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BROOKHAVEN GRAPHITE RESEARCH REACTOR DECOMMISSIONING PROJECT'S REMOVAL ACTION ALTERNATIVES STUDY: A BASIS FOR STAKEHOLDER INVOLVEMENT IN THE END-STATE DETERMINATION PROCESS

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ABSTRACT

Input from local community members and interested stakeholders at the Brookhaven National Laboratory (BNL), located on Long Island, New York, continues to be a valuable resource in the decision-making process. As the result of community roundtable meetings and discussions with stakeholders, the priorities of the Laboratory's next major cleanup project — the decommissioning of the Brookhaven Graphite Research Reactor (BGRR) — are being re-examined.

In March 1999, the U.S. Department of Energy, Chicago Operations Office (DOE-CH) made a major strategic change for decommissioning the Brookhaven Graphite Research Reactor. Previously, the strategy was to fully characterize the nearly 50-year-old shut down graphite-moderated and air-cooled research reactor over a period of two years and at a cost of approximately $6 million. Under that strategy, the actual decommissioning and cleanup of the reactor facility would not begin until the characterization was completed.

Because of mounting pressure from stakeholder groups, the DOE-CH Environmental Programs Group (EPG), headed by Anibal L. Taboas, instead decided to initiate aggressive decommissioning at the reactor, using the Department's removal action authority granted by the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA).

Bechtel National, Inc. (BNI), under contract to Brookhaven Science Associates (BSA) was selected to manage this new bias-for-action decommissioning project. By late March 1999, a BNI project manager was selected and the decontamination and decommissioning (D&D) project team began to form. DOE-CH EPG challenged the team to complete all planning and engineering, initiate actual field work, and involve stakeholders in the decision-making process, all by the end of FY 1999. This challenge was successfully met.

To minimize programmatic risk, the decommissioning project was broken down into seven major subprojects. The initial regulatory approach was to prepare an Engineering Evaluation/Cost Analysis (EE/CA) for each major subproject, which would then undergo stakeholder review and comment prior to preparing the Action Memorandum. A work sequencing strategy was developed to take on each of seven subprojects by priority, first completing the characterization followed by the decontamination and removal actions.

Although this approach would allow early and steady progress throughout the project's four to five year term, it also presented a decision-making and stakeholder involvement dilemma. The final end-state for the reactor facility, at large, would not be known for several years. In fact, it would be determined in a composite fashion, based on the cleanup decisions for the individual subprojects. The more controversial (and costly) decisions, such as the final end-state for the reactor's graphite core and massive concrete and steel biological shielding, would not get presented to the stakeholders or be finalized for at least three years into the future. Getting early stakeholder input on the final end-state decisions was critical to successfully plan for the project's future federal funding.

In April 1999, the DOE project manager organized an End-State Working Group to grapple with this decision-making dilemma. The outcome of the Working Group was a recommendation to prepare a high-level removal action alternatives study, whose objectives were to: a) develop a range of removal action alternatives; b) screen these alternatives against CERCLA criteria and *National Environmental Policy Act* (NEPA) values; c) present life-

cycle cost comparisons for the range of alternatives; d) involve stakeholders in the review and input to the study; and, e) make recommendations for the final end-state of the BGRR. These recommendations would then be further evaluated in subsequent subproject EE/CAs.

In May 1999, DOE-CH, EPG approved initiation of the *BGRR Removal Action Alternatives Study*, and BNI selected Cabrera Services, Inc., as the study contractor. Additionally, with assistance from Vector Resources, Inc., BNI prepared a Stakeholder Involvement Plan. This Plan identified ways to involve stakeholders early on, sustain their involvement throughout the project, and provide opportunities for meaningful and timely input into the decision-making process.

Roundtable meetings in the community were one of the techniques identified to accomplish these objectives. Designed as facilitated small group meetings, the roundtable setting encourages discussion and interaction among the attendees. To date, two series of highly successful roundtable meetings have been held, which have attracted a broad, diverse group of stakeholders.

Roundtable participants have included members of the BNL Community Advisory Council, civic organizations, environmental groups, representatives of regulatory agencies and elected officials, Laboratory employees, businesses, the general public and DOE officials representing the Office of Science (SC) and the Office of Environmental Management (EM). Not including representatives of the DOE, BNL, or the project staff, 56 people participated in the first series of meetings and 42 people participated in the second.

The focus of the first series in July and August 1999 was to discuss the project with stakeholders and get input on their values and expectations for the decommissioning project. The project team will use these values, along with NEPA and CERCLA criteria, to screen the removal action alternatives. Also, the community values are intended to be a basic reference point for discussing the pros and cons of various D&D alternatives over the course of the project. The second series of meetings in September and October 1999 addressed the *Removal Action Alternatives Study* and began discussions about the project's potential end-state.

Seven removal action alternatives are being analyzed in the *BGRR Removal Action Alternatives Study*. They range from no further action (continue surveillance and maintenance) as one bounding alternative, to full removal of the reactor core, biological shield, and the reactor containment building. An intermediate alternative (baseline planning alternative) considers leaving the reactor core and containment building, but removing all other contaminated structures including the above-grade cooling air ducts, the fuel handling and storage facility, the below-grade cooling air ducts, and contaminated soils surrounding the reactor facility.

DOE's objective is to use these first steps as the basis for an ongoing dialogue with the community to yield better, smarter decisions about environmental cleanup and decommissioning of the reactor complex. While many decisions about the decommissioning of the BGRR have not yet been made, it is through pro-active and focused dialogue with the project's stakeholders that the concerns of all interested parties can be addressed.

As this paper is being written, the next opportunity for public input in the decision-making process will be after the release of the *BGRR Removal Action Alternatives Study*, in January 2000. While not a legal requirement, a public comment period and two information sessions are planned to facilitate continued involvement by local stakeholders. Current information about the project's status and schedule — as well as announcements of upcoming public meetings and roundtables — can be found on the Brookhaven Graphite Research Reactor Decommissioning Project's web page at http://www.bgrr.bnl.gov.

