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THIRTEENTH ANNUAL

U.S. DOE Low-Level Waste Management Conference

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November 19-21, 1991

PROCEEDINGS

Idaho National
Engineering Laboratory

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PROCEEDINGS OF THE THIRTEENTH ANNUAL DEPARTMENT OF ENERGY LOW-LEVEL WASTE MANAGEMENT CONFERENCE

PROCEEDINGS

Prepared by the
National Low-Level Waste Management Program
Idaho National Engineering Laboratory
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DISCLAIMER

ABSTRACT

The papers in this document comprise the proceedings of the Department of Energy's Thirteenth Annual Low-Level Radioactive Waste Management Conference that was held in Atlanta, Georgia, on November 19 - 21, 1991. General subjects addressed during the conference included:

- Disposal facility design
- Greater-than-class C low-level waste
- Public acceptance considerations
- Waste certification
- Site characterization
- Performance assessment
- Licensing and documentation
- Emerging low-level waste technologies
- Waste minimization
- Mixed waste
- Tracking and transportation
- Storage
- Regulatory changes.

EXECUTIVE SUMMARY

The Thirteenth Annual U.S. Department of Energy Low-Level Waste Management Conference was held November 19–21, 1991, in Atlanta, Georgia. The 297 attendees represented the Department of Energy (DOE), other Federal and State agencies, academia, DOE national laboratories, commercial low-level radioactive waste generators, and associated industries.

The three-day conference consisted of 13 concurrent technical sessions. Topics included the following:

- Disposal facility design
- Greater-than-Class C waste
- Public acceptance considerations
- Waste certification
- Site characterization
- Performance assessment
- Licensing and documentation
- Emerging low-level waste technologies
- Waste minimization
- Mixed waste
- Tracking and transportation
- Storage
- Regulatory changes.

Seventy-nine speakers and panelists addressed current issues associated with the session topics.

The plenary session speakers included an address by Dr. Ann S. Bisconti, Vice President, Research and Program Evaluation, U.S. Council for Energy Awareness, who talked about the impact of waste management issues on the future of nuclear power. Ms. Kathleen S. Hain, U.S. Department of Energy-Headquarters, Office of Technology Development, spoke on the importance of emerging waste management technologies and how they are pertinent to low-level radioactive and mixed waste management.

A luncheon address was provided by Mr. David H. Leroy, U.S. Nuclear Waste Negotiator, Office of the U.S. Nuclear Waste Negotiator, who discussed the lessons he has learned in meeting with the public on sensitive waste management issues, and how those lessons could be applied to the low-level waste management arena.

A series of evaluations were solicited from chairpersons, liaisons, and attendees to assess the effectiveness of the conference. Questions were asked regarding the conference logistics, the value of the information exchange, and the pertinence of the selected topics and issues to on-going low-level waste management activities. The evaluations also asked for recommendations for future topics. Analysis of the evaluation responses shows that the conference continues to be an effective means of information exchange among persons involved in national low-level waste management. Recommendations for future topics will include: (a) more on storage, (b) more technical topics, (c) mixed waste, (d) public participation, and (d) monitoring methods. The session-specific evaluations included more detailed recommendations. These will be further assessed during organization of the next annual conference.

KEYNOTE ADDRESS

Public Opinion and Communication on Nuclear Waste

by

Ann S. Bisconti, Ph. D.
Vice President, Research and Program Evaluation
U. S. Council for Energy Awareness

I know you've asked me here to talk about polling data and trends, but I'd like to go beyond the numbers today to look at their implications for developing social solutions to nuclear waste issues.

I won't go into the need for public participation and two-way communication, but I want to acknowledge their importance up front. I'm assuming that no one in this room believes that the decide-announce-defend approach to siting facilities is a winning strategy. Besides, your landmark 1986 conference on public involvement covered that subject well. Instead, I thought it might be helpful to pull together some implications for communications from a large body of research conducted by or for USCEA.

The polls I'll refer to, by Cambridge Reports, Bruskin Associates and Gallup -- all respected polling firms -- are with national samples of 1,000-1,5000 people. They represent all U.S. adults with a margin of error of $\pm 3\%$.

Nuclear waste is not a subject that evokes pleasant thoughts. The words "nuclear" and "waste" suggest things to the public that seem not just bad, but evil. Just raising the subject of radioactivity makes people uneasy. In several polls by Cambridge Reports, Americans were asked which type of waste is potentially most harmful to the public -- toxic waste, chemical waste, hazardous waste, dangerous waste, or radioactive waste. Which one did people pick as potentially most harmful? Radioactive waste. Given the imagery, it is not easy to interact and communicate effectively with the public on this subject.

1. TAKE THE MORAL HIGH GROUND

Often the critics monopolize the moral high ground on waste issues, putting industry and government on the defensive. Defensive postures weaken credibility. Instead, the research we've done tells us that those who seek safe nuclear waste disposal solutions can command the moral high ground by pointing out that these solutions preserve benefits the public wants and that they help the environment.

Americans believe that nuclear energy will and should play an important role in meeting the nation's future energy needs. Those opinions are getting stronger. For instance, a Gallup poll in August 1991, found that the number of Americans saying that nuclear energy should play an important role was 73%. That's up 8 points from a year ago. Few people want to do without the benefits of nuclear energy. Although we hear criticism about health care systems and industry, most people are happy to reap the benefits that radioactive materials provide in these areas too.

People do not always associate radioactive waste with these benefits. They must be reminded. So in talking about radioactive waste, it's important to establish the associated benefits first.

This August, a national poll by Bruskin Associates for USCEA pointed out to the people being polled that "radioactive materials are widely used in medicine for diagnosing and treating disease, in developing new drugs, by industry, and in power plant to produce electricity. Those uses produce radioactive waste." Half the sample was then asked, "How important is it for the United States to build new facilities to dispose of this waste?" Almost everyone said it is important, 80% said "very important". The other half of the sample was asked to make a tradeoff between building more facilities and doing without the uses. The results were lopsided -- 80% to 12% for keeping the used.

Bruskin Associates also asked this related question on a separate national poll in August: "Which way of handling high-level radioactive waste do you think is more helpful to our environment in the long run -- taking the waste to a permanent waste disposal facility or leaving the waste at the plant sites, where it is now?" Again, the results were lopsided -- 70% to 19% for taking the waste to a permanent waste disposal facility.

These studies and a great deal of qualitative research show that Americans want nuclear waste disposal solutions, and they want them now. Another study, a USCEA test of messages to communicate monitored retrievable storage facilities found that one point stood out above the rest: building such a facility means taking care of our waste now rather than leaving it for future generations.

So siting safe nuclear waste disposal facilities is, from the public perspective, the environmentally sound thing to do. The public should know that those who oppose every solution and are not willing to be part of the solution are not true environmentalists. As far as the public is concerned, the moral high ground belongs to those who are truly working to achieve environmentally sound solutions.

2. CONVEY SCIENTIFIC CONSENSUS

In the past, the critics not only have monopolized the moral high ground, they have gained equal, or more than equal, hearing of their views. That creates the illusion that scientific opinion is divided on the subject, an illusion of uncertainty and lack of control. Several years ago I heard Gerard Piel (then publisher of *Scientific American*) make a passionate plea for demonstrating the weight of scientific consensus on scientific and technical issues. He said "The presentation of both sides as equal on all issues undermines public confidence in science."

The public needs to know where the weight of scientific consensus actually exists on radioactive waste disposal. They also need to know the difference between viewpoints and scientific facts relating to waste disposal. I'm not a technical expert, but I'm assuming that there are scientific facts governing current and planned disposal methods.

A number of studies for USCEA by Cambridge Reports and others over the last decade, consistently found the same point for lessening concerns people have about nuclear waste. The point is that major scientific organizations around the world agree that the technology exists for nuclear waste's safe and permanent disposal. However, few were aware of that consensus. The large majority guessed that most scientists do not believe a safe method exists or that scientists are equally divided.

Many Americans believe that we have the ability to find a solution. In one of the Bruskin pools this August, 61% thought that the United States has the scientific and technical expertise to construct a safe and reliable nuclear waste disposal facility-25% were skeptical, and 15% unsure. But at the same time, many are not convinced that the solution has been found.

Let me give you an example of how we in industry avoided adding to this sense of uncertainty. In the mid-80s, USCEA's ad agency, Ogilvy and Mather, prepared a detailed two page advertisement on the subject of nuclear waste.

In an effort to show balance, the ad presented differing viewpoints. The headline read "Nuclear Waste: Do Scientists Have an Answer?" Fortunately, we tested the ad. The message it conveyed was not the one we intended. The message was that scientists do not have an answer. It made people more uneasy, not less. The revised version gave the message straight: scientists do have an answer, and this is the plan. The result: a very effective advertisement.

3. CONVEY CONTROLS

In addition to scientific consensus, the key concept for making people feel better about radioactive waste disposal is control. As with all things "nuclear," there are inevitable monster images attached. But people accept the idea that the monster can be controlled. We all know that electricity is lethal too. It can kill our kids if they poke things in electric outlets. So we control electricity. And we plug up our electric outlets when small children are around.

In discussing high-level waste, USCEA's own research finds that the fact that the waste is small, solid, compact, and manageable (controlled) is surprising and comforting.

We also tested concepts about low-level waste in a pilot study a couple of weeks ago, in order to report the results to you at this conference.

We used USCEA's brochure about low-level waste as the vehicle for testing concepts. Face-to-face interviews were conducted with a total of 40 people in two cities with different exposure to waste issues -- Melbourne, Florida and Santa Fe, New Mexico. Before reading the brochure, 36% were at least somewhat confident that "radioactive waste from medical centers, companies, universities and nuclear energy plants can be disposed of safely." After reading the brochure, the number of who were confident jumped from 35% to 60%. The number "not at all confident" dropped from 40% to 28%. What was the most important point in the brochure? Controls -- including strict standards, monitoring, and barriers. Respondents also liked learning how-tos about the process and reading about the beneficial uses of radioactive materials that produced waste.

Earlier this year, Gallup conducted a major study for USCEA to help us communicate better on the subject of radiation -- radiation in general and radiation specifically from nuclear energy plants. That involved a much larger national sample of 1,000 representing all U.S. adults. We found may misconceptions about radiation. We also found that certain points were more effective than others in reassuring people about radiation from nuclear energy plants. Number one was the fact the radiation is used in many beneficial ways in medicine, agriculture, and industry. That message conveys positive images and feelings; it also conveys the ability to harness (controls, standards, regulation, the scientific knowledge base, and precision of measurement.

Down at the bottom were messages about the relative amounts of radiation from nuclear energy plants and other sources of radiation. For instance, many felt that a comparison of radiation from nuclear energy plants with radiation from nature was not relevant. Natural is seen as good, unnatural as bad. Natural is meant to be there; unnatural is not -- it's extra. A comparison with radiation from consumer products failed to reassure. Instead, it raised worries about hazards in the world around us.

I find that both physical scientists and social scientists are fascinated with the concepts of relative risk and risk perception. Unfortunately, the public does not follow these concepts. In interviews about nuclear issues, Americans rarely use the word risk.

If they do use the term, they are likely to refer to something as risky, meaning dangerous -- they think of risk in absolute not relative terms. In general, I believe it is better not to raise the concept of risk at all unless it can be explained well, because the public is likely to go away with a poor understanding and a feeling of uneasiness.

In Conclusion

Communicating about any kind of nuclear waste is difficult because of the negative imagery and many misconceptions. It's more likely to be effective if, instead of being defensive, you take the moral high ground consistent with the public desire for solutions. To do that, acceptable reasons for the waste (beneficial uses) should be established first. Moreover, you -- all of us -- must show we are true environmentalists, that we share the public's values and concerns. Somehow, the weight of scientific consensus needs to be conveyed to counter the uncertainty and lack of confidence that the illusion of divided opinions engenders. And we need to emphasize the many different ways in which the "monster", nuclear waste, is and will be controlled.

These are general guidelines, but it is a mistake to assure that we always know what is on the public's mind and what will be reassuring or persuasive in particular instances. If you're dealing with small numbers of people, there is no equal substitute for dialog. With masses, there is no equal substitute for research. At USCEA we test and test and test. We learn something each time. And we avoid big mistakes. You may too.

My best wishes to you in your important endeavor. If we at USCEA can help, just give us a call anytime.

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THE TRANSITION FROM CONCEPTUAL DESIGN THROUGH FINAL DESIGN AT THE ILLINOIS LOW LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY

PAUL E. CORPSTEIN

CHEM-NUCLEAR SYSTEMS, INC.

The Illinois Low-Level Radioactive Waste Management Act, as amended, requires that the development, construction and operation of the Central Midwest Interstate Low-Level Radioactive Waste Disposal Facility reflect the best available management technologies that are economically reasonable, technologically feasible and environmentally sound.

Chem-Nuclear Systems, Inc. has contracted with the Illinois Department of Nuclear Safety to design, license, construct and operate the low-level radioactive waste disposal facility for the Central Midwest Compact states of Illinois and Kentucky. Chem-Nuclear, with the capable assistance of MK-Ferguson and Dames & Moore have completed the conceptual and preliminary design for the facility, have completed the design of the facility in support of licensing, and have submitted to the Illinois Department of Nuclear Safety, a license application to construct the facility.

Chem-Nuclear, the Illinois Department of Nuclear Safety, and the other project participants, along with both proponent and opponent public groups from Martinsville and Clark County, Illinois are, and have been since June of this year, involved in public hearings which, based on presented evidence, will result in a determination of safety and suitability for the Martinsville Site. The 1300 acre Martinsville Site, the proposed location for the Central Midwest Compact Disposal Facility, is located in east central Illinois along Interstate 70, about one and a half miles north of the town of Martinsville. As this hearing process which I just mentioned continues, Chem-Nuclear and MK-Ferguson continue in finalizing the design of the facility. Finalization of this design, anticipated by January of 1992, will culminate a two and one half year process involving over 80 earth science and engineering professionals. The design process of the facility was carefully planned to assure that the performance objectives required by the Illinois Administrative Code were met. These objectives require:

- Protection of the general population from releases of radioactivity
- Protection of individuals from inadvertent intrusion
- Protection of individuals during operations
- Stability of the facility after closure

The key note of the performance objectives, you will note, is protection of people. Besides the performance objectives there are also regulatory requirements included in the Illinois Administrative Code for licensing, disposal and protection against radiation. Included are special regulatory considerations which give the focus and direction to the design:

- The disposal facility design ... shall provide for the use of above ground modules....
- Disposal modules shall be designed and constructed to incorporate multiple engineered safety features....
- The disposal unit shall be modular....
- Wastes designated as Class C ... protected by a barrier of a minimum of 5 meters or must be disposed of with intruder barriers that are designed to protect against inadvertent intrusion for at least 500 years.
- The facility shall be designed to accept waste throughout the 50 year operational period.
- The disposed waste packages must be monitorable and retrievable.

All of these, the performance objectives, the regulatory requirements, and the special regulatory considerations become and direct the design basis.

How did we transition from conceptual design through final design? The Illinois design was conducted in three distinct phases, which coincide with the engineering industry's accepted definitions for the sequential tasks which precede and support bidding and construction. On the Illinois project, each phase has begun and ended with interactive discussions between the owner -- the Illinois Department of Nuclear Safety; the site characterization contractor -- Battelle; the developer -- Chem-Nuclear; and the design and licensing subcontractors -- MK-Ferguson and Dames & Moore.

The first, or conceptual, phase involved "scoping" the needs of the project. Specific focal points included assessment of regulatory requirements, potential socioeconomic and environmental ramifications, and feasible alternatives; and preparation of schematic layouts, sketches, and conceptual design criteria. During this stage, key attributes for the safety features were defined. As an example, primary attention was paid to selection of an appropriate layout for the above-grade waste disposal units. This phase began during the summer of 1989 and was completed in the fall of that year.

Preliminary design began immediately after conclusion of the conceptual stage. This phase included a confirmation of the project definition and scope; preparation of preliminary drawings, sketches, outline specifications, narrative descriptions, and final design criteria; and studies to confirm the safety, adequacy, and appropriateness of the design. Extensive field and laboratory programs were conducted by MK-Ferguson to gather site-specific geotechnical, geological, and hydrological data to support continuing design and assure long-term safety and site stability. Preliminary design concluded in July 1990 and was documented in the project's Design Basis Specification.

In July 1990, CNSI and MK-Ferguson began final design in support of licensing. During this stage, the team refined the preliminary design and introduced further design and performance improvements. The overall site layout and the arrangement of the disposal area were finalized, and engineering for development of the disposal units, buildings, ancillaries, and support systems was completed. Certain of the assumptions, criteria, and approaches outlined during preliminary design were revised to reflect changes in the basic facility parameters or to reflect new data obtained from site characterization studies, geotechnical investigations, pre-operational monitoring programs, and other characterization activities which were ongoing at the Martinsville Site.

These new concepts were presented in various design documents and were an integral part of the license application, which was submitted in May 1991. The engineers are now completing the preparation of drawings and specifications in sufficient detail to allow procurement of materials and services, and to support actual construction of the facility. At completion, the design will be represented by 350 detailed construction drawings and 200 specifications.

What we are really trying to design for is to keep the radioactivity in place and prevent it from moving, both within and outside, while it decays to safe levels. This is done by reliance on:

- Natural site characteristics;
- Engineered Safety Barriers; and
- Acceptable waste characteristics

The Engineered safety barriers required by Illinois regulations are achieved through a multiple barrier design approach developed by Chem-Nuclear. Safety barriers preventing a release of radiation include:

- the dry solid nature of the waste form itself;
- the steel and polyethylene waste containers;
- the concrete and epoxy coated steel reinforced overpacks;
- the 2 and 1/2 foot thick concrete and epoxy coated steel reinforced waste modules; and
- the multilayered engineered earthen cap and underliner which contain and surround infiltration collection and detection systems.

Waste packages containing dry, solid low-level radioactive wastes are grouted into concrete overpacks of two designs: 8 foot cylinders to accept industry standard liners and drums; and 10 foot rectangular overpacks for lower activity class A materials. The waste package transfer and grouting takes place in the facility's Waste Packaging Building. Located inside the restricted area, the Waste Packaging Building will provide a safe, controlled environment in which incoming low-level radioactive waste shipment containers can be unloaded, inspected, accepted, logged into the facility's waste management tracking system, and loaded into concrete overpacks. The approximate 10,000 square foot building will be equipped with systems to allow remote handling of high activity packages and incorporates a high-efficiency particulate air ventilation and exhaust system.

The grouted overpacks will be transported with a self-propelled, shielded gantry transporter from the Waste Packaging Building to a reinforced concrete disposal module. The modules are approximately 60 feet wide by 90 feet long by 20 feet in height and are constructed in rows facing across an open access aisle.

In total, the facility design includes 192 disposal modules arranged in double rows forming four disposal units. The disposal unit concept allows for progressive closure of the facility. In fact, at the end of the 50 year operational life of the facility, the State will have forty eight years of closure performance monitoring data for analysis of the site stability performance objectives.

Covering all four disposal units and their 192 disposal modules and their multitude of overpacks containing some 10 million cubic feet of low-level radioactive waste will be a multilayered earthen cap. The cap is constructed in alternating layers for drainage of infiltrated rainwater, for a barrier to infiltrate of water past the drainage layer, part of the inadvertent intrusion requirements, and thermal protection of the concrete in a sometimes harsh Illinois climate.

We have developed a design, from a conceptual design two and a half years ago, to a final design today, upon which can be concluded:

- The design is safe;
- The design meets applicable laws and regulations;
- The design embodies best engineering practices;
- The design can be built safely and efficiently;
- The design encourages operating excellence; and
- The modular design can accommodate evolution in waste disposal technology.

In summary:

- The engineered safety barriers, and other facility design features required by law, work in an integrated fashion to achieve the performance objectives.
- The proposed design is compatible with the Martinsville Alternative Site.
- The engineered disposal systems substantially increase the Martinsville Alternative Site's safety margins.

THE NEBRASKA FACILITY ENGINEERED BARRIERS, MOISTURE COLLECTION SYSTEMS AND ENVIRONMENTAL MONITORING

JOHN H. DEOLD, CHARLES E. COLEMAN

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Introduction

US Ecology is developing and will operate the Central Interstate Compact's Low Level Radioactive Waste Disposal Facility near Butte, Nebraska. Bechtel National is the prime subcontractor. The facility will consist of above-grade, reinforced concrete disposal units covered after closure with an engineered multi-layered cap. (Figure 1.)

The 320-acre (1/2 square mile) site is in a sub-humid region having a 30-year average precipitation of approximately 23 inches. Successful site performance depends on isolating the waste from moisture during both operations and after closure.

The design of the disposal cells, drainage systems, and closure cap, the site's natural characteristics and the operational and monitoring procedures are all geared to ensuring long-term waste isolation and compliance with performance objectives.

Cell Design

Two waste units will be constructed.(Figures 2 and 3). One unit for Class A waste will consist of up to 20 disposal cells or buildings. Each Class A cell will be 280 feet long, 20 feet high and 60 feet wide. Class B and Class C waste will be disposed of in a separate unit. This unit will consist of one cell. The Class B/C cell has the same general dimensions as a Class A cell except it is 30 feet high. The cells have 3 or 3.5 foot thick walls and roofs. The base thickness is 4.5 feet.

Class A cells are accessed through openings at grade; the Class B/C cell is accessed through removable roof panels. While the sizes and configurations may differ, the moisture protection and monitoring systems are essentially the same for the two disposal units.

In-Cell Drains (Fig. 4).

Each cell has floor drains and a piping system embedded in the base mat exiting at the cell end in an inspection sump. Each pipe end is fitted with a main shut-off valve, a sight glass and a sampling port. A preliminary design considered the Class A cell floors to slope towards the drains. After considering concerns in waste package stacking operations and the minimal extent of any potential moisture puddling between drains, the floor will be level.

Leachate Collection System

The cells will be constructed on a sand layer overlying clay. Perforated drain pipes are installed in the more permeable sand to collect any liquid which may infiltrate through the base mat. This leachate collection system is routed to the same inspection sumps as the in-cell liquid collection system and are similarly fitted at their ends.

The system will be extended when the closure cap is installed to a new sump at the closure cap toe to permit post-closure monitoring.

Closure Cap. (Figure 5).

At the end of the facility operations, (the earlier of 30 years or receipt of 5,000,000 cubic feet of waste) closure operations will start. Above grade cell penetrations will be sealed (the in-cell drains will not) with concrete including a six inch thick topping slab poured over the B/C cell roof panels. The closure cap layers are then installed in the following sequence.

A. Synthetic liner. A synthetic liner will first be placed over each cell extending partially down the side and end walls. This liner provides a measure of infiltration protection during placement of addition cap elements.

B Compacted sand backfill. Sand is placed around the cells and develops the configuration of the cap slopes. The sand permeability allows any infiltrating water to rapidly enter the collection systems beneath the units, thereby minimizing the residence time in and around the cells.

The sand is allowed to settle until the expected settlement is achieved before installing the additional cap layers. This settlement serves to minimize cap subsidence that could increase maintenance activities. The maximum allowable cap slope is 4:1, and the minimum allowable cap slope, after settlement, is 3 percent.

C. Clay layer. Following completion of the sand fill placement and settlement, a three-foot thick layer of clay is placed over the entire area. The clay layer is designed to minimize water intrusion into the disposal unit. The clay is placed and compacted to provide permeability of not greater than 1 x 10^{-7} cm/sec.

To ensure that the clay layers develop the required permeability, a test fill will be performed. The test fill clay is compacted to 95 percent of modified maximum dry density at a moisture content range from 1 to 5 percent above optimum. A double ring infiltrometer is then set up on the test fill to determine the actual *in situ* permeability of the clay.

The Clay layer in the closure cap is protected (covered) to minimize erosion, and the sand fill/clay layer is then allowed to consolidate. The clay layer is then reworked, recompacted, and regraded to develop the final cap permeability and configuration. After the clay layer has been regraded to the design contours, the remaining layers of the closure cap are installed.

D. Concrete layer. The reinforced concrete layer is 1.5 feet thick and is cast directly on the clay layer. This layer assists the clay as a water barrier, hardens the caps against erosion, provides a cut-off to vertical crack propagation caused by freeze and thaw cycles, and serves as an intrusion barrier.

E. Sand layer. The sand layer above the concrete layer is 6 inches thick. It provides lateral drainage for water percolating through the overlying cover layers. The water is directed to the toe of the caps, where drainage pipes transport the water from the cap to the site watercourse.

The sand layer is covered with geotextile that acts as a filter, allowing water to pass through the geotextile to the sand drainage layer but retaining soil particles from the overlying layers. The geotextile will provide additional filtering capability beyond that of the engineered sand gradation. However, the sand layer design does not rely on the geotextile for the entire design life of the closure caps; instead, the sand and soil gradations are engineered to minimize clogging.

F. Native soil cover. A five-foot thick native layer is placed directly on the geotextile over the sand. This cover protects the underlying layers from frost penetration, plant root intrusion, erosion by concentrated run-off, temperature fluctuations, and evapotranspiration and assists in slope stability of the caps.

G. Erosion control layer. An erosion control layer is placed over the entire cap. The upper portion of the caps will be covered with interlocking concrete grid blocks with open areas that permit vegetation growth. The cap sides will be covered with rock armor (riprap). This layer placed over the native soil on the caps minimizes soil loss without retaining water in the caps. Rock will also be placed in drainage ditches and other areas of high run-off. The rock armor provides a low-maintenance surface that will not require periodic revegetation or watering.

The engineered closure caps are constructed with materials that are resistant to degradation by surface geomorphic processes and biotic activity. Cap design objectives are to minimize surface (wind and water) erosion, deter biologic (plant and animal) intrusion, and provide long-term durability. A natural vegetative cover is established on the three percent slopes (upper areas of the caps) to minimize surface erosion of the cap. The vegetative cover consists of native grasses rooted into soils, which are held in place by the interlocking concrete grid blocks. On the 4:1 cap slopes, where erosion would otherwise be excessive, the rock armor is used as a surfacing material. The rock armor also acts as a barrier to deter plants and animals from penetrating.

Operational Procedures

The engineered features of the facility provide substantial protection against moisture infiltration. To ensure these are not compromised during operations, specific procedures are being developed for the State's review and acceptance.

