CHAPTER 1: INTRODUCTION

In the context of carrying out its mission to support continued U.S. leadership in science and technology, the Department of Energy (DOE) is proposing to construct and operate a major new scientific research facility, the Spallation Neutron Source (SNS). The proposed SNS is designed to be a world-class neutron scattering science user facility serving a broad national community of researchers from federal laboratories, academia, and private industry. It is anticipated that this facility would be used by 1,000 to 2,000 scientists and engineers annually and that it would help meet the nation's demand for research capabilities in neutron scattering science well into the next century. This chapter provides background information about neutron scattering science and associated research facilities, describes the environmental analysis process, introduces the proposed action and alternatives included in this Environmental Impact Statement (EIS), and describes how this document is organized.

1.1 BACKGROUND ON NEUTRON SCATTERING SCIENCE AND FACILITIES

Neutron scattering science is a specialized field of basic research having to do with using a subatomic particle, the neutron, as a means to probe and derive an understanding of the fundamental structure and behavior of matter. Among all types of radiation used to probe materials (including X-rays, protons, and electrons), neutrons are uniquely capable of penetrating deeply beneath the material's surface to reveal its innermost characteristics. In basic terms, this is accomplished by directing a beam of neutrons at a material sample, detecting the neutrons that are scattered from collisions with atomic nuclei within the sample, and measuring the angles of their scattering paths and their post-collision energies. From these data, scientists can determine a wide range of characteristics about how a solid or liquid material's molecules are structured and how they behave under various physical conditions.

Development of neutron scattering techniques as a means to analyze material properties was pioneered by U.S. scientists beginning in 1945 when the first nuclear reactors became available for research. This type of research eventually spread to Europe and Japan as neutron sources became available there. DOE (and its predecessor agencies) has served as the prime steward of this field throughout the entire course of its development. Two of the leaders in this field, Clifford Shull of the Massachusetts Institute of Technology and Bertram Brockhouse of McMaster University in Canada, were jointly awarded the 1994 Nobel Prize for Physics for their development of neutron diffraction and neutron spectroscopy, respectively. Diffraction refers to patterns followed by the scattered neutrons; these patterns are a direct result of the molecular structure of a material sample. The diffraction patterns can be used to understand how atoms in the molecules are arranged. This information can, in turn, be used to predict how a material will behave under various physical conditions (e.g., high temperature or extreme pressure). Spectroscopy involves measuring the energies of the scattered neutrons, which can be used to reveal information about the movements of atoms within a material sample (e.g., their individual and collective oscillations).

Neutron beams can be either continuous (steady streams of neutrons) or pulsed (short bursts of neutrons). Both types are used and are uniquely valued in neutron scattering research. Continuous beams can be easily generated by nuclear reactors, and reactor sources were used exclusively up through the 1970s for neutron scattering experiments. These reactors tend to be relatively small and specially designed for neutron research purposes, in contrast to those built for commercial power generation. Pulsed neutron beams can be optimally produced from short bursts of high energy protons or electrons from a particle accelerator impinging on a heavy metal target, such as tungsten, tantalum, or mercury, to generate bursts of neutrons through a nuclear process called spallation. Spallation occurs when an incoming high energy proton hits a heavy atomic nucleus and knocks one or more neutrons out of it (Figure 1.1-1). Other neutrons are “boiled off” as the bombarded nucleus heats up. For every proton striking the nucleus, 20 to 30 neutrons are expelled. The power of a spallation source is characterized by the power [in kilowatts (kW) or megawatts (MW)] of the proton beam coming from the accelerator and directed onto the target. The first pulsed spallation source was built at Argonne National Laboratory (ANL) and began operation in 1973.

Regardless of whether the neutron source is continuous or pulsed, the emerging neutrons must be slowed

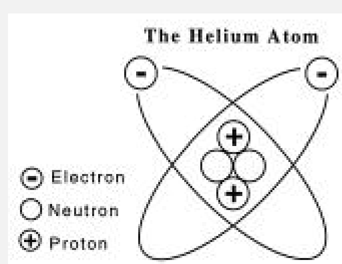
What Are Neutrons and What Can They Do?

Neutrons are one of the fundamental particles that make up matter. They were first identified in 1932 by Sir James Chadwick in England, for which he was awarded the 1935 Nobel Prize in Physics. This uncharged particle exists in the nucleus of a typical atom along with its positively charged counterpart, the proton. Protons and neutrons each have about the same mass, and both can exist as free particles apart from the atomic nucleus. In the universe, neutrons are abundant, making up more than half of all visible matter.

Neutrons traveling on their own can collide with the atomic nuclei of any material that they encounter and bounce off in a new direction, usually at a different speed or energy. This interaction is referred to as neutron scattering, which can be used to identify the positions of atoms in a molecule. It is especially good at locating light atoms such as hydrogen, carbon, and oxygen. Since these light atoms are prevalent in organic compounds, neutron scattering is a particularly effective means of studying biological materials. Because neutrons weakly interact with materials, they are highly penetrating and can be used to study bulky or highly complex samples, as well as samples inside thick-walled metal containers.

As an alternative to scattering, neutrons can be absorbed into a nucleus upon colliding with it. This can result in the formation of a nucleus of a different element, which can be either stable or radioactive. This is the process used to produce radioactive isotopes for medical applications such as implants for treating some forms of cancer. When neutrons are absorbed into the nuclei of certain heavy elements, such as uranium, those nuclei can be split apart. This is the fission process that occurs in a nuclear reactor, generating heat and producing more neutrons.

Lastly, another valuable feature of neutrons is that they are slightly magnetic, which makes them one of the best probes for the study of magnetic structure and magnetic properties of materials.