INTRODUCTION

The U.S. Department of Energy (DOE) has begun a project to decommission the Brookhaven Graphite Research Reactor (BGRR) located at the Brookhaven National Laboratory (BNL) on Long Island, New York. The BGRR is an air-cooled, graphite-moderated research reactor that was last operated in 1969. Bechtel National, Inc. is decommissioning the reactor under contract to Brookhaven Science Associates who manages BNL for the Department of Energy. DOE has authority to perform decommissioning under the *Comprehensive Environmental Response, Compensation, and Liability Act* of 1980 (CERCLA), as updated by the *Superfund Amendment and Reauthorization Act* of 1986 (SARA), and the *National Environmental Policy Act* of 1969 (NEPA). Under this authority, the decommissioning project is being carried out as a series of removal actions to achieve environmental cleanup at the Laboratory.

The primary objectives of the BGRR Decommissioning Project are to remove and/or permanently isolate sources of contamination; reduce any potential threat to public health and the environment; comply with all local, state and federal regulatory requirements; address community and stakeholder values; and retire a facility that is no longer needed by the DOE.

Cabrera Services, Inc. was selected by BNL to prepare a *Removal Action Alternatives Study* (RAAS) for the BGRR Decommissioning Project. The purpose of the RAAS is to evaluate a range of Removal Action Alternatives for final decommissioning of the BGRR. The RAAS is not intended to serve as a Feasibility Study or an Engineering Evaluation/Cost Analysis (EE/CA); rather it is intended as a screening tool and preliminary assessment to determine how the decommissioning alternatives compare relative to the CERCLA criteria and NEPA values that apply to the project. In addition to its screening function, the RAAS may be used as the basis for one or more future EE/CAs involving a more detailed evaluation of alternatives for individual sub-projects and removal actions.

The process for determining the final end state for the reactor complex includes early and ongoing opportunities for stakeholder involvement and input. A plan to involve community members and other stakeholders in the decision-making process was developed by BNL with assistance from Vector Resources, Inc. The plan identifies roundtable meetings with stakeholders as an effective means of communicating information about the decommissioning project and obtaining input from the community on removal actions that define the end state for the reactor facility.

History of BGRR

The BGRR was the first peacetime reactor constructed in the United States to provide neutrons exclusively for research purposes. Construction of the BGRR was completed in August 1950 and the reactor pile reached criticality on August 22 of that year. During its operation, the reactor contributed to many scientific and technical advances in the fields of medicine, biology, chemistry, physics, and nuclear engineering.

The BGRR was designed as an air-cooled, graphite-moderated and reflected reactor, originally fueled with aluminum-canned natural uranium (NU) elements. The original fuel elements were subject to stress-related failures. These fuel failures resulted in the oxidation of uranium metal causing dispersion of uranium, fission product, and plutonium oxide particles to the graphite channels, air ducts, and air filters within the reactor facility.

In 1958, the natural uranium fuel elements were replaced with aluminum-clad, enriched uranium-aluminum alloy plate fuel elements. The newer enriched uranium (EU) fuel elements were not subject to deterioration or in-service failure with the exception of occasional fuel plate overheating due to blockage in the graphite channels. The nominal power level of the BGRR was 28 megawatts thermal (MWt) during the NU fuel loading, and 20 MWt during the EU fuel loading.

Experimental use of the BGRR terminated in June 1968 with the introduction of the Brookhaven High Flux Beam Reactor (HFBR). The HFBR produced more than a 100-fold increase in neutrons over the BGRR facility and has a lower background radiation level. Deactivation activities for the BGRR were initiated in 1969. The graphite moderator was regularly annealed during operation, and was again annealed in 1970 to remove any residual stored energy. Following permanent shutdown, the control rods were disconnected from the drives and inserted into the

graphite reactor pile. The biological shield penetrations for the control rods were covered with metal plates that were tack-welded into place and the experimental openings were closed or plugged.

Between 1985 and 1986, the piping and equipment were removed from the water treatment and canal house, the sumps and drains in the east yard pads were sealed, paint flaking from the walls of the canal walkway was scraped, and all accessible areas in the canal facility were cleared of debris. The BGRR facility was described as being in a safe shutdown condition by the U.S. Atomic Energy Commission (AEC) and became an "orphaned" facility within the DOE complex.

Areas of Concern under the Brookhaven National Laboratory Interagency Agreement

The BGRR was identified as an Area of Concern (AOC) in the May 1992 Interagency Agreement (Federal Facilities Agreement) between DOE, the U.S. Environmental Protection Agency (EPA), and the New York State Department of Environmental Conservation (NYSDEC). There are four sub-AOCs, described as a) BGRR Canal Contaminated Soils; b) Underground Ductwork Contaminated Soils; c) Spill Sites Associated with the East Yard; and, d) Pile Fan Sump Soils. Under the Interagency Agreement (IAG), DOE must address specified AOCs as part of the environmental cleanup program at BNL. Most of the environmental cleanup activities are covered by CERCLA, including facility decommissioning, which may be managed as either time-critical or non-time-critical removal actions. In conjunction with CERCLA and other federal laws, NEPA establishes policies and goals for protecting the quality of the environment. In accordance with DOE Order 5400.1E and 10 Code of Federal Regulations (CFR) 1021, the considerations (values) of NEPA must be evaluated during the CERCLA process.

Compliance with the *National Historic Preservation Act* is another requirement pertinent to the BGRR Decommissioning Project. In accordance with this Act, the BGRR facility was assessed and found to be historically significant and potentially eligible for listing on the National Register of Historic Places. Eligibility for listing on the National Register requires that the project identifies effects of decommissioning on the BGRR and develops a mitigation plan to address these effects. Accordingly, DOE has submitted a draft Memorandum of Agreement to the New York State Historic Preservation Office (SHPO) with the final *Request for Determination of Eligibility* and final *Determination of Effects Findings.*

SYSTEMATIC APPROACH TO DEVELOP END-STATE ALTERNATIVES

Decommissioning is a controlled process used to safely retire a facility that is no longer needed. During decommissioning, radioactive and hazardous materials, equipment or structures are decontaminated, isolated, sealed, enclosed, or removed so that the facility does not pose a risk to public health or the environment.