In a general order of occurrence as a shipment progresses from the point of waste generation to ultimate disposal, they are:

1. Generator Inspections. A proposal to the State has been made to have the site operator, a state agency or a third party (or any combination thereof), perform periodic inspections of the generators waste processing and packaging activities. Among other items covered will be the means to ensure liquids are properly absorbed or solidified.
2. Site Receipt Inspection. The license application includes a program of randomly opening and inspecting waste packages for the presence of liquids. Additionally, the presence of liquids in some containers can be detected simply by handling.
3. Off-loading Operations. Class A waste will be handled inside a building erected between disposal cells. No cell penetrations are exposed. The Class B and C cell is accessed through removable roof panels.. Waste will not be placed in this cell during inclement weather periods.
4. Class B/C Cell Roof Inspections and Maintenance. The roof panel joints have been recognized as a potential infiltration path. The cell is subdivided into compartments such that only one or two compartments may be in active use.

   The roof panels and their bearing surfaces will be gasketed to limit infiltration.

The panel's over-filled compartments and those not yet used will be seal-welded as to provide an additional protection level. The panels over the active compartments will be covered with an easily moved weather cover. A regular inspection of these barriers will be conducted to ensure their effectiveness.

SURFACE WATER INTRUSION CONCERNS

A significant factor in the candidate site screening process was a minimal upstream drainage area. This site has, including the site area proper, less than one square mile of upstream drainage (Fig. 6).

The primary contributor to this drainage area is approximately one-quarter square mile off-site entering the site through a road culvert. An additional area of 0.5 square mile(s) is adjacent to the site but run-on is mitigated somewhat by a topographic depression run.

Flooding Determinations

The site drainage system consists of engineered ditches and defined swales designed to carry a 100-year, 24-hour storm runoff without flooding any operations or support facilities.

Approximately 130 acres on-site consist of areas that drain to wetland areas along the east and northeast boundaries of the site. These areas are not affected by the facility construction and runoff from these areas does not affect the drainage of the designed facility.

All drainage ditches and any on-site areas where constricted flow velocity exceeds 4 feet/second are lined with riprap to minimize erosion. All other surfaces are seeded with native vegetation.

There are paved areas between the Class A cells. Thee are drained by catch basins and storm sewer piping sized to carry runoff from a 100-year, 24-hour storm.

No flooding of the operations or support facilities occurs during a 100-year storm.

All finish grade elevations for the operation facility are established at least two feet above the Probable Maximum Precipitation (PMP) event flood elevations.

The dikes that create the drainage ditches around the disposal units are designed to allow PMP flow to overtop the dike before a backwater condition is created around the cells.

Retention ponds are designed to store runoff from a 100-year, 4-day storm. A PMP event that exceeds this volume is automatically discharged from the pond through an emergency spillway designed to carry a 100-year, 24-hour storm flow. The retention pond dikes will not overtop during a maximum design storm.

The flood control system during postclosure is the same system used during operations. All drainage ditches are maintained during the institutional control period; however, all retention pond dikes are removed at closure.

The Class A unit, the Class B/c unit, and all critical facility structures are sited to make use of existing high areas of the site. The locations are improved to elevate the structures to ensure they are not flooded.

The Class A unit is sited as far south as possible to make use of the higher elevations on the south side of the site. The bottoms of the base mats are set at approximately the highest existing ground elevation within the unit's footprint (MSL elevation 1822.5 feet). The rest of the area is then built up to match that elevation.

The Class B/C unit is sited on a ridge that runs northwest-southeast through the north-central portion of the site. Analysis of the probably maximum flood (PMF) shows the ridge elevation is also above the PMF elevation.

Following closure of the facility, the conservative sizing of drainage ditches, placement of rock on highly erodible surfaces, and revegetation of disturbed areas minimize the need for ongoing maintenance.

The Probable Maximum Flood (PMF) estimates that the maximum water elevation resulting from a PMP event is 2 feet lower than the lowest Class A unit pavement elevation and 10 feet lower than that of the Class B/C unit. This eliminates any possibility that the PMF could flood either unit or inundate the waste.

Surface Water Drainage Retention Ponds.

During operations, any precipitation accumulating near areas directly adjacent to the disposal units is directed to retention ponds, where the water is collected and sampled. The retention ponds are of sufficient capacity to contain water produced from the equivalent of a 100-year frequency, 4-day duration storm. A vegetative cover is established on the side slopes of the pond to provide erosion control. A rock lining is placed on areas of the side slopes expected to be frequently inundated.

Environmental Monitoring

The environmental monitoring program will consist of taking samples of the different media which could be affected by disposal of waste at the site. The media were selected from dose assessment studies. The media selected were air, surface water, surface water sediments, groundwater, surface soil, and native grass. Farm produce and milk from local dairy herds will also be sampled and an array of dosimeters will be placed around the site to measure ambient radiation levels.

The primary monitoring systems intended to verify the engineered barriers for the facility are the on-site groundwater wells, the surface water and sediment sampling, the retention pond water sampling, and the collection of liquids from the leak and leachate collection system.

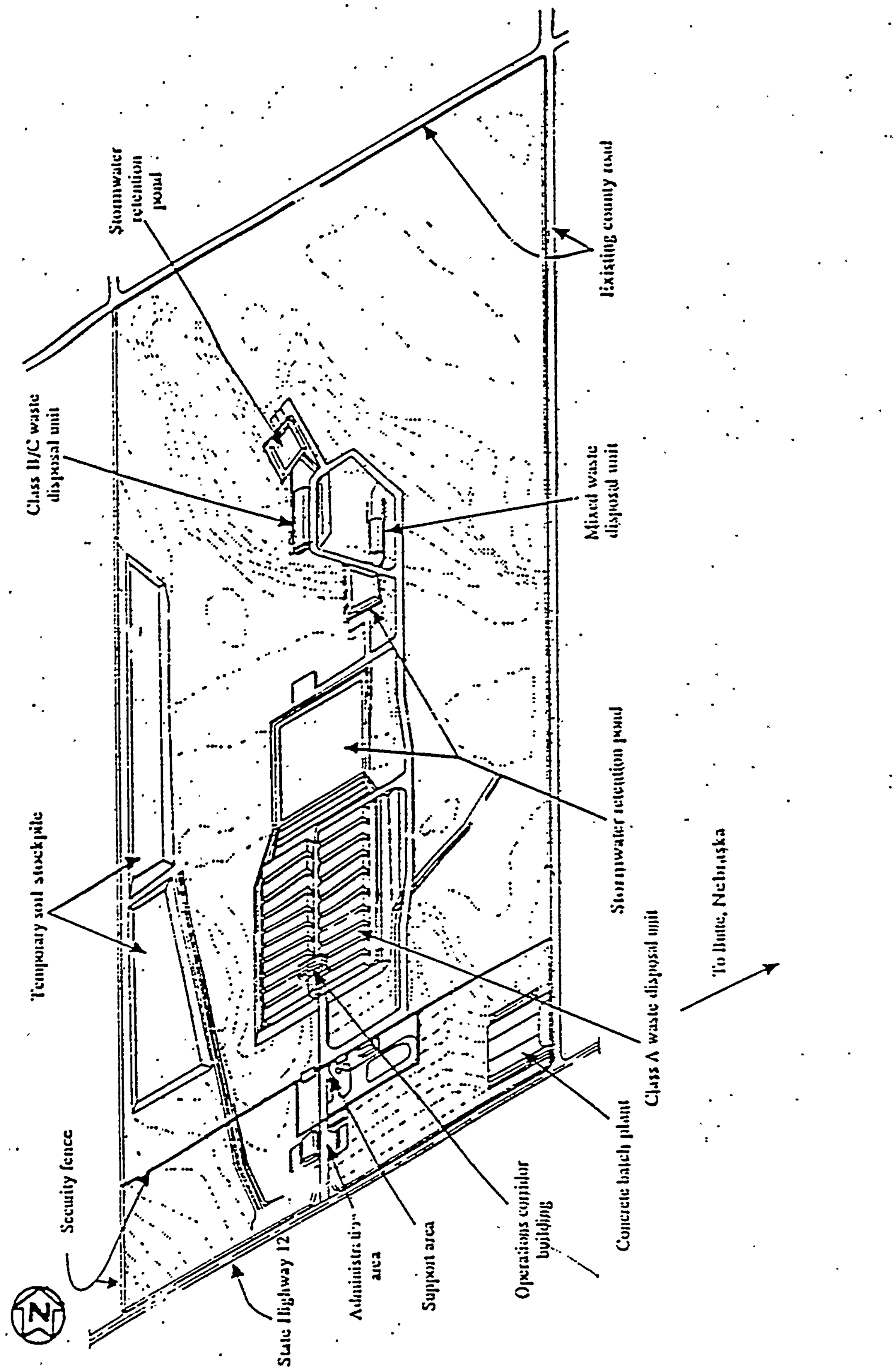
The groundwater system at the site includes two waterbearing zones. (Figure 7.) The facility layout includes two separate disposal units. More than a dozen groundwater monitoring well locatios will be selected to monitor upgradient and downgradient water in both zones for each location. The locations will be close to the unit to provide early warning of any release.

At least six on-site environmental monitoring stations will be established on the site periphery. (Figure 8.) One of these stations will be used to collect meteorology data (wind speed and direction, humidity, air pressure) as well. Four off-site stations (Figure 9) will be used to monitor the environment at nearby residences and in the town of Butte. A control station, located over six miles from the site, will be used to establish background levels. The environmental monitoring station will be the locations from which air samples, surface soil samples and vegetation samples are collected.

Design considerations lead to other monitoring and surveillance activities. Samples of liquids collected in the leak and leachate collection system will be sampled and analyzed prior to release. Samples of retention pond water will also be analyzed as will sediment samples from various locations on the site. Surveillance activities includes routine area surveys to check for possible contamination in waste vehicle traffic routes and handling areas.

The monitoring program is further divided within the media. For example, air monitoring will include collection and analysis of airborne particulates at the environmental monitoring stations and in areas where waste is handled. The Class A Units, which have an air ventilations system, will be equipped with an air monitoring system to measure the concentrations of radioactive contaminants in the air exhaust. Some of the stations will be used to sample for tritium in air moisture, carbon-14 concentrations, and radioiodines. As another example, groundwater monitoring includes not only the on-site monitoring wells but will include sampling of privately owned off-site wells and drinking water from the municipal water supply for Butte.

The monitoring system is designed to give an early warning of radioactive maerial release from the units and, in the long term, to detect any trends of increased radioctive contamination. The facility design and site characteristics were selected to preclude such problems. The monitoring system will verify the performance of the facility and allow ample time for corrective action, if necessary, to protect the public health and safety.



Stormwater retention pond
Existing county road
Class B/C waste disposal unit
Mixed waste disposal unit
Temporary soil stockpile
Stormwater retention pond
To Butte, Nebraska
Class A waste disposal unit
Security fence
State Highway 12
Administration area
Support area
Operations control building
Concrete batch plant

Figure 1

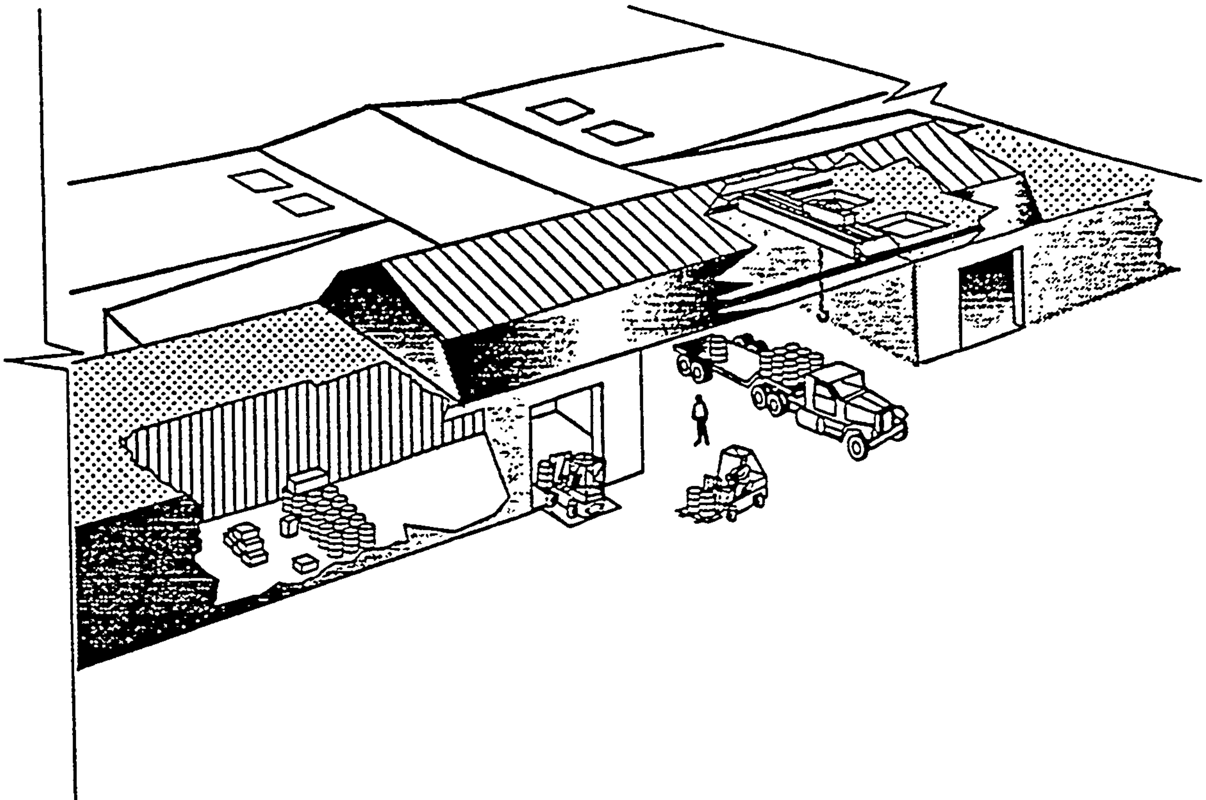


Figure 2 Class A disposal unit.

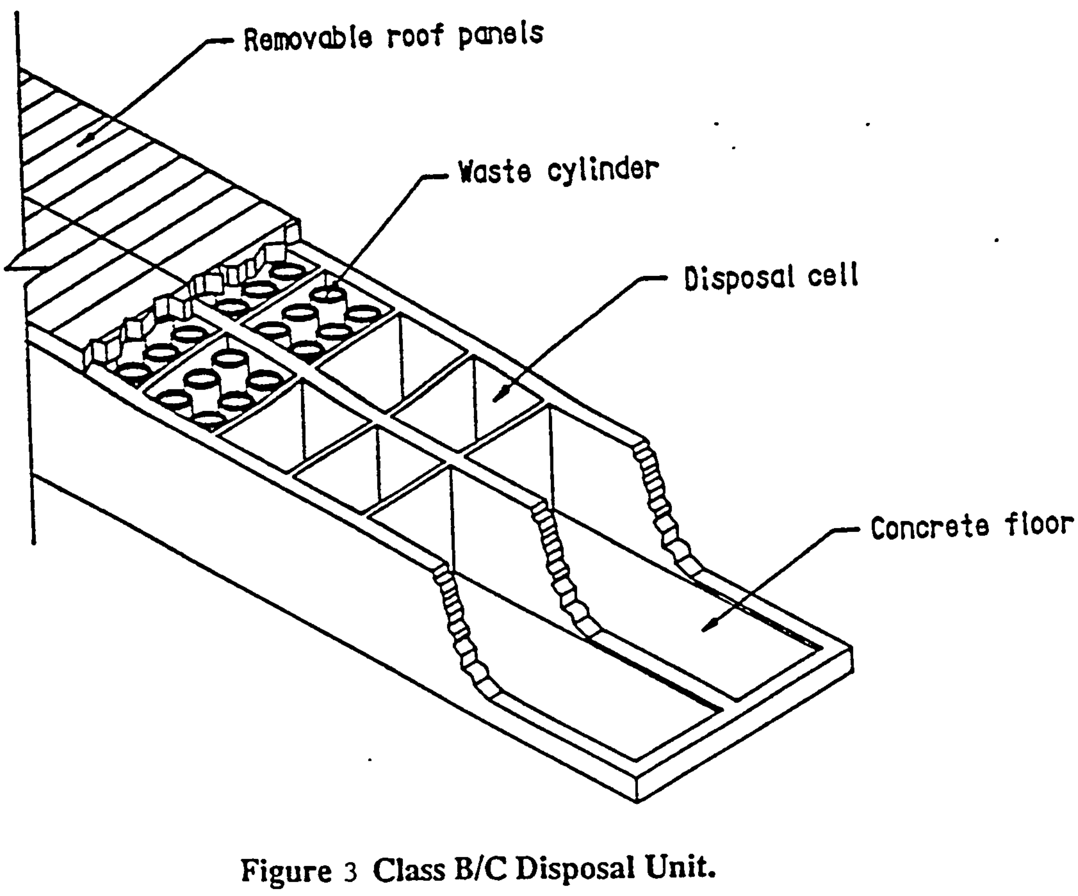


Figure 3 Class B/C Disposal Unit.

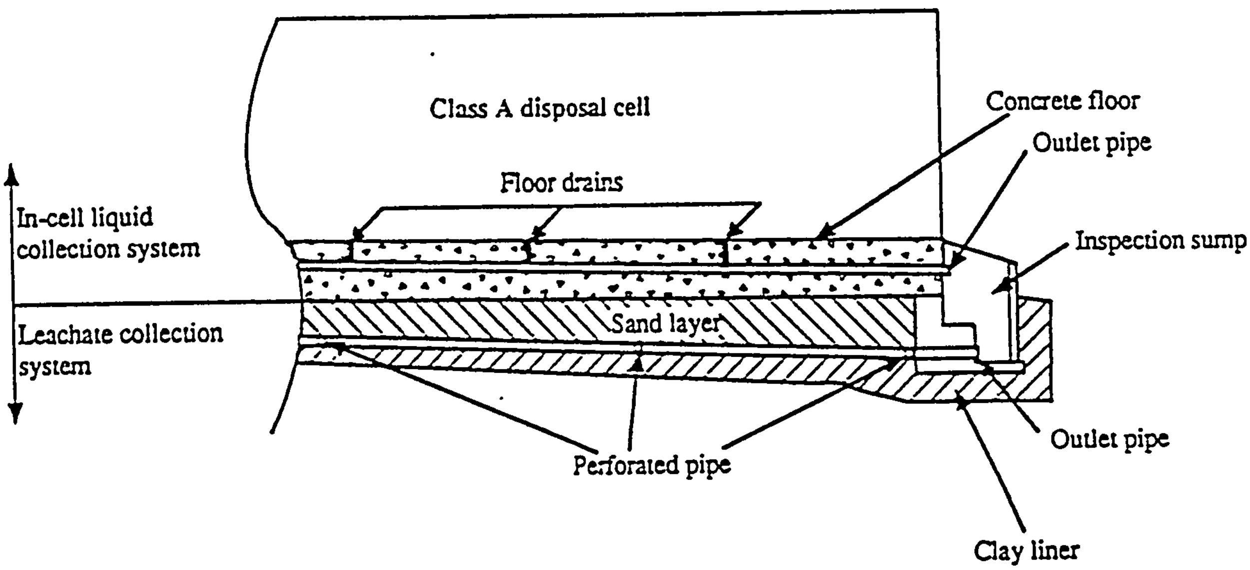


Figure 4 Class A unit in-cell liquid collection system and leachate collection system.

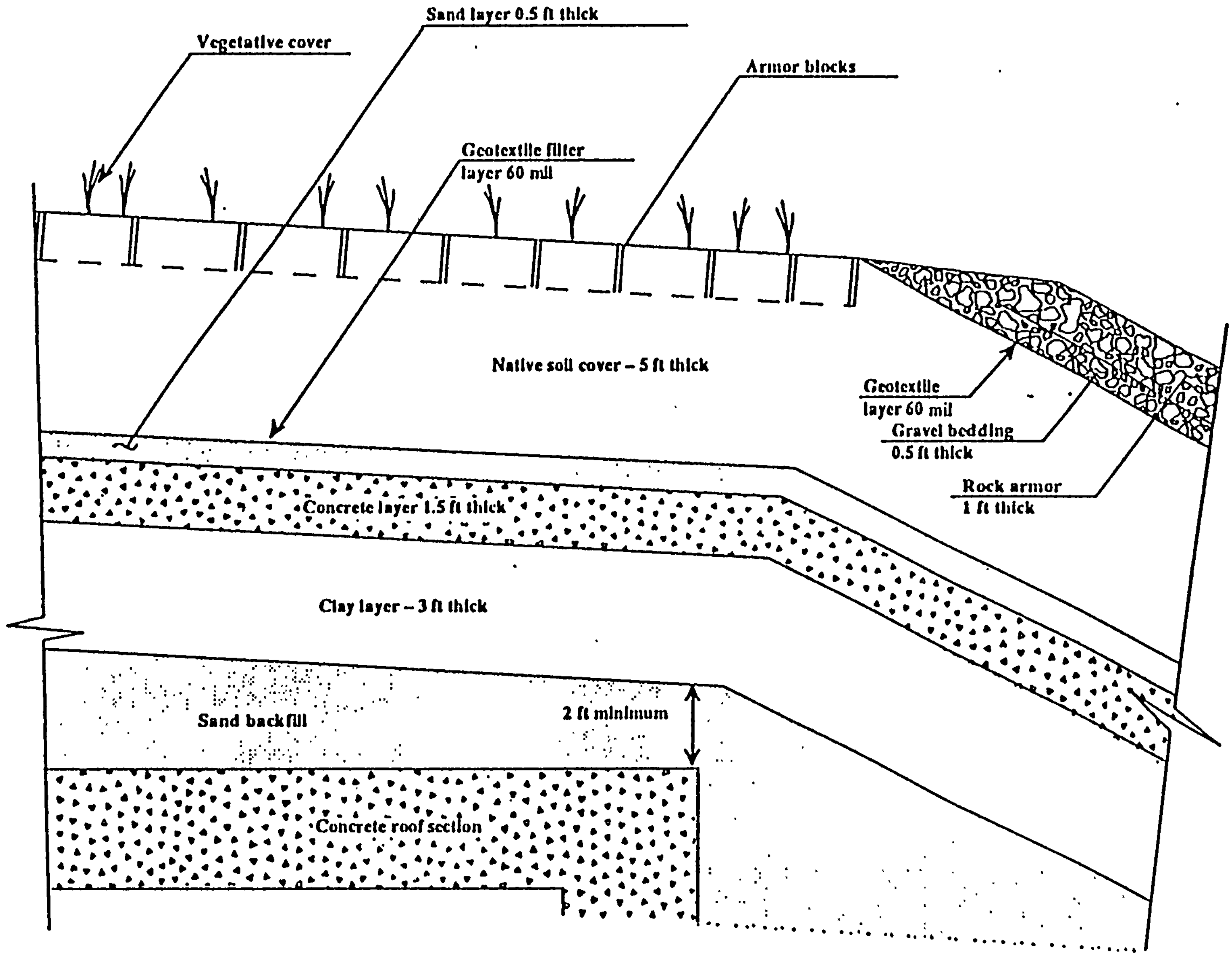
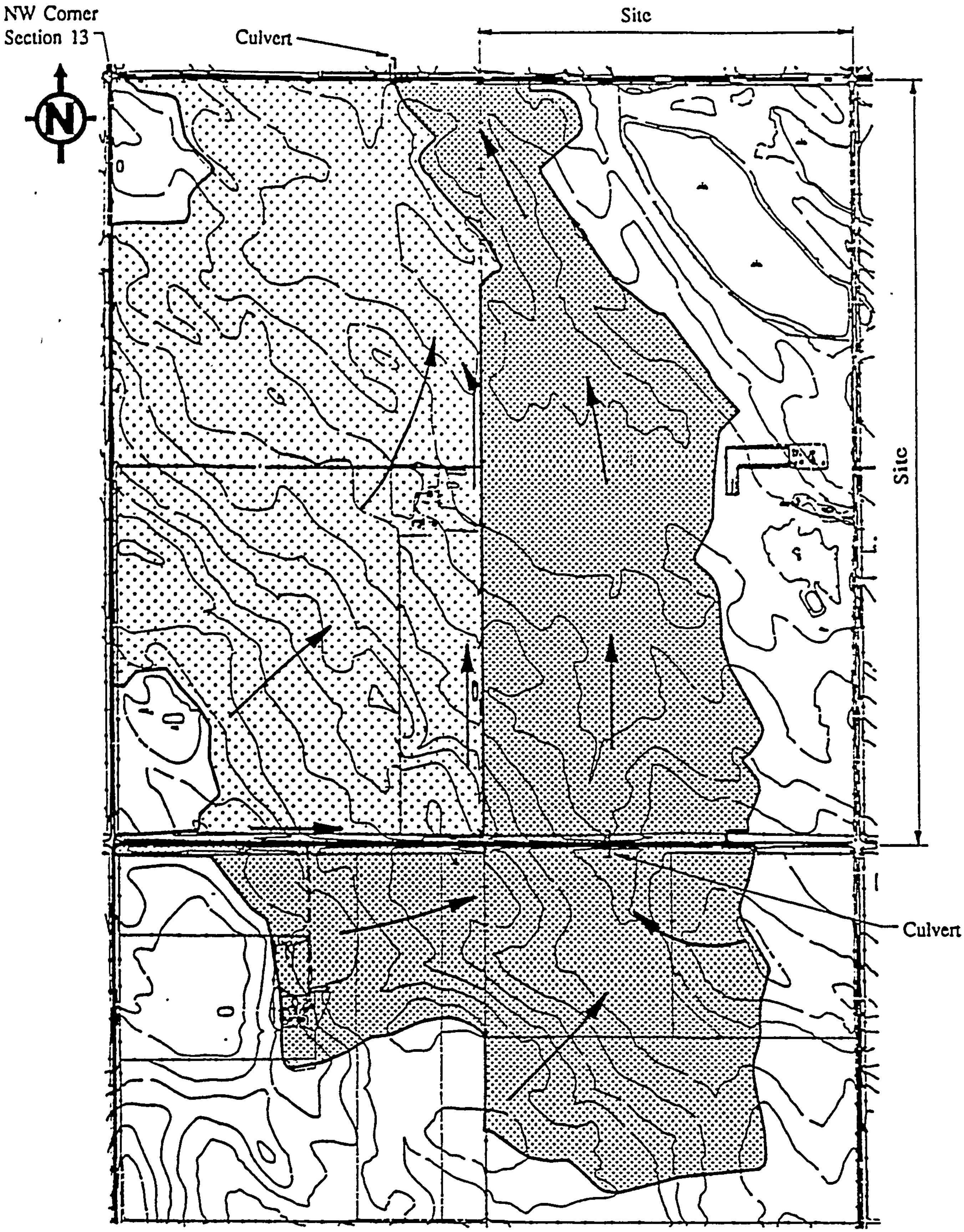


Figure 5 Detailed cross-section of closure cap. (Typical for all disposal units.)