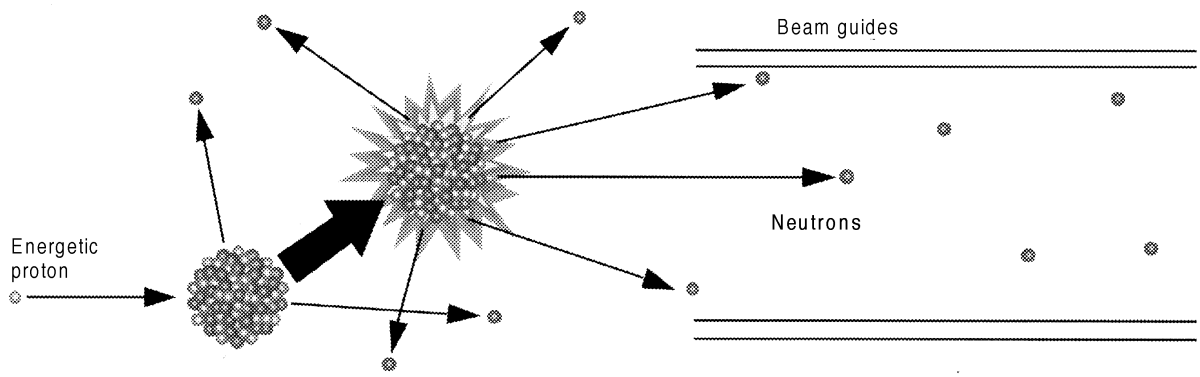


Figure 1.1-1. Neutron spallation process.

down, or moderated, to energies that are applicable to studying the kinds of materials chosen by the scientist conducting a particular experiment. This is usually accomplished by surrounding the reactor core or spallation target with a material containing hydrogen (e.g., water), which is most effective at slowing neutrons. The neutrons are then channeled in a beamline to an experiment station equipped with instruments capable of collecting and processing the desired kinds of information. Neutrons that are moderated to the energy or temperature of their surroundings are called thermal neutrons [0.002 to 0.1 electron volts (eV)], and those that slow down even further are termed cold neutrons (0.1 eV to 0.001 eV). In the late 1960s, neutron guides were developed for cold neutrons. These guides, which are evacuated glass channels with a metallic coating, can transport neutrons long distances with low losses. More recently, guides were developed for thermal neutrons. Guides for cold and thermal neutrons enable remote placement of instruments in buildings or rooms that are removed from the reactor core or the spallation target; such structures are called guide halls. The geometry involved in locating the instruments farther away from the neutron source allows more instruments to be installed, which makes the facility far more scientifically productive and flexible.

It is important to note that continuous and pulsed neutron sources are complementary and equally valuable as research tools. While many classes of experiments can be performed at some level with either type of source, there are some kinds of experiments that cannot be done with one or the other. For instance, with a pulsed source it is possible to achieve much higher neutron beam intensities (i.e., a greater number of neutrons per unit of time or higher flux) enabling deeper penetration into a material sample, and its pulsed nature permits time-of-flight analysis of the scattered neutrons. Time-of-flight analysis is based on the fact that each pulse contains neutrons with a range of energies, so neutrons of different energies can be separated by letting them run down a path of several meters. The highest energy neutrons reach the sample ahead of the rest, and because the neutron energies are spread out in time, the energy of an individual neutron is determined by its time-of-flight to the sample. Another area where pulsed sources are desirable is neutron scattering from samples subjected to very high pressures or very high magnetic fields that can be sustained only for brief periods of time. A reactor source is superior for performing experiments requiring cold neutrons, such as studying polymer dynamics. Apart from neutron scattering, reactors are better suited to conducting radiation damage studies and producing radioisotopes, both of which require neutron fluxes over large volumes. The neutron science community has expressed its view that both reactor and spallation neutron sources must remain available to support a strong, comprehensive U.S. neutron scattering research program (DOE 1993a).

Future advances in neutron scattering science and its applications depend to a large extent upon the number, technical capability, and research capacity of neutron sources available to the scientific research community. In addition to the previously mentioned distinction of continuous versus pulsed beams, the technical capability of a neutron source can be described by several other principal characteristics. Probably the most important is the flux or brightness of the neutron beam, and like a flashlight in a dark room, a high flux beam allows the researcher to look deeper inside a sample specimen and more clearly discern its structural features. Because neutrons only interact weakly with matter, most neutrons pass through a sample without producing a detectable interaction. As a result, experiments tend to be extremely flux-limited. This situation is further exacerbated because, unlike X-rays and charged particles, neutrons cannot be easily focused. The combination of weak interaction and focusing difficulties has driven the quest for higher-flux neutron sources. Existing spallation sources have produced beams with higher brightness than reactor-based sources, and unlike reactors, they have the potential to achieve even higher levels of brightness by employing even higher power proton accelerators. Lastly, pulsed sources can be characterized by their pulse repetition frequency (generally in the range of 10 to 100 Hertz). Research capacity can be characterized by the number of beamlines a facility has and the capability of their associated instrumentation, how many weeks per year it typically operates, and its operational reliability.

1.2 CURRENT AND FUTURE NEUTRON SOURCES

A worldwide scientific community, on the order of 6,000 scientists, presently uses approximately 20 major neutron sources worldwide, most of these being nuclear reactors and the remainder being spallation sources (see Table 1.2-1). Among the seven U.S. sources are five reactors: the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory (BNL), the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL), the Neutron Beam Split-Core Reactor (NBSR) at the National Institute of Standards and Technology (NIST), the Missouri University Research Reactor (MURR), and a smaller reactor at the Massachusetts Institute of Technology (MIT). The other two are pulsed spallation sources: the Intense Pulsed Neutron Source (IPNS) at ANL and the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory (LANL). All of these facilities except the smaller reactors at MIT, NIST, and MURR are supported by DOE, and all are currently in operation except HFBR. The HFBR has been shut down since 1997 to resolve issues related to a tritium leak into the groundwater from its spent fuel storage pool. A decision expected in June of 1999 on the future of HFBR will be made by DOE after completing an

Table 1.2-1. Present and future neutron sources worldwide.

