian age strata in Missouri. This crystalline, extremely fossiliferous limestone covers most of the state and extends into Iowa and Arkansas. Typical characteristics include white-to-gray, medium-to-coarsely grained layers of chert nodules, and a coarse-grained sedimentary structure called "styolites" formed from pressure solution. The pores in the styolites are often filled with chert or quartz deposits (MDNR, 2013d).

Burlington limestone is the principle limestone exposed in quarries, creek banks, and road cuts near and around Columbia. The limestone is approximately 49 m (160 ft) thick in the Columbia area, but the thickness can be variable. The limestone may also contain minor amounts of pyrite and limonite. This formation has historically been economically important as a limestone resource where exposed and as host rock for lead and zinc deposits in the presently inactive Tri-State mining district of Missouri, Kansas, and Oklahoma (MU, 2006a).

Burlington limestone contains many relatively shallow drilled wells and yields sufficient quantities of relatively hard water for rural domestic supplies. The limestone is relatively soluble and contains many caverns and solutions passages. Solution features, including caves and sinkholes, are commonly present in this formation (MU, 2006a). Terracon reported the following:

> *No caves or sinkholes are known to exist, or are published to exist within approximately 1 mi of the Discovery Ridge Research Park. However, several areas of known karst activity are present west and southwest of this project area and are in various stages of development. Site grading and drainage may alter site conditions and could possibly cause sinkholes in areas that have no history of this activity.* (Terracon, 2011b)

19.3.3.2.4 Mississippian Age Kinderhookian Series Chouteau Limestone (Mk)

The Mississippian age Chouteau Limestone stratum is a very fine-grained carbonate and, for the most part, is an evenly bedded bluish gray limestone. The upper part is somewhat massive and high in magnesium. Chouteau limestone is relatively impermeable due to its fine texture, restricting the movement of water to joints and small fissures. This unit is a poor source of water but yields small quantities to a few wells (MU, 2006a).

19.3.3.2.5 Late to Early Devonian Limestone (D)

Devonian limestone strata deposits greatly vary in lithology, and range from very fine-grained to coarsely textured beds. Some of the beds are slightly sandy. In some areas of Columbia, Missouri, the Devonian limestone beds are approximately 9 m (30 ft) thick; in other well locations this limestone bed is completely absent. Devonian limestone is not a valuable water producer (MU, 2006a).

19.3.3.2.6 Early Ordovician Age Ibexian Series Dolomites (Ojc)

Ordovician age deposits found in the Columbia area include the following, from youngest to oldest (MU, 2006a):

- **St. Peter Sandstone** – This formation, which is a very important aquifer in eastern and northern Missouri, has no importance in the Columbia area. The formation is present only as localized masses in the depressions of older rocks.
- **Jefferson City Formation** – This predominantly dolomite formation averages approximately 122 m (400 ft) in thickness in the Columbia area, and wells drilled into the formation produce moderate quantities of relatively hard water. The formation probably has more rural domestic wells terminating in it than any other formation is this area.
- **Roubidoux Formation** – This formation consists of alternating sandstone and dolomite beds and averages approximately 30.5 m (100 ft) in thickness. This formation is a very dependable water producer.
- **Gasconade Formation** – This unit consists of mostly light-gray dolomite with sandstone (Gunter) at the base. The thickness is approximately 85.3 m (280 ft). This dolomite unit is very cavernous and contains many interconnected solution passages. The sandstone is approximately 4.6 m (15 ft) thick, is very permeable, has a wide aerial extent, and is a good source of water.

19.3.3.3 Site-Specific Volcanic Hazard Analysis

The proposed RPF site is located in a tectonically stable region of the North American continental plate, identified as the Interior Plains Province. Volcanoes tend to cluster along narrow mountainous belts, where folding and fracturing of the rocks provide channelways to the surface for the escape of magma. The lack of magma forming in the Interior Plains Province prevents the formation of volcanoes in the region.

19.3.3.4 Onsite Soil Types

The USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic database for Boone County (NRCS, 2014) lists the soil type beneath the proposed RPF site as the Mexico Silt Loam, 1-4 percent slopes (Map No. 50059). In addition to the Mexico silt loam, 27 other soils types are located within a 1.6 km (1-mi) radius of the proposed site, as depicted in Figure 19-30.

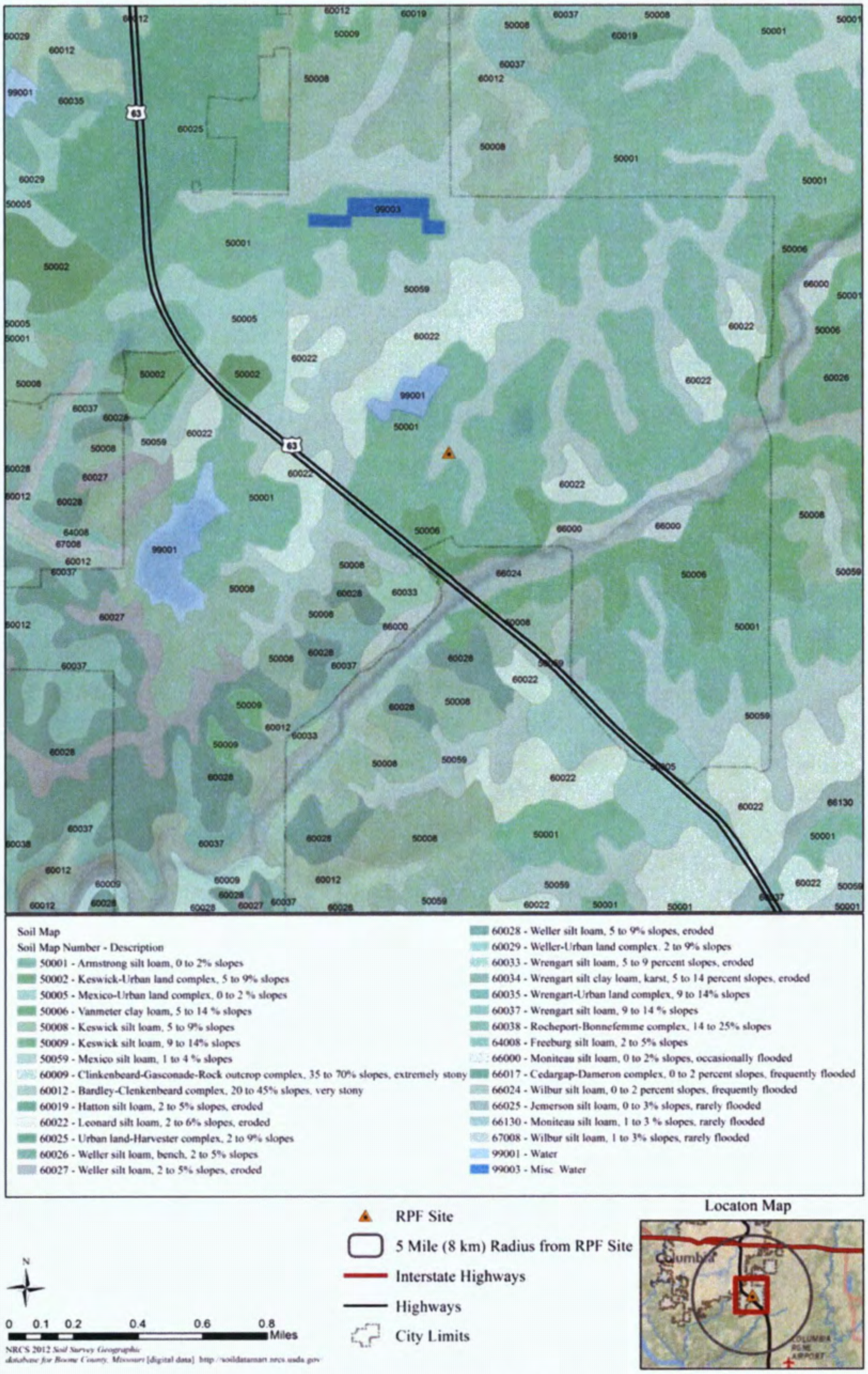


Figure 19-30. Soil Map within a 1.6 km (1-mi) Radius of the Proposed Radioisotope Production Facility Site

19.3.3.4.1 Site Soil Physical Characteristics

The soils were formed primarily from glacial processes that occurred in the region. Reworked loess is the primary parent material of the soil. The site soil composition, physical characteristics, and typical profile for the Mexico Silt Loam, 1–4 percent slopes (Map No. 50059) are listed in Table 19-28.

Table 19-28. Description of Soil Type, Mexico Silt Loam, 1–4 percent Slopes, Eroded

[a]Description	
Map Unit Setting *Landscape*: Till plains, uplands *Elevation*: 183 -396 m (600–1,300 ft) *Mean annual precipitation*: 94–119 cm (37-47 in.) *Mean annual air temperature*: 52–57°F *Frost-free period*: 184–228 days	**Map Unit Composition** *Mexico and similar soils*: 85% *Minor components*: 15%
Description of Mexico Setting *Landform*: Hillslopes, interfluves *Landform position (two-dimensional)*: Summit, backslope *Landform position (three-dimensional)*: Side slope, interfluve *Down-slope shape*: Concave, convex, linear *Across-slope shape*: Linear, convex *Parent material*: Loess over pedisediment	**Properties and qualities** *Slope*: 1–4% *Depth to restrictive feature*: More than 203 cm (80 in.) *Drainage class*: Poorly drained *Capacity of the most limiting layer to transmit water (Ksat)*: Very low to moderately low 0-0.15 cm/hr (0.00–0.06 in./hr) *Depth to water table*: Approximately 15.2 -45.7cm (6–18 in.) *Frequency of flooding*: None *Frequency of ponding*: None *Maximum salinity*: Nonsaline (0.0-2.0 mmho/cm) *Available water capacity*: High (approximately 27.4 cm [10.8 in.])
Typical profile *0 -17.8 cm (0–7 in)*: Silt loam *17.8 – 30.5 cm (7–12 in)*: Silty clay loam *30.5 – 66.4 cm (12–26 in)*: Silty clay *66.4 – 86.4 cm (26–34 in)*: Silty clay loam *86.4 – 203 cm (34–80 in)*: Silty clay loam	**Minor Components** **Leonard** *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Shoulder *Landform position (three-dimensional)*: Head slope *Down-slope shape*: Concave *Across-slope shape*: Concave *Ecological site*: Mollic loess upland prairie (R113XY002MO) *Other vegetative classification*: Mixed/transitional (mixed native vegetation)
Armstrong *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Backslope *Landform position (three-dimensional)*: Side slope *Down-slope shape*: Convex *Across-slope shape*: Convex *Other vegetative classification*: Mixed/transitional (mixed native vegetation)	**Mexico, severely eroded** *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Backslope, shoulder *Landform position (three-dimensional)*: Side slope *Down-slope shape*: Linear *Across-slope shape*: Concave, convex

[a] Source: USDA, 2013a, "Web Soil Survey," Online Mapping Tool, websoilsurvey.nrcs.usda.gov, U.S. Department of Agriculture, Washington, D.C., accessed July 10, 2013.

19.3.3.4.2 Site Soil Chemical Characteristics

The site soil chemical characteristics of the Mexico Silt Loam, 1–4 percent slopes (Map No. 50059) and the definitions of each chemical characteristic are listed in Table 19-29.

Table 19-29. Site Soil Chemical Characteristics for Boone County, Missouri

Map unit and soil name	Depth		Cation-exchange capacity (mEq/100 g)	Effective cation-exchange capacity (mEq/100 g)	Soil reaction (pH)	Calcium carbonate (%)	Gypsum (%)	Salinity (mmho/cm)	Sodium adsorption ratio
	cm	in.							
50059 Mexico Silt Loam, 1–4% slopes	0–17.8	0–7	11–24	9.1–20	5.6–7.3	0	0	0.0–2.0	0
	17.8–30.5	7–12	14–20	12–18	5.2–7.1	0	0	0.0–2.0	0
	30.5–66.4	12–26	22–38	17–30	4.5–5.2	0	0	0.0–2.0	0
	66.4–86.4	26–34	21–36	21–28	4.7–6.8	0	0	0.0–2.0	0
	86.4–203	34–80	20–29	16–23	4.9–7.1	0	0	0.0–2.0	0

Source: NRCS, 2014, "Soil Data Mart," soildatamart.nrcs.usda.gov/ReportViewer.aspx?File=a27391c0-b6ab-4278-871f-6f091cc147fa.PDF&Name= Chemical_Soil_Properties&Wait=1, Natural Resources Conservation Service, Washington, D.C., accessed July 16, 2013.

19.3.3.5 Prime Farmland

Prime farmland, as defined by the USDA, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. Prime farmland can be cultivated land, pastureland, forestland, or other land, but is not urban or built-up land or water areas. The soil qualities, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops when properly managed, including management of water and applying acceptable farming methods (NRCS, 2013).

In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. The land is permeable to water and air. Prime land is not excessively erodible or saturated with water for long periods, and is either not frequently flooded during the growing season or is protected from flooding. Areas of prime farmland in Missouri that do not require draining or flooding protection are comprised largely of Weller silt loam, Jemerson silt loam, and Lenzburg silty clay loam.

Farmland that is considered of statewide importance is land, in addition to prime farmlands, that is of statewide importance for the production of food, feed, fiber, forage, and oilseed crops. Criteria for defining and delineating this land are to be determined by the appropriate State agency or agencies. Generally, additional farmlands of statewide importance include those that are nearly prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce as high a yield as prime farmlands if conditions are favorable. In some states, additional farmlands of statewide importance may include tracts of land that have been designated for agriculture by State law. Farmlands of statewide importance in Missouri primarily include the Weller silt loam, Weller–Urban land complex, Wrengart silty clay loam, and Hatton silt loam (NRCS, 2013). Of these, the predominant soil type found in both prime farmland and farmlands of statewide importance is Weller silt loam. Approximately 4218 ha (10,424 acres), or one-fifth of the 8 km (5-mi) ROI, are prime or important farmland (NRCS, 2013). The proposed RPF site and the research park lie in areas not listed as prime farmland (Figure 19-31).