SAR 56



LEGEND

- Existing grade contour
- Drainage area (0.45 square miles) to culvert at north road of Section 13
- Drainage area (0.52 square miles) for the facility site (east 1/2 section of Section 13)
- Direction of surface water flow

Contour interval: 5 ft
Scale: 1 in. = 1000 ft
See drawing No. 19185-1800-CDD-101 for existing site elevations.

Figure 6 Butte site drainage area.

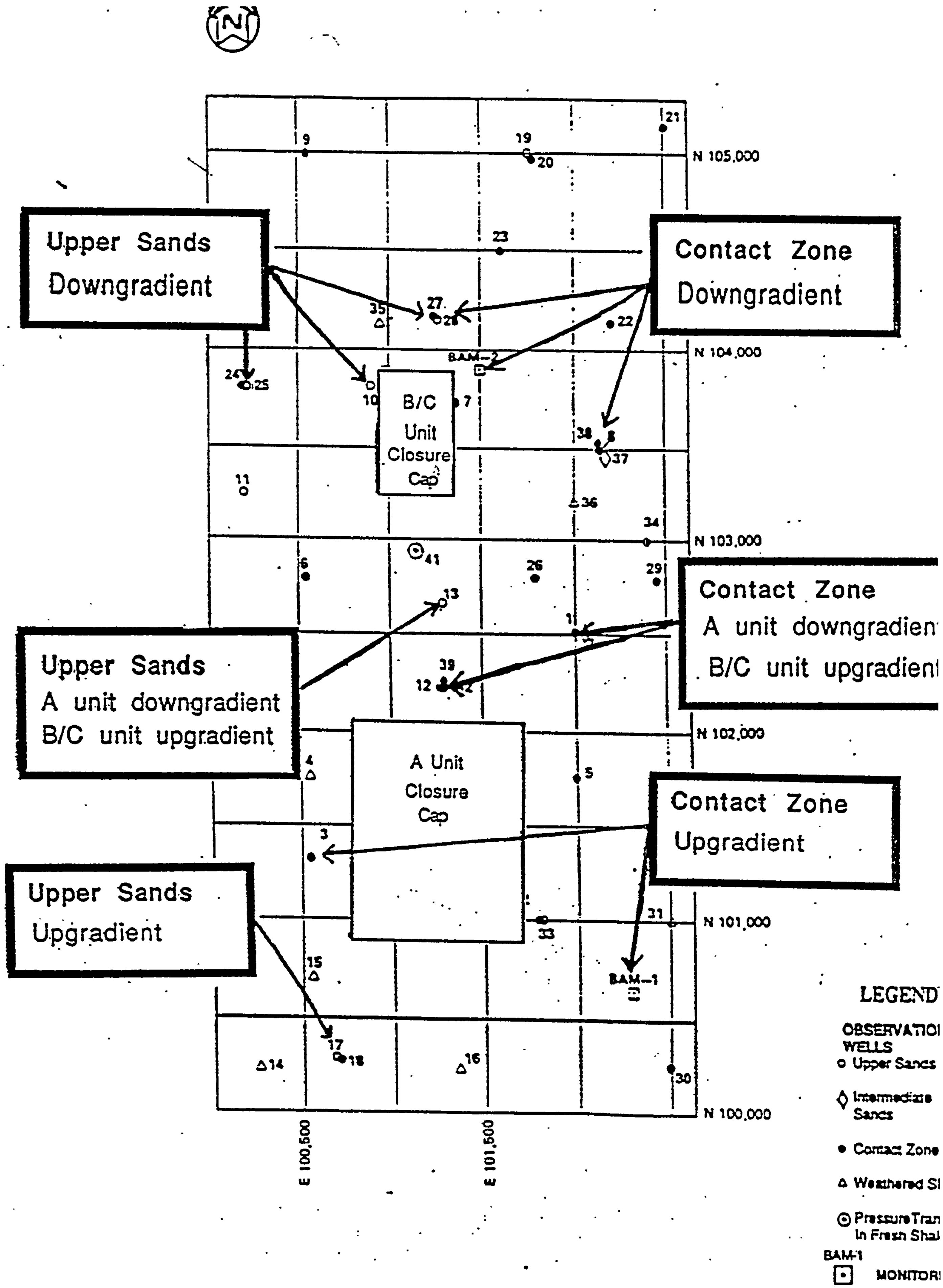
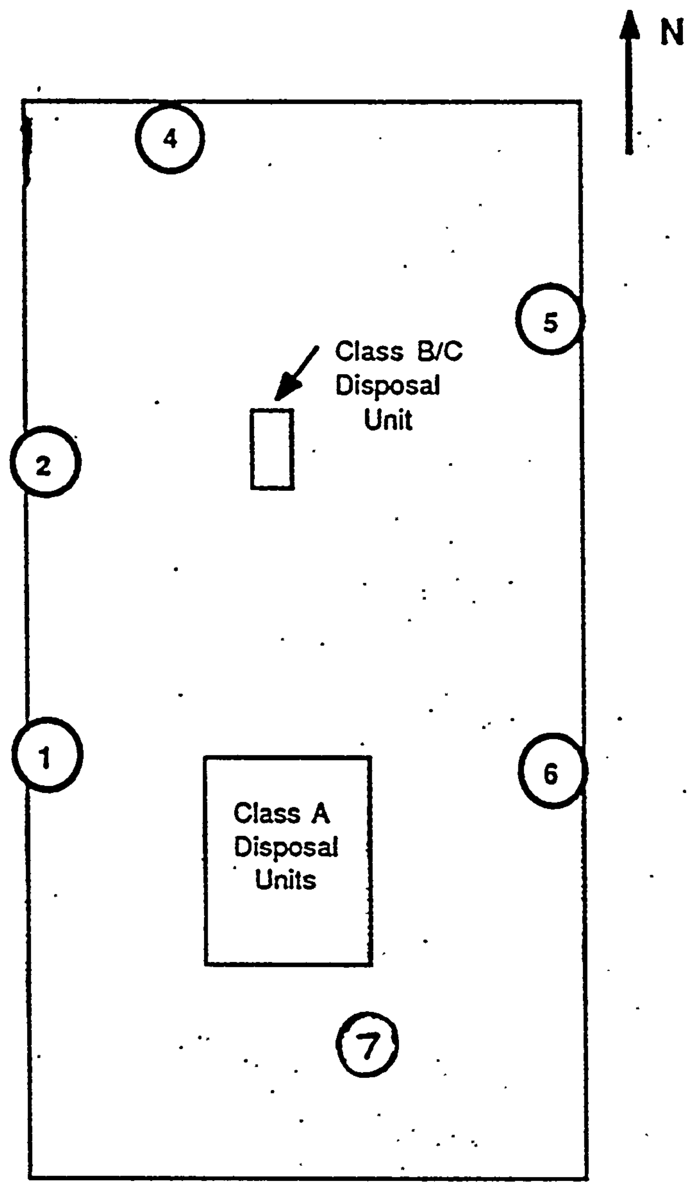


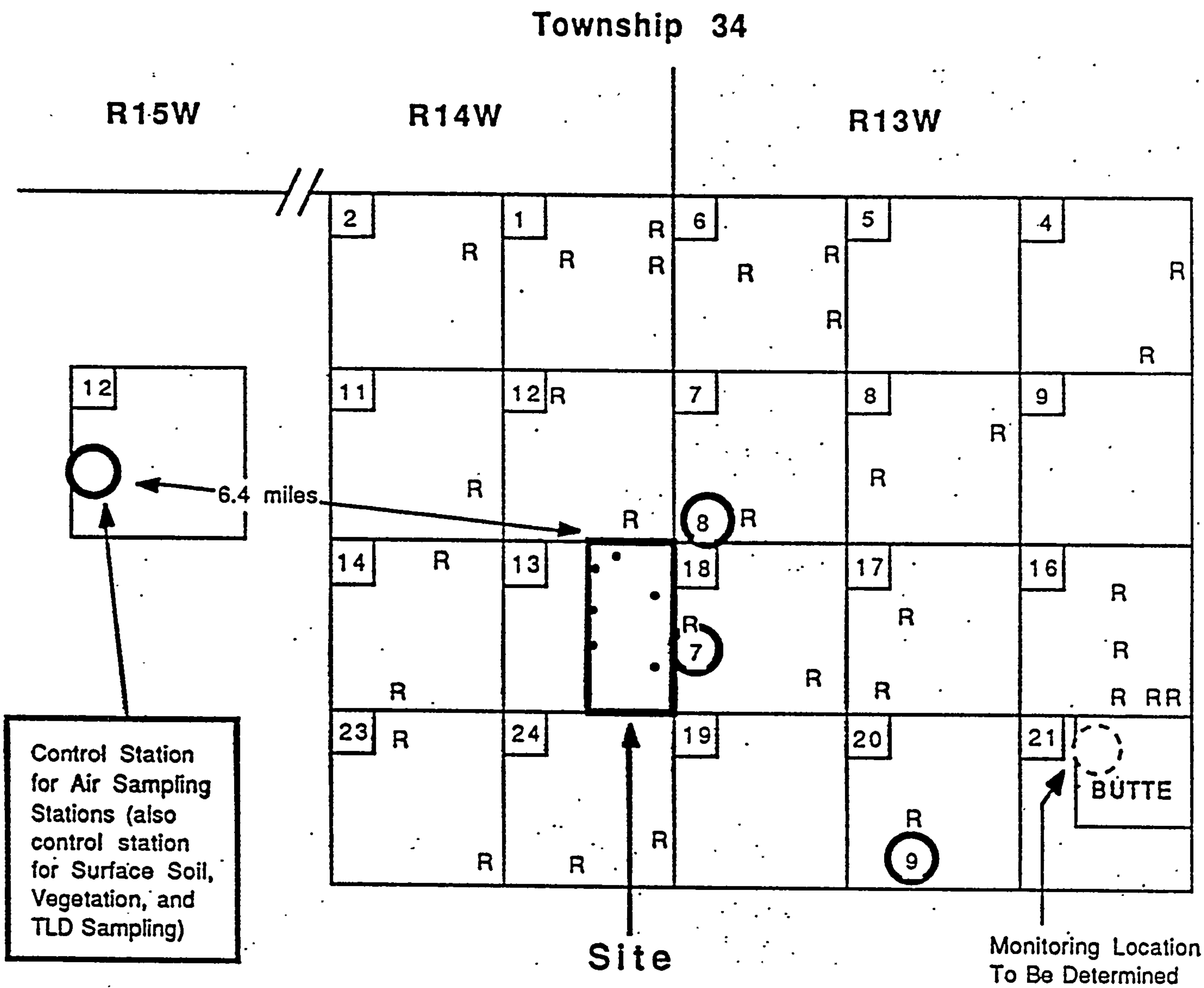
Figure 7 On-Site Monitoring Wells



Sketch of Butte Facility
(not to scale)

Sketch Showing Locations of On-Site Air Sampling Stations

Figure 8



Sketch Showing Locations of Off-Site Air Sampling Stations

 Figure 9

Oak Ridge Low-Level Waste Disposal Facility Designs

S. D. Van Hoesen, L. S. Jones
Martin Marietta Energy Systems, Inc. Engineering and Central Waste Management Division

This paper will describe the two designs currently being considered for the solid low-level radioactive waste (LLW) disposal facilities planned for construction by the U. S. Department of Energy (DOE) in Oak Ridge, TN. The facilities are being designed for the disposal of two classes of waste, Class L-I and Class L-II. The wastes classifications are based on the results of performance assessments which establish the allowable waste radionuclide concentrations. Class L-I waste contains very low levels of radioactive contamination, primarily generated at uranium processing facilities. Class L-II waste contains primarily short-half life fission product contamination, primarily generated at the Oak Ridge National Laboratory (ORNL).

The Class L-I design consists of a "state-of-the art" industrial landfill. The design contains provisions to meet all the requirements of the State of Tennessee Solid Waste Management regulations. Design features include a plastic liner with leachate collection system, and a secondary collection system under the liner for monitoring purposes. The disposal unit is sized to receive approximately 1.6 million ft^3 of waste. Waste is planned to be unloaded directly from trucks driven to the bottom of the disposal unit. Daily soil cover and a final low-permeability cap are planned to reduce water contact with the waste.

The Class L-II design is based on the "tumulus" disposal concept currently in use at ORNL. The tumulus concept involves sealing containerized LLW in concrete vaults which are stacked on a specially designed grade-level concrete disposal pad. The disposal pad is provided with a drainage system to collect water which contacts the waste vault for monitoring. The pad is also underlain by a collection system for monitoring purposes. After waste placement is complete the waste stack is covered with a low-permeability multi-layer cover to reduce water contact with the waste.

Based on work performed at Oak Ridge National Laboratory, operated for the U. S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

Oak Ridge Low-Level Waste Disposal Facility Designs

S. D. Van Hoesen, L. S. Jones
Martin Marietta Energy Systems, Inc. Engineering and Central Waste Management Division

The strategic planning process that culminates in the identification, selection, construction, and ultimate operation of treatment, storage, and disposal facilities for all types of low-level waste (LLW) generated on the Oak Ridge Reservation (ORR) was conducted under the Low-Level Waste Disposal Development and Demonstration (LLWDDD) Program. This program considered management of various concentrations of short half-life radionuclides generated principally at Oak Ridge National Laboratory (ORNL) and long half-life radionuclides (principally uranium) generated at the Y-12 Plant and the Oak Ridge K-25 Plant.

The LLWDDD Program is still ongoing and involves four phases: (1) alternative identification and evaluation, (2) technology demonstration, (3) limited operational implementation, and (4) full operational implementation.

Alternative Identification and Evaluation

The alternatives evaluation phase consisted of the identification of the range of technical alternatives to be considered, identification of evaluation criteria for ranking the alternatives, and the actual evaluation and ranking of the alternatives. The technical alternatives considered were narrowed down to seven using broad screening criteria. These criteria considered the technical feasibility of actual implementation (e.g., do the hydrology and geology of the site allow implementation) and the appropriateness of the technology to the types of LLW to be managed. The seven alternatives considered were (1) landfill, (2) shallow land burial, (3) earth covered tumuli, (4) above-grade concrete structures, (5) deep trenches, (6) augured shafts, and (7) below-grade concrete structures.

Criteria used for evaluating the alternatives considered the ability of each technology to meet the fundamental facility performance objectives, the anticipated performance of the technology, the acceptability of the technology to the regulators and the public, and the anticipated cost. Facility performance objectives were based on the requirements of Department of Energy (DOE) Order 5820.2A "Radioactive Waste Management" which defines dose limits to the public and the intruder from LLW disposal facilities. In addition, State of Tennessee groundwater protection standards were

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Based on work performed at Oak Ridge National Laboratory, operated for the U. S. Department of Energy under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

also considered. In evaluating the anticipated performance of the technologies, the operating record of each technology at other facilities was reviewed and, to the extent practical, extrapolated to the ORR. Maintenance and monitoring requirements, complexity of operation,and actual performance history were reviewed. Regulatory and public acceptability were gauged based on discussions with state and federal regulators, reviews of technology selection processes underway in the state compacts and in foreign countries, and comments received during the public scoping meeting for the project Environmental Impact Statement. Finally, general construction, operation, and maintenance cost information were considered where available.

The analysis resulted in the development of a strategy for the management of four classes of waste. Each waste class reflects a combination of performance derived waste concentration limits and management technology. The four classes of waste are described in the following sections.

Class L-I waste contains low levels of uranium contamination which will be disposed in a state-of-the-art, lined industrial landfill. Class L-I waste is primarily generated at the Y-12 and K-25 Site plants.

Class L-II waste contains primarily short-half life (<30 year half-life) fission product containing waste and will be disposed utilizing the above-grade tumulus disposal concept. Class L-II waste is primarily generated at the ORNL.

Class L-III waste contains concentrations of radionuclides which would require intruder protected disposal. This type of waste is generated at all three Oak Ridge plants and is planned to be stored for the foreseeable future.

Class L-IV waste contains concentrations of radionuclides which are not acceptable for disposal on the ORR. This waste class will be stored until treatment processes are implemented which will produce lower class waste which can be disposed on the ORR and a highly concentrated, low volume stream of waste which will require long-term storage and/or shipment off-site for disposal.

TECHNOLOGY DEMONSTRATION

Class L-I Disposal Technology Description

The Class L-I technology is based on state-of-the-art lined landfill design. At this point in time no demonstrations of this technology are planned or underway. A line item project, the Class L-I Disposal Facility (CIDF), is currently being developed by DOE.

As indicated in Figures 1 and 2 the CIDF disposal technology will employ a low-permeability earth liner overlain by a geogrid, membrane liner, leachate collection system, and stone operating floor. As shown in Figure 3 the CIDF disposal unit will consist of a 210-ft by 630-ft by 30-ft deep below-grade trench. Waste will be placed directly in the trench by transport vehicles then compacted in place and covered with soil. Several "lifts" of waste will be placed to complete loading of approximately 1.6 million ft3 of waste before a low-permeability cover is placed over the unit.

Several facilities are planned to be constructed to support the CIDF operation including a disposal operations control center, a waste staging area, a waste verification station, a vehicle monitoring and decontamination station and a heavy equipment storage building.

The estimated cost of the CIDF, including the support facilities, all site grading for 15 disposal units, and the first two disposal units is $90 million.

Class L-II Disposal Technology Description

Figure 4 provides a schematic of the tumulus disposal technology.

The concrete vaults provide enhanced confinement and structural stability for the waste. The concrete pad provides a "cut-off" for communication with groundwater, thus making this disposal approach suitable for areas with shallow depths to groundwater. The proposed disposal configuration also provides capabilities to monitor all water flows that may come in contact with the waste and facilitates recovery should disposal unit performance not be acceptable.

The Solid Waste Storage Area (SWSA) 6 Tumulus Disposal Demonstration was conducted to develop experience and information to help in evaluating the suitability of this technology for the management of solid LLW on the ORR. Information was developed on environmental and health, operational, and construction aspects of the technology.

The Tumulus demonstration unit was constructed with monitoring features which should ultimately allow measurement of the environmental performance of this technology. The curbed pad on which the waste is placed was designed to collect all water which may come in contact with the waste containers. This water drains from the pad to a monitoring station where the flow is measured and samples collected. In addition, a plastic liner was placed under the pad to allow monitoring of any inadvertent leakage and to provide an additional barrier against groundwater contamination. Monitoring features were also included in the cap design to allow evaluation of its performance. Additional information on the Tumulus Disposal Demonstration is provided later in the paper.

Limited Operational Implementation

As a result of the successful implementation of the technology demonstration phase, limited operational implementation of the technology is being undertaken in the form of the Interim Waste Management Facility (IWMF). Implementation is considered "limited" for several reasons: (1) the IWMF is located in SWSA 6 (the current LLW disposal site at ORNL) and did not require a new site selection process, (2) the space available in SWSA 6 limits the size and the operational life of the IWMF to approximately 5 to 6 years, (3) waste acceptance criteria and characterization programs that will be developed for the new facilities are not yet in place. Within that context, construction is currently being finalized and operation is scheduled to begin in late 1991 or early 1992.

Full Operational Implementation

Full operational implementation will occur in the form of the new Class L-II Disposal Facility (CIIDF) currently planned for SWSA 7 at ORNL, contingent upon completion of the Environmental Impact Statement. As currently planned, facility construction will begin in 1994, and it will provide approximately 20 years of disposal capacity, beginning in 1997.

TUMULUS OPERATING EXPERIENCE AND LESSONS LEARNED

Tumulus disposal technology has been successfully utilized at ORNL for almost four years, and to date approximately 50,000 ft^3 of solid LLW have been disposed of via the Tumulus. The following sections summarize the important "lessons learned" from tumulus operations to date.

Pad Configuration

The size of disposal pads have been reduced from 65-ft by 110-ft on Tumulus I to 60-ft by 90-ft in Tumulus II and IWMF. The pads were reduced in size to eliminate the construction difficulties associated with the integral pour approach which was utilized. The 30-mil plastic liner utilized on Tumulus I was eliminated on later units due to construction difficulties and significant in-leakage of groundwater from the underpad gravel system. The pad thickness was increased to 15-in. for Tumulus II and IWMF to accommodate a three high waste vault stack.

Drain Line Gallery

Difficulties were encountered in both Tumulus I and II with leakage of the below-grade drain piping. A concrete utility tunnel system has been adapted for use as a drain line gallery for the IWMF to provide access to the drain lines for inspection and monitoring. The gallery entrance will be extended to the earthen cover surface to provide access after closure.

Disposal Vaults

The handling mechanisms for the disposal vaults were changed form forklift slots on the Tumulus I vaults to cable lift rings for the Tumulus II. Significant difficulties were encountered with the forklift movements during loading of Tumulus I which resulted in damage to the vault edges and increased vault loading times. No difficulties have been encountered with the removable lift rings which are currently being utilized. Chamfers were added to all edges of the Tumulus II vault which has reduced the chipping and spalling noted during handling of the Tumulus I vaults.

The efficiency of loading of the containerized LLW into the vaults and backfilling with grout has been improved by the development of special hold-down fixtures to prevent container float.

Operational Monitoring

Monitoring has been conducted for worker exposures during vault loading and placement operations. To date worker exposures have been kept within control limits and appear to actually be reduced from exposures experienced during the previously utilized trench loading operations. It appears that the concrete vaults provide significant shielding for the workers once the waste is placed inside.

Gross beta levels from Tumulus I are slightly above background levels, due to the presence of Potassium-40 (K-40). The K-40 is thought to be the result of leaching of naturally occurring materials form the large concrete surface areas present in the tumulus disposal system.

The elevated K-40 levels appear to be consistent with the high pH levels noted in the pad drain water. The pH levels are in the range of 8-10, and appear to be dependent on the number of vaults placed on the pad. The drain lines from both pads have been closed and water is being collected and hauled to treatment since the high pH violates the regulatory discharge limits. The impact of placement of the planned earthen cover on the pH levels is currently being evaluated.

COST SUMMARY

The estimated cost for the alternatives identification and evaluation phase is approximately $7 million. This is a working estimate since the Environmental Impact Statement has yet to be finalized.

A summary of the cost of the design, construction, and operation and the tumulus demonstration projects is provided in Table 1. Design costs include Title I and II efforts, as well as additional documentation on construction experience that was developed by the demonstration program as a part of Title III design. Construction costs include the fixed price contract for site preparation, tumulus pad and monitoring station construction, as well as in-house costs for monitoring instrument procurement and installation, and utility hookups. The vault costs reflect the fixed price manufacture contract for the vaults currently being utilized. Operating costs include waste container placement in the vaults, concrete backfill, vault lid placement and sealing, and vault placement operations. The cost of the cover is based on estimates developed during a conceptual cover design effort conducted during 1987.

It is estimated that the design, construction, operation, and closure costs for the tumulus demonstration phase are approximately $\$62/ft^3$ on an "as disposed" basis. Projected design, construction, operation, and closure costs for the IWMF on an "as disposed" basis are approximately $\$88/ft^3$. Costs on an "as generated" basis could be much lower, depending on the degree of waste compaction achieved in waste container loading. It should be recognized that these costs may change significantly for future tumuli as a result of site characteristics, technology evolution, and effects of scale.