Facility	Location	Type	Age (years)	Status
HIFAR	Australia	Reactor	40	Operating
HIFAR II	Australia	Reactor	NA	Planned replacement for existing HIFAR in 2005
Austron	Australia	Spallation	NA	Planned
Riso	Denmark	Reactor	39	Operating
IRF	Canada	Reactor	NA	Planned
ILL	France	Reactor	27	Operating; further instrument upgrades planned
Orphee	France	Reactor	18	Operating; further instrument upgrades planned
KFA	Germany	Reactor	36	Operating
KFA Replacement	Germany	Reactor	NA	Planned replacement for existing KFA reactor
Berlin	Germany	Reactor	7	Operating
FRM II	Germany	Reactor	NA	Under construction; operation planned for 2001
KENS	Japan	Spallation	18	Operating
JRR-3	Japan	Reactor	8	Operating
JHF	Japan	Spallation	NA	Project start and funding approved
NSRP	Japan	Spallation	NA	Planned
Petten	Netherlands	Reactor	37	Operating
IBR-2	Russia	Reactor	14	Operating; upgrades planned
PIK	Russia	Reactor	NA	Planned
IN-06	Russia	Spallation	NA	Planned
Studsvik	Sweden	Reactor	38	Operating
SINQ	Switzerland	Spallation	2	Operating (continuous; not pulsed)
ISIS	United Kingdom	Spallation	23	Operating; power upgrade planned (ISIS II)
ESS	Europe	Spallation	NA	Planned to be world's best spallation source (5 MW); R&D underway; site TBD
HFBR	USA (BNL)	Reactor	33	Shut down; decision to restart or remain shut down pending completion of an EIS
HFIR	USA (ORNL)	Reactor	32	Operating; cold source and instrument upgrades in progress; new guide hall proposed
IPNS	USA (ANL)	Spallation	17	Operating
LANSCE	USA (LANL)	Spallation	13	Operating; power upgrade in progress
NBSR	USA (NIST)	Reactor	29	Operating; upgraded (cold neutron research facility)
MURR	USA (U of MO)	Reactor	33	Operating
MIT	USA (MIT)	Reactor	40	Operating
SNS	USA (the Proposed Action)	Spallation	NA	Project authorized by Congress in FY 1999; initiating preliminary design

NA – Not applicable

Sources: DOE 1993a: 37–38; OECD 1998

PRACTICAL BENEFITS OF NEUTRON SCATTERING SCIENCE

Over the past 40 years, neutrons have become an increasingly essential tool in broad areas of the physical, chemical, and biological sciences, as well as in nuclear medicine and materials technology. In the latter area alone, neutron probes have made invaluable contributions to the understanding and development of many classes of new materials ranging from high temperature superconductors to polymers (plastics) — materials with enormous industrial applications and future potential.

Some specifics:

- In materials science, neutron scattering research can be used to study diffusion, crystal structures, impurity concentrations, and residual stresses in forgings, castings, and welds. Residual stress studies have been used to predict failure modes in critical structural components (e.g., aircraft engines) and to help design ways to avoid these failures.

- In condensed matter physics, neutron scattering has vastly improved our understanding of the static and dynamic aspects of glasses, liquids, amorphous solids, and phase behavior. This, in turn, has enabled the optimized design of a variety of useful materials: metallic glasses with unique mechanical and magnetic properties that make them the preferred choice for many industrial uses; amorphous semiconductors that have wide use in the electronics industry and solar energy conversion; molten salts that have important applications in electrochemical processes that are as wide ranging as plating of steel and waste treatment; integrated optical systems including lasers and fiber optic transmission channels; and thin films for use in various magnetic data storage systems.

- Neutron scattering, particularly with cold neutrons, is becoming increasingly important to the investigation of molecular structures in biological materials. This has opened new opportunities to obtain information crucial to understanding biological functions and processes. Neutrons are already being used to study the role of water and hydrogen bonds in enzyme reactivity and protein chemistry and to make major contributions to the design of new drugs to treat a wide range of medical conditions.

- Neutron research on polymers and other complex fluids has led to improved pressure-sensitive adhesives, better oil additives, light-weight durable plastics, and improved detergent and emulsification products. Measurement of real-time changes in scattering profiles caused by changes in an externally applied field (e.g., pressure, shear stress, temperature) is valuable to chemical manufacturers, who are interested in improving the design, control, and reliability of industrial manufacturing processes like extrusion, molding, and cold drawing.

- Neutron research on magnetism has led to the development of higher strength magnets for more efficient electric generators and motors and better magnetic materials for magnetic recording tapes, high density computer hard drives, and other information storage devices.

Although not obvious to most people, the benefits of applying scientific knowledge gained from neutron scattering research are all around us in the form of products that have markedly improved our standard of living. Thus, neutron science lies at the foundation of the ability of American industry to develop, produce, and market new or improved products vital to the future growth of our nation's economy.

Environmental Impact Statement, which is now being prepared.

In Europe, the leading neutron scattering research facilities are the Institut Laue-Langevin (ILL) reactor in Grenoble, France; the ISIS short-pulse spallation source at the Rutherford Appleton Laboratory in England; and the SINQ steady-state spallation source in Switzerland. Smaller reactors are also in operation in Australia, Canada, Denmark, France, Germany, the Netherlands, Russia, and Sweden. With its guide halls, ILL accommodates more instruments than the two largest U.S. reactor sources (HFIR and HFBR) combined. The ISIS and SINQ spallation sources are far more powerful than the best U.S. spallation source (LANSCE), although work is now underway to upgrade LANSCE to the same power level as ISIS. Germany is constructing a new reactor neutron source, FRM II, with world-class cold source capabilities roughly equal to those of ILL. It is scheduled to be completed and to enter operation within the next few years. Lastly, a joint European effort is in the early stages of design for a next-generation spallation source, the European Spallation Source (ESS).