Screening Criteria Development

To facilitate decommissioning planning for the BGRR, the project team gathered input on community and stakeholder values during a series of roundtable meetings in the summer of 1999. The results of these meetings were published in a document entitled *Summary of Roundtable Discussions on Decommissioning of the BGRR*. This input has been considered during the evaluation and screening of decommissioning alternatives. As the project proceeds, stakeholders will have additional opportunities to provide input to the BGRR End-State decision-making process.

Along with stakeholder input, the following broad categories of evaluation criteria were considered in developing a range of decommissioning alternatives:

- Overall protectiveness to public health and the environment
- Feasibility/implementability of alternatives in achieving the prescribed removal action objectives
- Potential costs (order of magnitude) associated with implementation of each alternative, and
- Impacts to the overall Environmental Restoration Program

Standard Approach

In keeping with the CERCLA process for determining removal actions, the standard approach used to develop the range of decommissioning alternatives also includes:

1. Determination of potential exposure pathways
2. Determination of Contaminants of Potential Concern (COPCs)
3. Determination of potential Applicable or Relevant and Appropriate Requirements (ARARs)
4. Development of Removal Action Objectives (RAOs) and Preliminary Remediation Goals (PRGs) which address the land use, COPCs, ARARs, and exposure pathways determined in Steps 1 – 3 above
5. Development of general response actions capable of addressing the RAOs in Step 4
6. Screening of technologies capable of achieving the general response actions in Step 5. Technologies can be eliminated from consideration for an alternative based upon such criteria as unfeasibility, prohibitive costs, or lack of proven success in similar circumstances
7. Development of representative process options for the technologies retained in Step 6
8. Combining of process options into viable alternatives for decommissioning the BGRR facility. These alternatives should cover a range of cost and complexity, from No-Action (which is considered as a baseline for comparison under CERCLA) to complete removal of all buildings, structures, appurtenances, and environmental media impacted by historical activities

Steps 6 and 7 have been combined and are referred to as "development of representative process options".

Future Land Use

To identify appropriate RAOs, the future land use must be considered. Potential future land use was discussed with stakeholders, the public, and the project team during the roundtable meetings. Additional land use options will be considered after the nature and extent of contamination has been determined at the BGRR facility. The BGRR facility is located within a developed area of BNL, ranging from 100 to 120 feet above sea level. The structures within the reactor complex that were built to support the BGRR operation include the Reactor Building (Building 701), the Reactor Pile (Building 702, which is wholly enclosed by Building 701), the Reactor Laboratory (Building 703, which is not included in the scope of the project), the Fan House (Building 704), the Reactor Stack (Building 705 which is also outside the project scope), the Instrument House (Building 708), the Canal House (Building 709), the Water Treatment Facility (Building 709A), the Hot Laboratory (Building 801, not included in the scope of the project), and the Pile Fan Sump.

Without a complete characterization and risk assessment, exposure pathways will be based on existing information and thus will be more qualitative than quantitative. Conceptual models may include "rural residential", "subsistence farming", "industrial", and "residential". The selected conceptual model will form a part of the basis for conducting a qualitative risk analysis of the alternatives under consideration. The evaluation will include risks to workers, the general public, and the environment.

Contaminants of Potential Concern

In the context of the *Removal Action Alternatives Study*, COPCs are the contaminants present that may have to be addressed by decommissioning actions. COPCs are not fully defined at this point in time. Additional characterization will be performed to determine and document actual COPCs as part the development of future CERCLA documentation, such as EE/CAs, Action Memorandums, Completion Reports and the Final Record of Decision. COPCs are those contaminants associated with the previous operation of the BGRR, which may include:

- Fuel residues, including uranium and transuranic radionuclides
- Long-lived fission products exclusive of inert gases
- Activation products in structural material and equipment within and around the Reactor Pile and biological shield wall
- Activation of experiments introduced into the Reactor Pile

- Radioactive material stored in Building 701's Nuclear Material Storage Vault
- Residual radionuclides that remain in the fuel storage canal, deep pit, canal house, and water treatment building
- Miscellaneous chemicals and radionuclides dispersed through the facility in equipment (control rod drive mechanisms) and remaining experimental equipment (chemical loop experiment)
- Known or suspected leaks and spills outside the confines of the facility resulting in surface and possibly subsurface contamination near the facility (fuel canal and below-grade duct leaks)

Potential Applicable or Relevant and Appropriate Requirements, and To Be Considered Requirements

The National Contingency Plan (NCP), 40 CFR 300, and Section 121(d) of the CERCLA, as amended by SARA, require that primary considerations be given removal alternatives implemented at a federal facility that attain or exceed promulgated federal and state applicable or relevant and appropriate requirements (ARARs) to the extent practicable, or that a waiver of an ARAR be obtained. State requirements must be attained under Section 121 of SARA, if they are legally enforceable and consistently applied statewide. The U.S. EPA has indicated that ARARs must be identified for each site on the National Priority List (NPL).

The removal actions associated with the BGRR Decommissioning Project will meet the ARARs referenced in the RAAS to the fullest extent practicable. The ARARs section of the RAAS identifies federal, state, and local non-enforceable criteria, advisories, and guidance that could be used for evaluating removal alternatives, defined as To Be Considered (TBC) requirements.

In general, there are three categories of ARARs:

- Chemical-specific requirements
- Location-specific requirements
- Performance, design, or other action-specific requirements

TBCs consist of non-enforceable advisories, criteria, or guidance developed by federal, state, or local agencies that may be useful in developing CERCLA remedies. TBCs are not promulgated regulatory standards or requirements, and, therefore, are not under the definition of ARARs.