TABLE 1

TUMULUS DISPOSAL DEMONSTRATION COST SUMMARY

		Tumulus I	IWMF
- Design		$ 60,000	$ 200,000
- Tumulus Construction		$ 180,000	$ 2,650,000
- Vault Manufacture		$ 234,000	$ 4,300,000
- Tumulus Operations		$ 660,000	$ 4,800,000
- Tumulus Closure		$ 425,000	$ 2,300,000
	Total	$ 1,559,000	$14,250,000
		$ 62/ft^3	$88/ft^3

ORNL-DWG 90-15489

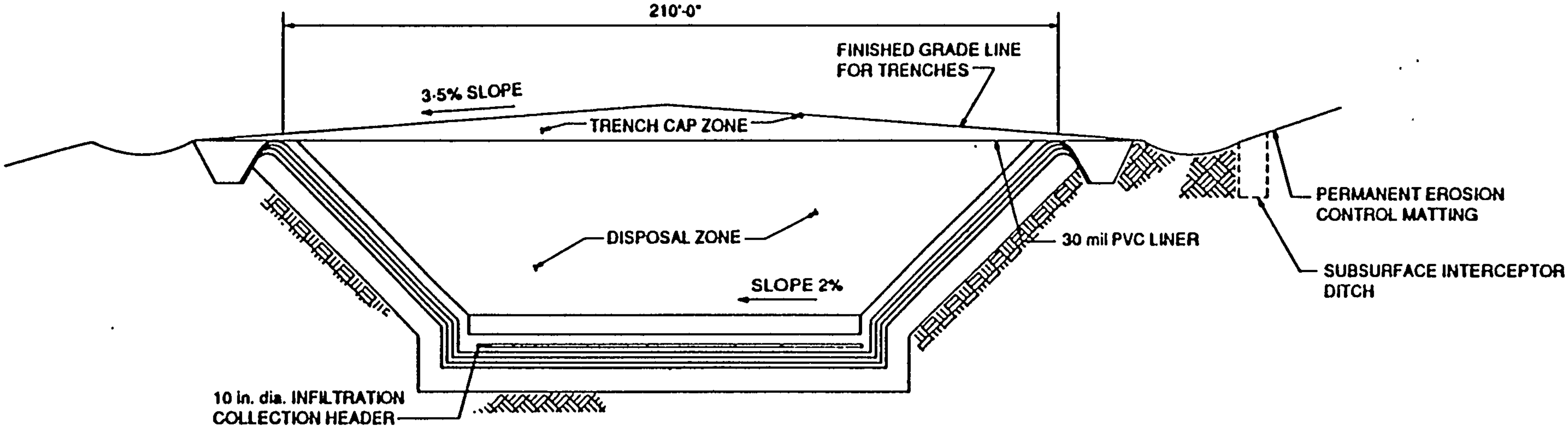

Figure 1 **Class I Disposal Trench Cross Section**

ORNL-DWG 90-15488

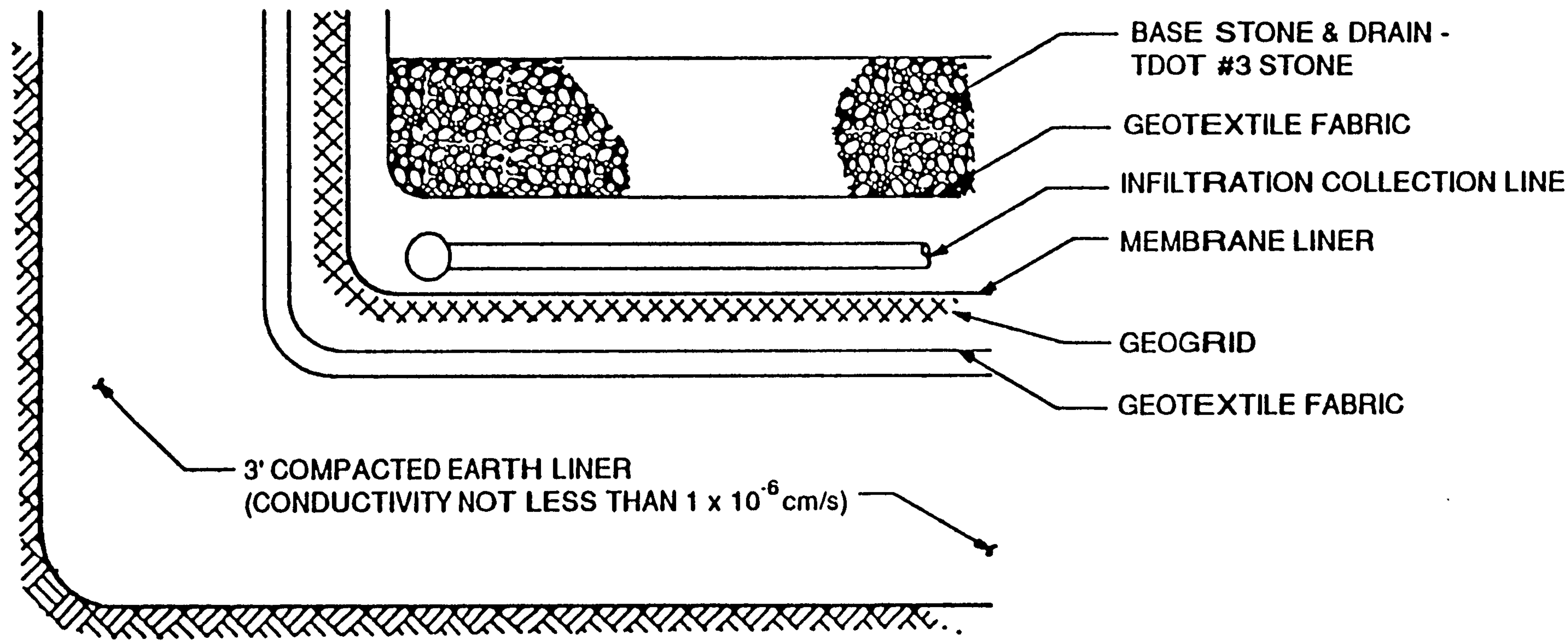

Figure 2 **Class I Disposal Trench Detail**

ORNL-DWG 90-15502

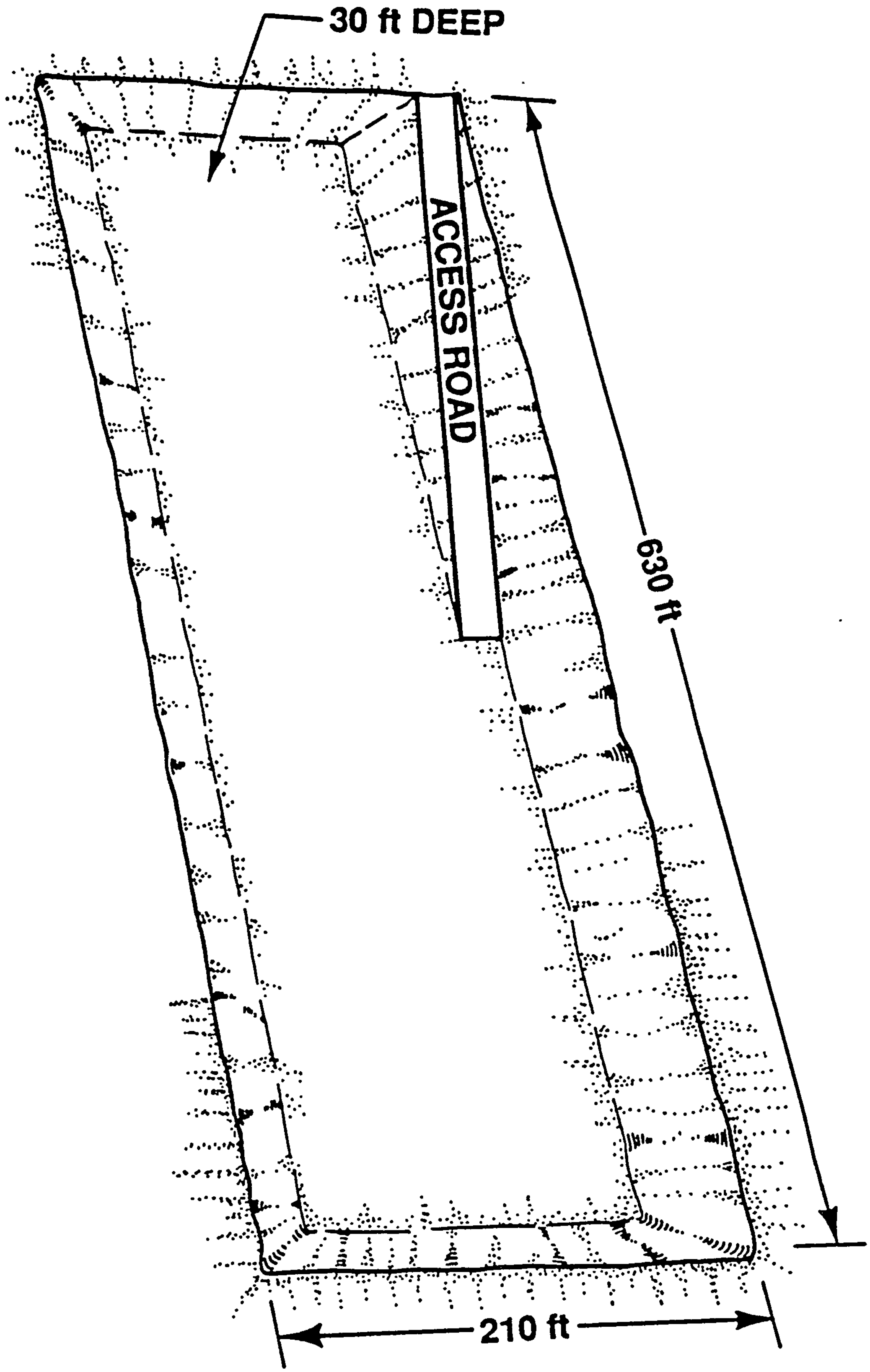

Figure 3 **Empty Trench**

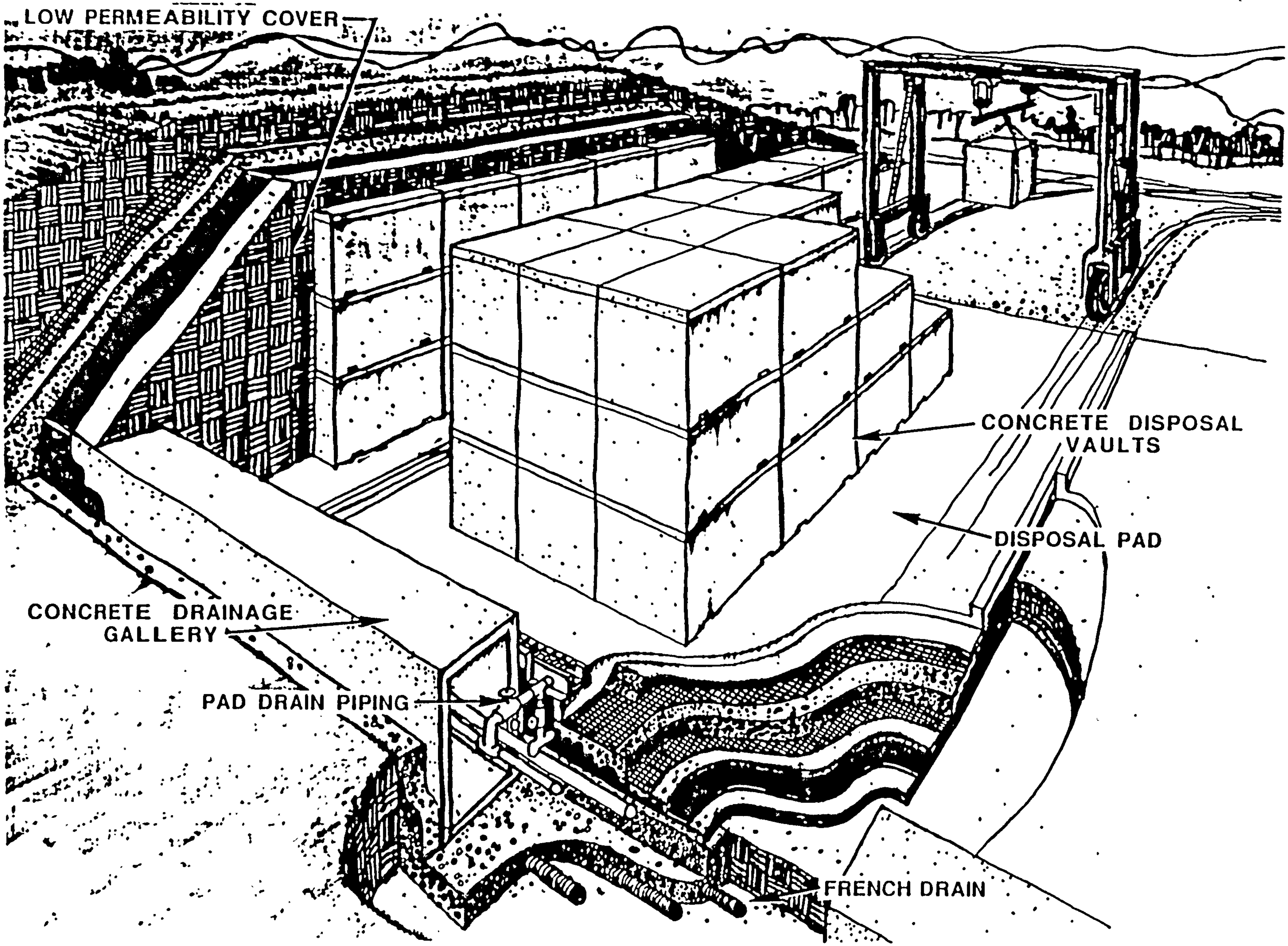

Figure 4 TUMULUS DISPOSAL TECHNOLOGY

WSRC-MS-91-488X

Mixed Waste Disposal Facilities at the Savannah River Site

Abstract

Michele N. Wells and Lora L. Bailey

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The Department of Energy's Savannah River Site (SRS), located in Aiken, South Carolina, produces nuclear materials for use in the national defense program and medical and space research. Some operations at SRS generate mixed waste streams. SRS is currently designing two facilities to provide treatment and permanent disposal of these wastes. Both of these facilities will comply with Resource Conservation and Recovery Act (RCRA) regulations.

The M-Area Waste Disposal (Y-Area) facility will provide RCRA treatment and disposal of the site's liquid mixed waste streams. The wastes will be transported to Y-Area by tank truck, then mixed with cementitious solids to form a grout. The grout will be pumped into double-lined, reinforced concrete vaults and allowed to harden. Pending approval of the RCRA Permit Application, operations are scheduled to begin in 1995.

The Hazardous Waste/Mixed Waste Disposal Facility (HW/MWDF) will provide storage, treatment, and permanent disposal facilities for SRS's solid mixed wastes. The HW/MWDF will be completed in two phases. Phase I, the Disposal Vaults, will be designed to accept packaged wastes emplaced by an overhead crane. Pending approval of the RCRA Permit Application, the first Disposal Vault is scheduled to be operational in 1994. Phase II, the Treatment Building, will provide several treatment processes to accommodate the variety of solid mixed wastes in preparation for final disposal. The Treatment Building is currently scheduled to begin operations in 1996.

Mixed Waste Disposal Facilities at the Savannah River Site

Michele N. Wells and Lora L. Bailey

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INTRODUCTION

The Savannah River Site (SRS) is a key installation of the U.S. Department of Energy (DOE). The Site is managed by DOE's Savannah River Field Office and operated under contract by the Westinghouse Savannah River Company (WSRC). This unique complex covers over 300 square miles of western South Carolina, and borders on the Savannah River. The SRS was established by the U.S. Atomic Energy Commission in 1950 to support the nation's defense program by producing tritium and Plutonium-239 and recovering highly enriched uranium from spent reactor fuel. The SRS also produces Plutonium-238 heat sources for use in space programs. The versatility of the site's reactors has led to the production of many other nuclear materials for use in research, medicine and industry, including Californium-252, Americium-243, Uranium-233, Curium-244, Polonium-210 and Cobalt-60.

The Savannah River Ecology Laboratory, an environmental research center that is operated by the University of Georgia, and a lumber and forestry research center, managed by the U.S. Forest Service, are also located at SRS. As the nation's first Environmental Research Park, the Site is home to two endangered species: the bald eagle and the red-cockaded woodpecker. Other endangered species that visit or live on the site include the peregrine falcon, wood stork, and shortnose sturgeon. Alligators, white-tailed deer, wild turkeys, and otters are common residents on the SRS.

The Site's waste management policies reflect a continuing commitment to the environment. Waste minimization, recycling, use of effective pre-disposal treatments, and repository monitoring are high priorities at the site. One primary objective is to safely treat and dispose of process wastes from operations at the site. To meet this objective, several new projects are currently being developed, including the M-Area Waste Disposal Project (Y-Area) which will treat and dispose of mixed liquid wastes, and the Hazardous Waste/Mixed Waste Disposal Facility (HW/MWDF), which will store, treat, and dispose of solid mixed and hazardous wastes.

THE M-AREA WASTE DISPOSAL FACILITY, (Y-AREA)

Mission: The proposed M-Area Waste Disposal Project, more commonly known as "Y-Area", is designed to treat and dispose of up to 1.2 million gallons of SRS mixed waste salt solutions and slurries each year. This facility will fully comply with the Resource Conservation and Recovery Act. Based on the current Best Developed Available Technology (BDAT), these liquid wastes will be converted to a solid, cement-based waste form for disposal in Y-Area. The proposed Y-Area treatment process relies heavily on technology developed for the production and disposal of saltstone, a solid industrial waste also produced at the site. The proposed Y-Area would be constructed adjacent to the Z-Area Saltstone Processing and Disposal Facility, a unit of the Defense Waste Processing Facility (DWPF), located near the center of the site. An artist's conception of the facility is shown in Figure 1.

Scope: As presently conceived, the Y-Area project includes a waste transport truck and two trailers; two 22,000 gallon waste hold tanks; a process building that contains administrative areas, waste processing equipment, and a ventilation system with scrubbers, dust collectors, and HEPA filters; and one reinforced, concrete RCRA disposal vault constructed with a double liner and a leachate collection/detection system. A temporary steel roof will be installed on the vault to prevent rainwater intrusion during filling operations. Additional vaults would be built as needed; projections for the project estimate approximately twenty vaults would be needed over the lifetime of the Y-Area facility (20 years).

Waste Streams: Two waste streams are currently identified for treatment and disposal in Y-Area. One is a sludge from the Reactor Materials Production Facility that is generated from electroplating operations during the fabrication of reactor targets. Sludge constituents include sodium nitrate, aluminum, phosphate, silica, depleted uranium, nickel, and trace amounts of zinc and nickel. Approximately 270,000 gallons of this sludge are currently stored in above-ground tanks; continuing operations in M-Area would generate an additional 40,000 gallons per year.

The other liquid waste stream will be generated by the proposed Consolidated Incineration Facility (CIF) which will reduce the volume of solid waste at the site. The CIF will be a rotary kiln incinerator that will burn combustible waste generated at the SRS, including waste that is classified as low level radioactive and hazardous mixed waste. The incinerator offgas will be cooled by rapid quenching and neutralized by a wet scrubber. The liquid used in the quench and scrubber will be filtered and recycled, with the concentrate, or "blowdown," being removed from the system. This blowdown will contain principally sodium chloride and suspended ash particulates. It could also contain non-volatile radionuclides, and trace levels of hazardous metals such as mercury, lead, or chromium. Approximately 370,000 gallons of blowdown will be generated each year, after the CIF begins operations (now projected for 1994).

Processing and Disposal: Waste will be shipped to Y-Area via tank truck and unloaded into the waste hold tanks, where 50 wt percent sodium hydroxide will be added to adjust the pH to greater than 12.5. The waste will be agitated to prevent settling of suspended solids.

Three key ingredients in the stabilization process (Portland cement, blast furnace slag, and flyash) will be delivered to the facility by railcar and pneumatically conveyed into dedicated storage silos, each with a nominal capacity of 23,000 cubic feet. These dry materials will be pneumatically blended in prescribed proportions and conveyed into a storage bin located on the roof of the Y-Area process building.

Processing will occur in batches. Each waste will be campaigned separately to ensure proper mixture ratios are used, consistent with the waste composition. During processing, the blended dry material is gravity fed into a horizontal, twin-screw mixer where it is combined with liquid waste. The resulting grout mixture gravity drains to a 400 gallon hold tank from which it is pumped via a transfer line to a RCRA disposal vault. The transfer line will approach the vault at ground level, then run up the side of the vault and across the cell cover to its peak. The grout will discharge directly into the vault and will hydrate into a "saltstone" monolith. Saltstone is a durable, environmentally stable waste form that provides primary containment for the waste. The vault provides secondary containment to isolate the waste from the environment.

Each grout production campaign is followed by a thorough equipment flush with clean process water. The flush water is collected for processing and disposal by combining it with additional waste in subsequent campaigns. The grout transfer line to the vault is cleaned by a "pig," a round polyurethane ball whose diameter is slightly larger than the inner diameter of the transfer line. Pressurized air is used to push the pig through the line, thus clearing the line of any residual grout. The project's Process Flow Diagram is shown in Figure 2.

Vault Design: The Y-Area disposal vaults are designed in accordance with RCRA regulations. The base, inner, and outer walls of the vault will be constructed of reinforced concrete at grade level. The base will be 24" (61 cm) thick and the walls will be 18" (46 cm) thick. Overall vault dimensions are nominally 200' (61m) long x 50' (15m) wide x 25' (8m) high. Each vault is divided into four cells. Each cell will have its own double liner and leachate collection/detection system. The primary liner, made of 80 mil High Density Polyethylene (HDPE), and the secondary liner, made of 60 mil HDPE, will sandwich an HDPE drainage net. The liner system will provide a continuous impermeable surface across the cell floor and up the walls. A 2" (5 cm) layer of concrete will be poured over the primary liner on the cell floor to protect the liner from damage during subsequent disposal operations. All leachate removed from the vault leachate collection system will be handled as hazardous waste.

Y-Area Vault Interim Closure: Partial closure will take place as each vault is filled. Grout will be poured to within approximately 12" (30cm) of the top of the vault walls. A clean cap of concrete will then be poured on top of the saltstone to completely isolate the saltstone from the environment. A concrete roof with a sloping surface will be installed as a separate operation. (Final site closure information is provided in the section titled "RCRA Vault Final Closure.")

Shared Facilities: As noted above, the Y-Area facility design is based on the existing Z-Area Saltstone Processing Facility, which uses the same cement stabilization process to convert an aqueous waste stream to a non-hazardous industrial solid waste called saltstone. Z-Area has been operating successfully since its startup in June 1990. To maximize use of personnel training and experience and minimize cost, the Y-Area facilities have been designed to be integrated into the existing Z-Area facilities to the greatest extent possible. For example, dry material unloading, silo storage, and blending facilities belong to Z-Area; Y-Area will tie-in to the system downstream of the pneumatic blenders. The water systems of the two facilities will be connected, and air compressor systems will be mutually supporting. Change rooms, shower and locker facilities, process laboratories, maintenance shops and Health Protection facilities already provided in Z-Area will also be used by Y-Area personnel. Most importantly, the same staff will operate both facilities to take advantage of the pool of knowledge and experience already available.

RCRA Part B Permitting: A RCRA Permit Application was submitted to the South Carolina Department of Health and Environmental Control in November 1990. The permit application was revised in August 1991 to incorporate a Location Standards Demonstration for the chosen facility site, in compliance with South Carolina Hazardous Waste Regulations, SCWMR R.61-104. Permit approval is scheduled in November 1992.

Schedule: The Y-Area facility is currently in design, with approximately 25% of the design completed. Construction start is dependent upon RCRA Permit approval. Facility start-up is projected for mid 1995, assuming all approvals are obtained as scheduled.

THE HAZARDOUS WASTE/MIXED WASTE DISPOSAL FACILITY

Mission: The Hazardous Waste/Mixed Waste Disposal Facility (HW/MWDF) is a two-phase project that will provide for storage, treatment and disposal of solid and hazardous mixed wastes generated at SRS. The HW/MWDF will be located near the center of the SRS.

Scope: Disposal vaults will be constructed during Phase I of the project. Preparation of a 10 vault site, design and construction of the first two vaults, and procurement of a mobile gantry crane for waste placement are included in this phase of the project. These vaults will provide permanent disposal capacity for solid hazardous and mixed wastes that have been processed into acceptable disposal forms. Eventually ten disposal vaults will be built. An artist's conception of the Disposal Vaults is shown in Figure 3.

The Treatment Building, which will provide a controlled environment and required processes to treat solid hazardous and mixed wastes in preparation for final disposal in the HW/MW Disposal Vaults, will be constructed during Phase II. Planned processes include handling of tritiated waste, macroencapsulation, stabilization and a variety of treatments to either remove mercury or to stabilize mercury-contaminated waste. Figure 4 shows an artist's conception of the Treatment Building.

Phase I - Disposal Vaults

Design and Operation: Final design of the Disposal Vaults was completed in October, 1990. Because Y-Area and HW/MWDF are both RCRA disposal facilities, the basic design features of the HW/MW vaults are similar to the Y-Area vaults. Like the Y-Area vaults, the HW/MW vaults will be above-grade, reinforced concrete structures with a double-lined leachate collection and detection system. Nominal outside dimensions are the same as Y-Area vaults, at 200 ft (61 m) long x 50 ft (15 m) wide x 25 ft (8 m) deep. The vaults will each be subdivided into four independent cells. Each cell will have its own HDPE double liner system consisting of an 80 mil (2 mm) primary liner and a 60 mil (1.5 mm) secondary liner sandwiching an HDPE drainage net and extending across the cell floor to the top of the walls. Each cell will have its own sump. Riser pipes with liquid level indicators will be installed in each sump to provide liquid detection and a means for leachate recovery. Any leachate removed will be treated as hazardous waste.

Unique design features are incorporated into the roofs of the HW/MW vaults, and in the waste packaging itself; both the roofs and the packaging system are specially designed to accommodate disposal of individual waste packages. Each vault cell will have its own removable steel raincover. A gantry crane will be used to remove the raincovers, which can be stacked during operations. The waste containers will be either palletized drums or specially designed concrete boxes, equipped with iso-twist locks. These locks were originally developed for use with containerized cargo, but in this application, they will allow totally remote handling of waste packages from the cab of the crane. This design has an added advantage of allowing waste to be retrieved from the vault later if necessary. To minimize rainwater intrusion, vault loading operations will not be done during inclement weather.

Waste Streams: The first two HM/MW disposal vaults will be dedicated to the disposal of ash from the CIF. The ash is a secondary particulate waste stream produced during normal CIF operations. The waste generator, CIF, will be responsible for the waste treatment (cement stabilization) and packaging (palletized drums) of the waste prior to shipment to the HW/MW vaults. Future vaults will also contain wastes that have been treated and/or repackaged at the HW/MW Treatment Building.

Interim Closure: Partial closure will take place as each vault is filled. The temporary raincover will be replaced by a permanent concrete cap, which will be constructed in three steps. First, precast concrete tees will be positioned to span the width of each cell. The tees will support the weight of a sloped concrete cap, which is poured-in-place in the second step. Finally, the top of the cap will be covered with an Ethylene Propylene Diene Monomer (EPDM) roofing membrane to prevent the infiltration of precipitation.

RCRA Part B Permitting: A RCRA Part B Permit Application was submitted to SCDHEC in September 1990. Approval is expected in September 1992.

Schedule: Final design of the disposal vaults was completed in October 1990. Construction start is dependent upon permit approval. Assuming timely permit approval, vault disposal operations should begin in 1994.

Phase II - Treatment Building

Design: The design of the Treatment Building is still in the preliminary stages. The technical baseline for this phase was first developed in 1988, at a time when the EPA had not yet proposed treatment standards for most SRS waste streams. It was also known that the EPA's Land Disposal Restrictions (LDR) would lead to a disposal dilemma for SRS when they were promulgated in May, 1990. Driven by pressure to continue project development in the face of the impending LDRs, project design proceeded on the assumption that waste encapsulation/stabilization would most likely be the prescribed treatment for most SRS wastes.

However, when the LDRs were promulgated, much interpretation was required to apply the regulations to the hazardous and mixed wastes at SRS. Fortunately, SRS had recently initiated programs to characterize all waste streams for treatment and final disposal.

Process Selection: A team of WSRC personnel with project, operational, technical, and regulatory expertise evaluated known and anticipated SRS hazardous and mixed waste streams against the EPA's Best Demonstrated Available Technologies (BDATs) and/or Treatment Standards to determine the best way to handle the greatest number of waste streams with the fewest treatment processes. Many solid wastes were considered including lead, mercury, contaminated process equipment, and contaminated soils.