The Japanese have a sizable neutron scattering program that is supported by a research reactor (JRR-3) and a relatively modest spallation source (KENS). The JRR-3 research center, commissioned approximately 6 years ago, represents a substantial investment (~$300 million in 1992 dollars), far more than all U.S. investments in neutron sources over the past decade. As will be described later, the Japanese government has also embarked on an ambitious plan to build two large spallation sources in the coming decade.

A study published by the European Science Foundation (European Science Foundation 1996) provided a forward look at the likely increase in worldwide demand for neutron scattering experimentation. It demonstrated that research using neutrons can be expected to grow in both traditional fields such as solid-state physics, materials science, and physical chemistry, and new and rapidly developing areas for neutron research such as biotechnology, drug design, engineering, and earth sciences. This will involve an increase in the complexity and sophistication of the scientific work rather than a mere growth in the number of experiments. In addition, the study confirmed that non-neutron tools for matter investigation (e.g., X-rays, electron beams) cannot be adequate substitutes for neutron beams.

Thus, the availability of neutron sources in the face of increasing demand is a global concern. In recognition of this, a Neutron Sources Working Group was established in January 1996 under the auspices of the Organization for Economic Cooperation and Development (OECD). This OECD Working Group, comprising government officials and scientists from 25 countries including the U.S., is investigating the refurbishment and upgrading of existing facilities, as well as the prospects for international collaboration on developing new instrumentation and new neutron sources. The group has concluded that by the year 2020, there could be a “neutron gap” caused by more than two-thirds of the world’s neutron sources reaching the end of their useful operating lives. It therefore recommended that new, advanced neutron sources be built in each of the three major user regions (Japan, Europe, and the U.S.). This is consistent with plans for next generation spallation sources that are already being planned for construction. Specifically, a consortium of European countries is designing a 5-MW short-pulse spallation source, the previously mentioned ESS; Austria has designed a 100-kW short-pulse spallation source, the Austron; and Japan has formally announced a plan to build a 600-kW short-pulse spallation source, the Japanese Hadron Facility (JHF), that will be progressively upgraded to 1.2 MW and is part of the high-energy physics Japanese Hadron Project. Japan is also planning another 1-MW spallation source that will be upgraded to 5 MW for nuclear technology development and neutron scattering. The construction of the proposed SNS in the U.S. would then complete the worldwide set of new neutron sources recommended by the OECD Working Group.

When compared with the global "neutron gap," the shortfall in our nation's neutron science capability is even more acute; this shortfall has been developing over the past two decades as a result of insufficient funding to invest in building new sources and upgrading existing facilities. It is clear from Table 1.2-1 and the preceding discussion that among the world's major neutron sources, those in the U.S. are older and becoming less capable than their foreign counterparts. Although there are modest efforts to upgrade and extend the useful life of these facilities (already underway at LANSCE and HFIR), a new neutron source has not been built in the U.S. in well over 10 years.

1.3 PROPOSED ACTION AND ALTERNATIVES ANALYZED

This section introduces DOE's proposed action and provides background information about the proposed neutron source. This section also introduces the alternatives analyzed in the EIS. Chapter 3 of this document provides a detailed description of the proposed action and alternatives.

1.3.1 THE PROPOSED ACTION

The proposed action is to construct and operate a state-of-the-art short-pulse spallation neutron source comprising an ion source, a linear accelerator (linac), a proton accumulator ring, and an experiment building containing a liquid mercury target and a suite of neutron scattering instrumentation. The proposed SNS facility would be designed to operate at a proton beam power of 1 MW and to be upgradable in the future (see Figure 1.3-1). The scope of these upgrades over the operating life of the facility is envisioned to encompass, in chronological stages:

1. Adding a second experiment building, including a second mercury target with its own suite of instrumentation (space for this is included in the facility footprint analyzed in this EIS).

2. Increasing the proton beam power to 2 MW by doubling the ion source output.

3. Increasing the proton beam power to 4 MW by adding a second ion source, modifying the linac, and adding a second proton storage ring (again, space for the upgrades is included in the facility footprint analyzed in this EIS).

The implementation of these upgrades would depend largely on availability of future funding. DOE would perform further NEPA review if and when the decision to upgrade the facility is made. For the sake of completeness, however, this EIS analyzes the impacts of the SNS facility