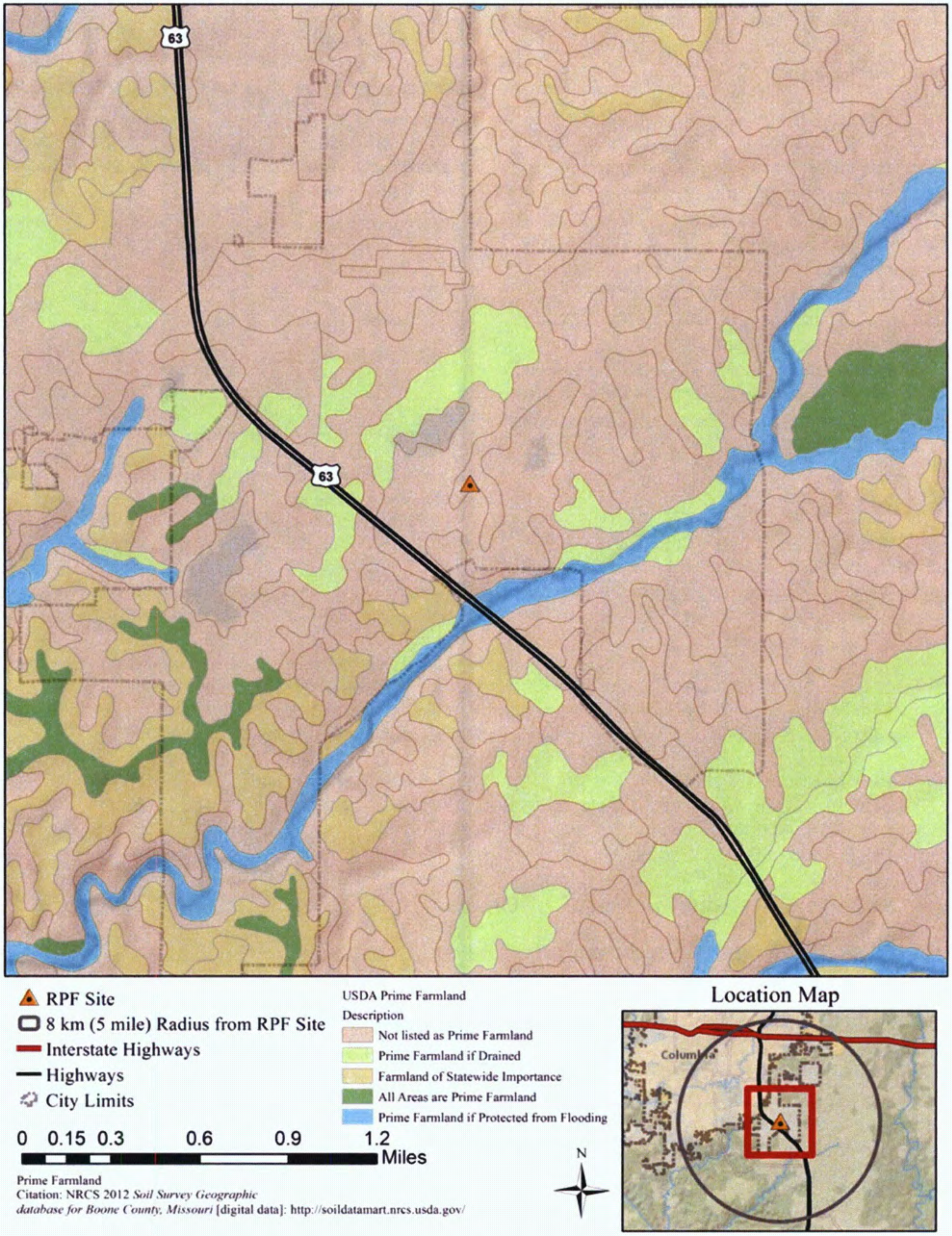


Figure 19-31. Map Showing U.S. Department of Agriculture Prime Farmland

Table 19-30 shows the breakdown of prime farmland and farmland of statewide importance within the ROI.

Table 19-30. Prime Farmland and Farmland of Statewide Importance

Description	Total	
	Acres	Hectares
Not listed as prime farmland	2,305	933
Prime farmland if drained	8,743	3,538
Farmland of statewide importance	9,102	3,683
All areas are prime farmland	1,322	535
Prime farmland if protected from flooding	2,793	1,130
Total	**24,265**	**9819**

Source: NRCS, 2013, "National Soil Survey Handbook," soils.usda.gov/technical/handbook/contents/part622.html, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, D.C., accessed July 25, 2013.

19.3.3.6 Shrink-Swell Potential

There are moderate to highly plastic clays at Discovery Ridge from approximately 0.9–3.7 m (3–12 ft) below ground surface (Terracon, 2011b). Such soils are commonly referred to as "expansive" or "swelling" soils because they expand or swell as their moisture content increases. These soils, in turn, contract or shrink as their moisture content decreases. Footings, floor slabs, and pavements supported on expansive soils will often shift upward or downward causing possible distortion, cracking, or structural damage (Terracon, 2011b).

19.3.3.7 Erosion

Erosion is a naturally occurring process that is unnaturally accelerated by land development. The highest risks for erosion occur in areas with fine soils, on steep slopes, and in areas undergoing active construction activities. Impervious surfaces do not allow water infiltration into the soils and instead cause increased stormwater runoff.

Soils denuded of vegetation and impervious surfaces are two potential effects of land development that contribute to greater peak flows, longer duration of high flows, and increased sedimentation. Eroded material is often deposited downstream where the material decreases culvert and channel capacity.

The soils beneath the proposed RPF site are Mexico silt loam and are listed as hydrologic soil Group D (NRCS, 2014). Group D soils have a very slow infiltration rate when thoroughly wet, leading to high runoff potential. Mexico Silt Loam consists chiefly of clays that have a high shrink-swell potential and have a high water table (NRCS, 2013).

19.3.3.8 Previous Geological Studies by Others

19.3.3.8.1 Preliminary Geotechnical Investigation

In 2011, Terracon completed a preliminary geotechnical investigation for the Discovery Ridge Certified Site Program, which included Lot 2 and Lots 5 through 18 of Discovery Ridge (Terracon, 2011b). The proposed RPF site (Lot 15) is within the investigation area. The purpose of the investigation was to provide preliminary geotechnical recommendations concerning earthwork and the design and construction of foundations, floor slabs, and pavements for Discovery Ridge properties. As part of the study, nine soil borings (B-1 through B-9) were installed to depths ranging from 4–6 m (13–20 ft) below ground surface to determine shallow subsurface soil geotechnical properties and shallow groundwater depth. Soil boring B-5 is nearest to the proposed RPF site, along the eastern boundary between Lots 14 and 15.

Discovery Ridge surface soils from 0.6–0.15 m (0.2–0.5 ft) below ground surface were found to be brown, friable topsoil with significant amounts of organic matter. Subsurface soils from approximately 0.9-3.6 m (3–12 ft) below ground surface were lean clay, lean-to-fat clay, and fat clay with moderate-to-high plasticity. Material beneath 3.6 m (12 ft) is listed only as limestone. Plasticity and liquid limit tests were completed for soils encountered from only four soil borings, as shown in Table 19-31.

Table 19-31. Plasticity and Liquid Limit Testing

Soil boring	Depth (m below ground surface)	Depth (ft below ground surface)	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
B-1	0.9-1.5	3–5	43	15	28
B-3	0.3-0.9	1–3	41	16	25
B-5	0.3-0.9	1–3	31	21	10
B-9	0.3-0.9	1–3	44	21	23

Source: Terracon, 2011b, *Preliminary Geotechnical Engineering Report Discovery Ridge–Certified Site Program Lots 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18*, Terracon Consultants, Inc., prepared for University of Missouri and Trabue, Hansen & Hinshaw, Inc., Terracon Project No. 09105094.1, February 11, 2011.

At the time of drilling, some of the soils displayed moisture levels greater their measured plastic limits. "Soils with moisture levels above their measured plastic limits may be prone to rutting and can develop unstable subgrade conditions during general construction operations" (Terracon, 2011b). Moderate to high plasticity clays were observed at the site. Such soils are commonly referred to as "expansive" or "swelling" soils because they expand or swell as their moisture content increases. These soils in turn, contract or shrink as the moisture content decreases. Footings, floor slabs, and pavements supported on expansive soils often shift upward or downward causing possible distortion, cracking, or structural damage.

19.3.3.9 Regional and Local Tectonics

The most significant seismological feature in Missouri is the New Madrid Seismic Zone (NMSZ), located in the southeastern corner of the state and extending into parts of the contiguous states of Arkansas, Tennessee, Kentucky, and Illinois. The NMSZ is the most seismically active region in the U.S. east of the Rocky Mountains and is located approximately 483 km (300 mi) southeast of the proposed RPF site. During the winter of 1811–1812, the NMSZ was the location of some of the highest intensity seismic events ever noted in U.S. history. Hundreds of aftershocks, some severely damaging, continued for years.

Records show that since 1900, moderately damaging earthquakes have struck the NMSZ every few decades. Prehistoric earthquakes similar in size to those of 1811–1812 occurred in the middle 1400s and around 900 A.D. Strongly damaging earthquakes struck the southwestern end of the NMSZ near Marked Tree, Arkansas, in 1843 (magnitude 6.0), and the northeastern end near Charleston, Missouri, in 1895 (magnitude 6.6) (USGS, 2011a).

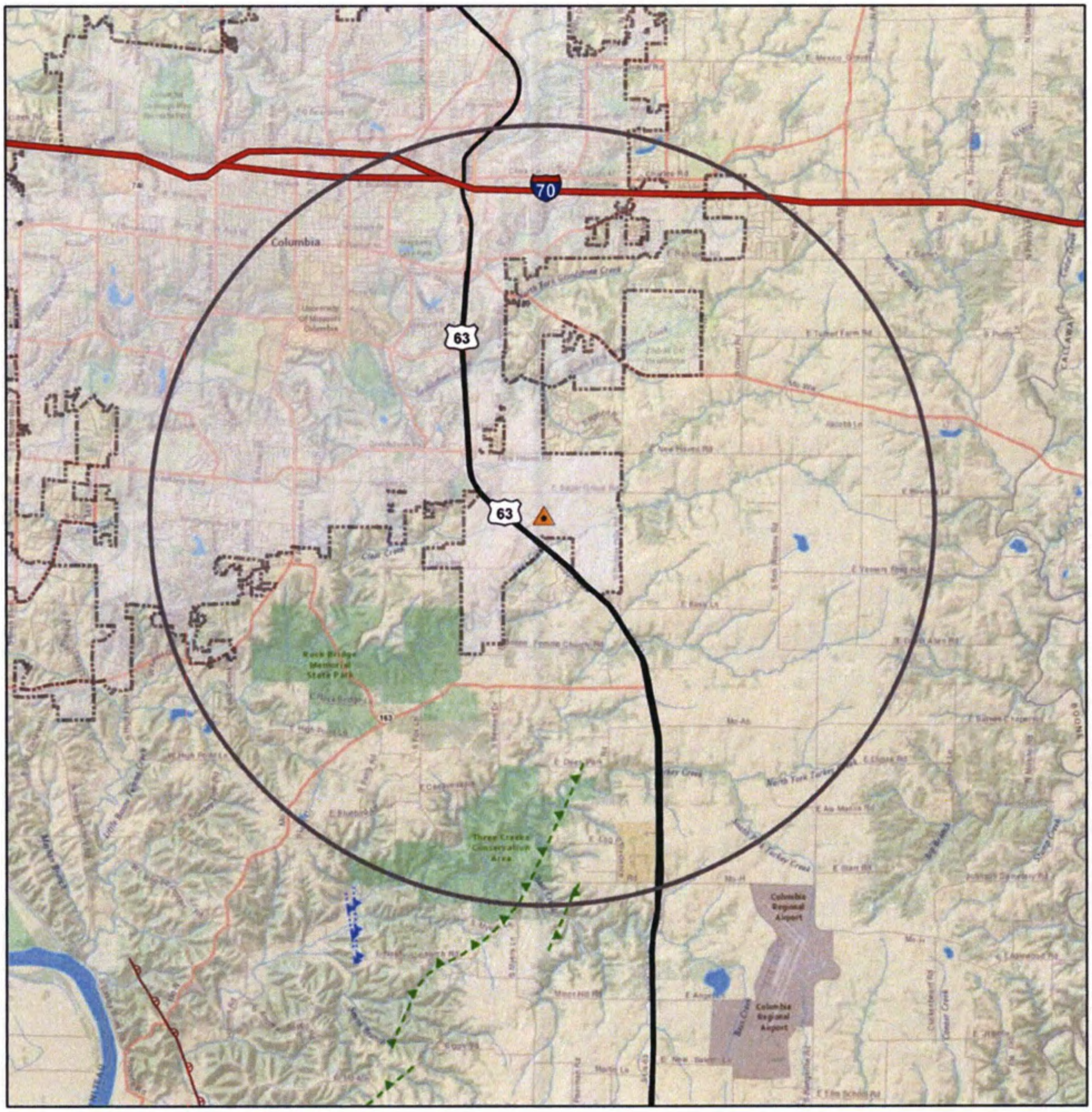
The NMSZ is made up of reactivated faults that formed when what is now North America began to split or rift apart approximately 500 million years ago. The resulting rift system died out before an ocean basin was formed, but a deep zone of weakness was created, referred to as the Reelfoot rift (USGS, 2011b). This fault system extends 241 km (150 mi) southward from Cairo, Illinois, through New Madrid and Caruthersville, Missouri, down through Blytheville, Arkansas, to Marked Tree, Arkansas. The Reelfoot rift dips into Kentucky near Fulton and into Tennessee near Reelfoot Lake, extending southeast into Dyersburg, Tennessee. The rift then crosses five state lines and crosses the Mississippi River in at least three places. The fault system is buried beneath as much as 8 km (5 mi) of sediment for much of the fault length and typically cannot be seen at the surface (USGS, 2011b).