Removal Action Objectives

Removal action objectives are media-specific or operable unit-specific objectives for protecting human health and the environment and are developed considering land use, COPCs, potential ARARs, and exposure pathways (conceptual models). Specific removal action goals are also identified so that an appropriate range of decommissioning alternatives can be developed for evaluation. The ROAs for the BGRR Decommissioning Project are stated below:

1. Protect workers from physical, chemical, and radiological hazards posed by the BGRR facility.
2. Prevent negative impact to human and ecological receptors by preventing contaminant releases to air, soil and groundwater above ARARs and health-based criteria, and prevent direct exposure to hazardous substances.
3. Minimize physical, ecological, or cultural impacts caused by removal actions or decommissioning of the BGRR facility.
4. Maximize opportunities to achieve cost efficiencies and cost savings to the extent that these practices do not adversely affect the protection of public and worker health and safety, and environmental quality.
5. Remove or permanently isolate contaminants of potential concern.
6. Minimize the amount of all types of waste generated from the decommissioning project in order to minimize waste management and disposal costs, transportation impacts, and potential for environmental release.
7. Maximize opportunities to preserve the historical significance and educational value of the Brookhaven Graphite Research Reactor.

8. Support future land uses objectives for BNL after determining the nature and extent of contamination at the BGRR facility.
9. Meet all applicable, relevant or appropriate standards, requirements, criteria, or limitations defined under federal and/or state environmental law.
10. Share information with the community in a timely and ongoing manner.

DEVELOPMENT OF DECOMMISSIONING ALTERNATIVES

Seven decommissioning alternatives were developed by combining BGRR Decommissioning Project work breakdown structure (WBS) elements with appropriate decommissioning methods and technologies. The objectives of this activity were to identify and introduce the potential combinations of decommissioning alternatives for each sub-project element. Different workable combinations were developed in a manner to bound a full range of alternatives that could then be compared against evaluation criteria. The alternatives were presented to stakeholders in the second series of roundtable meetings and to regulators and DOE decision-makers. The alternatives span levels of cost and complexity from a "no action" alternative to "full removal" of the entire BGRR facility (excluding non-contaminated below-grade structures that meet release criteria). No action is used as the baseline against which the other alternatives are evaluated, and is required for all analysis under CERCLA.

The EPA guidance for conducting EE/CA's under CERCLA requires that removal actions satisfy the following criteria:

- Meet CERCLA goals with respect to preventing or minimizing the migration of hazardous substances and simultaneously protect public health and the environment
- Minimally attain applicable or relevant federal public health and environmental standards
- Exceed applicable and relevant federal standards, where possible
- Involve off site treatment, storage, and disposal facilities which are permitted under the *Resource Conservation Recovery Act* (RCRA) and meet other applicable standards
- Represent containment technologies utilizing little or no treatment of contamination
- Include a "No Action" alternative, including monitoring and security activities as appropriate

A 50-year period of institutional control is required for all alternatives, and surveillance and monitoring (S&M) will be conducted during that time, as needed. The extent of the S&M will vary depending on the extent of the building, equipment, and appurtenance removal performed in each specific alternative.

Decommissioning Alternatives

The decommissioning alternatives are the remedies that satisfy the removal action objectives. These alternatives were developed based on physical characteristics, the type and concentration of contaminants present, the volume of contaminated material, and preliminary remediation goals. For each decommissioning sub-project, there are four fundamental potential decommissioning options available, as follows:

- **No Action** (Continue Surveillance and Maintenance). This action consists of no specific near-term decommissioning alternative but does require continuing surveillance to include adequate radiological monitoring, environmental monitoring (groundwater monitoring wells), and appropriate security measures to ensure public health and safety. Maintenance may include general maintenance such as roof repairs, re-pointing of brick work, or repair of any leaks, but not the removal of any contaminated materials.

- **Decontaminate and Leave in Place.** Under this option, all radiological residue (solid and liquid), wastes, and selected radioactive components will be removed from surfaces and soils. This necessitates establishing adequate radiation monitoring and environmental surveillance and appropriate security procedures to ensure public health and safety. Actions may include cleaning of steel duct linings, scabbling of concrete surfaces, or power washing of contaminated surfaces.

- **Isolate, Seal, or Enclose and Leave in Place.** This option, also known as entombing or cocooning, consists of removing all nuclear fuel residue, radioactive fluids and wastes, and selected components, followed by sealing of the remaining major radioactive and contaminated components within a structure that provides adequate shielding and integrity over the period of time in which significant quantities of radioactivity are to remain in place (thus allowing additional radioactive decay). An appropriate and continuing surveillance program is required to assure public health and safety. Actions may include applying a fixative to surfaces to prohibit leaching of surface contamination, construction of a protective enclosure over items (such as the Reactor Pile) which will create a barrier between contamination and the environments, and filling void spaces with grout to stabilize the structures and prevent any materials from entering or leaving the unit.

- **Remove and Dispose in Permitted Waste Disposal Facility.** This option consists of removing from the site all residual radioactivity and contaminated components and materials (concrete and soil) having contamination levels above acceptable release limits, packaging and transporting the materials, and disposing the materials in an appropriate waste disposal facility. These disposal facilities could be both owned and operated by DOE or by a private commercial company. To the maximum extent possible, non-contaminated materials will be recycled or reused. Units that are removed will not require continued maintenance, however, monitoring will continue in accordance with site wide practices as applicable.

Removal Action Alternatives

The BGRR Decommissioning Project work breakdown structure elements were combined to form seven different and distinct Removal Action Alternatives that yield solutions that vary in their level of complexity, cost, and protectiveness. The alternatives span from no action to total removal of affected areas including the Reactor Pile, the Reactor Building, and all associated fans, ductwork, piping and soils, leaving only concrete foundations that meet cleanup criteria.
Sealing the Reactor Pile openings is included in all of the alternatives, with the exception of the No Action Alternative. It should also be noted that, for purposes of the RAAS, six of the alternatives consider total removal of sub-project elements and any contaminated soil adjacent to those elements. Each alternative assumes that concrete structures at a depth of 3 feet below the original 100' grade elevation meeting release criteria will remain in place. Subsequent EE/CAs will evaluate the actual extent of the final removal actions and could evaluate other possible actions, such as in-place decontamination and/or isolating, sealing or enclosing the affected sites.