The team's ultimate recommendation was to expand the Treatment Building scope from the original encapsulation/stabilization concept to include: tritiated waste handling, macroencapsulation, stabilization, and a variety of mercury treatments.

Following is a brief description of each process:

Tritiated Waste Handling: Tritium mixed waste is a large volume waste stream for the Treatment Building scope. The handling of this waste stream will require special considerations for personnel safety, overall hazards, and engineered features to prevent releases. The main consideration in handling tritiated mixed waste is the constant off-gassing of tritium. The tritiated waste handling area will be equipped with its own off-gas system, which will have the ability to both monitor levels and recover tritium. The process design must minimize the space within the Treatment Building contaminated with Tritium.

Mercury Treatments: Several mercury treatments will be used to accommodate a variety of mercury wastes. Mercury amalgamation will be used to stabilize radioactively contaminated elemental mercury. Acid leaching and chemical oxidation will be used for "low mercury" wastes, having less than 260 ppm Hg. "High mercury" wastes, containing more than 260 ppm Hg, will be subjected to retorting.

Macroencapsulation: Macroencapsulation is a process that coats the surface of a waste with a non-hazardous material such as polymeric organics or inert organic materials in order to substantially reduce waste surface exposure to potential leaching media. SRS is evaluating a readily available macroencapsulation process that uses a thermoplastic polymer. Macroencapsulation is the specified technology for radioactive lead solids, but SRS may seek a variance to macroencapsulate other wastes as well.

Stabilization: Stabilization is the process of transforming wastes into a more manageable, less toxic, or non-leachable form. It involves the use of cementitious or other binders to immobilize characteristic and listed metal constituents and radioactive contaminants. The leaching potential of the treated constituent is mitigated by isolating the contaminants from environmental influences through microencapsulation of the waste particles. (This differs from solidification, where material is added to a liquid or semi-liquid waste to produce a solid monolith.)

Support of these treatment processes will also require initial waste monitoring, waste sorting, size reduction where applicable, packaging and/or repackaging, final waste monitoring, and wastewater handling.

RCRA Part B Permitting: Receipt of a RCRA Part B Permit is required prior to the start of construction of the Treatment Building. A RCRA Part B permit application will be prepared for submittal to SCDHEC in late 1992.

Schedule: The technical baseline has been established and preliminary design work has been performed. The Treatment Building is currently scheduled to be operational in late 1996.

RCRA VAULT FINAL CLOSURE

Although interim closure methods varied between the Y-Area vaults and the HW/MW vaults because of basic design differences between the two facilities, the final closure plan will be the same.

Final closure will take place after the last vault is filled and capped. The area surrounding the vaults will be backfilled to the tops of the roofs. Over the top of the backfill and vaults, a three layered final cover will be constructed per the requirements of the South Carolina Hazardous Waste Management Regulations (SCHWMR) R.61-79.264.310(a). The three layers will be as follows:

1. The top layer will be at least 24 inches (60 cm) thick and will support a grass cover to minimize erosion. This layer will have a final slope of 3-5%.

2. The middle layer will consist of at least 12 inches (30 cm) of sand with a hydraulic conductivity of at least 1.0 x 10^{-3} cm/sec. This sand layer will be overlain with a geotextile fabric to prevent plugging. The bottom layer will have a slope of at least 2%.

3. The bottom layer will be a composite clay/synthetic liner. The clay will be at least 23 inches (58 cm) thick and have a hydraulic conductivity of not more than 1 x 10^{-7} cm/sec. The clay will have a minimum slope of 3%. On top of the clay layer, a 60 mil (1.54 mm) thick HDPE liner will be installed.

Prior to backfilling and installing the final cover, the leachate collection and detection riser pipes will be extended above the elevation of the final cover surface. The liquid level sensors will be modified accordingly. The riser pipes will be large enough in diameter to allow a pump to be lowered into the sump. A minimum of 30 years of post-closure care will be provided.

FEDERAL FACILITIES COMPLIANCE AGREEMENT

To assure DOE-SR compliance with RCRA regulations, DOE-SR and the EPA signed a Federal Facility Compliance Agreement (FFCA) in

March 1991. The FFCA pertains to RCRA LDR requirements for past, ongoing, and future generation, storage, treatment and/or disposal of all radioactive mixed waste at SRS. Solvent and California list mixed wastes are also addressed. Y-Area and the HW/MW Treatment Building are included among the SRS facilities whose development is being closely tracked in this agreement.

SUMMARY

The Savannah River Site's diversified operations produce a wide variety of hazardous and mixed waste streams. SRS is actively pursuing new technologies to treat and dispose of these wastes in a manner that is safe for human health and the environment. Compliance with RCRA regulations is a high priority. New waste treatment and disposal facilities like the M-Area Waste Disposal Facility (Y-Area) and the Hazardous Waste/Mixed Waste (HW/MW) Treatment Building and Disposal Vaults will provide treatment and permanent disposal for existing wastes currently in temporary storage, as well as waste that will be generated in the future, to assure a cleaner and safer environment.

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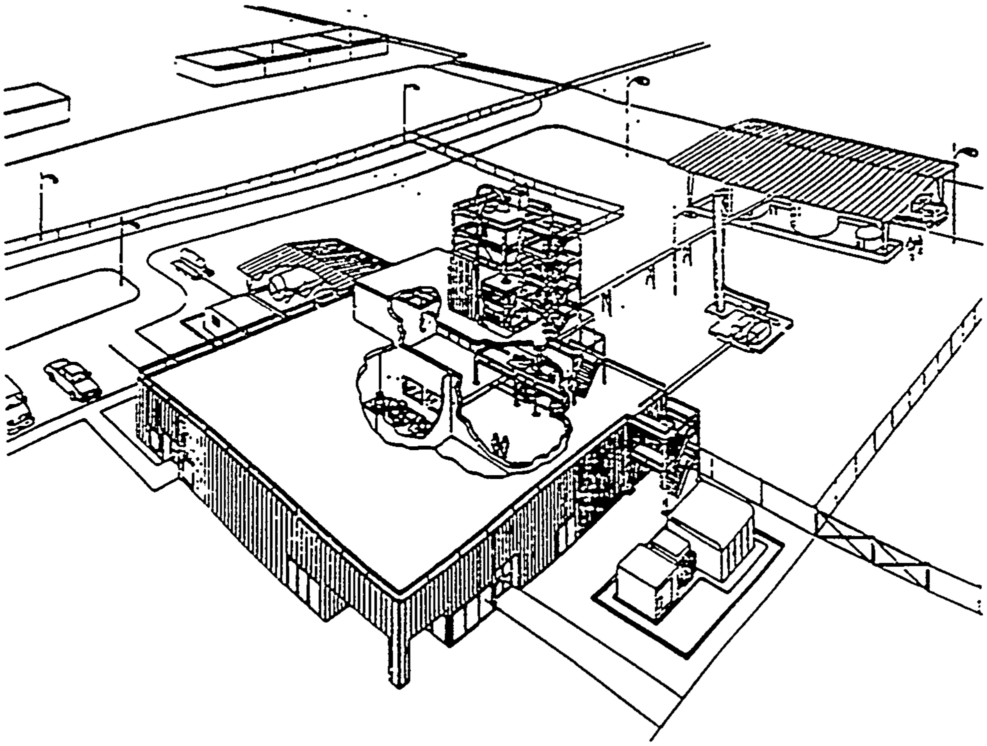

Figure 1: Y-Area Artist's Conception

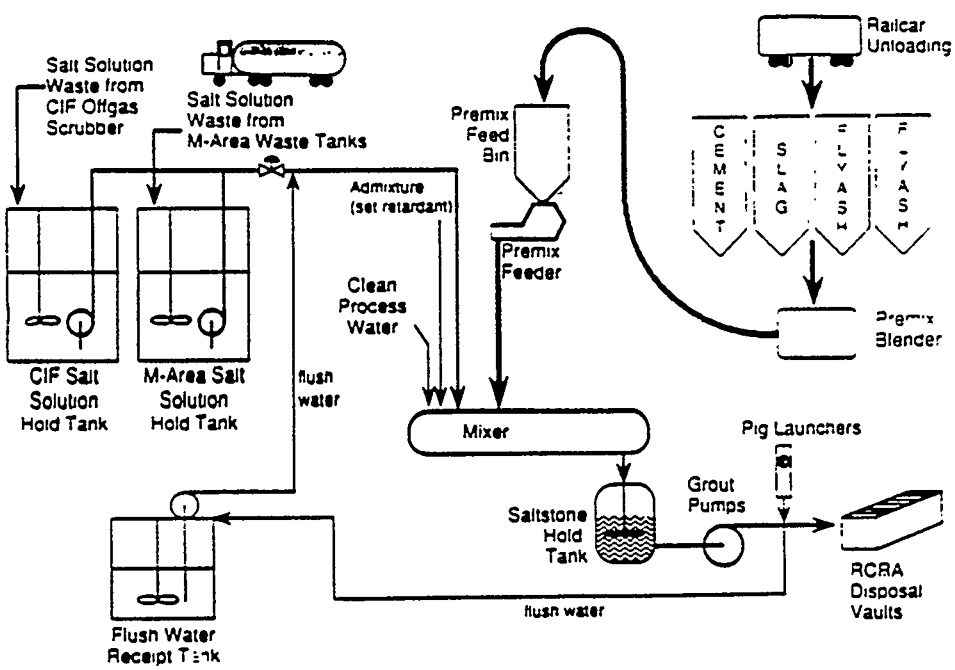

Figure 2: Y-Area Process Flow Diagram

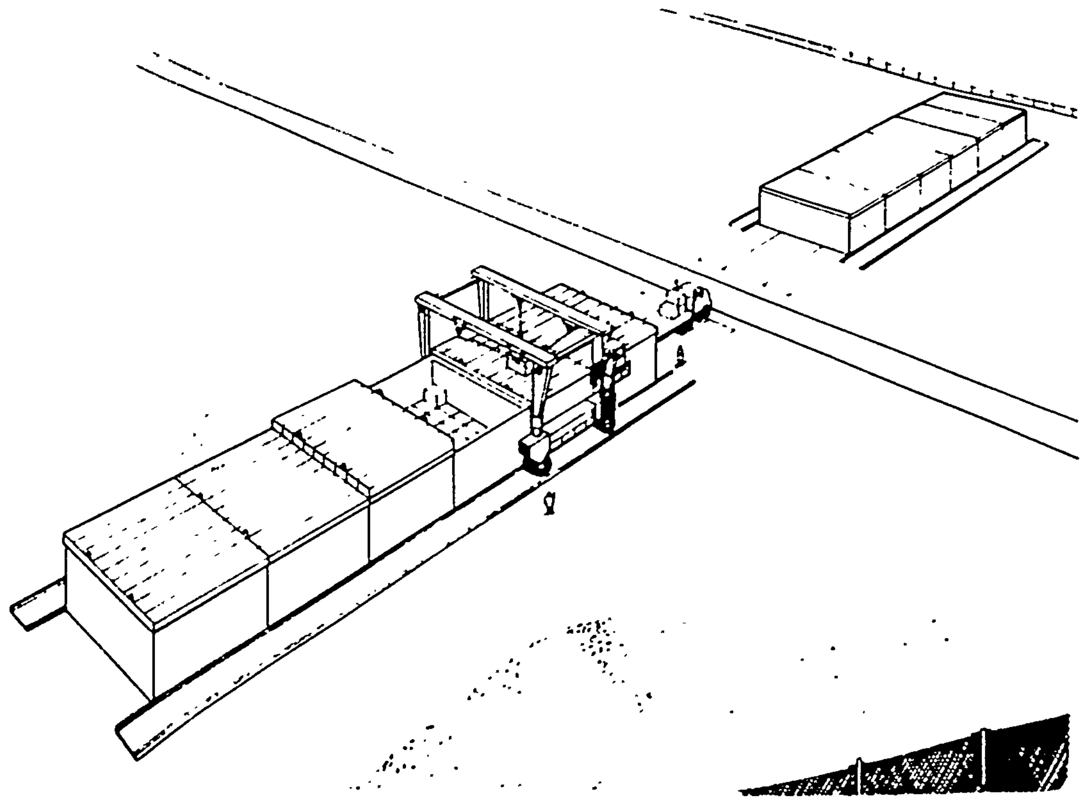

Figure 3: HW/MW Disposal Vault Artist's Conception

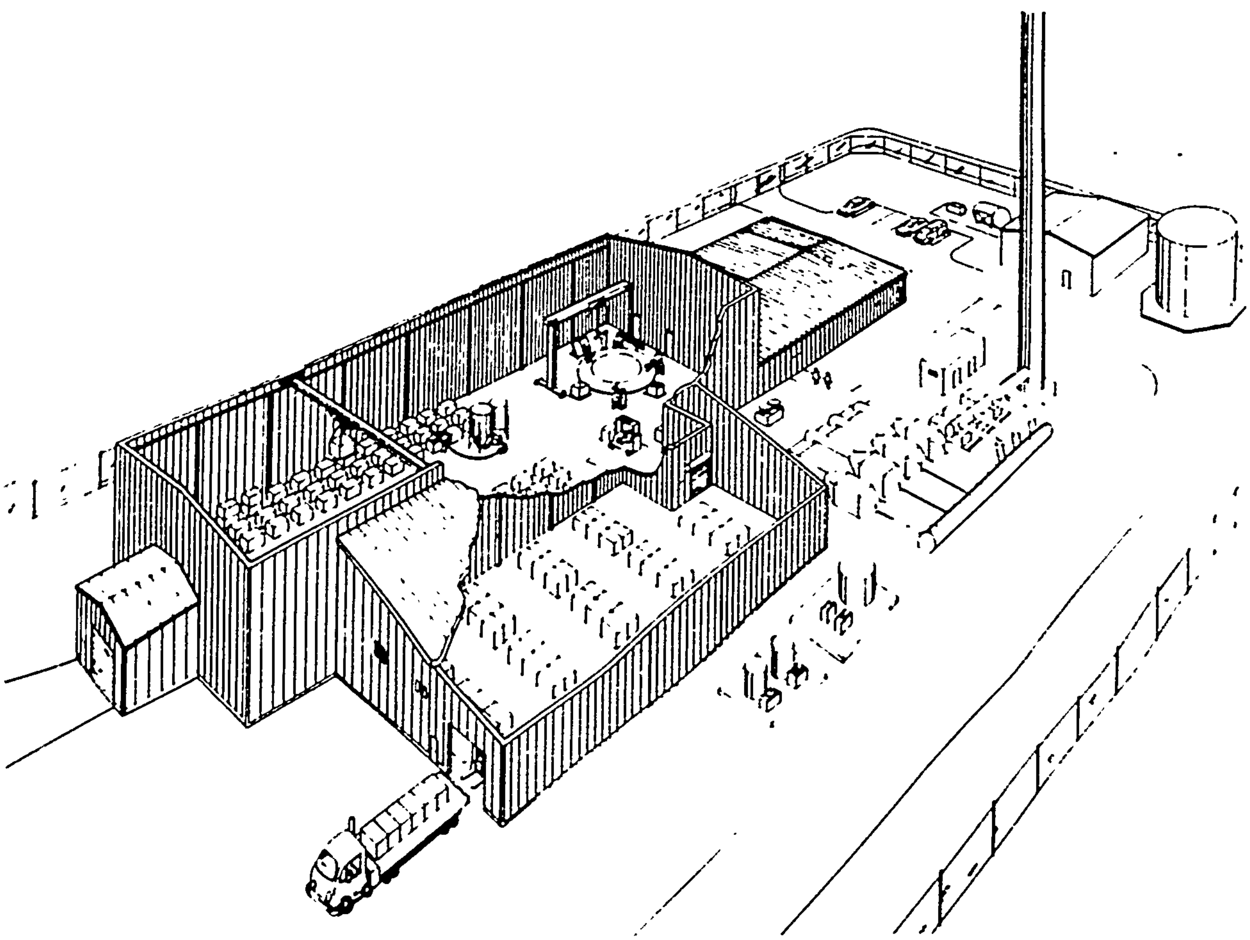

Figure 4: HW/MW Treatment Building Artist's Conception

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GREATER-THAN-CLASS C LOW-LEVEL WASTE

Storage for Greater-Than-Class C Low-Level Radioactive Waste[a]

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Abstract

EG&G Idaho, Inc., at the Idaho National Engineering Laboratory (INEL) is actively pursuing technical storage alternatives for greater-than-class c low-level radioactive waste (GTCC LLW) until a suitable licensed disposal facility is operating. A recently completed study projects that between 2200 and 6000 m^3 of GTCC LLW will be generated by the year 2035; the base case estimate is 3250 m^3. The current plan envisions a disposal facility available as early as the year 2010.

A long-term dedicated storage facility could be available in 1997. In the meantime, it is anticipated that a limited number of sealed sources that are no longer useful and have GTCC concentrations of radionuclides will require storage.

Arrangements are being made to provide this interim storage at an existing DOE waste management facility. All interim stored waste will subsequently be moved to the dedicated storage facility once it is operating. Negotiations are under way to establish a host site for interim storage, which may be operational, at the earliest, by the second quarter of 1993.

Two major activities toward developing a long-term dedicated storage facility are ongoing. (a) An engineering study, which explores costs for alternatives to provide environmentally safe storage and satisfy all regulations, is being prepared. Details of some of the findings of that study will be presented. (b) There is also an effort under way to seek the assistance of one or more private companies in providing dedicated storage. Alternatives and options will be discussed.

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Introduction

This paper was prepared under the auspices of the Greater-Than-Class C Low-Level Radioactive Waste Program for the Idaho Field Office of the Department of Energy, managed by EG&G Idaho, Inc.

The Greater-Than-Class C Low-Level Waste (GTCC LLW) Program was established in response to a responsibility Congress placed on the Department of Energy (DOE) by enacting Public Law 99-240.[1]

This paper discusses the problem of providing storage for GTCC LLW until a disposal option that satisfies the requirements of 10 CFR 61 is available and the waste has been removed from storage and placed in disposal. Until a long-term dedicated storage system is available, the DOE will arrange to accept GTCC LLW waste for interim storage on a case-by-case basis in order to avoid any negative impacts on the health and safety of the public or on the environment.

Centralized storage for GTCC LLW is still in the planning stages. Existing GTCC LLW must remain in storage at the generator's site. Although there is no apparent actual hazard under the current system, the concern is that, with time, safety incidents may arise. This concern is justified judging from previous experience with sealed sources (which could be classified as GTCC LLW). Past incidents of loss of control of sealed sources have resulted in serious injury and even death.[2]

This paper discusses: (a) the status of interim and long-term dedicated storage, (b) storage requirements, (c) possible locations and ownership of storage facilities, (d) waste acceptance criteria, and (e) the results of an engineering study that is still in draft form.

Only wastes that are being held under licenses issued by the Nuclear Regulatory Commission (NRC) or Agreement States are considered in this report.

Background

The wastes addressed in this report are specifically restricted to those generated by persons or organizations operating under NRC or Agreement State licenses that allow them to possess radioactive materials, and which are not otherwise excluded.

The Low-Level Waste Policy Act of 1982, as codified in 10 CFR 61, established waste Classes A, B, and C and defined applicable disposal options. GTCC LLW was defined by exception, but there was no responsible authority, nor were the specifics of how to dispose of it prescribed.

When the Low-Level Waste Policy Amendments Act of 1985 (Public Law 99-240) was passed, it clarified the issue of who was responsible for the disposal of GTCC LLW by assigning that responsibility to the DOE.

In a 1987 report to Congress,[3] DOE outlined its strategy for safely managing and disposing of such GTCC LLW. The strategy consists of three key tasks: interim storage on an emergency basis; long-term dedicated storage until a disposal option is available; and disposal of all the subject GTCC LLW.

Terminology

The description of the waste has been the subject of a prior presentation in this session, and in greater detail in a recent report.[4] The waste types are further subdivided into different categories, depending upon what type of information is being conveyed. In this paper we shall subdivide GTCC LLW into contact-handled (CH), remote-handled (RH), and sealed sources, as defined below. These categories are based upon handling considerations.

- Contact-Handled
  - Alpha wastes: Pu-239 or Am-241 from reactor operations, fuel fabrication, test, and inspection
  - Beta wastes: Some C-14 or an occasional reactor cleanup filter or resin with very limited amounts of hard gamma emitters
- Remote-Handled
  - Activated metals arising principally from the operation of nuclear power reactors
  - Filters and resins
- Sealed Sources
  - Sealed radioactive sources that have GTCC concentrations of radionuclides and have been declared waste.

The term "interim storage" refers to limited acceptance of GTCC LLW for storage by the DOE prior to the availability of dedicated storage. Acceptance will be restricted to sealed sources for which a potential safety or environmental hazard exists. All material in interim storage will be moved to dedicated storage as soon as dedicated storage is available.

The term "long-term dedicated storage" refers to a centralized storage facility developed and operated for the express purpose of safely storing GTCC LLW until disposal is available, which is generally assumed to be for at least 13 years. Figure 1 shows the interface between interim and dedicated storage, as well as disposal.

Currently, the DOE is seeking to site and develop several similar but distinct waste storage systems. These systems are presented here specifically to avoid confusion later on.

- Monitored retrievable storage (MRS) - The objective of this facility is to store high-level waste (HLW) or spent fuel destined for the first HLW deep geologic repository.

- Mixed LLW - The objective of this facility is to store NRC or Agreement State licensee generated Class A, B, or C wastes until an acceptable treatment or disposal option is available.

- RFP Mixed TRU - The objective of this facility is to store mixed transuranic (TRU) wastes generated at the Rocky Flats Plant until such time as the Waste Isolation Pilot Plant (WIPP) in New Mexico is able to receive it, or when an acceptable alternative TRU waste repository becomes available.

- GTCC LLW - The objective of this facility, as stated above is to store NRC or Agreement State licensee generated GTCC wastes until an acceptable treatment or disposal option is available.

System Requirements

Both interim and long-term storage must satisfy the following functional requirements: they must receive, inspect, store, monitor, retrieve, and transfer GTCC LLW as defined and regulated by 10 CFR 61. Any treatment required is independent of storage operations.

Some wastes will become available and require storage before a centralized facility can be prepared. These wastes are believed to be limited to several hundred sealed source wastes. Some of these wastes could require storage at almost any time.

Storage is required until a licensed disposal facility is available. Experience with both WIPP and the HLW repository indicates that a minimum of 20 years is required to open a disposal facility. Even if GTCC LLW were disposed of in a HLW repository, as suggested in 10 CFR 61.55, it would almost certainly be the second HLW repository, which may not be available until the year 2025. As can be judged from Figure 1, a reasonable design life for dedicated storage is 50 years. This provides a 25-year cushion for waste destined for the second HLW repository. This requirement is in conflict with the more optimistic GTCC LLW Program Strategic Plan to have a disposal option by the year 2010, but it is a good technical choice.

One of the major difficulties in planning for and developing long-term dedicated storage is the uncertainty over projected waste volumes, both in total and as a function of time. Volumes strongly depend upon packaging densities, concentration averaging, and future decisions such as who must ship to storage and when. Many of these uncertainties are discussed in Reference 4. Nevertheless, the storage facility is being planned for a total of 2300 m^3 of waste, 70% of which is remote-handled, 30% contact-handled, and 25,000 to 30,000 sealed sources that can be consolidated to a few cubic meters of storage. Interim storage will receive several hundred sources, which can, in theory, be consolidated to less than 1 cubic meter.

Ownership and Location

By definition, the waste arises from non-DOE operations, and is owned by utilities, universities, or private companies. Although DOE can and will accept waste if it presents a public health and safety hazard, and if no other options are available, a private concern could legally develop and provide for storage with no change to a law or regulation.

No location has yet been chosen for either interim or dedicated storage.

Interim Storage Plans and Status

The current strategy is for DOE to accept waste for interim storage and store it at an existing DOE storage facility. This will require the minimum capital development costs and rely on an existing support infrastructure. The early open-for-operation date is April 1993.

Only sealed sources will be accepted for storage, and the storage system will be site specific. If for some reason, such as political acceptability, a single site cannot be found, multiple DOE storage sites may be used.

An environmental assessment for this action has been drafted, but cannot be completed until a site has been selected and agreed to by both the affected DOE Field Office and the host State. Meanwhile, eligibility criteria (who may send sealed sources for storage and under what conditions), waste acceptance criteria, and a storage fee specification are being developed.

Dedicated Storage Plans and Status

The initial approach for dedicated storage is to seek an independent, privately owned storage system. If none can be found, DOE has other options such as fully subsidizing a private venture, contracting with a private company for storage, or developing a fully DOE-owned and operated storage facility.

The current strategy envisions a capability to receive all licensee-generated with an GTCC LLW with an open-for-operation date of October 1997. This date was the earliest date at which line-item-funded capital upgrades could be made to an existing DOE facility starting now. As a result of the recent request to review program direction, this date may slip at least a year.

It is hoped that an earlier availability could be achieved with private development. However, efforts to seek a private developer are still in the embryonic stage.

To provide technical support for the necessary decisions, studies are under way to develop waste acceptance criteria (WAC) for dedicated storage; also, a detailed engineering study has been drafted. The remainder of this paper discusses the contents of these two draft documents.

Proposed Waste Acceptance Criteria for Dedicated Storage

Because of the physical similarity of GTCC LLW with TRU waste, the WAC were patterned after WIPP WAC:

- No free liquids
- No combustible containers
- No pyrophorics or explosives
- Limits on respirable fines and particulates
- No corrosives
- CH containers < 200 mR/hr at surface)
- Standardized and detailed package identification, characterization, and certification

The major departures from the WIPP WAC are in the containers and packaging of the waste. Because of the limited waste volume to be received, it seems prudent to limit the number of acceptable containers. Furthermore, since a suggested disposal option is a HLW repository, it seems prudent to select container dimensions compatible with proposed HLW canisters. Based on these arguments, the following container types and sizes are proposed as the only acceptable containers.

Acceptable Waste Containers for Dedicated Storage

Waste Type	Container
Remote-handled	RH TRU waste containers in 7-, 10-, or 14-foot lengths
Contact-handled	30- or 55-gal drums
Sealed sources	Sealed sources to be consolidated in special steel casks

The WIPP project developed and qualified a 26-inch-diameter, 10-foot-long container,[5] Type A container for RH TRU waste. The container, shown in Figure 2, is handled in the vertical position, grappled by a pintle compatible with the pintle on the high-level vitrified waste containers currently planned for use at Savannah River, Hanford, and the West Valley vitrification facilities. The only significant change is a proposal to accept the container in 14-ft lengths, a length believed to be more compatible with reactor operations.