Four of the largest faults are recognized as alignments of abundant small earthquakes, and movements along two of these faults dammed rivers and created lakes during the earthquakes of 1811–1812. A few more deeply buried faults were detected during oil and gas exploration, and a few small faults are known from geologic mapping (USGS, 2011b).

The remainder of the state, including the proposed RPF site located in central Missouri, is typical of the stable midcontinent U.S. However, this area is not immune to seismic activity.

19.3.3.9.1 Local Fault Zones

There is one major fault zone located within the ROI of the proposed RPF site (Figure 19-32). The Fox Hallow Fault is located approximately 5.6 km (3.5 mi) southeast of the site. The Fox Hollow Fault is a small fault, striking northeast and fades into a monocline at its two ends. The fault is reportedly a normal fault with a throw of approximately 37 m (120 ft) down to the southwest, and shows Mississippian age Chouteau limestone beds faulted against Ordovician age Jefferson Dolomite (Union Electric Company, 2008).



RPF Site
8 km (5 mile) Radius from RPF Site
Interstate Highways
Highways
City Limits

0 0.5 1 2 3 4 Miles

Fault Structures
NAME
Bonne Femme Creek graben
Fox Hollow fault and monocline
Sapp monocline

MoDNR 2010. MO 2010 Tectonic Fault Structures (SHP)
MoDNR/DGLS/GSP [digital data]: ftp://msdis.missouri.edu/pub/
Geological_Geophysical/MO_2010_Tetonic_Fault_Structures_shp-.zip

Figure 19-32. Geologic Faults Map

19.3.3.10 Seismic Hazard Assessment

Earthquakes occur on faults within bedrock, usually several miles deep. According to the USGS, earthquakes in the central and eastern U.S. typically are felt over a much broader region than in the western U.S. East of the Rocky Mountains, an earthquake can be felt over an area ten times larger than a similar magnitude earthquake on the west coast.

The written record of earthquakes in Missouri prior to the nineteenth century is virtually nonexistent. Historical earthquakes along the NMSZ in southeastern Missouri have been some of the largest in U.S. history since European settlement. The Great New Madrid Earthquake of 1811–1812 was a series of over 2,000 earthquakes that caused destruction over a very large area. According to information from Missouri's State Emergency Management Agency Earthquake Program, some of the earthquakes measure at least 7.6 in magnitude and five of them measured 8.0 or greater (USGS, 2011a). The 1811–1812 series changed the course of the Missouri River, and some shocks were felt as far away as Washington, D.C., and Boston, Massachusetts (MMRPC, 2010). The NMSZ has experienced numerous earthquakes since the 1811–1812 series, and at least 35 aftershocks of Modified Mercalli Intensity (MMI) of V (i.e., felt by nearly everyone, many awakened) or greater that have been recorded Missouri since 1811. Numerous earthquakes originating outside of Missouri boundaries have also affected the state. Table 19-32 lists the historical earthquakes that have affected Missouri.

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
12/16/1811 (1811–1812 series)	New Madrid Region, Missouri	7.7	Generated great waves on the Mississippi River causing major flooding, high river back cave-ins. Topographic changes affected an area of 78,000 to 130,000 km^2 (30,116 to 50,193 mi^2). Later geologic evidence indicated that the epicenter was likely in northeast Arkansas. The main shocks were felt over an area covering at least 5,180,000 km^2 (2,000,000 mi^2). Chimneys were knocked down in Cincinnati, Ohio, and bricks were reported to have fallen from chimneys in Georgia and South Carolina. The first shock was felt distinctively in Washington, D.C., 1,127 km (700 mi) away.
12/23/1812 (1811–1812 series)	New Madrid, Missouri	7.5	Second major shock more violent than the first.
2/7/1812 (1811–1812 series)	New Madrid, Missouri	7.7	Three main shocks reaching MMI of XII, the maximum on scale. Aftershocks continued to be felt for several years after the initial tremor. Historical accounts and later evidence indicate that the epicenter was close to the town of New Madrid, Missouri. This quake produced the largest liquefactions fields in the world.
1/4/1843	New Madrid, Missouri	Not listed	Cracked chimneys and walls in Memphis, Tennessee, and reportedly collapsed one building. The earth sank in some places near the town of New Madrid, Missouri, and an unverified report indicated that two hunters were drowned during the formation of a lake. The total felt area included at least 1,036,000 km^2 (400,000 mi^2).

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
4/24/1867	Eastern Kansas	Not listed	Reports indicated that an earthquake occurred in eastern Kansas and was felt as far eastward as Chicago, Illinois. The earthquake may have been noticeable in Columbia.
8/31/1886	Charleston, South Carolina	Not listed	An MMI of II earthquake recorded in St. Louis, Missouri, and was felt as far westward as Columbia. There were no reports of structural damage.
10/31/1895	Charleston, Missouri	6.6	Largest earthquake to occur in the central Mississippi River valley since the 1811–1812 series. Structural damage and liquefaction phenomena were reported along a line from Bertrand, Missouri, in the west to Cairo, Illinois, to the east. Sand blows were observed in an area southwest of Charleston, Puxico, and Taylor, Missouri; Alton, and Cario, Illinois; Princeton, Indiana; and Paducah, Kentucky. The earthquake caused extensive damage (including downed chimneys, cracked walls, shattered windows, and broken plaster) to schools, churches, and private residences. Every building in the commercial area of Charleston was damaged. Cairo, Illinois, and Memphis, Tennessee, suffered significant damage. Near Charleston, 1.6 ha (4 acres) of ground sank and a lake formed. The shock was felt over all or portions of 24 states and in Canada. Ground shaking was recorded along the Ohio River Valley.
1903	New Madrid, Missouri	5.1	No information given.
4/9/1917	St. Genevieve/ St. Mary's Area, Missouri	Not listed	A sharp disturbance at St. Genevieve and St. Mary's, Missouri. According to the Daily Missourian, No. 187, dated April 9, 1917, the earthquake was not felt in Columbia. However, on the following day, several people reported feeling the shock and attributed it to an explosion. No damage was reported in Columbia. Reportedly felt over a 518,000 km^2 (200,000 mi^2) area from Kansas to Ohio and Wisconsin to Mississippi.
5/1/1920	Missouri or Illinois	Not listed	This earthquake reportedly shook buildings across St. Louis. Two shocks were felt in Mt. Vernon, Illinois, and three were felt in Centralia, Illinois. The epicenter of this earthquake is unknown and is thought to have originated east of Columbia in Illinois. In the Evening Missourian, No. 207, dated May 1, 1920, the U.S. Weather Bureau reported that the shock was not felt in Columbia. However, in a later investigation a few people reported feeling a slight tremor.
8/19/1934	Rodney, Missouri	Listed as strong	At nearby Charleston, windows were broken and chimneys collapsed or were damaged. Similar effects were observed in Cairo, Mounds, and Mounds City, Illinois, and at Wickliffe, Kentucky. The area of destructive intensity included more than 596 km^2 (230 mi^2)

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
11/23/1939	Western Illinois	Not listed	An earthquake occurred near Red Bud, Illinois, and a reported MMI of II was recorded in Columbia, Missouri. The approximately distance from the epicenter to Columbia was 213 km (132 mi).
3/3/1963	Near Menorkanut, Missouri	Not listed	MMI of III was recorded in Columbia. The approximately distance from the epicenter to Columbia was 317 km (197 mi).
10/21/1965	Eastern Missouri	Not listed	MMI of V in Columbia. The approximate distance from the epicenter to Columbia was 163 km) (101 mi).
11/9/1968	Wabash Valley Seismic Zone, southern Illinois	5.4	Strongest magnitude in central U.S. since the 1895 earthquake. Moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. Shaking was felt. Areas include all or portions of 23 states from Minnesota to Georgia and from Pennsylvania to Kansas, and in multi-story buildings in Boston, Massachusetts and southernmost Ontario, Canada.
1987	Wabash Valley Seismic Zone, near Olney, Richland County, SE Illinois	5.0	Chimneys and bricks fell, underground pipes were damaged, and sidewalks and streets cracked in at least four cities in Illinois, Indiana, and Kentucky. Shaking was felt in 17 states, from Pennsylvania to Kansas and from Alabama to Minnesota and southernmost Ontario, Canada.
2002	Wabash Valley Seismic Zone, Posey County, SW Indiana	4.6	Moderate earthquake caused chimney damage and cracked windows in and near Evansville, Indiana. Shaking was reported in seven states, including Missouri.

Sources:

USGS, 2013c, "Three Centuries of Earthquakes Poster," pubs.usgs.gov/imap/i-2812/i-2812.jpg, U.S. Geological Survey, Reston, Virginia, accessed July 23, 2013.

USGS, 2002, "Earthquakes in the Central United States 1699 -2002," pubs.usgs.gov/imap/i-2812/i-2812.jpg, U.S. Geological Survey, Reston, Virginia, June 18, 2002.

MU, 2006a, *Missouri University Research Reactor (MURR) Safety Analysis Report*, MU Project# 000763, University of Missouri, Columbia, Missouri, August 18, 2006.

MMI = Modified Mercalli Intensity.

In 2002, the USGS released the following projected hazards for Boone County, if an earthquake occurred along the NMSZ in the following 50 years (USGS, 2003):

- 25 to 40 percent chance of a magnitude 6.0 and greater earthquake
- 7 to 10 percent chance of a magnitude 7.5–8.0 earthquake

According to the USGS, Boone County is one of the 47 counties in Missouri that would be severely impacted by a 7.6 magnitude earthquake with an epicenter on or near the NMSZ.

According to the *Boone County Hazard Mitigation Plan* for 2010 (MMRPC, 2010), the Missouri State Emergency Management Agency has made projections of the highest earthquake intensities that would be experienced throughout Missouri if various magnitude earthquakes occur along the NMSZ (Figure 19-33), as measured by the MMI scale.

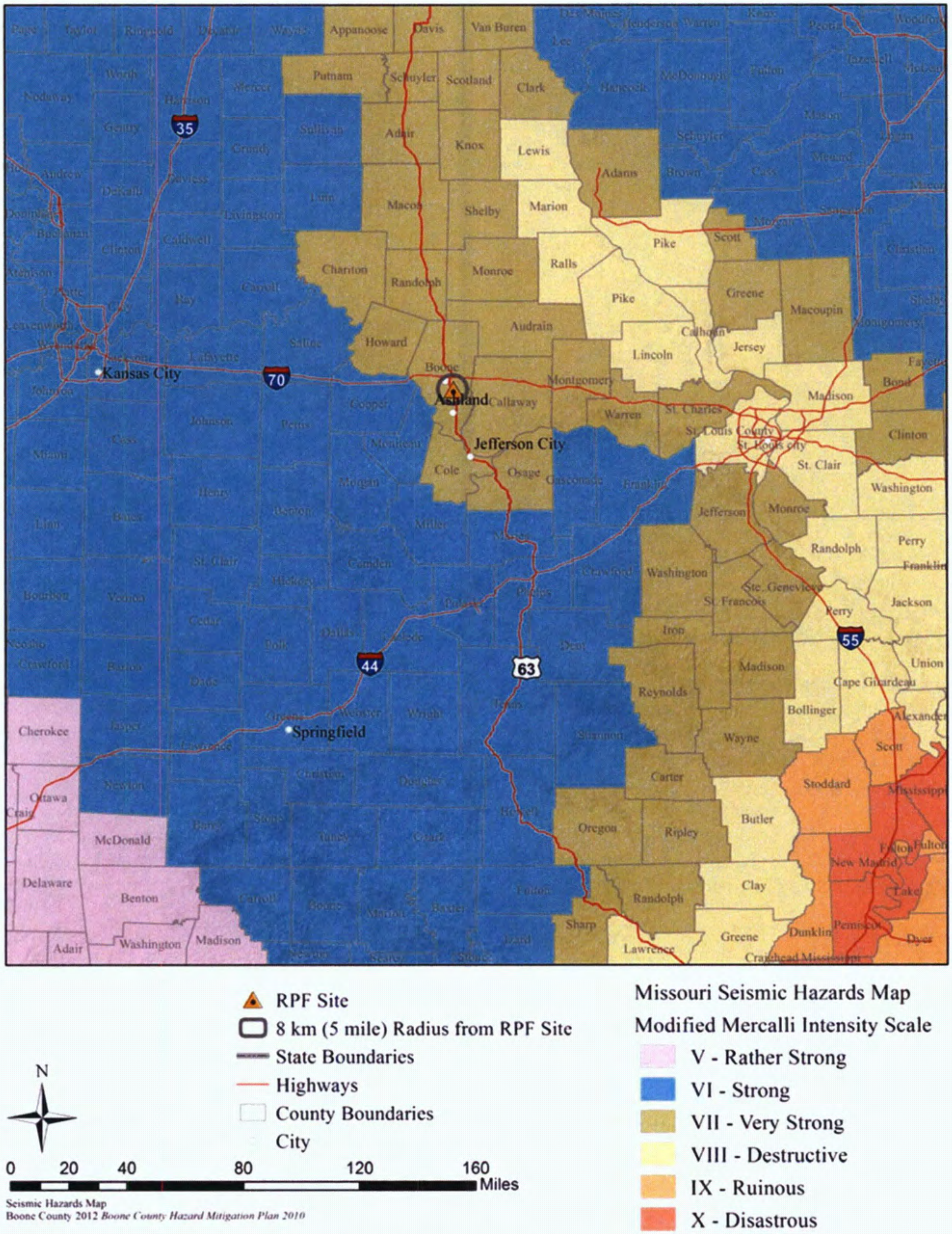


Figure 19-33. Hazard Mitigation Map

The pertinent earthquake hazard information for Boone County is summarized in Table 19-33.

Table 19-33. Projected Earthquake Hazards for Boone County

Magnitude at NMSZ	Probability of occurrence (2002–2052)	Intensity in Boone County (MMI)	Expected damage
6.7	25–40%	VI, strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
7.6	7–10%	VII, very strong	Difficult to stand; significant damage to poorly or badly designed buildings, adobe houses, old walls, spires, and other; damage would be slight to moderate in well-built buildings; numerous broken windows; weak chimneys break at roof lines; cornices from towers and high buildings fall; loose bricks fall from buildings; heavy furniture is overturned and damaged; and some sand and gravel streambanks cave in.