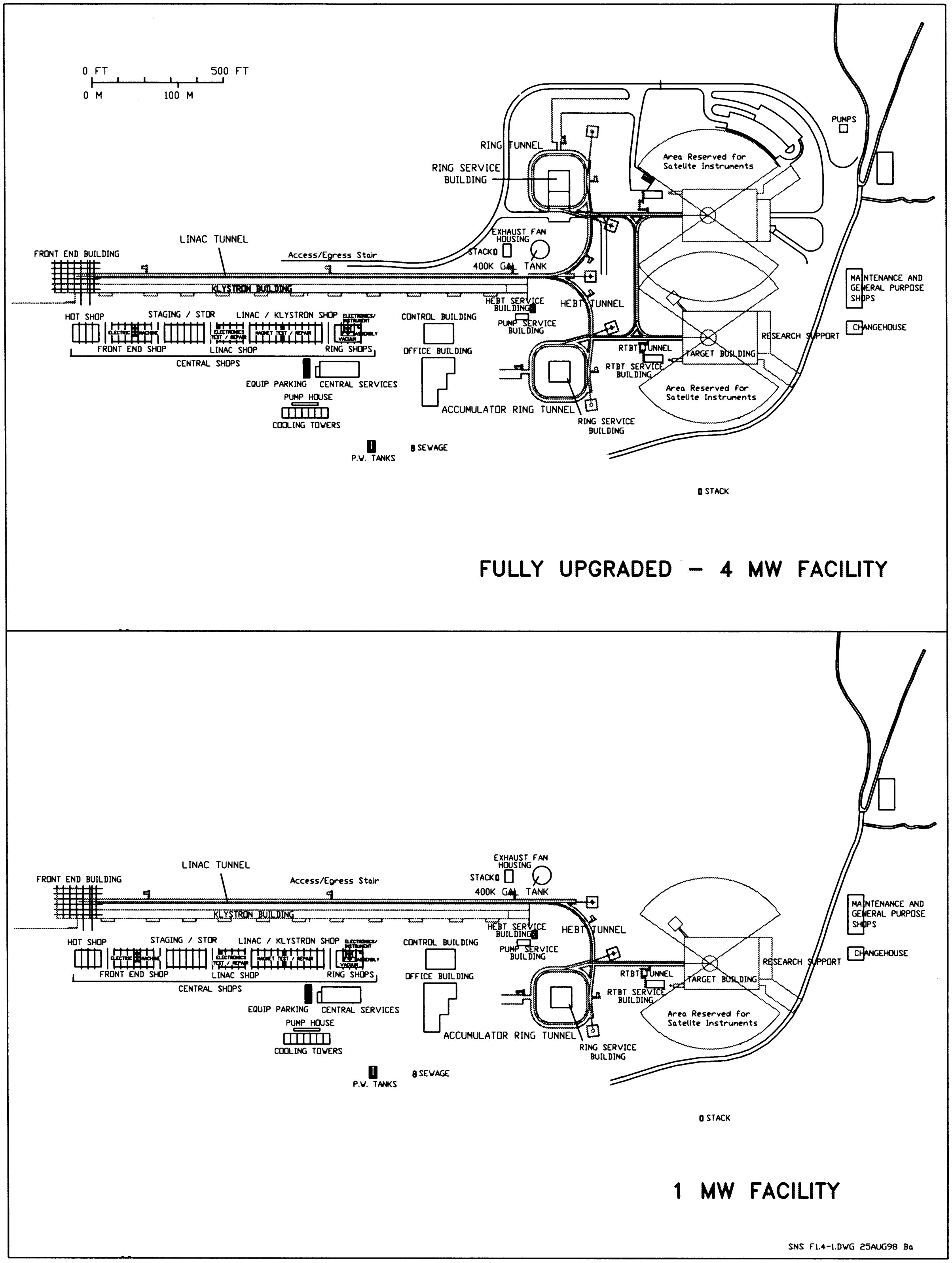


Figure 1.3-1. Site plan for SNS.

as it would originally be built as well as those corresponding to its fully upgraded configuration. The proposed action does not include decommissioning of the proposed facility. The fate of the SNS beyond its 40-year life span has not been determined. When the decision is made to decommission the facilities, a detailed decontamination and decommissioning plan along with the appropriate NEPA documentation would be prepared.

1.3.2 Basis of Proposed Action

DOE has been charged with the responsibility for planning, constructing, and operating the major scientific user facilities to provide special research capabilities (*Energy Policy Act of 1992*; Public Law 102-486, Section 2203). This is in recognition of the fact that these kinds of facilities tend to be large-scale, physically complex, and hence very expensive (hundreds of millions or even billions of dollars)—well beyond the means of most private and industrial organizations to build and operate. High performance neutron sources, based on reactors or accelerators, naturally belong in this category.

The use of these DOE facilities is open to all researchers (federal, industrial, and academic), usually at no charge as long as the scientific information derived from their experiments is kept in the public domain for the benefit of the entire scientific community.

The scientific justification and need for additional and more capable neutron sources in the U.S. has been established by numerous studies dating back to the 1970s. Two National Research Council studies (*Neutron Research on Condensed Matter* 1977 and *Current Status of Neutron Scattering Research and Facilities in the U.S.* 1984) urged DOE to build new neutron sources in order to keep up with research demand and to sustain U.S. scientific leadership in this field. The earlier study led to the construction of IPNS and LANSCE in the early 1980s. In 1984, the broad-based study *Major Facilities for Materials Research and Related Disciplines* recommended construction of four major new materials research facilities including an advanced, high-flux, steady-state neutron source, and a high-intensity pulsed neutron source. As a result, in 1987 DOE tasked ORNL with developing a design for a high-flux, steady-state source based on a nuclear reactor, a project that later became known as the Advanced Neutron Source (ANS). Action on the recommendation for a high intensity pulsed neutron source was to be deferred, due to funding constraints, until after the ANS was completed.

By 1992, a conceptual design for the ANS had been completed, and at the same time, a special panel under the DOE's Basic Energy Sciences Advisory Committee (BESAC) was asked to assess the importance of neutron science for the nation's science, technology, health, and economy, and to make recommendations for both short-term and long-term strategies for neutron sources. The panel was chaired by Professor Walter Kohn (University of California, Santa Barbara, winner of the 1998 Nobel Prize in Chemistry) and included both specialists and generalists from government laboratories (7 panelists), private industry (4 panelists), and universities (3 panelists). Their report, *Neutrons for America's Future* (DOE 1993) (1) reaffirmed the need for constructing ANS as the top priority, (2) recommended that DOE immediately initiate the design of a complementary, 1-MW pulsed spallation source, and (3) urged that existing neutron sources be upgraded. In their judgment, "failure to move ahead quickly with the construction of the ANS and development of a complementary 1-MW pulsed spallation source would have serious, long-lasting consequences for the nation's competitiveness in cutting-edge science, technology, industry, and medicine. The construction of these facilities represents a cost-effective and productive investment in the nation's future."

Although the President's budget requests to Congress for fiscal years 1994 and 1995 included funding to start the ANS construction project, no funds were ever appropriated for construction, and DOE elected to cancel the project in 1996. Concern over the high cost of the project (approximately $3 billion) was the primary factor in the decision. In lieu of ANS, the administration advised that a next-generation pulsed spallation source be pursued (since this was assumed to be much less expensive and was also consistent with the Kohn Panel's second recommendation) and that upgrades to existing DOE neutron sources be considered.