The material of construction for both the RH container and the CH drums is still being evaluated. If necessary a stainless steel will be specified over carbon steel in order to enhance corrosion resistance.

It is typical for a sealed source to be delivered integral with the device in which it is manufactured and used. Such devices, generally not contaminated, and definitely not GTCC, occupy hundreds of times the volume of the source itself. It is therefore proposed to dismantle all devices and consolidate the sources in an investment-cast steel cask, nominally the size of a 55-gal drum, with a minimum of 4 inches of steel between any source and the outer surface. The individual boreholes would be sealed by an upset welded plug. Figure 3 depicts a cutaway view of the storage cask. This cask will almost certainly be acceptable for direct disposal in any repository, potentially a near-surface disposal facility, and, alternatively, could easily be accessed to retrieve the sources for reuse, if otherwise deemed desirable.

Two other as yet unresolved waste acceptance criteria are a requirement for filtration, and allowable void volume. The alternatives under consideration are: carbon composite filter in every container, or filters accepted only under case-by-case exception; and limiting void volume to some number less than 20 volume percent.

Engineering Study

CH wastes have been in the past, and can be in the future, stored in simple buildings of almost any type. This study considers only metal buildings of the style being widely used at Hanford, and ammunition style bunkers. Ammunition bunkers were considered because of two interesting features. (a) they have been widely used throughout the world to successfully store extremely dangerous materials, and (b) recent realignment within the Department of Defense will make several thousand bunkers available for alternative usage within the next few years (Ref. 7).

The following storage systems were considered for RH wastes:

- Cask-on-a-pad (Figure 4)
- Underground vaults, one container per/vault
- Sub-floor vaults in a building (Figure 5)
- Pool storage (underwater)
- Cask within an ammunition style bunker (new or used) (Figure 6)
- Horizontal modular vault storage.

Figure 7 shows an RH container within a storage cask. The function of the cask is to provide secondary containment and radiation shielding. All of these storage alternatives have been used at one time or another, and not surprisingly, are quite similar to the alternatives being considered for the MRS.[6]

The following support facilities would be required regardless of which storage systems were used. In some cases, the support facility would be partially included in the storage system.

- Receiving bay with shielding and containment
- 100-ton crane
- Rail spur and highway access
- Decontamination facility
- Hot cell for sealed source consolidation
- Maintenance bay
- Onsite RH package transporter
- Office building and records storage
- Utilities.

Preliminary cost estimates for the storage casks, vaults, and/or storage buildings were prepared for each of the above storage concepts. Those cost estimates are shown below. However, these costs do not include the transfer facility (hot shop), onsite transporter, decontamination facility, and other support facilities.

Concept	(ft^3)	Cost (m^3) ($K)	Storage casks, pads, buildings ($ million)
Cask-on-a-pad	$460	16.0	30
Underground vaults	220	7.8	16
Sub-floor vaults in a building	887	31.0	54
Pool storage	200	7.1	15
Cask in a bunker - new	542	19.0	33
Cask in a bunker - used	440	15.5	29
Horizontal modular vault storage	332	12.0	23
CH metal building	65	2.3	

Total facility storage costs for 1610 m^3 RH and 690 m^3 CH waste ranges from $14 million (pool plus metal storage building for CH waste) to $54 million (indoor vaults plus metal storage building for CH waste). Completion of the facility is expected to double the cost. Annual operational costs may be assumed to be 5% of capital costs; 20 years of operation will therefore double the cost again. The total capital-plus-operational-cost range is therefore $56 to $200 million. Storage costs on a cubic meter basis for RH waste, using these values, range from $28,000 to $120,000.

Summary and Conclusions

An immediate need exists for storage for a small amount of GTCC LLW, perhaps several hundred sealed sources, which present an immediate public health or safety hazard. Although any one source could present an extreme emergency condition, the total storage volume is almost incidental. These sources will be accepted by DOE, beginning in 1993, with terms and conditions to be determined.

An added complicating factor is that storage may be costly, quite possibly exceeding the initial cost of the source, and yet there is no requirement that a possessor ship it to storage. This complication makes it particularly difficult to plan for waste receipts.

Long-term dedicated storage for any and all GTCC LLW will not be available before October 1997.

The opportunity exists now for an entrepreneur to develop a privately owned and operated dedicated storage facility. Such an entrepreneur would be welcomed by the DOE, but would also have to be innovative to develop a profit-making storage system.

The cost of long-term storage may seem particularly high. However, safe storage must be in a corrosion-free environment, it must be readily retrievable, and it must at all times must be stored to simplify inspection and monitoring. This necessarily brings the cost to a level well in excess of disposal costs. This is borne out by base storage costs, not including support facilities, to range from $65 a cubic foot for CH to $800 per cubic foot for RH, quite consistent with current disposal costs, which average somewhere around $350 per cubic foot.

The fact that it is as costly to store waste for 10 to 20 years as it is to dispose of it is an added incentive to accelerate development of disposal options.

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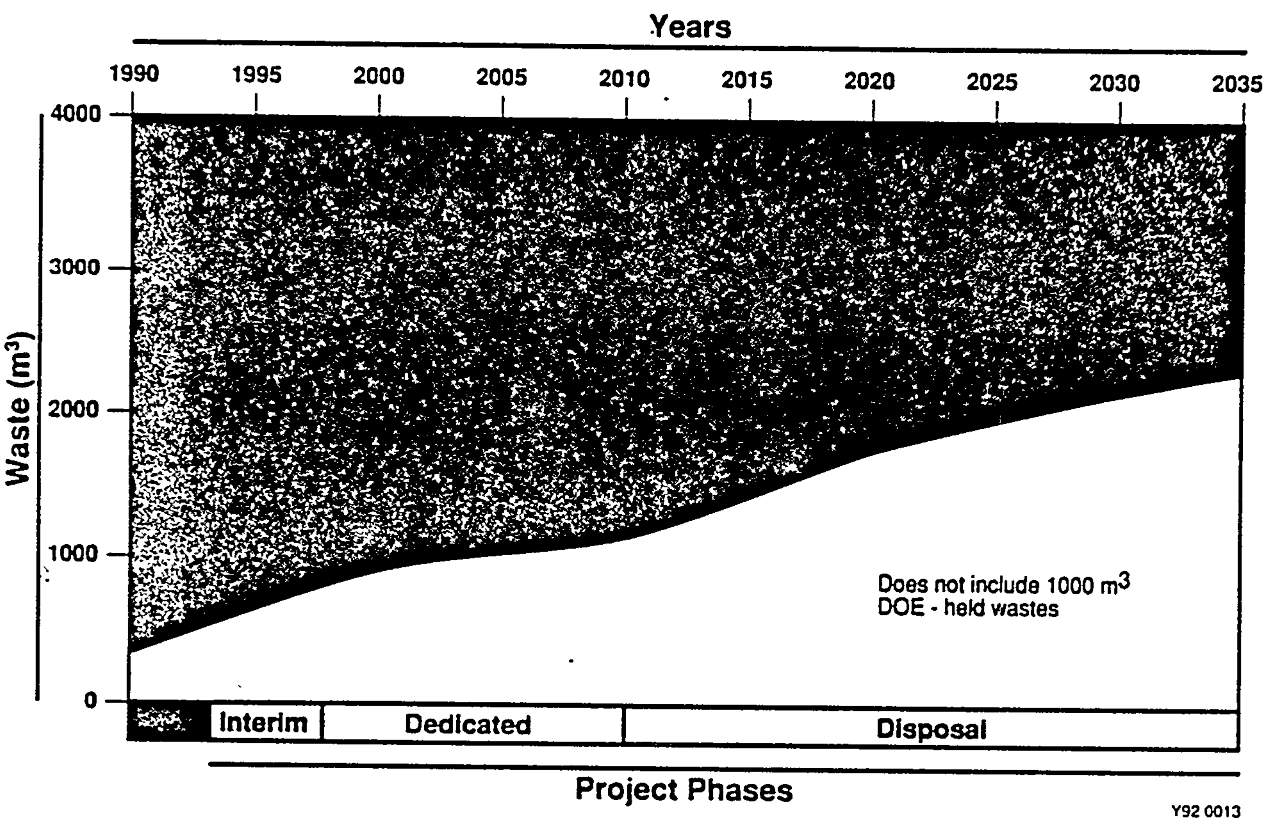

Figure 1. Interface between interim and dedicated storage and permanent disposal.

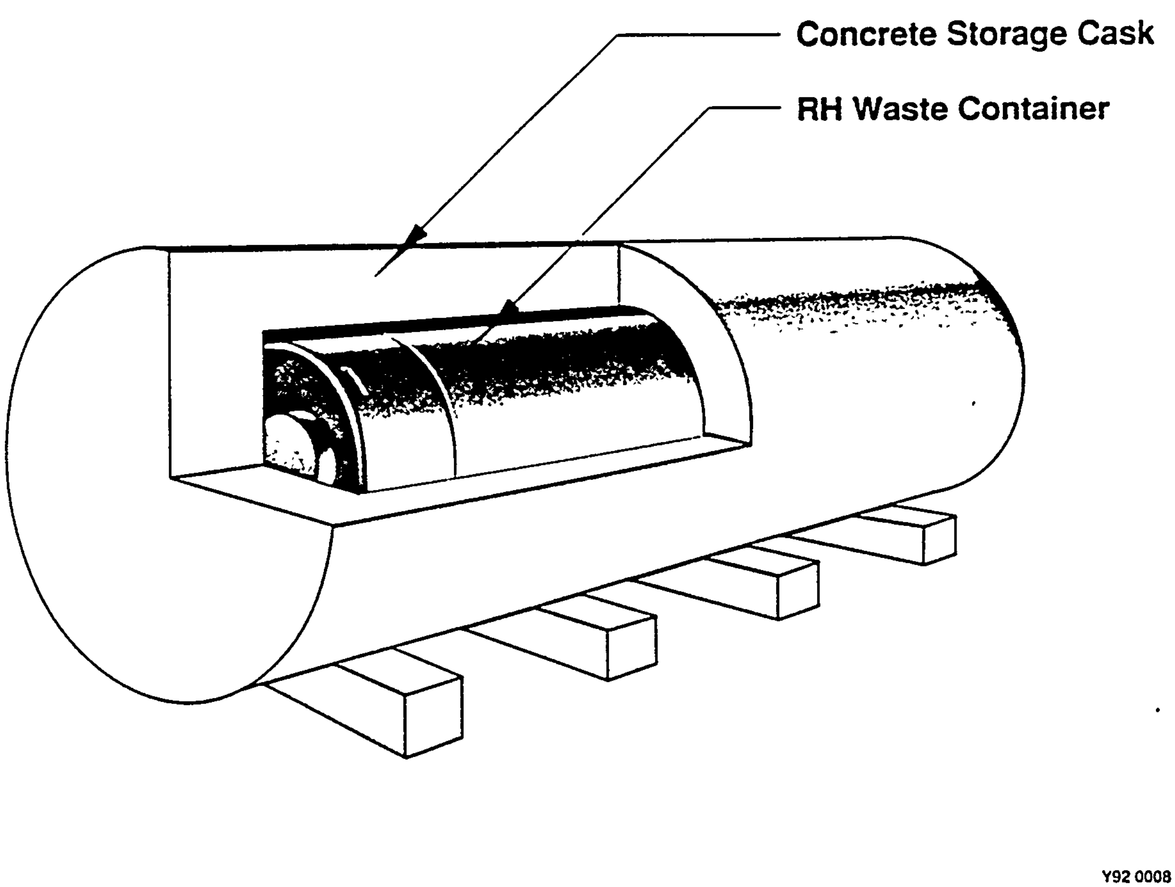

Figure 2. Type A container for RH TRU waste.

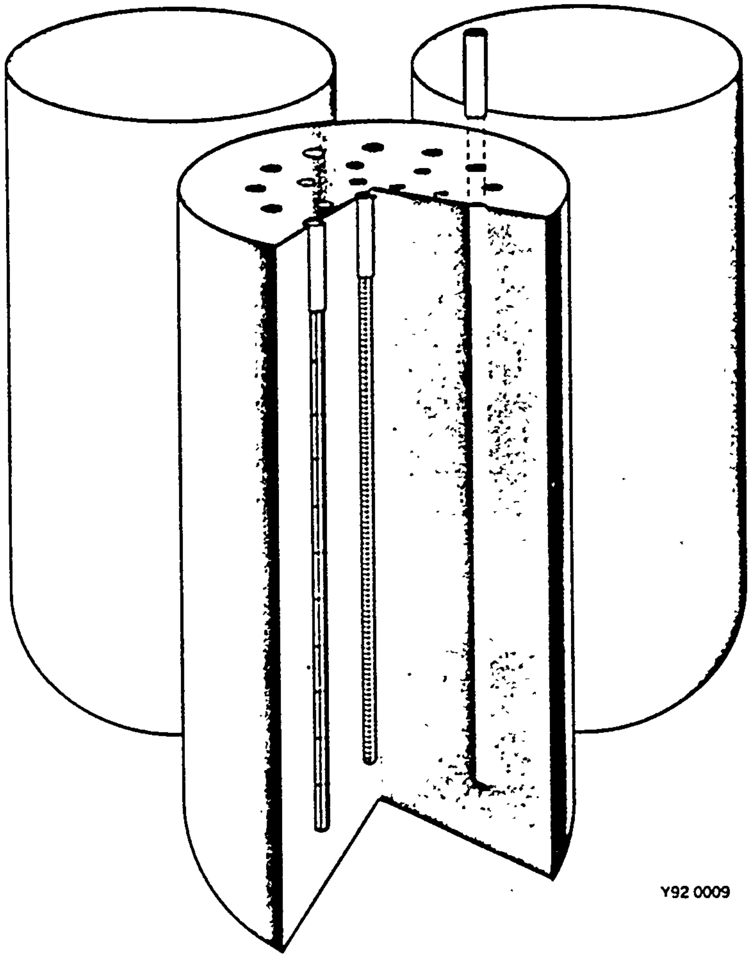

Figure 3. Cutaway view of the storage and disposal cask for sealed source wastes.

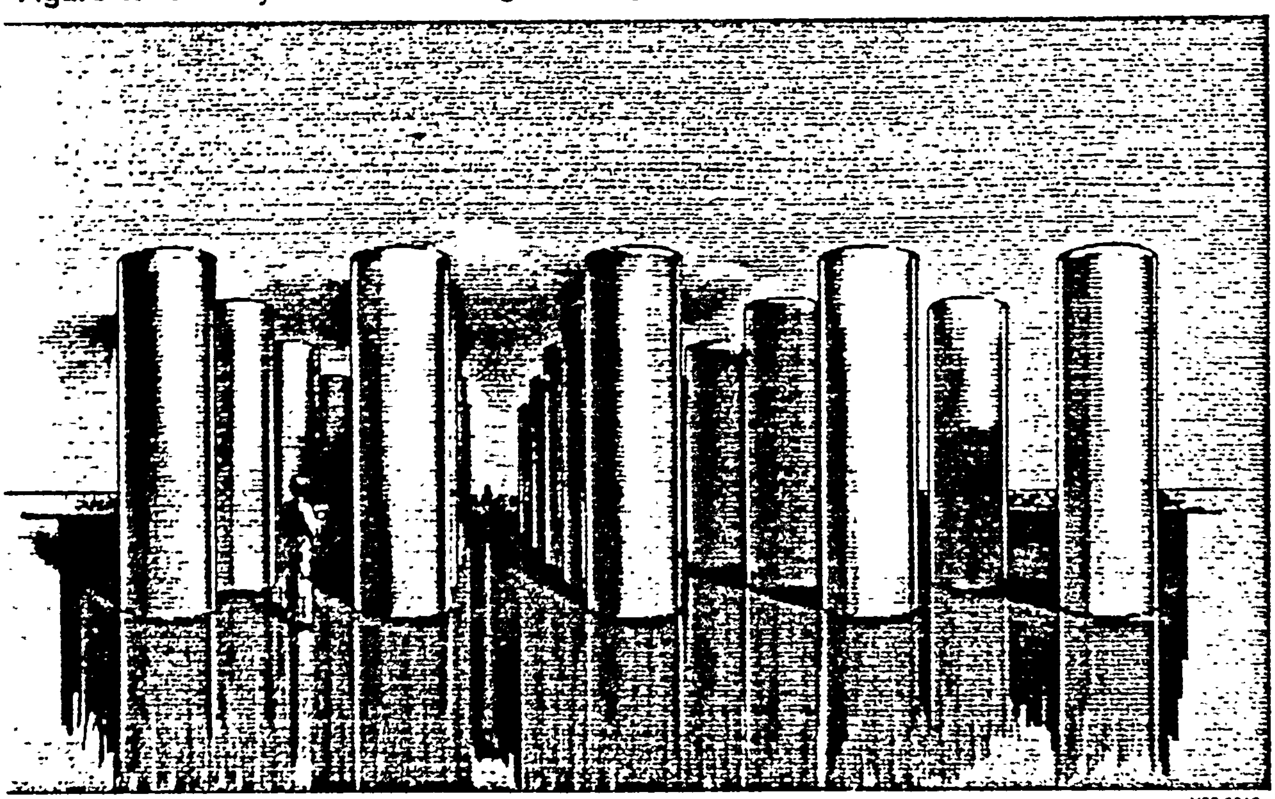

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Figure 4. Cask on a pad.

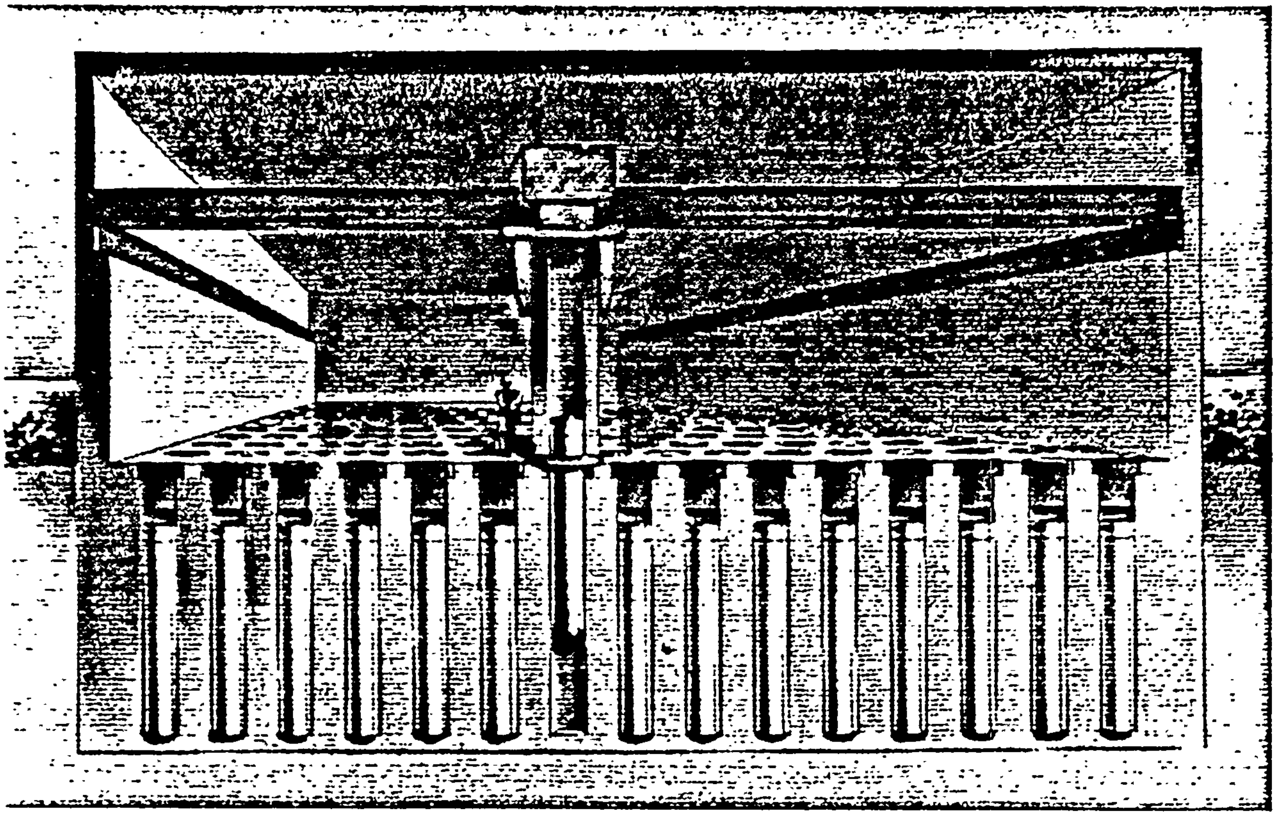

Figure 5. Subfloor vaults in a building.

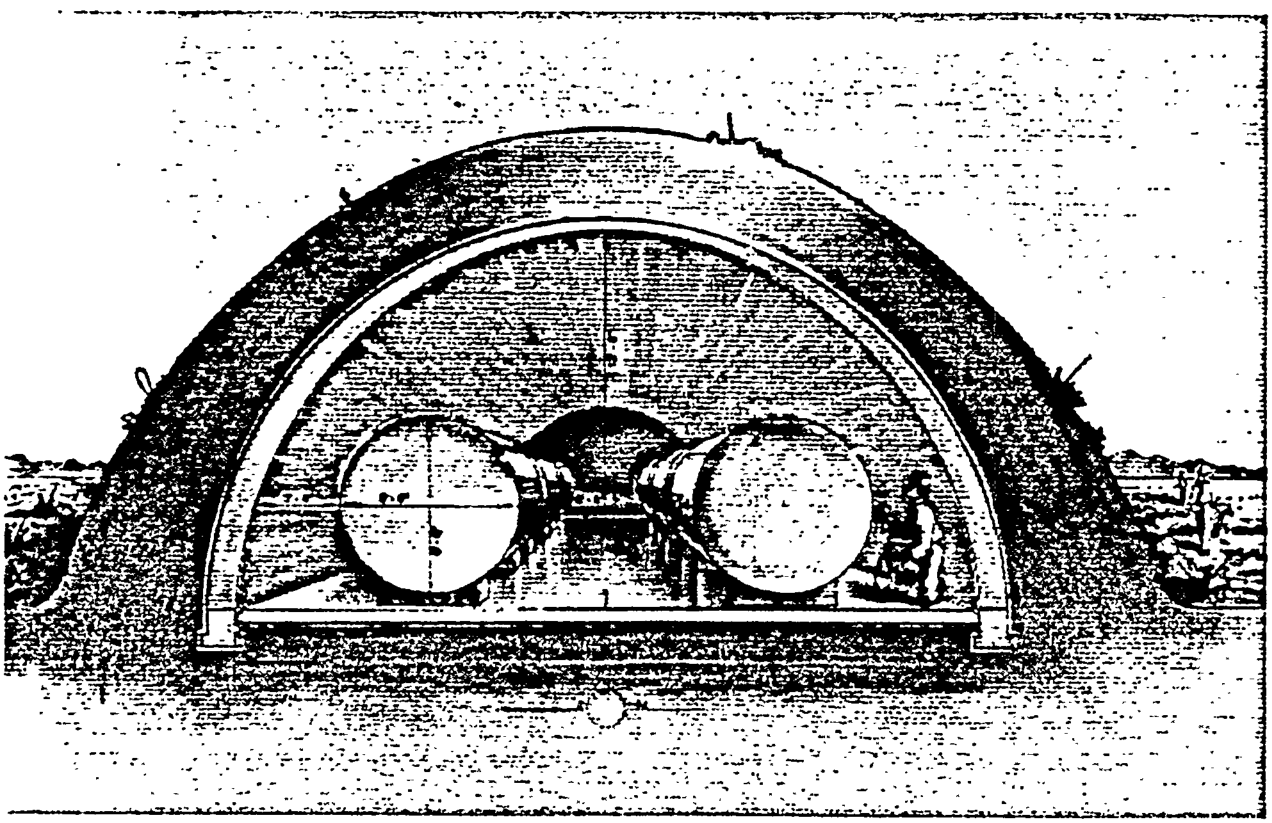

Figure 6. Cask within an ammunition style bunker.

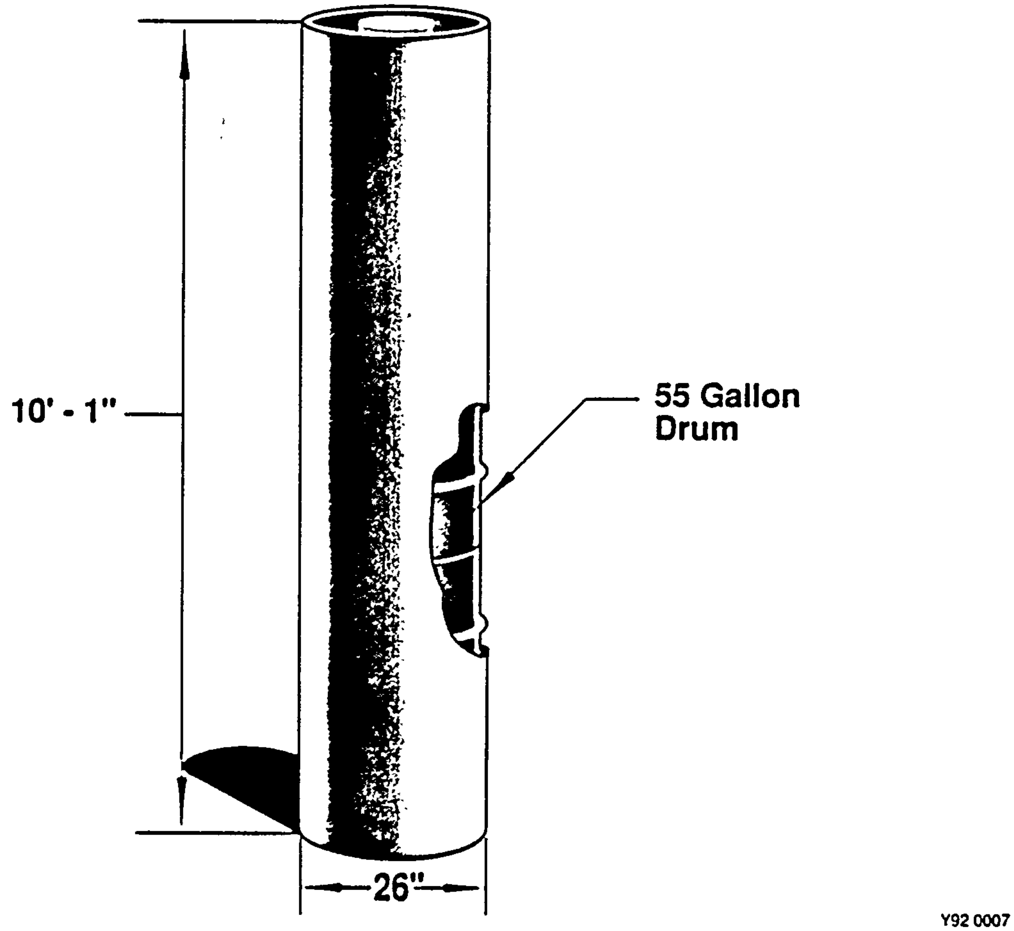

Figure 7. RH container within a storage cask.