Source: MMRPC, 2010, *Boone County Hazard Mitigation Plan*, www.mmrpc.org/the-region/boone-county, Mid-Missouri Regional Planning Commission, State of Missouri Emergency Management Agency, Ashland, Missouri, July 15, 2010.

MMI = Modified Mercalli Intensity.
NMSZ = New Madrid Seismic Zone.

The USGS National Seismic Hazard Maps display earthquake ground motions for various probability levels across the U.S. and are applied in seismic provisions of building codes, insurance rate structures, risk assessments, and other public policy. Updates to these maps incorporate new findings on earthquake ground shaking, faults, seismicity, and geodesy. The resulting maps are derived from seismic hazard curves calculated on a grid of sites across the U.S. that describe the frequency of exceeding a set of ground motions. In accordance with the 2008 USGS Scientific Investigation Map (No. 3195), the proposed RPF site is within the third lowest earthquake hazard area with peak acceleration potentials of 2–3 (USGS, 2008). This category indicates an estimated horizontal ground shaking level between 8-in-100 to 16-in-100 chance of being exceeded in a 50-year period.

According to the *Boone County Hazard Mitigation Plan* for 2010 (MMRPC, 2010), the entire county is at risk for effects of an earthquake along the NMSZ. Areas near the Missouri River could be particularly vulnerable due to the soil or alluvium along river channels being susceptible to liquefaction from amplification waves (MMRPC, 2010).

19.3.3.11 Other Geologic Hazards

Tectonic uplift and subsidence, ground-shaking amplification, landslides, and liquefaction are four specific hazards associated with earthquakes. The severity of these hazards depends on several factors, including soil and slope conditions, proximity to the fault, earthquake magnitude, and the type of the earthquake. Other geological hazards present in karst environments (i.e., Boone County) and prevalent in Missouri include caves and sinkholes.

19.3.3.12 Tectonic Uplift and Subsidence

Faulting due to compressive forces elevates rocks of the up-thrown side of the fault, while the down-thrown side of the fault undergoes tilting and subsidence. A regional example of this is the Ozark Plateau.

19.3.3.13 Earthquake Ground-Shaking Amplification

Earthquakes generate seismic waves at a wide variety of frequencies, and certain frequencies may be amplified by site-specific soil conditions. Soils and soft sedimentary rocks near the surface can modify bedrock ground shaking caused by an earthquake. This modification can increase (or decrease) the strength of shaking or change the frequency of the shaking. The nature of the modification is determined by the thickness of the geologic materials and their physical properties (e.g., stiffness).

Areas with thin sedimentary deposits experience less severe amplification than areas with thick deposits. In areas with thick sedimentary deposits, low frequency seismic energy is amplified, yielding slow, rolling-type shaking that can damage tall buildings, bridges, and overpasses. Areas with thin sand and gravel layers deposited on top of bedrock amplify high-frequency seismic waves that yield intense ground vibrations causing more damage to shorter buildings (USGS, 2011b).

Lateral spreading can occur during periods of extended seismic ground shaking. This is commonly seen in areas with saturated soils near bays or rivers. During the 1811–1812 New Madrid series of earthquakes, lateral spreading produced extensive ground deformation along the banks of the Mississippi River (USGS, 2009).

19.3.3.14 Earthquake-Induced Landslides

Earthquake-induced landslides are secondary hazards that occur from ground shaking, primarily in areas with steep slopes. Not all earthquake-induced landslides occur in the first few minutes following an earthquake, some can occur days later. A landslide occurs when the force that is pulling the slope downward exceeds the strength of the earth materials that compose the slope.

Large areas between the Missouri and Mississippi Rivers are blanketed by Pleistocene loess and glacial drift. Particularly susceptible to slumps and earth flows are loess along major river valleys and their tributaries, clayey till on slopes underlain by shale, and some Pennsylvanian shale units in southwestern Iowa, northwestern Missouri, and eastern Oklahoma.

The 1811–1812 earthquakes caused many types of ground failures, including landslides along the Mississippi River bluffs from Mississippi to Kentucky (USGS, 2009).

19.3.3.15 Liquefaction

Liquefaction is a process by which water-saturated sediment temporarily loses strength and acts as a fluid when exposed to strong seismic shaking. The shaking causes the grains to lose grain-to-grain contact, so the sediment tends to flow. Liquefaction most likely occurs in loose sandy soil with a shallow water table (which is common for areas around floodplains or bays). Liquefaction often leads to overpressured fluids that can erupt to the surface, forming features known as sand blows. The 1811–1812 earthquakes caused ground subsidence by soil liquefaction across the Mississippi River flood plain and along tributaries to the Mississippi River over at least 15,000 square kilometers (km^2) (9,320.6 square miles [mi^2]). Liquefaction along the Mississippi River Valley during the 1811–1812 earthquakes created one of the world's largest sand-blown fields. According to the USGS, recent sand blows dot the landscape surrounding New Madrid, Missouri (USGS, 2011b).

19.3.3.16 Caves and Sinkholes

In the U.S., the most damage in areas composed of karst terrain tend to occur in the states of Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. Karst, as defined by the USGS, "is a terrain with distinctive landforms and hydrology created from the dissolution of soluble rocks, principally limestone and dolomite. Karst terrain is characterized by springs, caves, sinkholes, and a unique hydrogeology that results in aquifers that are highly productive but extremely vulnerable to contamination" (MMRPC, 2010).

According to the MDNR, 59 percent of the state is underlain by thick, carbonate rock units that host a wide variety of karst features (MDNR, 2013c). The Missouri Speleological Survey reports that there are now more than 6,000 known caves in Missouri (MSS, 2013). Of those recorded, the most famous is the Devil's Ice Box in Rock Bridge State Park. According to the Boone County Stormwater Program (Boone County, 2013a), there are 418 documented sinkholes with a depth of 6.1 m (20 ft) or greater within the county. All of these sinkholes are relatively stable but some do discharge into the cave system and groundwater. About 290 of these sinkholes are located between U.S. Interstate 70 and Ashland, Missouri, in the southwestern corner of Boone County. The karst regions of the southwestern portion of the county make the area a prime location for this hazard. Development on karst terrain can present certain hazards such as unstable soil foundation for structures, flooding, groundwater contamination, and public safety hazards related to sinkhole collapses.

Sinkholes, like landslides, are a form of ground movement that can happen suddenly and without warning, causing major damage. Sinkholes are common where the bedrock below the land surface is composed of limestone, dolomite, or gypsum that can naturally be dissolved by circulating groundwater (USGS, 2007).

While many sinkholes occur as circular, bowl-shaped depressions, others are not readily visible on the surface because voids are plugged or capped with soil or thin layers of rock. The sinkholes begin with slow soil piping (erosion) over a long period. When the soil above the void can no longer support itself, the soil collapses to reveal a deep hole that connects to an underlying bedrock opening. These voids may be discovered during excavation, by drilling or through geophysical exploration. Residential and commercial development in a karst area can pose environmental and logistical problems. Aside from structurally impacting foundations of homes and other buildings, sinkholes often serve as direct conduits for rapid surface water infiltration into the underlying groundwater aquifer. Contaminants near or at the surface can quickly enter the aquifer and pollute drinking water supplies. Increased stormwater runoff resulting from parking lots, highways, and household guttering often is diverted into sinkholes. The increased inflow of water not only can transport contaminants but also can lead to the accelerated development and growth of sinkholes (MDNR, 2013e).

Sinkholes vary in size. They can be small and have little impact on people, or they can be catastrophic and destroy property, underground utilities, buildings, lagoons, and contaminate groundwater resources (USGS, 2007).

During the geotechnical investigation conducted by Terracon in 2011, there was no evidence of shallow bedrock, karst features, and/or extensive pervious deposits of water-bearing sand observed in the soil cuttings from Boreholes B-1 through B-9. In addition, Terracon reported that they did not observe evidence of subsidence or sinkholes within the Discovery Ridge project area (Terracon, 2011b).

19.3.4 Water Resources

The ROI for the water resource is defined as the 8 km (5-mi) radius surrounding the RPF site. About 66 percent of Missouri water resources are obtained from surface water bodies, and the remaining 34 percent are obtained from groundwater wells. During a normal precipitation year, approximately 45.4 trillion L (12 trillion gal) of water are supplied to Missouri by runoff from precipitation within the state. Rainfall averages approximately 97 cm (38 in.) statewide, with approximately 25.4 cm (10 in.) becoming surface water runoff or groundwater recharge. The remaining 71 cm (28 in.) are returned to the atmosphere by evaporation or plant use.

Surface water sources provide the bulk of water withdrawals statewide. In 1990, freshwater surface water withdrawals in Missouri were estimated at 1,866 ML/day (493 Mgal/day), compared to 700 ML/day (185 Mgal/day) from groundwater sources. The majority of these withdrawals came from surface water intakes along major streams and rivers where streams have adequate low flows. The Missouri and Mississippi Rivers supply municipal water to approximately one-third of the state population (DuCharme and Miller, 1996).

More than 500,000 Missourians rely on other surface water sources, including human-made reservoirs, for their water needs. Although many of the state's larger reservoirs (e.g., Truman Reservoir, Mark Twain Lake) serve some water supply purposes, a substantial segment of the population uses much smaller lakes constructed specifically to meet local water needs. Sufficient water supplies from these locations are readily available for local public water supply districts and municipalities. Approximately 123 reservoirs are currently in use as public water supply sources in Missouri, and all but eight of these reservoirs are located in northern and western Missouri (DuCharme and Miller, 1996).

Missouri groundwater resources come primarily from two sources: bedrock aquifers and shallower alluvial aquifers. Most public water supply facilities currently operating in Missouri rely, to some extent, on groundwater wells as a source of water supply. Most self-supplied residential, commercial, and industrial water withdrawals are extracted via groundwater wells.

19.3.4.1 Surface Hydrology

Surface waters in central and southern Boone County drain into the Missouri River through a number of tributaries, including Bonne Femme, Cedar, Little Cedar, Hinkson, Jemerson, and Perche Creeks (Figure 19-34). The other major drainage feature in the county is a system of karst topography west and south of Columbia. Numerous sinkholes, some filled with water, overlie a complex network of caves and springs. Gans Creek, which drains Discovery Ridge and the proposed RPF site, is located within the Bonne Femme Watershed.

19.3.4.1.1 Bonne Femme Watershed

The Bonne Femme Watershed is comprised of two major sub-watersheds: the Bonne Femme and the Little Bonne Femme. Topographical contours of the land define the Bonne Femme Watershed, which encompasses approximately 241 km^2 (93 mi^2) (approximately 15 percent) of Boone County, including the proposed RPF site (BFSC, 2007). The RPF site is located within the northern portion of this watershed (Little Bonne Femme sub-watershed) and is approximately 0.4 km (¼-mi) north of Gans Creek (see Figure 19-35).