In response to this guidance, a collaboration of DOE laboratories was organized to develop a conceptual design for a new state-of-the-art spallation neutron source. Given ORNL's long history in neutron scattering research (which dates back to Shull's pioneering work on the ORNL Graphite Reactor in the 1940s), their extensive materials research and testing program, and the project management infrastructure remaining from ANS, ORNL assumed the lead role. Together with four other national laboratories [ANL, BNL, LANL, and Lawrence Berkeley (LBNL)] the design work was carried out with each laboratory having lead responsibility for a major technical system in which they have prominent expertise:

- ANL–Instrumentation
- BNL–Proton storage ring and high energy beam transport
- LANL–Linac
- LBNL–Ion source and low energy beam transport
- ORNL–Target, moderators, and conventional construction

This collaborative design approach was chosen because it:

- Assembled the best available expertise to complete a conceptual design in the shortest time with limited funds,
- Accessed the best and most current technologies,
- Incorporated insights from existing feasibility studies done by U.S. and foreign laboratories, and
- Conserved DOE resources by using a "system-of-laboratories."

The collaboration's design work was guided by BESAC, which formed a panel under Dr. Thomas Russell (IBM Research Division) in late 1995 to evaluate technical aspects and basic design requirements. The panel's report (BESAC 1996) made several recommendations that were accepted by DOE and that served to establish the fundamental characteristics for the conceptual design of the SNS:

- Short-pulse operation in the 1-MW power range (1 microsecond proton pulses).
- Design that preserves long-pulse operation as an option.
- Upgradable to a significantly higher power at some point after commissioning.
- Horizontal proton beam injection into the target.
- One target and the capability to produce neutron pulses at frequencies in the range of

30 to 60 Hz, with the potential for installing additional targets and instrumentation in the future.

- Carefully selected initial set of instruments to maximize early scientific impact.
- Set of moderators to provide neutrons with appropriate characteristics to meet user needs.
- Highly predictable and reliable operation for at least 240 days/year.
- Use of low-risk technology initially, with parallel research and development on certain critical systems to advance the state-of-the-art while reducing risks to acceptable levels.

By mid-1997, the five-laboratory collaboration had produced a conceptual design for the SNS (ORNL 1997a, see Figure 1.3-1) that was favorably reviewed by a committee of outside experts (DOE/ER-0705, 1997). This site-independent conceptual design is the basis for the proposed action.

1.3.3 ALTERNATIVES ANALYZED

The two primary alternatives analyzed in this EIS are (1) the alternative to proceed with building an accelerator-based neutron source and (2) the No-Action Alternative.

Under the to-build alternative, the EIS analyzes the environmental impacts associated with constructing and operating the neutron facility. Four individual siting alternatives are analyzed in the EIS. The effects from the No-Action Alternative serve as a basis for comparison of the effects from the other alternatives. In addition, alternatives considered, but eliminated from consideration, are presented for completeness. Other conceivable technical design options for a spallation source have been evaluated; these technology alternatives and the elimination process are discussed at length in Chapter 3.

1.3.4 SITING ALTERNATIVES CONSIDERED IN THIS EIS

DOE used a systematic process to select suitable alternative sites for the proposed action (refer to Appendix B). The site-selection process began by identifying four major site exclusion criteria. When these criteria were defined, the process continued in two major phases. Phase 1 focused on using the exclusion criteria to identify the reasonable siting locations for the proposed SNS on a national level. Phase 2 focused on identifying a specific alternative site for the proposed SNS at each of these locations.

Specific SNS project requirements were used to develop the site exclusion criteria. These criteria were as follows:

- A site with a minimum area of 110 acres (45 ha) and a rectilinear shape to accommodate the length of the proposed linear accelerator and possible future expansion of the facility.
- A one-mile (1.6 km) buffer zone around the proposed SNS site to restrict uncontrolled public access and to insulate the public from the consequences of a postulated accident at the facility.
- Proximity and availability of an adequate electric power source. The regional power grid must be able to supply 40 MW of power during periods of operation. The site must be within one quarter to one mile (0.4 to 1.6 km) of existing transmission lines to minimize collateral construction impacts and costs.
- Presence of existing neutron science programs and infrastructure to provide a

pool of neutron science expertise and experience to meet mission goals. The site must have major facilities and programs utilizing neutron scattering techniques.

As a result of this process, DOE identified four reasonable alternative locations for the proposed SNS. These facility locations were ORNL, LANL, ANL, and BNL.

In Phase 2 of the site-selection process, each of the four national laboratories conducted its own systematic site-selection process to identify specific locations for the proposed SNS. These processes focused primarily on laboratory lands, and they involved the identification and evaluation of alternative sites at each laboratory. Site-selection criteria included project requirements and environmental protection considerations. These criteria were applied to the alternative locations to identify one specific location for the proposed SNS at each national laboratory.

This EIS assesses the environmental impacts associated with the four siting alternatives that would result from the construction and operation of the proposed SNS.

ORNL Alternative (Preferred Alternative): To construct and operate the proposed SNS at ORNL in Oak Ridge, Tennessee.

LANL Alternative: To construct and operate the proposed SNS at the LANL in Los Alamos, New Mexico.

ANL Alternative: To construct and operate the proposed SNS at the ANL in Argonne, Illinois.

BNL Alternative: To construct and operate the proposed SNS at the Brookhaven National Laboratory in Upton, New York.

1.4 ENVIRONMENTAL ANALYSIS PROCESS

This EIS is being prepared pursuant to NEPA [42 USC 4321 et seq.], the President's Council on Environmental Quality (CEQ) NEPA regulations in 40 CFR 1500-1508, and DOE NEPA regulations in 10 CFR 1021.