Seven Removal Action Alternatives were selected for initial analysis in the study. In general, the level of effort and degree of remediation increases as the alternative number increases. The alternatives also define a potential project end-state for the BGRR facility and are further described as follows:

- **Common Elements.** The following items are common to all the alternatives except for Alternative 1 (No Action):
  1. Dispose water collected from the underground cooling ducts (action completed in FY 1999)
  2. Remove fans and decontaminate the Fan House (action in progress)
  3. Remove the Pile Fan Sump (sub AOC 9D, in progress)
  4. Remove former museum walls and displays (completed in FY 1999)
  5. Isolate Building 703 from Building 701
  6. Seal the biological shield wall of the Reactor Pile (Building 702)

- **Alternative 1.** This alternative is defined as the "no action" alternative as required under CERCLA and excludes (for purposes of the RAAS) the work items considered under the Common Elements description above. Under this alternative, all structures will remain intact, with surveillance and maintenance for 50 years of institutional control by DOE. This alternative provides a baseline to which all of the alternatives can be compared. S&M will be performed to prevent deterioration of the facilities left in place and to control the spread of contamination.

- **Alternative 2.** This alternative represents the "minimal compliance" action alternative, which addresses only those elements that are required to meet the Interagency Agreement requirements for AOC 9 (sub-AOCs 9A, 9B, 9C, and 9D) and the common elements described above. The below-grade air cooling ducts, Instrument House, Fuel Canal House, Water Treatment House, and Fuel Canal will remain in place, however the associated soils that may be contaminated will be remediated. Buildings 701 and 702 remain in place under this alternative.

- **Alternative 3.** The work elements in this alternative include all the elements in Alternative 2, including the common elements. In addition, this alternative includes: a) remove the above-grade cooling air ducts and Instrument House; b) remove the Fuel Canal and Canal House; c) remove the Water Treatment House; d) remove the below-grade ducts, filters, and cooling coils; e) remove below-ground piping outside Building 701; and, f) remove experimental and chemical-loop equipment from Building 701. In this alternative, major equipment associated with the operation and functioning of the Reactor Pile would be left in place, which includes the fuel charging elevator, the control rod drive mechanisms, and the service elevator. Building 701 would be partially renovated to maintain a weatherproof containment around the Reactor Pile, to include major renovation of the roof membrane. Surveillance, monitoring and maintenance would be required for the designated 50-year institutional control period.

- **Alternative 4.** This alternative includes all of the elements defined in Alternative 3 as well as remove major equipment associated with the operation and function of the Reactor Pile as defined in Alternative 3 above. Additionally, this alternative includes renovation of Building 701, and surveillance, monitoring and maintenance for the designated 50-year institutional control period.

- **Alternative 5.** This alternative includes all elements defined in Alternative 4, however, in addition, Building 701 is removed in its entirety and a new containment structure is constructed over the Reactor Pile (Building 702). Surveillance, monitoring and maintenance of the Reactor Pile are required for the designated 50-year institutional control period.

- **Alternative 6.** This alternative is similar to Alternative 5 with the following exceptions. In this alternative, the Reactor Pile and biological shield wall (Building 702) are removed and Building 701 is renovated and left intact for some other future use by BNL. A reduced level of surveillance, monitoring and maintenance would still be required for the designated 50-year institutional control period.

- **Alternative 7.** This alternative removes all BGRR-related structures and equipment and represents the most complete removal action. This alternative does not require continued surveillance, monitoring and maintenance; however, some level of continued groundwater monitoring may be required. In this alternative, as with all previous alternatives, some remaining foundation materials will be left in place, however any residual radioactivity will be below acceptable cleanup standards for soil and remaining concrete structures.

Appendix A provides a graphical representation of the seven removal action alternatives.

DETAILED COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

In this section, each removal action alternative is compared to evaluation criteria to evaluate how each alternative achieves the criteria. Alternatives that are either not feasible or have severe limitations in meeting the criteria will be screened out from further consideration. Those alternatives that best achieve the evaluation criteria and removal action objectives will be retained for additional evaluation and analysis in subsequent Engineering Evaluation/Cost Analysis documents. Decision-makers will use the EE/CAs to make final removal action determinations, which will be documented in Action Memorandum(s). The EE/CAs will be presented to stakeholders and regulators for input on the removal action decisions.

CERCLA Criteria

CERCLA criteria constitute a major category of evaluation criteria for removal action alternatives on the BGRR Decommissioning Project. As shown in Table 4 - 1, the nine CERCLA criteria are divided into three groups: 1) Threshold Criteria, 2) Primary Balancing Criteria, and 3) Modifying Criteria.