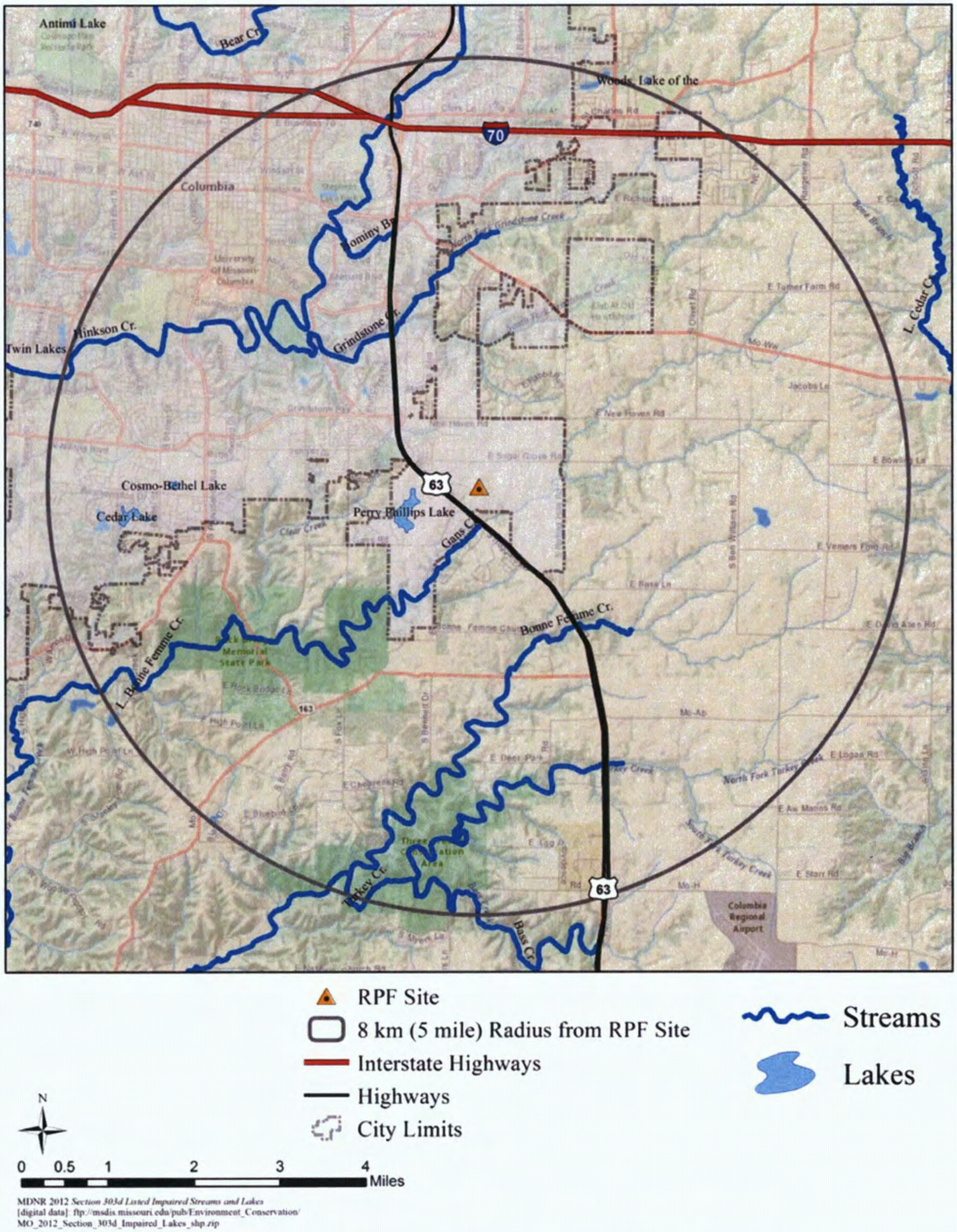


Figure 19-34. Streams of Southern Boone County, Missouri

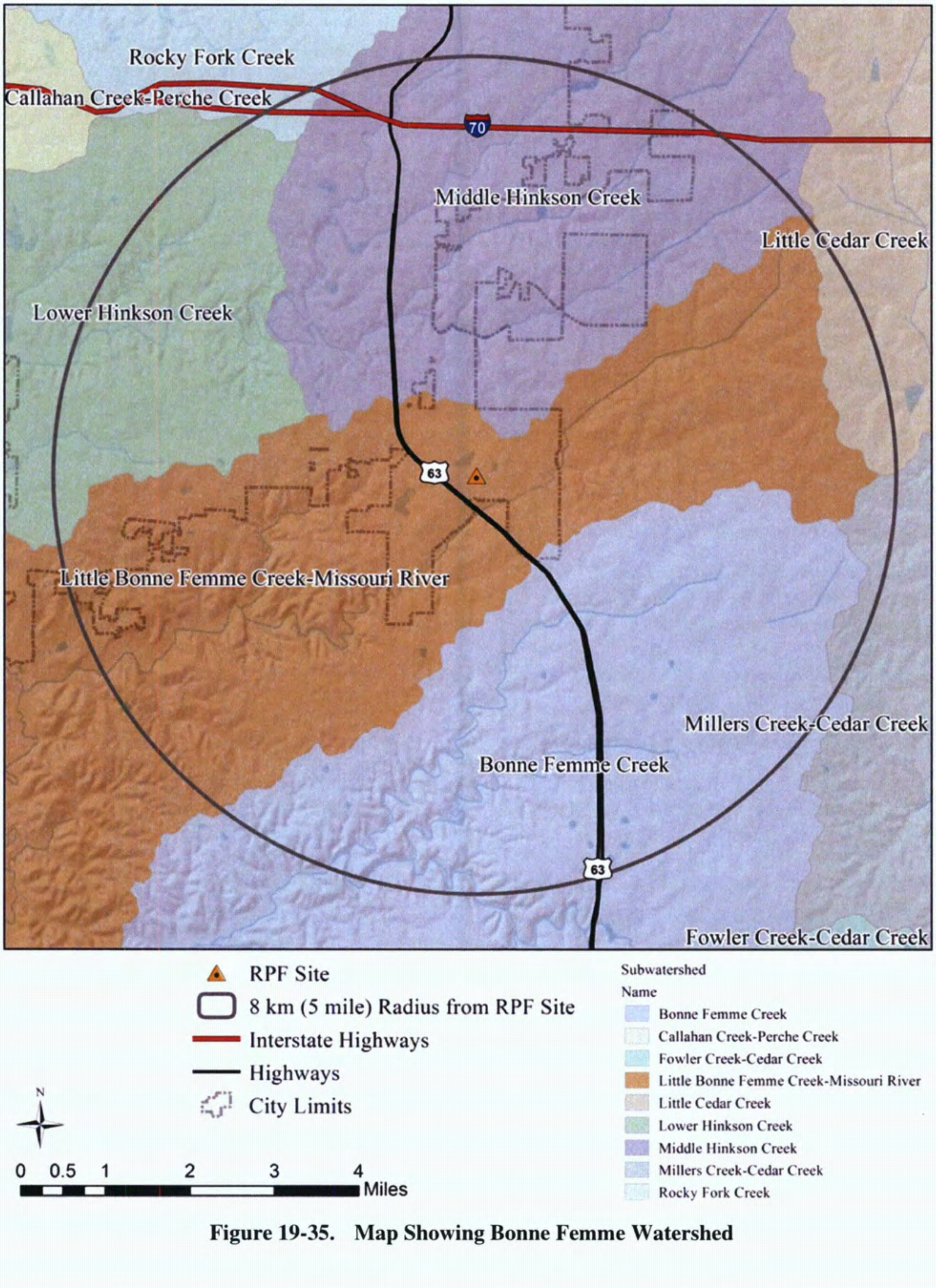


Figure 19-35. Map Showing Bonne Femme Watershed

Both the Bonne Femme and Little Bonne Femme creeks flow from east to west in a dendritic alignment into the Missouri River and are interconnected by the Devil's Icebox Cave Branch. Where Gans Creek meets Clear Creek, the Little Bonne Femme begins and flows south toward the Mayhan Branch. The Little Bonne Femme enters the Missouri River approximately 0.8 km (0.5 mi) south of this confluence. To the south, the Bonne Femme meets with the Fox Hollow Branch and then flows into the Missouri River (BFSC, 2007).

The most distinctive characteristic of the Bonne Femme Watershed is its karst topography. Within the karst terrain, the hydrology becomes complex because of losing and gaining sections of streams. Rough estimates show approximately 33 stream segments composing approximately 37 km (23 mi) of losing streams (143 km [89 mi] of gaining stream) within the watershed. There are two main recharge areas tied to these losing and gaining sections of stream, including (1) Devil's Ice Box recharge zone (3,397 ha [8,394 acres] of drainage), and (2) Hunter's Cave recharge zone (3,330 ha [8,228 acres] of drainage) (BFSC, 2007).

A mixture of land uses occurs within the Bonne Femme watershed. The predominant land use accounting for 61.5 percent of the watershed is agricultural activities, including row crop productions, pasture, and range lands. Forested areas make up nearly one-third of the watershed, mainly within the central and western portion of the watershed. These forested areas also encompass most of the publicly owned lands, including Rock Bridge Memorial State Park and Three Creeks Conservation Area (BFSC, 2007).

19.3.4.1.2 Water Quality of Bonne Femme Watershed

Water quality monitoring studies began in the Bonne Femme Watershed in 1999 and included two sites: Hunters and Devil's Icebox Spring Branches. In 2001, the monitoring program was expanded to include six surface sub-watersheds (Clear Creek, Upper Bonne Femme Creek [at U.S. Highway 63], Turkey Creek, Lower Bonne Femme Creek [at Nashville Church Road], Little Bonne Femme Creek, and Fox Hollow Creek), and the two cave systems. In 2003, two additional sub-watersheds (Gans Creek and Bass Creek) were included to the monitoring plan (BFSC, 2007).

19.3.4.1.2.1 General Stream Parameters

Samples were collected quarterly from the eight sites beginning with the third quarter of 2004. Samples were analyzed for general stream parameters, including temperature, pH, specific conductance, dissolved oxygen, and turbidity (BFSC, 2007). The results of the monitoring are listed in Table 19-34.

Table 19-34. General Stream Water Properties by Site (2 pages)

Site	Temperature		pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	[a]Turbidity (NTU)
	°C	°F					
Clear Creek	13.1	55.6	7.88	525	11.84	111.2	3.6
Gans Creek	11.7	53.1	7.76	397	11.57	105.2	17.5
Devils Icebox Cave	11.6	52.9	7.53	424	11.05	101.7	22.9
Upper Bonne Femme Creek	13.6	56.5	7.22	478	9.79	95.7	28.3
Turkey Creek	13.8	56.8	7.49	586	12.04	117.1	22.7
Hunters Creek	11.5	52.7	7.73	409	11.37	103.7	11.9
Bass Creek	13.7	56.7	7.80	455	14.39	140.3	12.6

Table 19-34. General Stream Water Properties by Site (2 pages)

Site	Temperature		pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	[a]Turbidity (NTU)
	°C	°F					
Lower Bonne Femme Creek	12.8	55.0	7.47	408	11.39	108.6	12.1
Little Bonne Femme Creek	12.6	54.7	7.63	446	11.06	99.4	19.4
Fox Hollow	14.6	58.3	7.60	520	10.92	107.0	3.3
Average across the sites	12.9	55.2	7.61	465	11.54	109.0	15.4
[a]Least significant difference	[b]NS	[b]NS	0.28	[b]NS	[b]NS	[b]NS	[b]NS

Source: BFSC, 2007, *Bonne Femme Watershed Plan*, www.cavewatershed.org/plan.asp, Bonne Femme Stakeholder Committee, Boone County Planning and Building Department, Columbia, Missouri, February 2007.

[a] This value is the minimum difference between sites to be considered statistically different.

[b] NS = not significantly different across sites. Data are averaged over 10 quarters (third quarter 2004 to fourth quarter 2006).

NTU = nephelometric turbidity units.

The following excerpt from the 2007 Bonne Femme Watershed Plan provides greater detail regarding the results of data analysis and general stream parameters for the sites listed in Table 19-34.

> *The pH concentration in the Upper Bonne Femme Creek site was lower than all other sites. This result is likely due to the fact that the Upper Bonne Femme Creek sub-watershed is primarily utilized for row crops (67% of the sub-watershed), and the lower pH may reflect the impact of fertilizer usage. The Upper Bonne Femme Creek and Turkey Creek occasionally had very high specific conductance levels exceeding 700 µS/cm. These results may have been due to the use of salt on U.S. Highway 63 during the winter months. Eight of ten sites had average dissolved oxygen levels that were at or near 100% saturation. The lowest observed dissolved oxygen levels occurred in the third quarter of each year when the stream water temperature was highest. The lowest dissolved oxygen level observed was 5.11 mg/L (62.6% saturation); therefore, no site was under the state standard level of 5.0 mg/L. The high saturation levels observed at Turkey and Bass Creeks reflected the persistent nuisance algal growth conditions at these sites. Turbidity measures the clarity of the water and, thus, both suspended sediment and algae can contribute to lower clarity and higher turbidity. Highest turbidity was observed under runoff conditions when the suspended sediment content of the water is high. Turbidity levels were occasionally elevated under low flow conditions, suggesting that algal growth was negatively impacting water clarity, especially in the second and third quarters of the year.* (BFSC, 2007)

Bacteria analyses – Two indicator groups of waterborne pathogens (fecal coliform and *E. coli*) were monitored in the streams within the Bonne Femme Watershed. Both groups are considered indicator organisms associated with improper waste management. Fecal coliforms represent a broad array of bacterial species present in mammal feces, while *E. coli* is a single bacterial species that is also present in mammal feces. These indicator bacteria generally do not survive long in soils or water; thus, their consistent detection in water over time indicates one or more sources of continual input.

The two sites with the highest fecal coliform concentrations, Turkey Creek and Fox Hollow, had statistically greater concentrations than the five sites with the lowest concentrations (Clear Creek, Gans Creek, Bass Creek, Hunters Cave, and Lower Bonne Femme Creek). Table 19-35 lists the average concentrations.

Table 19-35. Average Fecal Coliform and *E. coli* Concentrations

Site	[a]Fecal coliform (log10[cfu/100 mL])	[a]*E. Coli* (log10[cfu/100 mL])
Clear Creek	1.72	1.54
Gans Creek	2.07	1.91
Devils Icebox Spring Branch	2.30	2.06
Upper Bonne Femme Creek	2.17	1.95
Turkey Creek	2.46	2.38
Hunters Cave	1.93	1.73
Bass Creek	2.00	1.84
Lower Bonne Femme Creek	1.97	1.86
Little Bonne Femme Creek	2.14	1.94
Fox Hollow	2.49	2.26
Average across the sites	2.13	1.95
[b]Least significant difference	0.35	0.35

Source: BFSC, 2007, *Bonne Femme Watershed Plan*, www.cavewatershed.org/plan.asp, Bonne Femme Stakeholder Committee, Boone County Planning and Building Department, Columbia, Missouri, February 2007.

[a] Statistical analysis was performed on log transformed data.

[b] This value is the minimum difference between sites to be considered statistically different.

According to the 2007 Bonne Femme Watershed Plan:

> *The three sub-watersheds with the highest levels of bacterial contamination (Turkey Creek, Fox Hollow, and Devil's Icebox Spring Branch) have consistently greater inputs of fecal bacteria compared to the other sites. Although these data do not indicate the source of the fecal bacteria, there are three likely sources in the Bonne Femme watershed – onsite sewers, livestock, and wildlife.* (BFSC, 2007)

Specific water-borne pathogens – In the third quarter of 2005, the USDA Agricultural Research Service conducted additional analyses of three specific water-borne pathogens: *E. coli O157:H7*, salmonella, and shigella. These three organisms are known human pathogens capable of causing food-borne gastrointestinal illnesses, but they are also associated with feces and, therefore, may contaminate streams and lakes, causing disease through oral contact or ingestion of contaminated water. Like fecal coliforms and generic *E. coli*, these disease-causing bacteria can enter surface waters through sewage overflows, polluted stormwater runoff, and polluted agricultural runoff.

> *Each of the three pathogens was detected at most of the ten sites monitored, and at least one pathogen was detected at every site. Shigella was detected at eight of ten sites, but generally at lower frequency than Salmonella or E. coli O157:H7.*

Salmonella was the most commonly detected pathogen at four of the ten sites, with 33% of the samples collected from Turkey and Little Bonne Femme Creeks testing positive for Salmonella. E. coli O157:H7 was the most commonly detected of the pathogens, with at least one detection at every site. Five of the ten sites had multiple detections of E. coli O157:H7. Three sites (Gans Creek, Turkey Creek, and Lower Bonne Femme Creek) had E. coli O157:H7 detected in 33% of their samples, and Fox Hollow had E. coli O157:H7 detected in 58% of the samples.