GREATER-THAN-CLASS C LOW-LEVEL WASTE CHARACTERIZATION[a]

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ABSTRACT

In 1985, Public Law 99-240 (Low-Level Radioactive Waste Policy Amendments Act of 1985) made the Department of Energy (DOE) responsible for the disposal of greater-than-Class C low-level radioactive waste (GTCC LLW). DOE strategies for storage and disposal of GTCC LLW required characterization of volumes, radionuclide activities, and waste forms. Data from existing literature, disposal records, and original research were used to estimate characteristics, project volumes, and determine radionuclide activities to the years 2035 and 2055. Twenty-year life extensions for 70% of the operating nuclear reactors were assumed to calculate the GTCC LLW available in 2055.

The following categories of GTCC LLW were addressed:

- Nuclear Utilities Waste
- Potential Sealed Sources GTCC LLW
- DOE-Held Potential GTCC LLW
- Other Generator Waste

It was determined that the largest volume of these wastes, approximately 57%, is generated by nuclear utilities. The Other Generator Waste category contributes approximately 10% of the total GTCC LLW volume projected to the year 2035. DOE-Held Potential GTCC LLW accounts for nearly 33% of all waste projected to the year 2035. Potential Sealed Sources GTCC LLW is less than 0.2% of the total projected volume. The base case total projected volume of GTCC LLW for all categories was 3,250 cubic meters. This was substantially less than previous estimates.

GTCC LLW DEFINITION AND REGULATORY HISTORY

In 1983, 10 CFR Part 61 codified disposal requirements for three classes of low-level radioactive waste considered generally suitable for near-surface disposal: A, B, and C, with Class C waste requiring the most rigorous disposal specifications. Waste with concentrations above Class C limits for certain short- and long-lived radionuclides, as defined in Tables 2-1 and 2-2 of 10 CFR Part 61, was identified as greater-than-Class C low-level radioactive waste (GTCC LLW). GTCC LLW was

a. Work sponsored by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, under DOE Idaho Field Office, Contract No. DE-AC07-76ID01570.

recognized as being generally not suitable for near-surface disposal. In 1983, 10 CFR Part 61 defined the categories of LLW, but it did not relieve the states of their statutory requirement to dispose of such waste.

In 1985, Public Law 99-240 (National Low-Level Waste Policy Amendments Act of 1985) corrected the situation by assigning the states responsibility for disposal of Classes A, B, and C radioactive low-level waste and by making the Federal Government (Department of Energy) responsible for the disposal of GTCC LLW.

In order for the Department of Energy (DOE) to carry out its responsibilities under this act, characterization of GTCC LLW was a necessary first step. The characterization effort, reported in this paper, supplied necessary information to support the decisions that must be made for storage and disposal of GTCC LLW by the DOE.

PRIOR GTCC LLW ESTIMATES

Information gained in the 1986 Energy Information Administration (EIA) survey[1] was initially planned for use in the waste characterization report. 1250 potential GTCC LLW generators were surveyed. The survey form requested information about GTCC LLW generators, waste-generating activities, current waste inventories, future waste generation (including decommissioning waste), and capabilities of storing the waste.

Analysis of data in this survey revealed incomplete results, and in several cases, inconsistent trends in the data reported by specific generators. Inconsistencies in this data may be attributed to one or all of several factors.

- Generators were not familiar with GTCC LLW definitions
- Some generators failed to devote the time or effort necessary to accurately complete the survey
- Some generators lacked detailed information to characterize waste on hand
- Generators have operating procedures that can vary with time

After evaluating these inconsistencies, it was felt that more accurate data could be obtained, and the 1986 survey was augmented with additional research and new data.

Two additional documents were evaluated for use in this report. Those documents were NUREG/CR-0130[2] and NUREG/CR-O672.[3] The documents were reviewed for data on volumes, activities, and radionuclide concentrations of nuclear utility decommissioning waste. The volume and activity data in these reports are estimated from projections made on a limited number of nuclear reactors.

Research into volumes and radionuclide concentrations of nuclear utility decommissioning waste suggested that the NUREG estimates were greater than observed data from operating commercial nuclear reactors. Packaged waste volumes reported in these documents use very conservative packaging factors, allowing for large void volumes inside the disposal liner and incorporating less waste volume per disposal liner than were used in this study.

Again it was felt that more accurate information could be developed than was available in the NUREG documents. Actual experience with actual waste components was emphasized as the basis of information for this study.

GTCC LLW CHARACTERIZATION REPORT, DOE/LLW-114

The remainder of this paper addresses the details of the current GTCC LLW report titled: *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated volumes, Radionuclide Activities, and Other Characteristics*, DOE/LLW-114, August 1991.

GTCC LLW Generator Types

GTCC LLW was categorized into four main generator types. These major types are shown on Figure 1 and include Potential Sealed Source GTCC LLW, DOE-Held Potential GTCC LLW, Other Generator Waste, and Nuclear Utility Wastes.

Potential Sealed Source GTCC LLW consists of small capsules, usually stainless steel, that encapsulate relatively high concentrations of a single nuclide. Sealed sources are used in a wide range of applications, including industrial and medical, and become waste when they are no longer usable. Two distinct groups of these sources have been identified in this study: (a) those containing TRU radionuclides and (b) those containing other radionuclides. Typical uses of each category are shown in Figure 1. The primary source of information for this category of waste was a 1989 Nuclear Regulatory Commission (NRC) survey of NRC and Agreement State licensees.[4]

DOE-Held Potential GTCC LLW is waste that was accepted by DOE from NRC and Agreement State licensees through contractual arrangements or because of immediate health or safety concerns. This waste is stored by DOE until a disposal facility becomes operational. It is unclear whether all currently inventoried waste in this category will require disposal in a NRC-licensed facility. In some situations, such as receipt of waste for research and development activities, waste may be disposed of at a DOE facility. Listed on Figure 1 are the DOE facilities that currently store, or plan to store, DOE-Held GTCC LLW.

Other Generator Waste is the name given in this study to waste generated by miscellaneous sources that do not fall in the other three categories. Information on this category was taken from the EIA survey with follow up telephone conversations to verified and amend data. Specific generators that fall in this category are listed in Figure 1.

Nuclear Utility Wastes constitute the majority of GTCC LLW and for this reason was further subdivided into the categories listed on Figure 2. Operations Waste and Decommissioning Waste were considered separately because they constituted inherently different waste forms and quantities. Operations Waste was further broken down into Activated Metals, Process Waste, and Dry Contaminated Solids. Examples of the types of waste streams that are included in these subcategories for pressurized water reactor (PWR) and boiling water reactor (BWR) facilities are included in Figure 2. The primary source of data for Operations Waste comes from actual characterization data used in prepackaging analysis of commercial nuclear power reactor-generated LLW. Decommissioning Waste is comprised primarily of activated metal components. Expected activated metal components for PWR and BWR facilities are listed in Figure 2. Material volumes for Decommissioning Waste components were taken from engineering drawings, and radionuclide concentrations were calculated using ANISN[5] and ORIGEN2;[6] model results were normalized using surveillance capsule data.

Volume and Activity Models

A computer model was developed that took input data and predicted volumes for a number of different scenarios. This process is depicted in Figure 3 and shows typical input data that were processed by the computer model into an array of nine possible volumes. The scenario array is composed two sets of assumptions: Unpackaged, Packaged, and Concentration Averaged volumes in columns across the top and High, Base, and Low volumes in rows down the side.

Unpackaged, Packaged, and Concentration Averaged volumes follow the typical sequence of events that occur when a waste component is handled and disposed. Unpackaged volume is the volume of GTCC LLW when first generated. Packaged volume considers any change in volume due to waste processing and the placement in a waste container. Concentration averaging is the practice of placing similar LLW materials together in a container and averaging the radionuclide concentrations of those materials. For example, when GTCC LLW activated metals are combined with Class C activated metals, the resulting packaged waste may meet Class C standards. This practice can reduce the volume of packaged GTCC LLW.

High, Base, and Low volumes address factors, other than packaging, that affect the volume of the waste. The Base case scenario considers the most realistic data available and reflects current operating, decommissioning, and disposal practices for potential GTCC LLW. The High and Low cases account for upper and lower limits of the Base case data. An example of how this works can be seen by examining the High, Base, and Low case for nuclear utility cartridge filters. The Base case for cartridge filters considers no volume reduction and random placement in waste containers. This is the current practice used by the nuclear utilities to handle these waste components. The High volume case considers encapsulation of the filters in a cementation process. This process results in a doubling of the volume. The Low volume case assumes that the filters are shredded and encapsulated. Figure 4 shows schematically how filter volumes would change for the High, Base, and Low case.

Radionuclide activity of waste steams are added to the model and accumulated annually. Radioactive decay is incorporated into the model.

Volume and radionuclide activity of the generator's current inventory and future generation rates were projected to the year 2035. This year represents the point in time when current nuclear power plant life times have expired. Waste generation was also projected to the year 2055 under the assumption that 70% of the operating nuclear reactors would get a 20-year life extension.

GTCC LLW Projections

Results of volume projections through the year 2035 are shown on Figure 5. It is seen that Nuclear Utility Wastes, composed of both operations and decommissioning waste, makes up the largest projected volume (approximately 57%) of GTCC LLW. This is followed by DOE-Held Potential GTCC LLW (33%), Other Generator Waste (10%), and Potential Sealed Source GTCC LLW (0.2%).

Results of radionuclide activity projections are shown in Figure 6. Trends in projected activity closely follow the trends in projected volume with the exception of Potential Sealed Source GTCC LLW. Due to this waste's high specific activity, the total activity that it represents is much larger than its relative volume.

Total projected base case GTCC LLW volume for all waste categories is 3.25E+03 m^3. This is substantially less than previously projected volumes[7] that were as high as 1.70E+04 m^3. The projected total activity for all waste categories is 6.58E+07 Ci.

Uncertainties with GTCC LLW Projections

A number of assumptions were made during the development of the report and uncertainties remain with some of the assumptions upon which the GTCC LLW projections were based. Major uncertainties, which may cause the projected volumes and activities to increase or decrease, are briefly discussed below.

Interpretations of the Standard Contract (10 CFR 961) may result in larger or smaller quantities of GTCC LLW. Terms defined in Appendix E of this CFR have been and continue to be points of much discussion and interpretation. If the final definition of "Nonfuel Components" covers a wide range of in-core components, then the quantity of GTCC LLW may decrease. If the definition is very narrow, GTCC LLW volumes may increase.

The degree to which concentration averaging is allowed in LLW disposal sites will affect the quantities of GTCC LLW. Each regional compact and unaffiliated state may establish different rules governing concentration averaging. This adds a large uncertainty factor to the final GTCC LLW that will be generated.

Current measurement and analysis methods, used to calculate metal activation inside decommissioned reactor vessels, are not accurate enough to firmly predict whether or not decommissioning waste will be GTCC LLW. Decommissioning components such a core barrels represent large volumes of potential waste that may or may not be GTCC LLW.

Some DOE-Held Potential GTCC LLW has been placed on the GTCC LLW inventory without a rigorous legal determination of their waste classification. Some of this waste may not qualify as commercially owned waste and could be removed from the inventory.

CONCLUSIONS

Volumes and radionuclide activities that are presented in DOE/LLW-114 represent a major step toward improved understanding of existing and projected GTCC LLW. In order to increase the accuracy in predicting GTCC LLW, this study emphasized the use of actual data from actual waste streams. This emphasis gives these GTCC LLW projections, particularly in the area of Nuclear Utility Wastes, a much stronger basis than the previous estimates.

Based on the analysis of GTCC LLW in this study, the projected volume of GTCC LLW is much lower than previously estimated. This lower value will form the basis upon which decisions on storage and disposal of GTCC LLW will be based.

Uncertainties still exist with the projections of GTCC LLW. Work is planned in the upcoming year to refine estimates in the area of DOE-Held Potential GTCC LLW and activation analysis of decommissioning components. Developments in the interpretation of the Standard Contract and concentration averaging will also be followed and changes that occur in these areas will be incorporated into the estimates of GTCC LLW.

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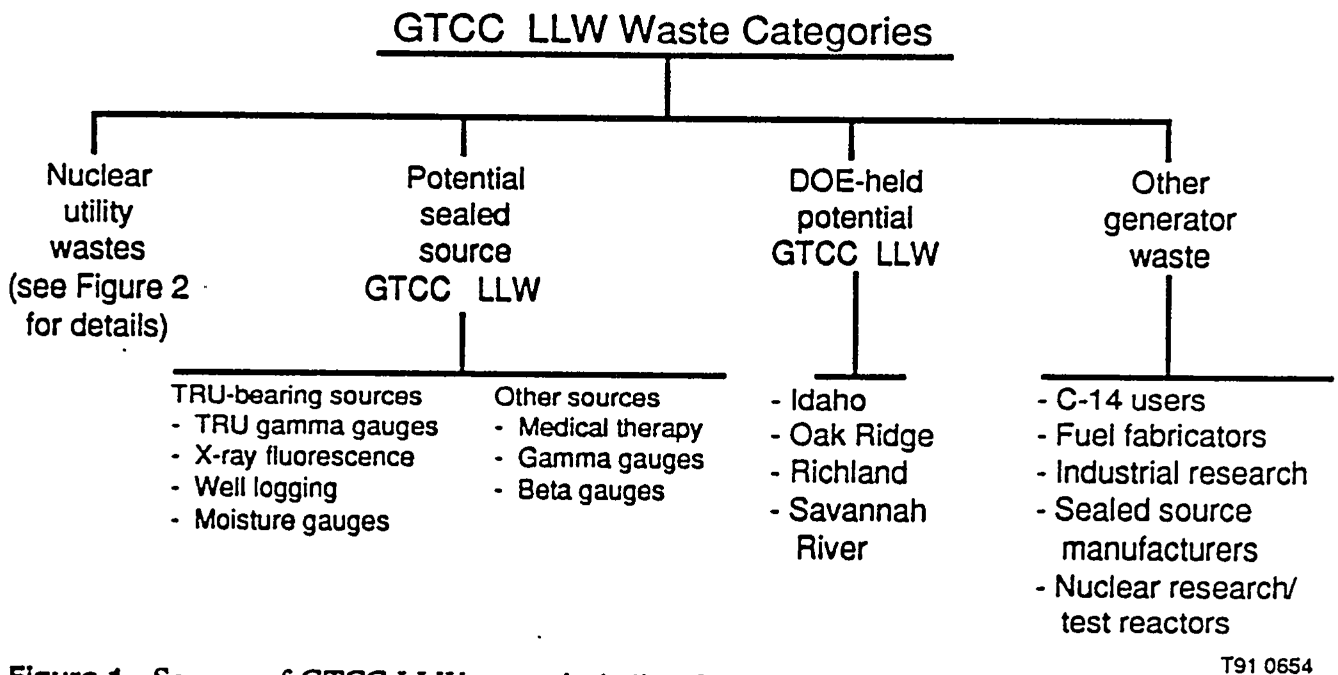

Figure 1. Sources of GTCC LLW waste, including Other Generator Waste.

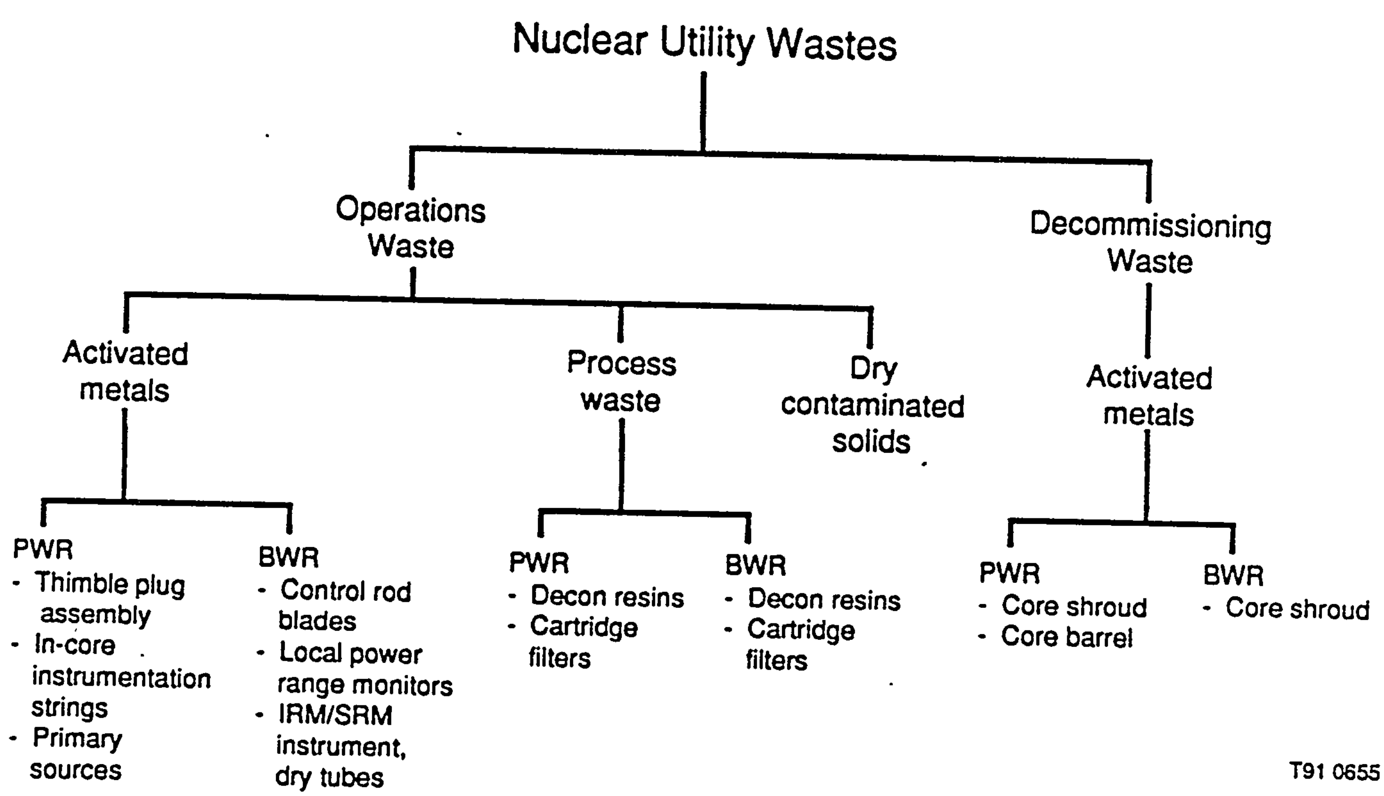

Figure 2. Nuclear utility waste streams.

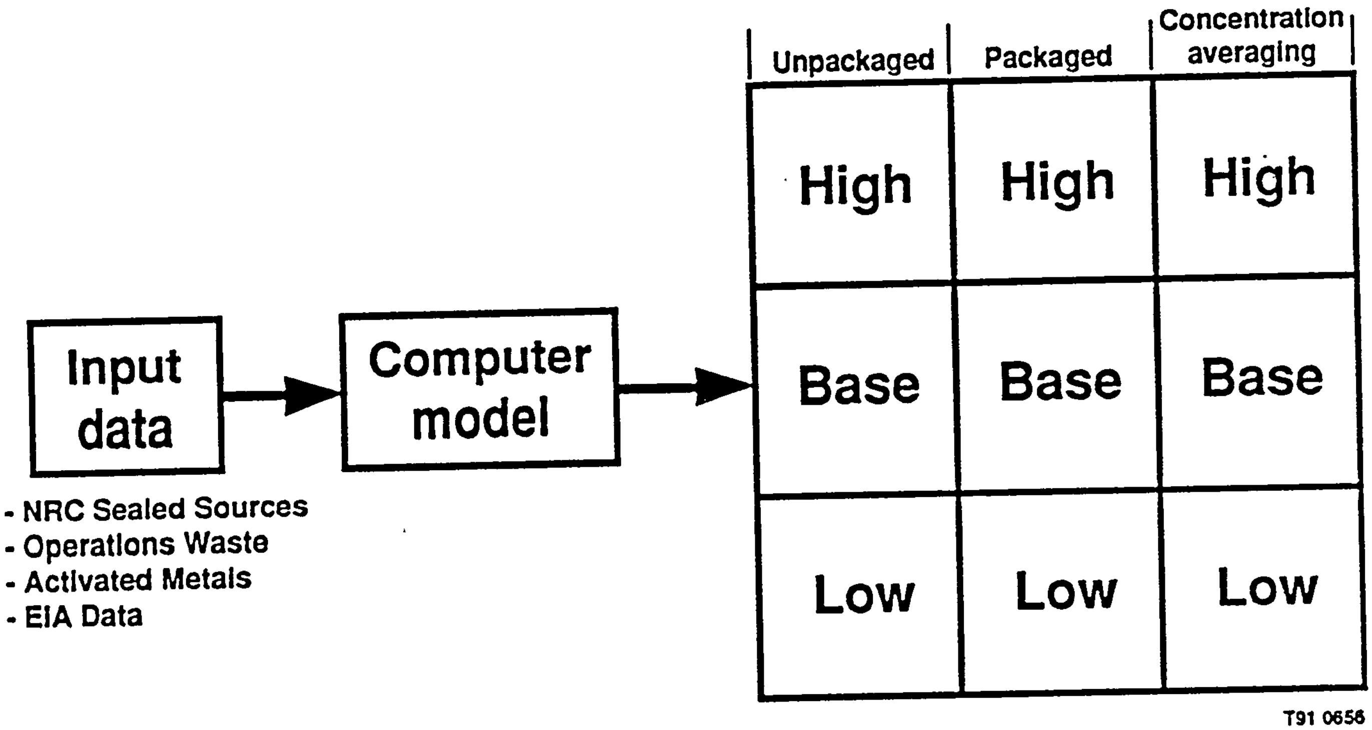

Figure 3. Input data used to generate high, base, and low cases for GTCC LLW.

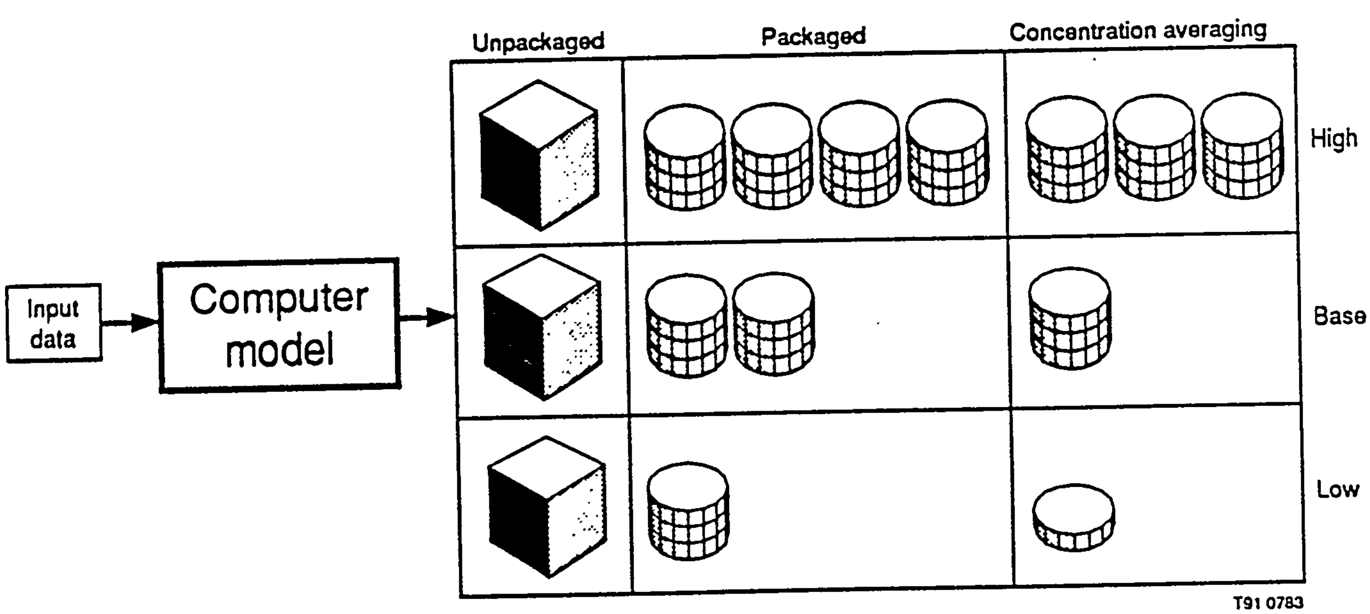

Figure 4. Predicted volumes for unpackaged, packaged, and concentration averaged GTCC LLW.