Table 4 – 1. CERCLA Criteria

Threshold Criteria	
Overall Protection of Human Health and the Environment	This criterion evaluates whether or not a remedy provides adequate protection of human health and the environment, and describes how risks posed through each pathway are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.
Compliance with ARARs	This criterion addresses whether or not a remedy will meet all of the applicable or relevant and appropriate federal and state environmental statutes and requirements (ARARs) or whether grounds exist for a waiver. Removal actions under CERCLA are required to comply with ARARs to the extent practicable, or be waived. A list of potential ARARs is included in the RAAS.
Primary Balancing Criteria	
Long Term Effectiveness and Permanence	This criterion assesses the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup goals have been met.
Reduction of Toxicity, Mobility, or Volume	This criterion assesses the anticipated performance of the treatment technologies that may be selected for each of the alternatives.
Short-term Risks to Public Health, Workers, and the Environment	This criterion addresses the period of time needed to achieve protection and any adverse impacts on human health and the environment that may be posed during the construction and implementation period until cleanup goals are achieved.
Ease or Difficulty in Implementing the Alternative	Implementability addresses the alternatives' technical and administrative feasibility. Technical feasibility includes the availability of materials and services needed. Availability includes personnel and technology, off-site treatment, storage and disposal, services and materials, and prospective technologies.
Capital and Annual Operating and Maintenance (O&M) Costs	Each removal action alternative is evaluated to determine its projected cost. The cost factors include direct capital costs, indirect capital costs, and annual costs. Annual costs include surveillance, monitoring and maintenance.
Modifying Criteria	
State Acceptance	This criterion indicates whether state regulatory agencies concur, oppose or have no comments on the proposed alternatives. State regulatory agencies will be asked to comment on the RAAS document and provide their input on the proposed or recommended alternatives.
Community and Stakeholder Acceptance	This criterion indicates whether community members and other stakeholders concur, oppose or have no comments on the proposed alternatives. Community members and stakeholders will be asked to comment on the RAAS document and provide their input on the proposed or recommended alternatives.

NEPA Values/Resources Impacts

In addition to the nine CERCLA criteria, specific environmental resources and NEPA values are considered during the screening and selection of removal action alternatives. Consideration of environmental resources and NEPA values are required to meet the DOE Secretarial Policy on NEPA (DOE 1994) and contributes to a complete evaluation of the removal alternatives. Table 4 – 2 presents definitions of the NEPA values and resource impacts that were included in the evaluation of the BGRR Decommissioning Project removal action alternatives.

Table 4 – 2. NEPA Values/Resource Impacts

Transportation Impacts	The proposed decommissioning alternatives are not expected to create any long-term negative transportation impacts. If adverse impacts are detected, decommissioning alternatives will be modified or halted until the impact is mitigated. Commercial shipping, by rail or truck, is a means of transportation that is being investigated to eliminate problems of transport through populated metropolitan areas of New York City and suburban communities.
Ecological Impacts	Removal alternatives are evaluated to determine their potential impact on existing natural resource conditions. Alternatives do not include revegetation or other habitat enhancement activities.
Air Quality Impacts	The proposed alternatives are not expected to cause long-term negative impacts to existing air quality. Short-term effects will be analyzed and measures taken to control or otherwise mitigate any potential for impacts to the air quality during decommissioning activities.
Cultural Resources	Mitigation measures to preserve the cultural and historical significance of the BGRR have been developed and submitted to the New York State Historic Preservation Officer in a draft Memorandum of Agreement. This memorandum outlines DOE's intent to preserve the cultural and historic value of the BGRR facility through mitigation measures.
Socioeconomic Impacts	None of the alternatives has a major impact to the local socioeconomics of the Brookhaven National Laboratory or surrounding communities. The necessary workforce to complete the selected decommissioning alternatives is expected to be readily available.
Noise and Visual Resource Impacts	No long-term noise impacts are anticipated from any of the decommissioning alternatives. Minor short-term impacts may be expected during any major equipment removal and would be mitigated through compliance with standards imposed at BNL.
Irreversible and Irretrievable Commitment of Resources	None of the alternatives would involve irreversible or irretrievable commitment of resources because they would not consume natural or depleted raw materials or fuel and would not require the taking of additional lands for construction or waste management purposes. All waste management activities will use existing facilities or sites that have previously been constructed and permitted.
Direct and Indirect Cumulative Impacts	All alternatives, except Alternative 1, would have positive cumulative impacts to the overall cleanup actions that are being taken at the BNL site. Potential sources of contamination to workers, air, and groundwater are being removed under Alternatives 2 through 7.
Environmental Justice	None of the alternatives would have environmental justice impacts because there would be no substantial economic or health impacts to any potentially affected populations. Therefore, there would be no disproportionate adverse impacts to either low-income or minority populations.

Community Values

Public roundtable meetings were held in the summer of 1999 to discuss the BGRR Decommissioning Project and to determine the values and expectations of the community regarding the planned decommissioning. From these roundtable meetings, a set of community values was developed for the project. For the purposes of the RAAS, the community values were grouped by category and are included in Table 4 – 3. The removal action alternatives for the BGRR Decommissioning Project were screened against community values as well as CERCLA criteria and NEPA values discussed above. All of the community values, with the exception of cost and schedule, and communication and trust, are also considered NEPA values. Community members and other stakeholders will have opportunities to provide additional input during the course of the public review and comment periods that are planned for the RAAS, subsequent EE/CAs, and the draft Record of Decision for the decommissioning project.

Table 4 – 3. Community Values

Environmental Safety and Health	Prevent negative impacts to public health and the environment by minimizing contaminant releases to the air, soil, and groundwater and through direct exposure to hazardous substances. Utilize qualified and experienced personnel, communicate within the project team, and coordinate with appropriate environmental, health and safety professionals, and emergency response organizations to ensure overall project safety, including the safety of workers and the public. Achieve the established environmental clean-up goals and demonstrate that these clean-up goals are met. Exceed the established clean-up goals to extent practicable.
Waste Management, Transportation and Disposal	Minimize the amount of all types of waste generated in order to minimize waste management and disposal costs, transportation impacts, and the potential for environmental release. Maximize opportunities for recycling and reuse of materials, equipment, and structures to the extent that these practices are economically feasible and comply with environmental requirements. When waste is transported, use the route and transportation method that has the least impact on the public.
Cost and Schedule	Maximize opportunities to achieve cost efficiencies and cost savings to the extent that these practices do not adversely affect the protection of public health and safety, and the environment. Assure that adequate funding is available and obtained so that the project can be completed in a safe, timely and efficient manner. Minimize the annual surveillance, monitoring, operations and maintenance costs.
Future Land Use	Determine future land use issues after determining the nature and extent of contamination present. Consider opportunities for reuse of the building and structures following clean up to the extent that reuse is cost efficient, safe, and reflective of DOE, laboratory, and community needs and interests.
Cultural and Historic Resources	Maximize opportunities to preserve and provide public access to the historically significant aspects and educational value of the BGRR facility. Ensure that historic preservation actions do not adversely impact public health, worker safety, or environmental protection. Avoid demolition and removal of unique and culturally significant structures, components, and equipment necessary and desirable from a historic preservation perspective. Consider the life cycle costs for such preservation.
Local Economy and Employment	Utilize qualified workers from the local area, including BNL employees, to the extent possible.
Communication and Trust	Share information with the community in a timely and on-going manner. Use a variety of methods to communicate information and ensure that communications are clear, easy to understand, and straightforward. Avoid the use of technical terms and jargon. Provide regular, on-going opportunities throughout the project for public involvement, information exchange, and input on project decisions. Demonstrate to the community that the project is being conducted in a safe and responsible manner and that those community values are being considered in the decision making process.