These data do not definitively indicate source, but they do point to cattle as a probable source of E. coli O157:H7 at those sites with frequent detections. Of the common carriers of E. coli O157:H7 (cattle, swine, and deer), swine can be eliminated as there are no sizable swine operations within the Bonne Femme watershed. Deer are likely responsible for the widespread nature of the detections, explaining the presence of E. coli O157:H7 at sites with otherwise low fecal contamination, such as Clear Creek and Hunters Cave. Although data on specific numbers of cattle by sub-watershed cannot be reliably compiled, there are major cattle operations in the four watersheds with the highest detection frequency of E. coli O157:H7. Furthermore, the Fox Hollow sampling site is immediately downstream from a large cattle grazing operation. (BFSC, 2007)

19.3.4.1.3 Impaired Waters

The USGS and the MDNR ambient water quality monitoring network collect water quality data each year pertaining to Missouri water resources. These data are stored and maintained in the USGS National Water Information System database. The MDNR is responsible for the implementation of the Federal CWA in Missouri. Section 305(b) of the CWA requires that each State develop a water quality monitoring program and periodically report the status of its water quality. Water quality status is described in terms of the suitability of the water for various uses, including drinking, fishing, swimming, and support of aquatic life. These uses formally are defined as "designated uses" in Federal and State regulations. Section 303(d) of the CWA requires that certain waters that do not meet applicable water quality standards must be identified and total maximum daily loads (TMDL) must be determined for these waters. TMDLs establish the maximum amount of an impairing substance that a water body can assimilate and still meet the water quality standards. A TMDL addresses a single pollutant for each water body (Barr, 2012).

Impaired waters within close proximity to the proposed RPF site are discussed in greater detail in the following sections.

19.3.4.1.3.1 Gans Creek

In accordance with Section 303(d) of the CWA, MDNR identified Gans Creek (Water Body ID No. 1004) as an impaired water body in 2012 (Figure 19-36).

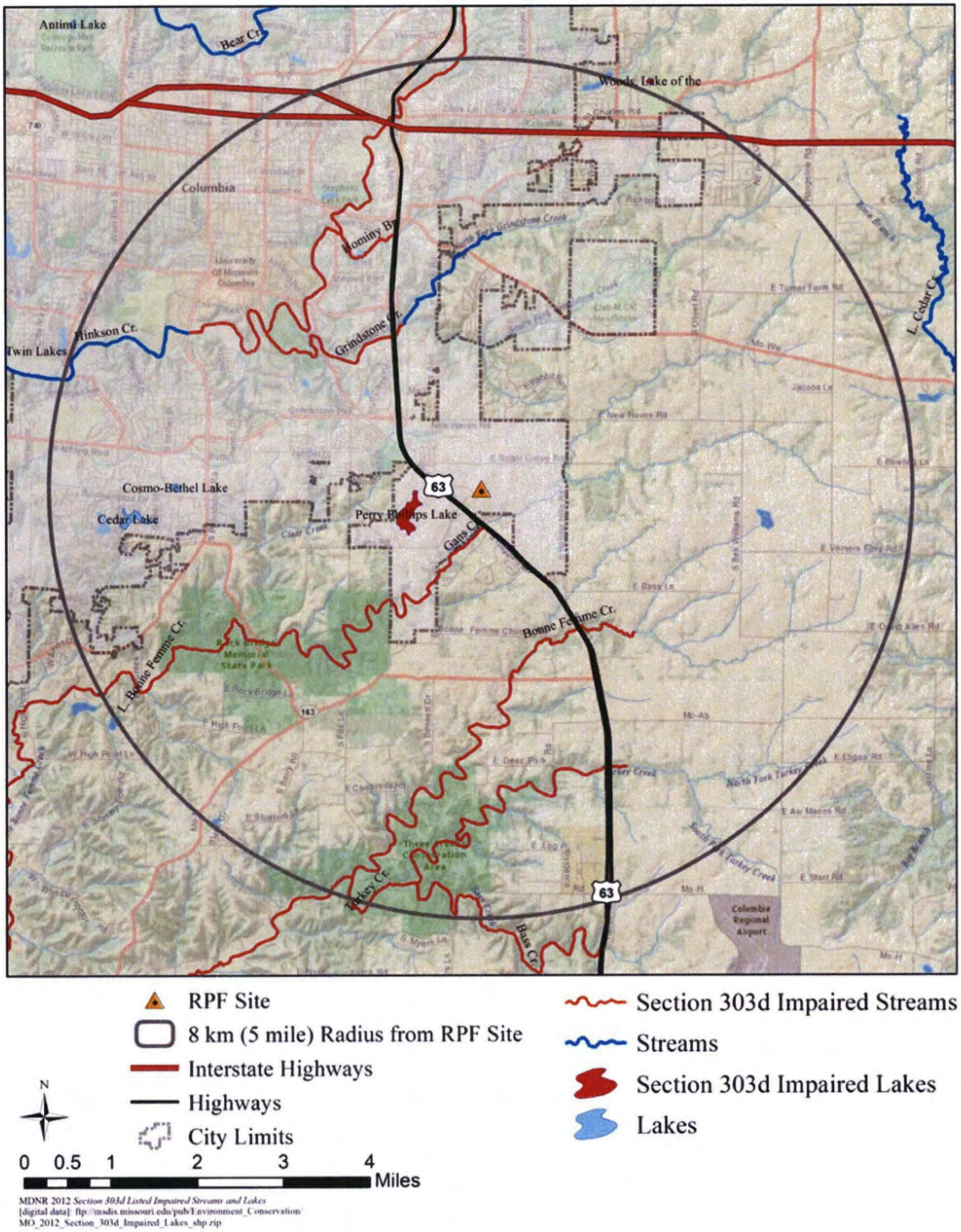


Figure 19-36. Impaired Streams Map

Gans Creek is listed as impaired by bacteria on the Missouri 2012 303(d) list of impaired waters, which was approved in whole by the EPA on November 13, 2012 (EPA, 2012). Gans Creek is designated for the whole body contact recreation (Category A use). 10 CSR 20-7.031, "Water Quality Standards," state that for waters designated for whole body contact recreation (Category A), the *E. coli* bacteria count, measured as a geometric mean, shall not exceed 126 colonies per 100 milliliters (mL) (3.4 ounces [oz]) of water during the recreational season (defined as being from April 1 to October 31).

> *DNR judges a stream to be impaired by bacteria if the water quality criterion for E. coli is exceeded in any of the last three years for which there is adequate data (minimum of five samples taken during the recreational season). High counts of E. coli are an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. E. coli are bacteria found in the intestines of warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic (disease causing) bacteria or viruses. Missouri's whole body contact bacteria criteria are based on specific levels of risk of acute gastrointestinal illness. The level of risk correlating to the Category A criterion is no more than 8 illnesses per 1,000 swimmers in fresh water (0.8 percent). Sufficient recreational season E. coli data to assess the Gans Creek was collected in 2008 and 2009. The geometric means of the data exceeded the whole body contact Category A criterion in both years. For this reason, Gans Creek has been assessed as impaired by E. coli.* (MDNR, 2013f)

The TMDL information for Gans Creek includes a segment stream length of 8.9 km (5.5 mi) and an affected watershed size of 39 km^2 (15 mi^2). The four designated beneficial uses of Little Bonne Femme Creek include:

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Protection of human health (fish consumption)
- Whole body contact recreation – Category A

Category A whole body contact recreation is the only impaired designated beneficial use.

19.3.4.1.3.2 Little Bonne Femme Creek

In accordance Section 303(d) of the CWA, MDNR identified the Little Bonne Femme Creek (Water Body ID No. 1003) as an impaired water body in 2012.

Little Bonne Femme Creek is also listed as impaired by bacteria on Missouri 2012 303(d) list of impaired waters. Little Bonne Femme Creek is designated for the whole body contact recreation Category B use. Missouri's Water Quality Standards in 10 CSR 20-7.031(4)(C) state that for waters designated for whole body contact recreation Category B, the *E. coli* bacteria count, measured as a geometric mean, shall not exceed 206 colonies per 100 mL (3.4 oz) of water during the recreational season.

> *Missouri's whole body contact bacteria criteria are based on specific levels of risk of acute gastrointestinal illness. The level of risk correlating to the Category B criterion is no more than 10 illnesses per 1,000 swimmers in fresh water (1 percent). Sufficient recreational season E. coli data to assess the Little Bonne Femme Creek was collected in 2008 and 2009. The geometric means of the data exceeded the whole body contact Category B criterion in both years. For this reason, Little Bonne Femme Creek has been assessed as impaired by E. coli.* (MDNR, 2013g)

The TMDL information for Little Bonne Femme Creek includes a segment stream length of 14.5 km (9 mi) and an affected watershed size of 102 km^2 (39.2 mi^2). The four designated beneficial uses of Little Bonne Femme Creek include:

- Livestock and wildlife watering
- Protection of warm water aquatic life

- Protection of human health (fish consumption)
- Whole body contact recreation – Category B

Category B whole body contact recreation is the only impaired designated beneficial use.

19.3.4.1.3.3 Perry Phillips Lake

Perry Phillips Lake, located approximately 1.2 km (¾-mi) west of the proposed RPF site, was first listed as an impaired water body in 2010. This lake was originally given the State-listed water identification number MO 1003U-01. In 2012, that number was changed to MO 7628. The TMDLs are to be established by Missouri in 2015. Information available for this impaired water body is as follows (MDNR, 2013h):

> State Listed Water ID Nos. MO 7628 and MO 1003U-01
> Location: Boone County
> Hydrologic Unit Code 8, No. 10300102
> State Water Body Type: Lakes, reservoirs, and ponds
> Impaired Segment Size (mi/acres): 32
> Classified Segment Size (mi/acres): 32
> Cause of Impairment: Mercury in fish tissue
> Impaired Uses: GEN

19.3.4.2 Groundwater Resources

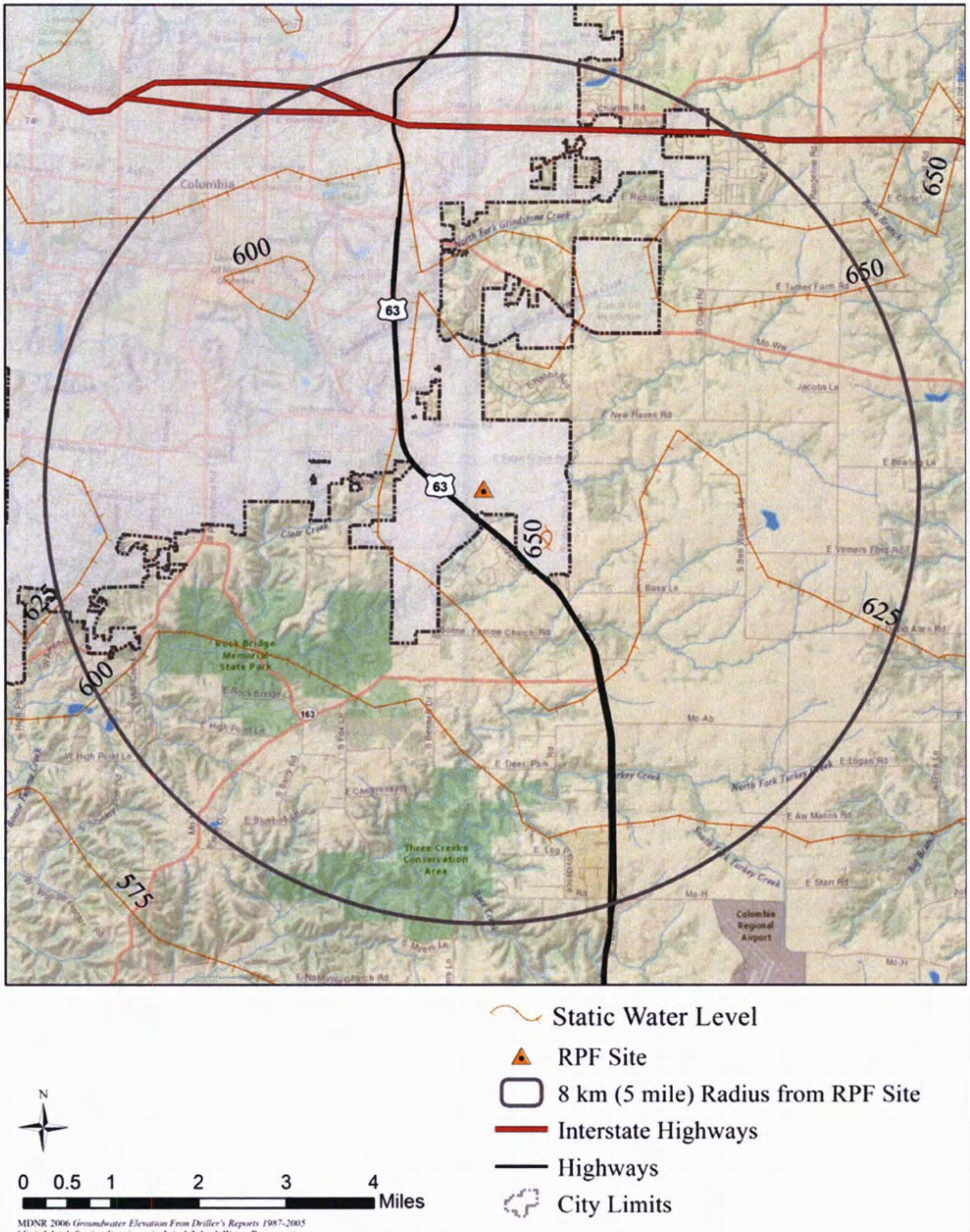
Less than one-half of the Missouri population obtains its water supply from groundwater resources. Groundwater is the major source of drinking water in the Ozarks and the Southeast Lowlands for both public and private supplies. The cities of St. Joseph, Independence, Columbia, and St. Charles use groundwater from the alluvial aquifer of the Missouri River. In the plains region of the state, many small communities are able to obtain adequate water from shallow alluvial wells near rivers or large creeks. Many individual households still rely on the shallow upland aquifer even though it yields only very small amounts of water (MDNR, 2012b).