This EIS analyzes the potential environmental impacts of two primary alternatives: the proposed action (to construct and operate an accelerator-based neutron source) and the No-Action Alternative. This proposed facility would meet many of the nation's neutron science needs well into the next century. An artist's conception of the completed neutron facility is shown in Figure 1.4-1.

The preliminary scope of this EIS was defined through examination of the National Environmental Policy Act (NEPA) and safety assessment documents for other DOE accelerator facilities. This review indicated that appropriate topics to address in the EIS analysis would include land use, facility waste streams, and accident scenarios that might impact human health or the environment (ORNL 1997b: 9-1 to 9-2). Other issues of public concern, including socioeconomics and waste management issues (see Section 1.5), were documented through the public scoping processes for each of the four alternative sites.

Preparation of this EIS allows a full dialogue between DOE and all interested parties

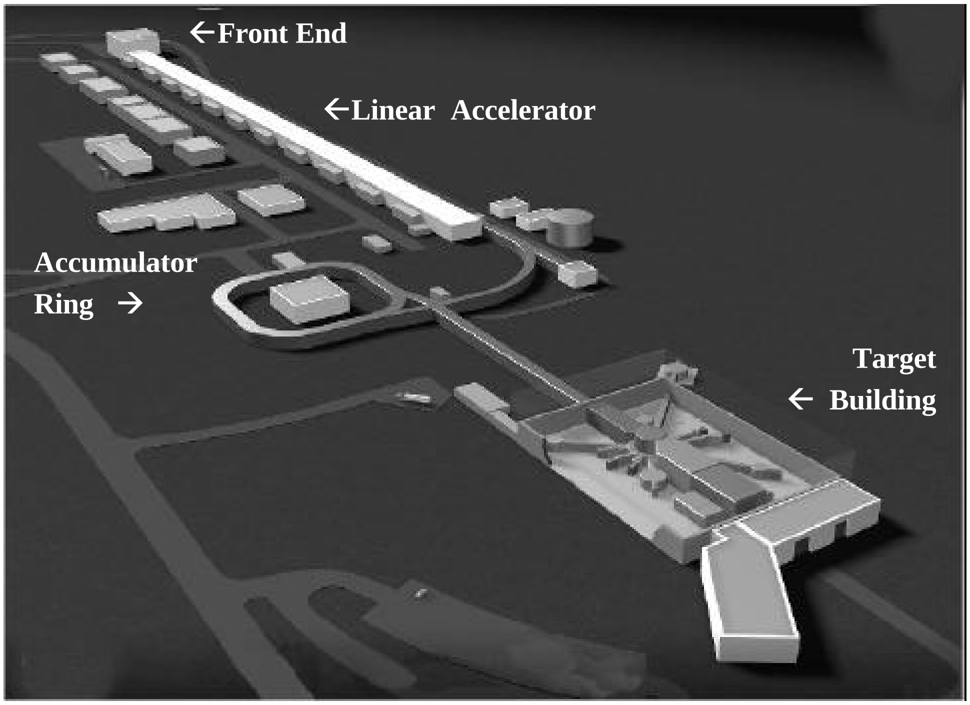


Figure 1.4-1. Artist's conceptual drawing.

regarding the potential environmental consequences of the proposed action and alternatives. Potential interested parties or stakeholders may include the general public; state, county, municipal, and tribal governments; and other federal agencies. The EIS provides the environmental input for decision-making and also the basis for appropriate mitigation measures, if needed, for the course of action selected.

This draft EIS is being distributed to U.S. congressional members and committees; the states of Illinois, New Mexico, New York, and Tennessee; the tribal governments of Cochiti, Jemez, Santa Clara, and San Ildefonso Pueblos; the county governments of Anderson/Roane County (Tennessee), DuPage County (Illinois), Los Alamos/Santa Fe County (New Mexico), and Suffolk County (New York); and the general public for review and comment. DOE invites comments to correct factual errors or to provide insights on matters related to this environmental analysis. In addition to its invitation for written comments, DOE has scheduled public hearings to solicit both oral and written comments on the draft EIS.

After considering the comments received, DOE will revise the draft EIS, as appropriate, and publish a final EIS. The final EIS will be distributed to tribal, state, and local governments; other federal agencies; all parties who commented on the draft EIS; and any interested parties. DOE intends to publish all comments received with a complete response. However, if the number of comments is too voluminous, DOE may publish a comment summary in the final EIS. All comments and responses will be available for public review in DOE reading rooms.

About NEPA

NEPA was enacted to ensure that federal decision-makers consider the effects of proposed actions on the human environment and to open their decision-making process for public scrutiny. NEPA also created the President's Council on Environmental Quality (CEQ) to establish a NEPA review process. DOE's NEPA regulations (10 CFR 1021) augment the CEQ regulations (40 CFR 1500).

An EIS documents a federal agency's analysis of the environmental consequences that might be caused by major federal actions, defined as those proposed actions that might result in a significant impact to the environment. An EIS:

- Explains the purpose and need for the agency to take action.
- Describes the proposed action and the reasonable alternative courses of action that the agency could take to meet the need.
- Describes what would happen if the proposed action were not implemented—the "No-Action" (or Status Quo) Alternative.
- Describes what aspects of the human environment would be affected if the proposed action or any alternative were done.
- Analyzes the changes, or impacts, to the environment that would be expected to take place if the proposed action or an alternative were implemented, compared to the expected condition of the environment if no action were taken.

The DOE EIS process follows these steps:

- Notice of Intent, published in the *Federal Register*, identifies potential EIS issues and alternatives and asks for public comment on the scope of the analysis.
- Public scoping period with at least one public meeting, during which public comments on the scope of the document are collected and considered.
- Draft EIS, issued for public review and comment, with at least one public hearing.
- Final EIS, which incorporates the results of the public comment period on the draft EIS.
- Record of Decision that states:
  - The decision.
  - The alternatives that were considered in the EIS and the environmentally preferable alternative.
  - All decision factors, such as cost and technical considerations, that were considered by the agency along with environmental consequences.
  - Mitigation measures designed to reduce adverse environmental impacts.
  - Mitigation Action Plan, as appropriate, which explains how the mitigation measures will be implemented and monitored.