Summary Evaluation of Alternatives

Based on the RAAS, all seven of the alternatives are considered technically feasible (to some degree) and capable of protecting human health and the environment (to some degree) with the exception of Alternative 1, No Action. Alternative 1, although not considered a viable option, will be retained to provide a baseline against which the remaining alternatives will be measured, as required by CERCLA.

RECOMMENDED REMOVAL ACTION ALTERNATIVES

All seven of the alternatives were evaluated against the CERCLA, NEPA, and Community Values, and this information was used to assign a ranking among the alternatives. The purpose of this ranking is to provide the basis to screen out alternatives that do not meet the minimum specified requirements and to provide a preliminary rank ordering of the remaining alternatives. A qualitative assessment was then made to show how alternatives compare relative to the evaluation criteria and the Removal Action Objectives. Those alternatives that best meet the criteria will be recommended for additional analysis through the EE/CA process. The outcome of the EE/CA, which undergoes public and stakeholder review, is a final removal action decision. The final removal action decision (or end-state decision for the BGRR facility) will be documented in an Action Memorandum. As each BGRR sub-project is completed, a Completion Report will be written, which documents how clean-up goals have been met. At the conclusion of all decommissioning sub-projects, a Final Record of Decision will be prepared, which, again, will undergo public and stakeholder review and comment prior to final approval by the federal and state environmental regulatory agencies.

Summary of Alternatives Comparison

Each alternative was reviewed and assigned a ranking from 1 to 7 that represents subjectively how well the alternative addresses a particular criterion with respect to the other six alternatives. The evaluations consider the removal action objectives. A value of 7 is assigned to the alternative which most completely and effectively addresses the criteria, and conversely, a score of 1 is assigned to the alternative which least completely and effectively addresses the criteria. In some cases, there is no difference between two or more alternatives and they each receive the same ranking. Table 5 – 1 presents a summary ranking of the seven alternatives when evaluated against the CERCLA, NEPA, and Community Values criteria.

Table 5 – 1.
Alternatives Analysis Ranking Summary

Alternative	**1**	**2**	**3**	**4**	**5**	**6**	**7**
CERCLA Values	31	37	41	43	40	38	40
NEPA Values	60	49	49	49	36	40	34
Community Values	83	88	113	123	90	84	85

Issues Requiring Further Evaluation

In addition to the screening and ranking process presented above, each alternative was also qualitatively evaluated. The primary purpose for this activity was to present additional considerations that are important to the decision-makers. Examples of these considerations include:

- Programmatic and institutional factors, such as future utilization of Building 701 for other mission requirements at BNL
- Requirements for additional removal actions at the end of the 50-year institutional control period (such as the remaining legacy of the Reactor Pile for all alternatives except 6 and 7)
- The relative priority of the BGRR Decommissioning Project in relation to other significant environmental restoration and groundwater protection programs at BNL
- The characterization of the BGRR facility is still in progress and data gathered during characterization can have a significant impact on the work process and scope, as well as costing.
- Volume of soil to achieve clean-up criteria and protect groundwater.
- Structural interface between the 701 Building and the 703 Building.

Recommendation

Alternatives 1, 3, 4 and 6 are recommended for inclusion in the next level of analysis through the EE/CA process. Alternatives 2, 5, and 7 are not recommended for further analysis. Alternative 1 will be retained to provide a baseline for comparison against the remaining alternatives. Alternative 2 was screened out because it only addresses the known contamination that has leached to the soil column and potentially to the underlying water table but does not remove any of the major sources of contamination. Alternative 4 was retained because it was the best fit for meeting the CERCLA criteria, NEPA values, and stakeholder values. Alternative 5 was screened out because it did not increase the overall protection of the environment, is significantly more expensive than Alternative 4, and there are structural challenges, programmatic impacts, and occupant safety concerns of removing the 701 Building in relation to leaving the 703 Building. Alternative 6 was retained because it removes the major radiological source term and eliminates a future environmental and waste management legacy. Alternative 7 was screened out because of the same reasons presented for alternative 5 and there has not been a decision regarding the potential re-use of the 701 Building for other research purposes.

Conclusions

The BGRR Decommissioning Project is planned as a series of removal actions under CERCLA. Use of this approach will allow BNL to achieve early and steady progress in decommissioning and environmental cleanup throughout the project's four to five year term. Although this approach offers many advantages, it also presents a number of challenges related to end-state determination and stakeholder involvement. As originally conceived this approach would not result in a final end-state decision for the reactor facility, at large, for several years. In fact, the end state would be determined in a composite fashion, based on decisions regarding the individual removal actions that make up the decommissioning project. The more controversial (and costly) decisions, such as the final end state for the reactor's graphite core and massive concrete and steel biological shielding, would not get presented to the stakeholders or be finalized for at least three years into the future. Getting early stakeholder input on the final end-state decisions was critical to successfully plan for the project's future federal funding.

The project team addressed these challenges by developing a *BGRR Removal Action Alternatives Study* to screen alternatives for final decommissioning of the reactor complex, and by implementing a strategy to involve stakeholders in the decision-making process regarding removal action objectives and end-state determination. In developing the RAAS, a systematic approach was used to identify and screen removal action alternatives that represent options for the final end-state configuration. The stakeholder involvement plan developed for this project identifies ways to involve stakeholders early on, sustain their involvement throughout the project, and provide opportunities for meaningful and timely input into the decision-making process.