Groundwater is the source of 74 percent of all rural domestic self-supplied water, 75 percent of all irrigation water, and 39 percent of all industrial self-supplied water, excluding water for thermoelectric power generation. The groundwater is generally suitable for most uses, except where it is saline. Median concentrations of total dissolved solids (TDS), hardness, nitrate, fluoride, and sulfate are less than the primary and secondary national drinking water regulations established by the EPA; however, localized contamination from manufactured organic compounds has been recognized in four of the six principal aquifers in Missouri, including both shallow and deep aquifers (USGS, 1986).

The six principal aquifers in Missouri include:

- Major river valleys
- Alluvial (in southeastern Missouri)
- Wilcox and Claiborne
- McNairy
- Ozark
- Mississippian aquifer (Kimmswick-Potosi)

The groundwater aquifer beneath the proposed RPF site is the Mississippian aquifer (also referred to as the Kimmswick-Potosi aquifer). Figure 19-37 is a map of the aquifer.



MDNR 2006 *Groundwater Elevation From Driller's Reports 1987-2005* [digital data]. ftp://msdis.missouri.edu/pub/Inland_Water_Resources/MO_2006_Groundwater_Elevation_shp.zip

Figure 19-37. Aquifer Map

The Mississippian aquifer is the principal aquifer supplying groundwater to Boone County. In accordance with drillers reports generated from 1987 to 2005, the estimated static water level in the area near the proposed RPF site was approximately 198.1 m (650 ft) below ground surface (MDNR, 2006).

19.3.4.2.1 Mississippian Aquifer

The Mississippian aquifer consists of consolidated dolomite, limestone, and some sandstone beds that are generally confined. The Keokuk limestone and Burlington limestone are the principal water-yielding formations within this aquifer. Both formations consist of crystalline limestone and yield water primarily from solution cavities. In most places, the aquifer is overlain by a confining unit of Pennsylvanian shale and sandstone and glacial till. The aquifer is typically underlain by a confining unit of Mississippian shale. Recharge occurs primarily from precipitation infiltrating overlying aquifers. The top of this aquifer is approximately 548.6 m (1,800 ft) below ground surface and is a primary source of water in seven counties north of the Missouri River (Miller and Appel, 1997).

19.3.4.2.2 Water Quality of the Mississippian Aquifer

The quality of water obtained from wells drilled into the Mississippian aquifer varies considerably across Missouri due to the aquifer containing both freshwater and slightly saline to very saline water. Total dissolved solids concentrations of water from the aquifer generally are greatest where the aquifer is overlain by a thick confining unit and least where it is unconfined or overlain by a thin or semi-confining unit. Very saline water is thought to have entered the Mississippian aquifer either by upward leakage from the underlying Cambrian-Ordovician aquifer or by the discharge of eastward-moving saline water from the upper aquifer unit of the Western Interior Plains aquifer system (Miller and Appel, 1997).

In a study conducted by the USGS in 1985, the Mississippian aquifer was determined to have low permeability with a median TDS concentration of approximately 500 milligram per liter (mg/L) (0.06 oz/gal). The maximum TDS concentration measured in this study was approximately 4,700 mg/L (0.572 oz/gal) to the north, where water becomes saline. The median concentration of fluoride was 1.0 mg/L (0.00012 oz/gal) and the median concentration of sulfate was 56.0 mg/L (0.0068 oz/gal). These were the largest median values of all of the six principal aquifers in Missouri (Miller and Appel, 1997).

According to the study, the Mississippian aquifer is intensively used for public water supply and irrigation; however, since the early 1900s, water quality in this aquifer has not changed appreciably (Miller and Appel, 1997).

A more recent assessment was conducted by the MDNR in 2002 (MDNR, 2002), which determined that the aquifers in Missouri consisting of Mississippian age limestone and Ordovician and Cambrian age dolomites and sandstones can yield 56.8–1,892.7 L/minute (min) (15–500 gal/min) of water. Yields locally exceed 3,785.4 L/min (1,000 gal/min) in some areas, including in Springfield, Columbia, and Rolla.

19.3.4.3 Preexisting Environmental Conditions

The RADIL facility at Discovery Ridge is a regulated State hazardous waste facility (SHWF) located approximately 0.16 km (0.1 mi) northwest of the proposed RPF site. A second SHWF, ABC Laboratories, is located approximately 0.54 km (0.33 mi) west of the proposed RPF site. These facilities are discussed in greater detail in the following sections and in Section 19.2.2.5. Based on a regulatory review and site assessments conducted by others, these SHWFs do not appear to represent environmental concerns to the proposed RPF site.

19.3.4.3.1 2011 Phase I Environmental Site Assessment Discovery Ridge, Lot 2 and Lots 5 through 18

A Phase I environmental site assessment included interviews with the MU Genetics Farm Manager and a USDA site employee to determine the historical uses of the Discovery Ridge area. The interviews revealed that minor amounts of herbicides and fertilizers are currently used on the MU Genetics Farm property (Lots 16, 17, and 18 of Discovery Ridge) (Terracon, 2011a).

The review identified one MDNR State-regulated RCRA large-quantity generator facility, ABC Laboratories (Lot 1 of Discover Ridge). However, this facility was not found to be a recognized environmental concern due to its regulatory status and duration of operation (built in 2007) (Terracon, 2011a). Additional information is listed in Table 19-36 and Sections 19.3.8.2 and 19.3.8.3.

Table 19-36. State-Regulated Facility

Listed facility name/Address	Database listings	Distance/direction from proposed RPF site	Potential contamination source
Analytical Bio Chemistry Laboratories 4780 Lenoir Street (Lot 1 of the Discovery Ridge Research Park)	RCRA-LQG	Approximately 0.54 km (0.33-mi) west	No

LQG = large-quantity generator.
RCRA = Resource Conservation and Recovery Act.
RPF = radioisotope production facility.

Other observations noted during the Phase I environmental site assessment that could pose preexisting environmental conditions included the following (Terracon, 2011a):

- Three pad-mounted transformers were observed on the southwestern portion of Lot 15 (proposed RPF site), one pad-mounted transformer was located on the southeastern portion of Lot 17, and three inactive pole-mounted transformers were observed on the northern portion of Lot 17. However, there were no signs or staining that would be evidence of possible polychlorinated biphenyl (PCB) release.
- Approximately 0.4 ha (1 acre) of fill dirt was observed on the northern portion of Lot 9. Per the MU South Farms Field Office, fill material had been placed onsite over the past two years and originated from the future location of the Missouri Conservation Facility located south of Gans Road, approximately 2.4 km (1.5 mi) south of the ROI.
- An intermittent stream was observed on Lots 9, 10, and 11 of the Discovery Ridge ROI, traversing the site in a north-to-south orientation. No evidence of chemical sheens was observed on the surface of the pools of water, and no noxious odors were observed emanating from within the intermittent stream at the site during site reconnaissance.

19.3.4.3.2 2011 Preliminary Geotechnical Engineering Investigation of Discovery Ridge Lot 2 and Lots 5 through 18

A 2011 preliminary geotechnical engineering investigation report stated the following (Terracon, 2011b):

- Fill soils were encountered in borings B-3 and B-4 at depths ranging from 0.9-3.7 m (3–12 ft) below ground surface. Boring B-3 was drilled on the central portion of Lot 2, and Boring B-4 was drilled on the central portion of Lot 8. The engineered fill material was placed as part of a mass grading project in 2008; that placement was observed and the soil density and moisture content tested during placement.

- Based on a USGS map and aerial photographs, a pond may have been located in the vicinity of Lot 16, and the existing pond located north of the RADIL facility previously extended west onto a portion of Lot 2.
- The near-surface soils have shrink/swell potential and are prone to volume change with variations in moisture content.
- The 2006/2009 International Building Code seismic site classification for the ROI is C. For Class C soils, the 2006/2009 code requires that a site soil profile determination extending to a depth of 30.5 m (100 ft) be conducted.
- The MMI scale for seismic events for Boone County, Missouri, is VII.
- Groundwater was observed in Boring B-5 (located midway between Lots 14 and 15) and in Boring B-6 (located on Lot 10) at depths ranging from approximately 3.7–5.6 m (12–18.5 ft) below ground surface.

19.3.4.3.3 2006 Phase I Environmental Site Assessment Discovery Ridge East of Lenoir Street and South of Sugar Grove Lane

According to the Phase I environmental site assessment (Terracon, 2006), the MU South Farms facility was identified as an SHWF. An interview with Mr. John Poehlmann, Director of the Missouri Agricultural Experiment Station and MU South Farms Superintendent, identified the historical uses of the facility. These uses include agricultural research of maize genetics crop research, swine nutrition, beef cattle management and grazing, agricultural equipment development, and cropping for grain silage and uptake of nutrients from lagoon application. According to Mr. Poehlmann, the nine buildings on the property within the ROI were built between 1970 and 2002, and there are pits for the collection of animal waste beneath one building that housed sheep and swine. The wastes were surface and injection applied as plant nutrients. The on-site lagoon operated under MDNR permit MO-G010024.

19.3.4.4 Historical and Current Hydrological Data

There is no historical or current hydrological data for the proposed RPF site.

19.3.4.5 Proposed Radioisotope Production Facility Water Use

Water use by the proposed RPF is described in Section 19.2.4.1 and would be supplied from the Columbia, Missouri, standard municipal water system.

19.3.4.6 Water Rights and Resources

Missouri water resources, including surface water and groundwater supplies, are applied to a variety of uses. Large consumptive water uses included thermal electrical generation, municipal, industrial, and agricultural uses. Nonconsumptive water uses include recreation, commercial navigation, hydroelectric power generation, and mining operations.

Missouri is called a riparian water law state, meaning that each individual landowner is entitled to make use of the water found on or beneath his/her property. The laws that address riparian rights are restrictive in that the landowner cannot make unlimited or unrestricted use of that water in any way he or she chooses. "Riparian lands," as defined by the courts, include all lands above underground waters and beside surface waters (MDNR, 2000).

19.3.4.7 Quantitative Description of Water Use

19.3.4.7.1 Drinking Water Supply

The potable water supply to Discovery Ridge is provided by Public Water District No. 1. Additional detail on the water supply system is provided in Section 19.3.7.1.9.3.

19.3.4.7.1.1 Wastewater Treatment Systems

Two main wastewater collection providers service the metro area: the Columbia sewer utility and the Boone County Regional Sewer District. Several private, on-site wastewater treatment systems also serve the metro area. These systems require permits from and are inspected by the MDNR.

The ultimate wastewater service area is 311 km^2 (190 mi^2) and includes three major watersheds: the Perche, Hinkson, and Little Bonne Femme. In 2010, the actual connected population was approximately 100,000; this figure is projected to reach 160,000 users by 2030. Approximately 45.4–56.7 ML/day (12-15 Mgal/day) of wastewater are currently generated; this is estimated to increase to 106 ML/day (28 Mgal/day) by 2030 (City of Columbia, 2013a).

A large number of older homes are connected to private common collector sewers. These systems are shared by two or more residences; many are poorly designed and prone to backing up (Columbia Source Water Protection Task Force, 2013).

19.3.4.7.1.2 Stormwater Management

In 2012, Columbia maintained over 304,800 m (1 million linear feet) of storm sewers. With its client base surpassing 100,000 residents, a change in the type of NPDES storm sewer permit, granted by the EPA, was required. The city transitioned from a Phase II permit to a Phase I permit, an effort that included specific measures to address the minimization of pollution in city storm sewers and other areas (City of Columbia, 2013a).

19.3.4.7.2 Nonconsumptive Water Use

The MDNR reported that in 2000, the total water usage for Boone County totaled approximately 26,876 ML (7,100 Mgal) (MDNR, 2003). Water usage categories are listed in Table 19-37.

Table 19-37. Water Use in Boone County, 2000

Water use category	Water usage	
	ML/day	Mgal/day
Domestic	379–1,514	100–400
Irrigation	379–3,028	100–800
Electric	0–75,708	0–20,000
Industrial	0–379	0–100
Municipal	11,356–37,854	3,000–10,000
Recreation	57–227	15–60

Source: MDNR, 2003, *Major Water Use in Missouri: 1996-2000*, Water Resources Report No. 72, Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, Jefferson City, Missouri, 2003.

19.3.4.7.3 Water Impoundments

The MDNR regulates all non-Federal, nonagricultural dams that are at least 10.6 m (35 ft) in height. Currently, there are 590 dams regulated in Missouri. The MDNR inspects each regulated dam at least once every 5 years to determine if the dams pose a safety threat to the public.

As of March 9, 2007, the MDNR listed a total of 127 dams within Boone County (MDNR, 2007). Of these 127, a total of 17 dams are regulated by the MDNR. Two dams are located within 1.6 km (1 mi) of the proposed RPF site. The MU R1 Dam is located approximately 152.4 m (500 ft) northwest of the proposed RPF site. This dam is not a regulated water body. The Bristol Lake Dam is located approximately 0.8 km (0.5 mi) west-southwest of the proposed site and is listed as regulated. Additional information on each of these water bodies is provided in Table 19-38.

Table 19-38. Missouri Dam Report, by County

Name	ID No.	Location	Year completed	Height	Length	Drainage area	Lake area (acre)	Hazard class	Permit no.
Bristol Lake Dam	MO10019	S32 T48N R12W	1965	14 m (46 ft)	300 m (985ft)	146 ha (360 acres)	13.4 ha (33 acres)	2	R-223
University of Missouri R1 Dam	MO11606	S33 T48N R12W	1959	5.5 m (18 ft)	Unknown	56.7 ha (140 acres)	4.9 ha (12 acres)	2	NA

Source: MDNR, 2007, "Missouri Dam Report by County," www.dnr.mo.gov/env/wrc/damsft/Crystal_Reports/damsfty_state_nid.pdf, Missouri Department of Natural Resources, Jefferson City, Missouri, March 9, 2007.

NA = not applicable.