At least 30 days following the issuance of the final EIS, DOE will issue a Record of Decision (ROD) that will explain all factors, including environmental impacts, that DOE considered in reaching its decision on selecting the alternative to be implemented. The ROD will specify the selected alternative after due consideration of environmental consequences. DOE anticipates that, in addition to environmental impacts, the ROD will be based on cost and infrastructure considerations. Any mitigation measures, monitoring, or other conditions adopted as a part of DOE's decision will be summarized in the ROD, as applicable, and included in a Mitigation Action Plan (MAP) if needed. The MAP will explain how and when mitigation measures would be implemented and how DOE would monitor the mitigation measures over time to ensure their effectiveness. The ROD and MAP, if prepared, will be placed in public reading rooms and will be available to interested parties upon request.

1.5 THE SCOPING PROCESS AND MAJOR ISSUES IDENTIFIED FOR ANALYSIS

DOE published the Notice of Intent to prepare this EIS in the *Federal Register* (62 FR 40062) on July 25, 1997. The public comment period was from July 25 to September 12, 1997. During this period, public meetings were held in Oak Ridge, Tennessee; Argonne, Illinois; Los Alamos, New Mexico; and Upton, New York. A total of 61 individuals representing 15 citizen groups, 14 government organizations, one Native American pueblo, one educational institution, and four elected officials representing themselves and their constituents submitted comments during the public scoping period. Comments received included 152 oral and written comments and 21 endorsements and resolutions. These comments were analyzed and classified according to 21 subject categories.

The subject categories that contained the most substantive comments were socioeconomics, siting alternatives, waste management, and project justification. Nineteen socioeconomics comments were received. The majority of these comments requested analyses of the beneficial effects the proposed action would have in terms of new jobs, personal income, tax revenues, spin-off businesses, need for support from the host state, and other economic factors. Nineteen comments were received on siting alternatives for the proposed action. Most of these comments were in support of or against siting the proposed action at one of the alternative national laboratories, and one recommended consideration of the Hanford site. Others requested more detailed analyses of the criteria used to select alternative sites for the proposed action and analyses of the potential effects that would result from implementing the proposed action on these sites. Fifteen comments on waste management were received. These comments were concerned with waste generation, particularly radioactive waste and hazardous metals, and the proper management of these wastes in compliance with federal and state regulatory requirements. Project justification received 13 comments, most of which were supportive of the proposed action with several opposed to the project. One comment suggested pursuing a cooperative agreement with European countries to use their existing neutron sources.

All of the scoping comments received were summarized in a document entitled *Results of Public Scoping for the Spallation Neutron*

Source/Environmental Impact Statement (DOE-ORO 1997). This document is available to the public in the following reading rooms:

1. U.S. Department of Energy
   Freedom of Information Public
   Reading Room
   Forrestal Building, Room 1E-190
   1000 Independence Avenue, S.W.
   Washington, D.C. 20585
   Telephone: (202) 586-3142

2. U.S. Department of Energy Reading Room
   Oak Ridge Operations Office
   55 Jefferson Circle, Room 113
   Oak Ridge, Tennessee 37831
   Telephone: (423) 241-4780

3. Los Alamos National Laboratory
   Public Outreach and Reading Room
   Los Alamos, New Mexico 87544
   Telephone: (505) 665-2127

4. Argonne National Laboratory
   c/o Documents Department
   University Library, Third Floor Center
   University of Illinois at Chicago
   801 South Morgan Street
   Chicago, Illinois 60607
   Telephone: (312) 996-2738

5. BNL Research Library
   Bldg. 477A Brookhaven Avenue
   Upton, New York 11973
   Telephone: (516) 344-3483

6. Longwood Public Library
   800 Middle Country Road
   Middle Island, New York 11953
   Telephone: (516) 924-6400

7. Mastics-Moriches-Shirley Community
   Library
   301 William Floyd Parkway
   Shirley, New York 11967
   Telephone: (516) 399-1511

DOE considered all comments during preparation of the draft EIS. Individuals and organizations will have an opportunity to review the draft EIS and to provide further comments prior to the preparation of the final EIS.

1.6 ORGANIZATION OF THE EIS

This EIS is organized into two volumes. Volume I contains the Summary and Chapters 1 through 6, which are further outlined below. Volume II contains the appendices that are referenced throughout Volume I.

Chapter 1 – Introduction. Background information on the state of neutron science in the U.S. and its relationship to a next-generation neutron source are discussed. The internal organization of the EIS is presented in this chapter, and the environmental analysis process under NEPA is covered.

Chapter 2 – Purpose and Need for DOE Action. This section includes the reasons DOE proposes to take action at this time.

Chapter 3 – Proposed Action and Alternatives. This chapter describes how DOE proposes to meet the specified needs and alternative ways the specified needs could be met. It includes a summary of expected environmental impacts if the preferred alternative or any of the other analyzed alternatives were to be implemented.

Chapter 4 – Affected Environment. The various aspects of the existing environment (natural, social, and manmade) that might be affected by the preferred alternative or any of the other alternatives are described.

Chapter 5 – Environmental Consequences. The changes or impacts that the alternatives would be expected to have on elements of the affected environment are analyzed. Impacts are compared to the environment that would be expected to exist if no action were taken (the No-Action Alternative).

Chapter 6 – Permits and Consultations. CEQ NEPA regulations require preparation of an EIS in coordination with other applicable environmental requirements that may involve permits and consultations with federal, state, tribal, local, and other agencies. The additional requirements and consultations applicable to the alternatives are described in this chapter.