DOE's objective is to use these first steps as the basis for an ongoing dialogue with the community to yield better, smarter decisions about environmental cleanup and decommissioning of the reactor complex. While many decisions about the decommissioning of the BGRR have not yet been made, it is through pro-active and focused dialogue with the project's stakeholders that the concerns of all interested parties can be addressed.

As this paper is being written, the next opportunity for public input in the decision-making process will be after the release of the *BGRR Removal Action Alternatives Study*, in January 2000. Current information about the project's status and schedule — as well as announcements of upcoming public meetings and roundtables — can be found on the Project's web page at http://www.bgrr.bnl.gov.

Appendix A
Removal Action Alternatives Matrix

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
No further action, Continue S&M	Surveillance & Maintenance	Surveillance & Maintenance	Surveillance & Maintenance	Surveillance & Maintenance	Surveillance & Maintenance	Surveillance & Maintenance
	Remove Common Elements	Remove Common Elements	Remove Common Elements	Remove Common Elements	Remove Common Elements	Remove Common Elements
	AOC 9 Soil Removal	AOC 9 Soil Removal	AOC 9 Soil Removal	AOC 9 Soil Removal	AOC 9 Soil Removal	AOC 9 Soil Removal
	No Further Action	Leave 701 Bldg Equipment	Remove 701 Bldg Equipment	Remove 701 Bldg Equipment	Remove 701 Bldg Equipment	Remove 701 Bldg Equipment
		Remove Above Grade Ducts	Remove Above Grade Ducts	Remove Above Grade Ducts	Remove Above Grade Ducts	Remove Above Grade Ducts
		Remove Fuel Canal & Canal House	Remove Fuel Canal & Canal House	Remove Fuel Canal & Canal House	Remove Fuel Canal & Canal House	Remove Fuel Canal & Canal House
		Remove Below Grade Ducts	Remove Below Grade Ducts	Remove Below Grade Ducts	Remove Below Grade Ducts	Remove Below Grade Ducts
		Seal Reactor Biological Shield Wall	Seal Reactor Biological Shield Wall	Seal Biological Shield Wall and Safe-Store/Enclose Reactor Pile	Remove Reactor Pile	Remove Reactor Pile
		Leave 701 Bldg Intact	Leave 701 Bldg	Remove 701 Bldg	Leave 701 Bldg	Remove 701 Bldg
		No Further Action	No Further Action	No Further Action	No Further Action	Leave Below Grade Structures

Common Elements	Areas of Concern	701 Building Equipment/Disposition
1. Remove Museum Walls 2. Remove/dispose of Contaminated Water from Below-Grade Ducts 3. Remove Primary and Secondary Fans from Fan House 4. Isolate the 701 Bldg from the 703 Bldg	1. Fuel Canal Soils (AOC 9a) 2. Below-Grade Duct Soils (AOC 9b) 3. East Yard Contaminated Soils (AOC 9c) 4. Pile Fan Sump Contaminated Soils (AOC 9d)	1. Control Rod Drive Mechanisms 2. Charging Elevator 3. Service Elevator 4. Chemical Loop Experiment Equipment 5. Other Experimental Equipment 6. Repair/Replace Roof Membrane, General Maintenance 7. Decontaminate and Release 701 Bldg for Other Use

Appendix B
Summary Cost Normalization Table ($1,000)

Task	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Annual S & M/Operations	$ 1,400	$ 800	$ 600	$ 500	$ 200	$ 200	$ 0
Common Elements [1]		$ 5,200	$ 5,200	$ 5,200	$ 5,200	$ 5,200	$ 5,200
Remove Above Grade Ducts			$ 2,800	$ 2,800	$ 2,800	$ 2,800	$ 2,800
Remove East Yard Soils (AOC9c)		$ 2,900	$ 2,900	$ 2,900	$ 2,900	$ 2,900	$ 2,900
Remove Below Grade Ducts And Soil (AOC9a)		$ 1,200 [2]	$ 9,700	$ 9,700	$ 9,700	$ 9,700	$ 9,700
Remove Fuel Canal, Canal House and Canal Soils (AOC9b)		$ 1,100 [2]	$ 3,600	$ 3,600	$ 3,600	$ 3,600	$ 3,600
Remove Below Grade Piping and Systems			$ 1,300	$ 1,300	$ 1,300	$ 1,300	$ 1,300
Remove 701 Bldg Equipment and Systems			$ 800	$ 2,500	$ 2,500	$ 2,500	$ 2,500
Cocoon Reactor Pile					$ 1,100		
Remove Reactor Pile						$ 27,600	$ 27,600
Disposition 701 Building			$ 7,900	$ 7,900		$ 7,900	
Remove 701 Building					$ 14,100		$ 14,100
Project Management	$ 100	$ 2,000	$ 4,800	$ 4,800	$ 5,300	$ 7,100	$ 7,100
Construction Cost (PV)	$ 0	$ 12,400	$ 39,000	$ 40,700	$ 47,900	$ 70,600	$ 76,800
Construction Cost (w / Inflation)	$ 0	$ 12,700	$ 40,000	$ 41,700	$ 51,100	$ 74,500	$ 81,000
50-Year S & M/Ops Cost (PV) [3]	$ 20,500	$ 11,800	$ 6,800	$ 6,500	$ 1,600	$ 3,200	$ 0
Total Alternative Cost	**$ 20,500**	**$ 24,500**	**$ 46,800**	**$ 48,200**	**$ 52,700**	**$ 77,700**	**$ 81,000**

Footnotes:
[1] Removal of Pile Fan Sump and Soils (AOC 9d) Included with Common Elements
[2] Removal of AOC contaminated soil only
[3] Escalated for 50-years and corrected to present value (1999)