19.3.4.7.4 Major Water Users

In Missouri, a major water user is defined by the MDNR as any surface or groundwater user with a water source and the equipment necessary to withdraw or divert 378,541 L/day (100,000 gal/day) or more from any stream, river, lake, well, spring, or other water source. All major water users are required by law to register water use annually. In Boone County, there are a total of 19 major water users registered with the MDNR. The registration of major water users in Missouri helps the MDNR with the following:

- Providing information required for technical assessment of current and future requirements for the regulation of water
- Gaining foresight on water supplies
- Applying conservation measures during periods of limited or diminishing supplies of water
- Determining where to locate stream and reservoir gauges and the groundwater level observation wells

19.3.4.8 Contaminant Sources

The most likely contaminant sources that may be affecting groundwater and/or surface water resources within the Columbia area include unregulated discharges from commercial and industrial processes, land development, pesticides from agricultural land-use practices, stormwater runoff, sediment erosion, and wastewater discharges. Other contaminant sources may include solid waste landfills and surface or underground mining operations.

Development within a watershed can contribute to water quality problems. Loads of sediment, petroleum hydrocarbons, metals, nutrients, and other pollutants are also higher in developed areas. This further decreases the natural habitat value of the streams and riparian areas.

Pollutants are carried by stormwater from upland areas into receiving waters. Land use not only influences the quantity of stormwater runoff, but also the quality of the runoff. Areas of high imperviousness (e.g., industrial areas, streets) can have some of the highest pollutant loads, while open spaces have the lowest.

19.3.4.8.1 Columbia Source Water Protection Task Force Contaminant Inventory for 2012

The Columbia Source Water Protection Task Force completed a contaminant inventory for Columbia in 2012. The contaminant inventory was conducted to identify contaminant materials and develop a line of defense to protect the city's deep bedrock wells and the McBaine Bottoms Well Field.

Contaminant inventories reviewed included fuel and oils, pesticides, nutrients, synthetic organic chemicals, volatile organic compounds (VOC), animal waste, and/or raw sewage. Other potential contaminant sources can include gas stations or retailers that may stock chemicals such as pesticides, oil, gasoline, and cleaners.

The Columbia Source Water Protection Task Force (2013) did not identify any potential threats to the old deep bedrock wells; however, seven potential threats to the McBaine Bottoms wells were identified:

1. Malicious tampering with individual source water (or nearby monitoring wells)
2. Use of pesticides, herbicides, and fertilizers
3. Seepage from Columbia wastewater treatment wetlands
4. Groundwater migration from under the Eagle Bluffs conservation wetlands
5. Infiltration from the Missouri River
6. Future activities in the McBaine bottoms area
7. Petroleum pipelines through the well field

19.3.4.8.2 MDNR Surface Water Assessment for the State of Missouri

According to the 2012 Missouri Water Quality Report (MDNR, 2012b), there are 39,318 km (24,431 mi) of classified streams, approximately 48,280 km (30,000 mi) of unclassified streams, and a total of 122,566 ha (302,867 acres) of classified lakes in Missouri. Classified streams are defined as permanently flowing streams or streams that maintain permanent pools during dry weather. Unclassified streams are defined as streams that are without water during dry weather. All classified waters of Missouri, including significant public lakes, are classified for protection of aquatic life, livestock and wildlife watering, and fish consumption by humans. The water quality standards for these uses set the maximum allowable concentrations for 117 chemicals in these waters. A subset of these waters classified for drinking water supply and groundwater has maximum allowable concentrations for an additional 79 chemicals in the standards. Waters protected for whole body contact recreation (e.g., swimming, water skiing) also have a maximum allowable bacteria standard (MDNR, 2012b).

19.3.4.8.3 Major Surface Water Pollution Sources in Missouri's Classified Waters

The major surface water pollution sources and major contaminants in Missouri classified waters are listed in Table 19-39 and Table 19-40.

Table 19-39. Major Surface Water Pollution Sources in Missouri Classified Waters

Source	Streams impaired		Percent of total miles	Lake impaired		Percent of total acres
	km	miles		ha	acres	
Unknown	3,229.0	2,006.4	8%	704	1,740	1%
Agriculture	1,751.1	1,088.1	4%	259	640	[a]
Grazing activities	89.8	55.8	[a]	--	--	--
Crop production	--	--	--	3.6	9	[a]
Urban runoff and construction	1,660.5	1,031.8	4%	19,852	49,055	16%
Atmospheric deposition	1,132.3	703.6	3%	9,939	24,560	8%
Mining	871.5	541.5	2%	--	--	--
Tailings	829.9	515.7	2%	--	--	--
Other mining activities	41.5	25.8	[a]	--	--	--
Municipal and other domestic point sources	521.6	324.1	1%	19,600	48,434	16%
Hydromodification	170.4	105.9	[a]	100	246	[a]
Channelization	106.9	66.4	[a]	--	--	--
Flow regulation/ modification	46.7	29.0	[a]	--	--	--
Upstream impoundment	16.9	10.5	[a]	100	246	[a]
Industrial point sources	67.3	41.8	[a]	--	--	--
Rural nonpoint sources	23.8	14.8	[a]	83.4	206	--
Natural sources	3.7	2.3	[a]	--	--	--
Recreational activities	12.1	7.5	[a]	--	--	--

Source: Table 3, p. 7, of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Less than 1%.

Table 19-40. Major Contaminants in Missouri Classified Waters

Contaminant	Stream length impaired		Percentage of total miles	Lake impaired		Percentage of total acres
	km	miles		ha	acres	
Bacteria	4,739.5	2,945.0	12%	--	--	--
Metals	1,119.8	695.8	3%	9,939	24,560	8%
Mercury	401.4	249.4	1%	9,939	24,560	8%
Lead	230.0	142.9	1%	--	--	--
Cadmium	203.9	126.7	1%	--	--	--
Zinc	17.2	10.7	[a]	--	--	--
Nickel	9.2	5.7	[a]	--	--	--
Copper	1.4	0.9	[a]	--	--	--
Arsenic	--	--	--	--	--	
Low dissolved oxygen	1,470.9	914.0	4%	--	--	--
Unknown	716.6	445.3	2%	--	--	--
Dissolved oxygen supersaturation	117.5	73.0	[a]	99.6	246	[a]
Chloride	105.9	65.8	[a]	--	--	--
pH	69.2	43.0	[a]	--	--	--
Sediment deposition	58.1	36.1	[a]	--	--	--
Thermal modification	54.6	33.9	[a]	--	--	--
Sulfate	32.2	20.0	[a]	--	--	--
Ammonia	28.5	17.7	[a]	--	--	--
Pesticides	18.2	11.3	[a]	3.6	9	[a]
Nutrients	7.9	4.9	[a]	40,495	100,066	33%
Chlorophyll	--	--	--	20,136	49,757	16%
Nitrogen	--	--	--	19,254	49,307	16%
Phosphorus	--	--	--	245	854	[a]

Source: Table 4, pp. 7–8 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Less than 1%.

19.3.4.8.4 Water Quality of Missouri Surface Water

The MDNR rates the quality of Missouri surface water by its conformance with the Missouri Water Quality Standards (10 CSR Division 20). The standards were first implemented in 1970 and are revised at least every three years. Table 19-41 lists the various uses of Missouri surface waters and the portions of the state waters that are protected for each use.

Table 19-41. Missouri Waters Protected for Various Uses

Designated use	Stream		Percent of total	Lake		Percent of total
	km	mi		ha	acres	
Protection of aquatic life and fish consumption	39,318	24,431	100	12,2563	30,2867	100
Subset: warm-water fishery	33,596	20,875	85	118018	291,635	96
[a]Cool-water fishery	5,241	3,257	13	0	0	0
[b]Cold-water fishery	479	298	1	4,545	11,232	4
Livestock and wildlife watering	39,318	24,431	100	12,2563	302,867	100
Whole body contact recreation	38,622	23,999	98	12,2563	302,867	100
Secondary contact recreation	14,279	8,872	36	103,840	256,601	85
Drinking water supply	5,488	3,410	14	54,102	13,3692	44
Industrial	2,558	1,590	7	2,816	6,959	2
Antidegradation: Outstanding National Resource Waters	275	171	--	--	--	--
Antidegradation: Outstanding State Resource Waters	327	[c]204	--	--	--	--
Total Classified Waters in Missouri	39,318	24,431	--	122,563	302,867	--

Source: Table 4, p. 15 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Smallmouth bass, rock bass.

[b] Trout.

[c] Outstanding State Resource Waters also include 109 ha (270 acres) of marsh wetlands in three locations.

19.3.4.8.5 Missouri Department of Natural Resources Groundwater Assessment

Less than one-half of Missourians rely on groundwater as the source of their drinking water. Groundwater is the major source of drinking water in the Ozarks and the Southeast Lowlands for both public and private supplies. In the Ozarks, groundwater yields are usually large and of excellent quality. Many municipalities pump groundwater directly into the water supplies without treatment. Due to large amounts of rainfall and surface water runoff funneling through the geologic formations of the Ozarks, groundwater can be more easily contaminated. This is due to surface water flows directly entering groundwater through cracks, fractures, or solution cavities in the bedrock, with little or no filtration. Contaminants from leaking septic tanks, storage tanks, or surface waters affected by domestic wastewater, animal feedlots, and other pollution sources can move directly into groundwater through these cavities in the bedrock (MDNR, 2012b).

Groundwater is of good quality in the southeast lowlands. Contaminants are filtered by thick deposits of sand, silt, and clay as they move through the groundwater system. While shallow groundwater wells are subject to the same problems as seen in the Ozarks, with elevated levels of nitrate or bacteria, deep wells are generally unaffected by contaminants. Shallow groundwater in northern and western Missouri tends to be more mineralized and to have taste and odor problems due to high levels of iron and manganese. Like shallow wells in the southeast lowlands, wells in this part of Missouri can be affected by nitrates, bacteria, or pesticides. In urban areas, alluvial aquifers of large rivers such as the Missouri River have occasionally been locally contaminated by spills or improper disposal of industrial or commercial chemicals (MDNR, 2012b).

The major sources and contaminants of groundwater in Missouri are listed in Table 19-42. Table 19-43 summarizes the MDNR groundwater contamination summary for Missouri.

Table 19-42. Major Sources of Groundwater Contamination in Missouri

Contaminant source	[a]10 highest priority sources (X)	Significant risk factors	Contaminants
Agricultural activities			
Agricultural chemical facilities	--	--	--
Animal feedlots	--	--	--
Drainage wells	--	--	--
Fertilizer applications	X	A, C, D, E	Nitrate
Irrigation practices	--	--	--
Pesticide applications	X	A, B, C, D, E	Organic pesticides
Storage and treatment activities			
Land application	X	A, D, E	Nitrate, pathogens (bacteria, protozoa, viruses)
Material stockpiles	--	--	--
Aboveground storage tanks	--	--	--
Underground storage tanks	X	A, B, C, D, E	Petroleum compounds
Surface impoundments	--	--	--
Waste piles	--	--	--
Waste tailings	--	--	--
Disposal activities			
Deep injection wells	--	--	--
Landfills	--	--	--
Septic systems	X	A, D, E	Nitrate, pathogens (bacteria, protozoa, viruses)
Shallow injection wells	--	--	--
Other sources			
Hazardous waste generators	--	--	--
Hazardous waste sites	X	A, B, C, D	Organic pesticides, halogenated solvents, metals, radionuclides
Industrial facilities	X	A, B, C, E	Nitrate, ammonia, pentachlorophenol, dioxin
Material transfer operations	--	--	--
Mining and mine drainage	X	A, E	Metals
Pipelines and sewer lines	--	--	--
Salt storage and road salting	--	--	--
Salt water intrusion	X	C	Salinity/brine
Spills	X	A, B, C, E	Organic pesticides, petroleum compounds, halogenated solvents, ammonia
Transportation of materials	--	--	--
Urban runoff	--	--	--

Source: Tables 10 and 11, p. 28-29 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Not in priority order.

A = Human health or environmental toxicity risk.
B = Size of population at risk.
C = Location of sources relative to drinking water sources.
D = Number and/or size of contaminant sources.
E = Hydrogeologic sensitivity.

Table 19-43. Missouri Department of Natural Resources
Missouri Groundwater Contamination Summary

Hydrogeologic Setting: All Aquifers. Data Reporting Period: 2010-2011.

Source type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number with confirmed groundwater contamination	[a]Contaminants	Number of site investigations (optional)	Number of sites that have been stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL	25	25	25	1	-	-	-	-	-
CERCLIS (non-NPL)	30	30	30	1	-	-	-	-	-
DoD/DOE	305	37	33	1, 2, 3, 4	50	213	231	18	45
LUST	3,578	195	55	3	165	82	—	1,090	74
RCRA Corrective Action	89	89	55	1, 2, 3, 4	49	39	27	26	16
[b]Underground injection	22	22	22	1, 3	22		22	22	
State sites	856	856	387	1, 2, 3, 4	847	575	575	49	575
Nonpoint Sources	-	-	-	-	-	-	-	-	-
Other (specify)	-	-	-	-	-	-	-	-	-

Source: Table 11, p. 30 of MDNR, 2012b, *Missouri Water Quality Report (Section 305(b) Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Contaminants: 1 = VOAs, SVOAs, solvents, PCBs, dioxin, PAHs, herbicides, pesticides, metals, explosives.
2 = VOAs, PCBs, pesticides, dioxin, metals, radionuclides, semivolatile organic compounds, etc.
3 = BTEX, TPH, methyl-t-butyl ether, PAHs, metals, SVOA.
4 = Creosote, pentachlorophenol, organic solvents, chlorinated solvents, petroleum, and asbestos.

[b] Includes sites where chemicals were injected into groundwater as part of approved remediation plan.

BTEX	=	benzene, toluene, ethylbenzene, and xylenes.
CERCLIS	=	Comprehensive Environmental Response, Compensation, and Liability Information System.
DoD	=	U.S. Department of Defense.
DOE	=	U.S. Department of Energy.
LUST	=	leaking underground storage tank.
NPL	=	National Priority List.
PAH	=	polycyclic aromatic hydrocarbon.
PCB	=	polychlorinated biphenyl.
RCRA	=	Resource Conservation and Recovery Act.
SVOA	=	semivolatile organic analyte.
TPH	=	total petroleum hydrocarbon.
VOA	=	volatile organic analyte.