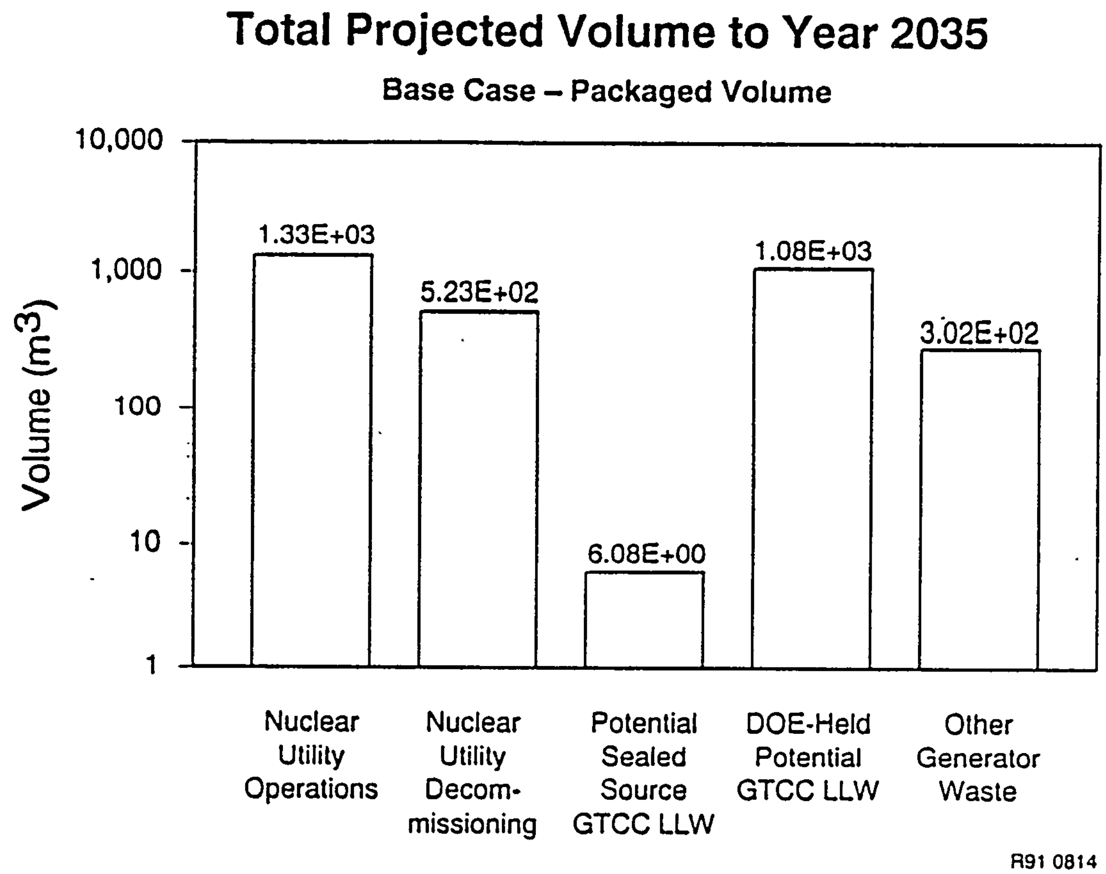

Figure 5. Total projected volume of GTCC LLW to the year 2035.

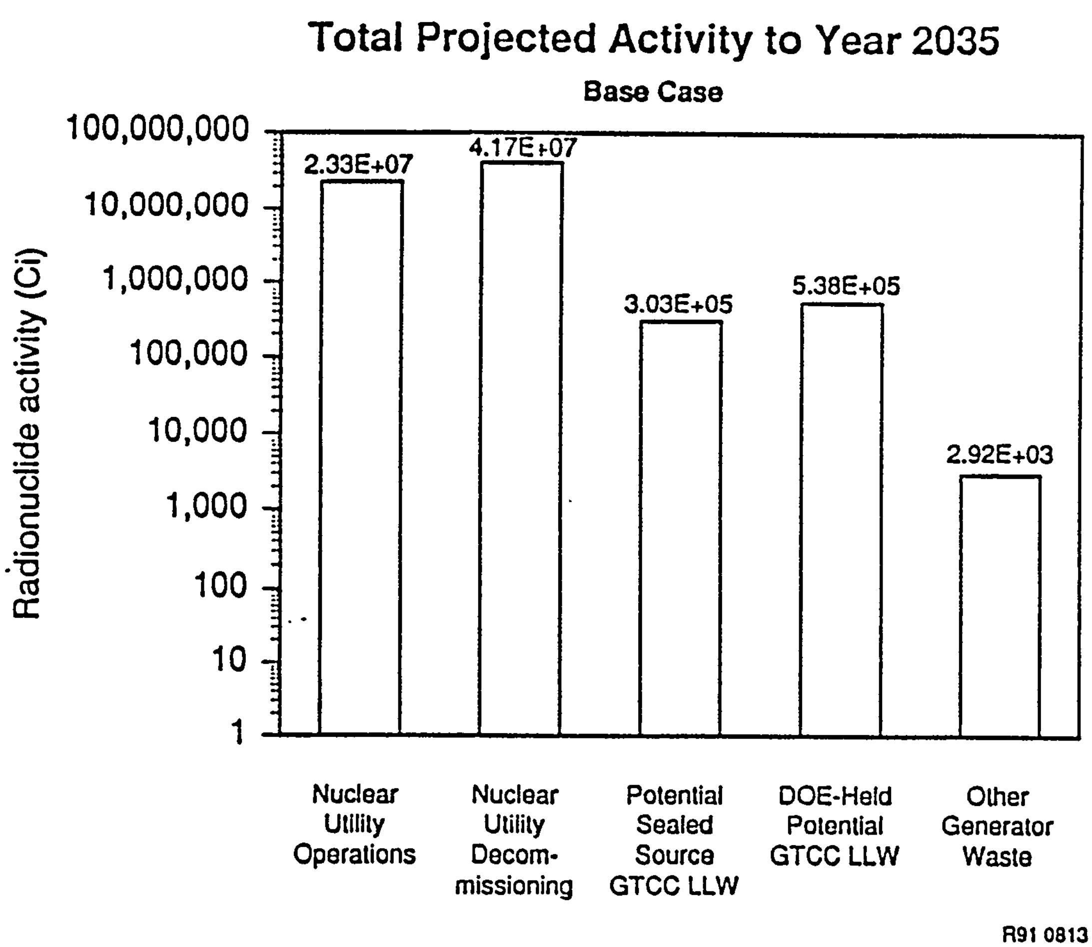

Figure 6. Total projected activity of GTCC LLW to the year 2035.

PUBLIC ACCEPTANCE CONSIDERATIONS

A NEIGHBOR'S PERSPECTIVE ON A PROPOSED LOW-LEVEL WASTE FACILITY

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ABSTRACT

The intent of the Low-Level Radioactive Waste Policy Act was for regional compacts to take responsibility for providing safe disposal of commercial low-level waste generated within its borders with an implication that their proposed facilities would not unnecessarily burdened neighboring states. It appears that some compacts have selected or are considering sites at the extremities of their borders because of public reluctance towards the acceptance of LLW facilities. Such is the case with the Central Interstate Compact which selected a site in Nebraska within 5 miles of the South Dakota border. Because this proposed LLW facility has generated much anxiety among the nearby South Dakota residents, the State of South Dakota funded a contract with an engineering consulting firm, RE/SPEC Inc., to perform independent investigations of this facility. These investigations included parallel calculations of credible groundwater and airborne release scenarios, assessment of potential impact to wetlands, and the review of the license application. Additionally, this independent investigation was considered necessary because of concern that Nebraska, which is an Agreement State, may have difficulty in separating developmental responsibilities from regulatory authority.

The partially saturated portion of the groundwater pathway was evaluated with a finite difference program, TRACRN, whereas the horizontal pathway was evaluated with a simple analytical model. Results indicate the hydrogeologic characteristics surrounding the proposed site provide relatively fast transport of released radionuclides, thereby placing substantial reliance on engineered barriers to protect the environment for hundreds of years. The airborne transport analyses were conducted with the Clean Air Assessment Package (CAP-88) which is an updated version of the popular program AIRDOS-EPA. This analyses considered a shipping and/or handling accident/incident at the proposed LLW facility. Results for the release scenario considered indicate that the location of the individual at maximum risk is approximately 0.3 miles north-northwest of the proposed site. Although this direction is toward the South Dakota border it is unlikely that South Dakota residents will receive a dose from an airborne release at the site greater than the performance objectives established by 10 CFR 61.41. The wetlands assessment was based on the "Federal Manual for Identifying and Delineating Jurisdictional

Wetlands". It appears, that for the conditions considered, the construction of the LLW facility may avoid impacting nearby wetlands. This evaluation was considered important to South Dakota because a wetlands impact would trigger an EIS which would ensure a federal forum to voice concerns. The review of the license application focused on the environmental report and was based on Nebraska's regulations and NRC's regulatory guides. Comments were categorized into four sections: (1) general, (2) site selection, (3) facility design, and (4) data sufficiency and quality. The review discovered that the environmental report was incomplete and that inconsistencies existed with state and federal regulations and guidelines. Most of the concerns identified in this independent study have been submitted to the State of Nebraska as part of the public participation process during the review of the license application.

1.0 INTRODUCTION

In 1980, Congress passed the Low-Level Radioactive Waste Policy Act (LLRWPA) to encourage states to form partnerships or compacts and develop facilities for multistate, low-level waste (LLW) disposal. In 1985, Congress amended the LLRWPA by requiring states to resolve their LLW disposal problems by 1993. A 320-acre site in Boyd County, Nebraska, was selected from three candidate sites in Nebraska by the Central Interstate Compact to host their LLW disposal facility. The Central Interstate Compact includes Arkansas, Kansas, Nebraska, Louisiana, and Oklahoma.

The proposed Boyd County LLW facility is located in the eastern half of Section 13, T34N, R14W, Boyd County, Nebraska. This proposed LLW site is approximately 5 miles south of the South Dakota/Nebraska border. The close proximity of the proposed site and concern that South Dakota residents may be impacted prompted technical investigations to better understand the impact of this proposed LLW facility.

The purposes of this study are (1) to identify and analyze the potential consequences of credible failure scenarios that pertain to operation and performance of the facility, (2) to generate conservative analyses of facility performance to identify critical technical issues and data needs that must be resolved to enhance confidence in facility performance, (3) to review the environmental report portion of the license application, and (4) to recommend measures that would enhance protection of the environment and residents of South Dakota.

Prior to the initiation of these technical investigations, a consensus was reached with representatives of the State of South Dakota on the primary issues of concerns arising from the development of the LLW facility in Boyd County, Nebraska. As a result, technical investigations were initiated on the categories below for the reasons summarized in the text that follows:

- Potential Impact on Wetlands
- Groundwater Pathway Analyses
- Airborne Pathway Analyses
- Review of Environmental Report.

2.0 POTENTIAL IMPACT ON WETLANDS

Wetlands have been considered a key issue in the development of the low-level waste (LLW) facility proposed for Boyd County, Nebraska. A manual [U.S.-Fish and Wildlife Service et al., 1989](1) was adopted by four federal agencies to identify jurisdictional wetlands in the United States. The procedures outlined in the manual represent a compromise of prior practices used collectively by these four agencies. The manual specifies multiple criteria in which all conditions must be met in order to achieve wetlands designation. Wetlands must have all of the following characteristics:

- **Hydrophytic Vegetation** - Plant life growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content.
- **Hydric Soils** - A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions.
- **Wetlands Hydrology** - Permanent or periodic inundation or prolonged soil saturation sufficient to create anaerobic conditions in the soil.

U.S. Ecology authorized Bechtel National Inc. to conduct environmental studies at the proposed site. Subsequently, Bechtel subcontracted with Erik Olgeirson to determine the extent of wetlands for the license application by U.S. Ecology. The primary basis for Olgeirson's study [Olgeirson, 1989](2) was the Federal Manual for Identifying and Delineating Jurisdictional Wetlands. In addition, Olgeirson [1989](2) considered three other studies during his wetlands assessment:

- The 1979 National Wetlands Inventory Map
- The U.S. Soil Conservation Service (U.S.-SCS) Soil Survey [1979](3)
- A Vegetation Survey by Gary Larson of South Dakota State University [Larson, 1989].(4)

The results of Olgeirson's study [Olgeirson, 1989][2] indicate the total wetlands within the 320-acre proposed site covers 42.61 acres (13.3 percent), which includes 5.88 acres of problem area wetlands. As mentioned previously, problem area wetlands are difficult to determine because of the absence of one or more of the mandatory criteria. Also, Olgeirson [1989][2] cites land use and drought as key factors in creating a trend towards a reduction in wetlands. Based on this study, it appears the discharge of dredged or fill material into wetlands (as per Section 404 - Clean Water Act) can be avoided.

3.0 GROUNDWATER PATHWAY ANALYSES

3.1 Introduction

Release of radionuclides into the biosphere from the LLW facility by way of a groundwater pathway is limited by (1) the containment integrity of the waste package, (2) the containment integrity of the LLW "cover system," and (3) the hydrogeologic transport system. Ideally, each of the three barriers would provide sufficient containment of any potential radionuclide releases, but in fact, they operate together as a multicomponent system. If one or more of the three system components is not a significant containment barrier, increased performance of the remaining barrier(s) must be demonstrated.

The hydrogeologic transport analyses of radionuclide release are divided into three segments: (1) transport of a potential radionuclide from the disposal facility downward through three partially saturated hydrostratigraphic units to the water table, (2) lateral transport of the radionuclide to the wetlands via the "Recent Sand" unit, as may occur if annual precipitation increased to a point that the water table migrated upward to the vicinity of the "Recent Sand" unit, and (3) lateral transport of the radionuclide from the site of the disposal facility in the groundwater to Ponca Creek via the "Rubble Zone." Various mathematical and hydrogeological assumptions were made when data was unavailable.

3.2 Radionuclide Release Scenario

The analyses in this section of the report are based on an assumption that sometime during the 500-year period of concern [NRC, 1989],[5] the engineered barriers including the LLW packages, the LLW cover system, and the concrete/clay liner become ineffective. The ability of the packages or the cover system to contain the waste cannot be evaluated because details of the systems are not available. Our analyses assume that precipitation enters the disposal cell and accumulates in the disposal cell. The analyses further assume that the waste package is degraded to the extent that radionuclides are available to dissolve in the water accumulating in the disposal cell. Finally, the analyses assume the concrete/clay floor of the disposal cell has been cracked or otherwise breached enabling contact between the native soils and the contaminated water.

The potential groundwater pathway at the LLW site involves (1) vertical transport through a partially saturated geologic sequence and (2) horizontal transport through a saturated geologic member to either the nearest wetlands or Ponca Creek. The partially saturated portion of the groundwater pathway is evaluated with the finite difference computer program TRACRN [Travis and Birdsell, 1988][(6)] and the horizontal portions of the pathway are evaluated with a simple analytical model.

3.3 Vertical and Lateral Flow Analyses

Results of the numerical vertical flow analysis revealed that upon release, radionuclides could conceivably reach the "Recent Sand" unit in approximately 2 days and could reach the "Rubble Zone" and the water table in approximately 53 days or 1.8 months. These results are based upon numerous hydrogeological and mathematical assumptions, which could affect the results substantially. However, the exact value of travel time is not as important as the range of possible travel times. If the 53-day travel time was increased by two or three orders of magnitude, the travel times would still be such that even many short-lived radionuclides would not have sufficient time for decay and would be of concern.

Radionuclide lateral transport analyses from the water table to the wetlands or Ponca Creek were performed using a analytical method outlined by Fetter [1988].[(7)] The method relies on a modification of Darcy's Law that can be used to estimate the average linear velocity of a solute front. Based on a modified Darcy's Law, it would take the solute front approximately 4,400 days or 12 years to reach the wetlands via the "Recent Sand." The resultant bilateral travel time is approximately 4,700 days or 13 years for the solute front to move approximately 3,500 m (11,480 ft) from the site to Ponca Creek via the "Rubble Zone." Rahn and Davis [1990][(8)] found several springs that are as much as 1,000 m (3,280 ft) closer to the proposed site than Ponca Creek. If these springs are hydraulically connected to the "Rubble Zone," as is believed by some [Rahn and Davis, 1990],[(8)] the 13-year travel time could conceivably be as little as 9 years.

The significance of these results is not the exact travel times determined for radionuclides to reach the wetlands or Ponca Creek. Rather, the important aspect of these results is that they could be increased by an order of magnitude and still be of concern, given the half-life of several radionuclides present in LLW. These results also suggest that the hydrogeologic characteristics surrounding the proposed site provide relatively fast transport of released radionuclides. Therefore, the burden of radionuclide containment relies heavily on the engineered barriers to maintain the integrity for hundreds of years.

4.0 AIRBORNE PATHWAY ANALYSES

4.1 Introduction

Release of radionuclides into the biosphere from the LLW facility by way of an airborne pathway is possible through (1) failure of the containment integrity of the facility, (2) release of radioactive contaminated effluents from the facility, and (3) shipping and/or handling accidents/incidents at or near the facility.

The performance objectives of the U.S. Nuclear Regulatory Commission [NRC, 1989, Subpart C, 10 CFR 61.41][9] state, in part, that "concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ to any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable."

It is not specifically stated that the above performance objectives do not apply to low-level waste accident/incident scenarios. Therefore, the results of the airborne release for an accident/incident scenario are compared to this performance objective in order to assess the impact of radionuclide releases to the general population, such as South Dakota residents living near the proposed facility.

4.2 Radionuclide Release Scenario

The airborne pathway analyses presented herein is based on a hipping and/or handling accident/incident at or near the proposed LLW facility. A radionuclide release from a shipping or handling accident/incident is an assumption based on a recent study by Cashwell [1990].[10]

The Radioactive Materials Incident Report (RMIR) database used in the study is a compilation of transportation accidents and incidents that have occurred during shipment of radioactive materials. Events are classified by the RMIR as

- **Incidents:** Actual or suspended release of radioactive material, or surface contamination exceeding regulatory requirements on either the package or the transport vehicle.

- **Transportation Accidents:** A transport event ranging from a minor accident to a major collision that involves the vehicle transporting the radioactive material.

- **Handling Accidents:** Damage to a shipping container during loading, handling, or unloading operations (e.g., a forklift puncturing a package at an air terminal).

Of the 1,319 accidents and incidents related to transportation of radioactive materials that have occurred since 1971, 20 percent are classified as transportation accidents, 62 percent are classified as incidents, and 18 percent are classified as handling accidents [Cashwell, 1990].(10) The study states that approximately 2 million shipments each year involve transport of radioactive materials. The most commonly used mode of transporting radioactive material is by highway, which accounts for 79 percent of accidents/incidents.

The RMIR data indicates that the probability of an accident/incident occurring during transporting and handling of a radioactive shipment is about 3.5×10^{-5} (i.e., 1,319 accidents/incidents over a 19-year period in which there was an average of about 2 million radioactive shipments per year). Although this probability of an accident/incident involving any single shipment of radioactive material is extremely small, it still can result in a substantial probability of an accident/incident involving at least one shipment among many shipments. The latter probability can be calculated by using the binomial distribution to describe the probability of i accidents/incidents out of n independent shipments, each of which has a probability of accident/incident of 3.5×10^{-5}. At a rate of three shipments per week [Patten, 1990],(11) there will be about 4,680 shipments over the 30-year operational lifetime of the proposed Boyd County facility. Based on the binomial distribution, the probability of no accidents/incidents ($i = 0$) among these 4,680 shipments is 85 percent. The probability of at least one accident/incident (the complement of no accidents/incidents) is 15 percent. Hence, there is a significant chance that at least one accident/incident involving a shipment of LLW to the Boyd County facility will occur over the facility's 30-year lifetime.

A summary of radionuclides comprising the low-level radioactive waste shipped by direct shipments in 1989 from the states of the Central Interstate Compact was obtained from EG&G, Idaho [1989(a)].(12) The Central Interstate Compact includes Arkansas, Kansas, Louisiana, Nebraska, and Oklahoma. The summary listed the radionuclides and their respective activities (in curies) shipped directly from the generator to disposal facilities by each state in 1989. The listing was condensed to a total of 49 radionuclides and their respective total annual activity. Waste that is not shipped directly but is shipped through a broker or processor is not tracked to the state of origin by nuclide. The activity of waste that was not shipped directly was identified using a summary supplied by EG&G, Idaho [1989(b)](13) that lists the total annual volume and activity for all shipments from the Central Interstate Compact in 1989. The annual direct shipment activities were multiplied by the total shipments to direct shipments ratio to reflect the additional radionuclides that were shipped through a broker or processor. The annual activity value for each radionuclide was assumed to remain constant for the projected 30-year period.

4.3 Airborne Transport Analyses

Airborne transport analyses were completed using The Clean Air Assessment Package – 1988 (CAP-88), an updated version of AIRDOS-EPA. CAP-88 is a computerized methodology for estimating environmental concentrations and dose to man from airborne releases of radionuclides. The AIRDOS-EPA program was developed at Oak Ridge National Laboratory (ORNL) to be used by the U.S. Environmental Protection Agency (EPA) to evaluate health risks to man from atmospheric radionuclide releases. The model is capable of estimating radionuclide concentrations in air, rates of deposition on ground surfaces, ground-surface concentrations, intake rates via inhalation of air and ingestion of meat, milk, and fresh vegetables, and radiation doses to man from airborne releases of radionuclides. The program is a modified version of AIRDOS-II, which has been used by the Environmental Sciences Division (ESD) and the Health and Safety Research Division (HASRD) of ORNL for several years to assess radiological impacts of routine operations of nuclear facilities.

CAP-88 is capable of employing either a circular or rectangular grid. For the circular option, the area around the repository is divided into sixteen 22.5° sectors emanating from the center of the source area. The midpoint of each sector is one of sixteen compass directions numbered 1 through 16, starting with direction 1 for due north and proceeding counterclockwise to NNE for direction 16. Each compass direction was extended a distance of 20 kilometers (12 miles) from the centroid which represents the proposed disposal facility. The area was then subdivided by ten concentric circles. These distances from the release point were entered as input to represent midpoints of environmental locations for all the sectors and resulted in a total of 160 cells in the grid.

Initially, the nuclides were assumed to be released uniformly throughout the source area. To bracket a range of concentration values, another execution of the program was completed using the original activities decreased by six orders of magnitude. Exposure and the resultant effective dose equivalent vary linearly with the percent of the shipment involved in an accident/incident and released to the biosphere. Based on the assumptions used in these analyses, South Dakota residents would not experience an individual dose exceeding 10 to 12 mrem/yr which is below the established limits.

5.0 REVIEW OF ENVIRONMENTAL REPORT

The basis for this review of the environmental report (ER) submitted by the U.S. Ecology to the Nebraska Department of Environmental Control includes the following documents:

Title 194 – *Rules and Regulations for the Disposal of Low-Level Waste* developed by the Nebraska Department of Environmental Control (NDEC), July 1989.

Regulatory Guide 4.18 – *Standard Format and Content of Environmental Reports for Near-Surface Disposal of Radioactive Waste*, developed by the U.S. Nuclear Regulatory Commission (NRC) – Office of Nuclear Regulatory Research, June 1983.

Regulatory Guide 4.19 – *Guidance for Selecting Sites for Near-Surface Disposal of Low-Level Radioactive Waste*, developed by the U.S. Nuclear Regulatory Commission (NRC) – Office of Nuclear Regulatory Research, August 1988.

Title 194 was developed by NDEC with the intent of complying with NRC's *Licensing Requirements for Land Disposal of Radioactive Wastes* (10 CFR 61). Title 194 represents the regulatory basis for NDEC to license a low-level waste (LLW) disposal facility in Nebraska. The ER submitted by U.S. Ecology is required by Title 194 as part of the license application. Regulatory Guides 4.18 and 4.19 (subsequently referred to as NRC 4.18 and 4.19, respectively) provide excellent resources for conducting this review because they were developed by NRC to provide guidance for preparing an environmental report and selecting sites for disposal of low-level waste. In fact, the structure and forms of the ER submitted by U.S. Ecology closely follow the recommendations in NRC 4.18. Although most of the comments are based on the three documents referenced above, some comments are based on other regulations or involve clarification questions stemming from lack of specificity, detail, and substantiation.

The review comments presented in subsequent sections represent only a portion of the anticipated comments for the following reasons:

- Insufficient time was allowed for review.
- Portions of the ER were incomplete which prevented an adequate assessment of numerous issues.
- Inconsistencies with federal and state regulations and guidelines require an explanation prior to completion of the review.
- The Safety Analysis Report and approximately 11 other supporting documents cited in the ER were not available.

Comments stemming from this review of the ER were categorized into four sections [RE/SPEC, 1990]:[14]

1. General
2. Site Selection
3. Facility Design
4. Data Sufficiency and Quality.

Each category begins with a citation of specific acts, regulations, and/or guidelines that form a basis for subsequent comments that include questions and requests. More than 100 questions and comments were documented and submitted for consideration by Nebraska's Department of Environmental Control.

6.0 SUMMATION

Investigations indicate wetlands will probably be avoided in terms of dredged or fill material stemming from the construction and operation of the proposed LLW facility. This assessment is based primarily on the evaluation of the U.S. Ecology wetlands study, newly promulgated applicable guidelines, the COE evaluation of the U.S. Ecology study, and soil surveys of the proposed site.

Preliminary technical investigations were performed on the proposed LLW facility in Boyd County, Nebraska, that included pathway analyses of radionuclide releases in groundwater. The release scenario assumes that the engineered barriers become ineffective during the 500-year period following waste emplacement and water, contaminated with radionuclides, is released. The hydrologic transport analyses of radionuclide release are divided into three segments: (1) vertical flow to the water table, (2) lateral flow through the "Recent Sands" to the wetlands, and (3) lateral flow through the "Rubble Zone" to Ponca Creek. For the assumptions considered, projected travel times are 1.8 months, 12 years, and 13 years for the three respective flowpaths cited above. The significance of these results are not the exact travel times projected, but rather that these rates could be increased by an order of magnitude and still be significant. Also, these relatively fast travel times indicate the hydrogeologic characteristics will not provide a sufficient natural barrier for containment purposes. Therefore, containment of contaminants will need to rely heavily on the engineered barriers, which includes the cover, the disposal cell, and the concrete/clay floor, to maintain their integrity for hundreds of years.

The airborne pathway analyses were based on a release scenario involving a shipping and/or handling accident/incident at or near the proposed LLW facility. The analyses indicate the performance objectives, which was established by NRC involving acceptable radiation dosages to the general public would not be exceeded for residents of South Dakota.

The review of the environmental report was based on state and federal documents that reflect pertinent acts, regulation, and/or guidelines. Questions and comments were grouped into the following four categories: (1) general, (2) site selection, (3) facility design, and (4) data sufficiency and quality. More than 100 questions and comments were submitted to Nebraska's Department of Environmental Control as part of the public participation process.

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WASTE CERTIFICATION

Development of Waste Acceptance Criteria

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OVERVIEW

The development of a formal program for certifying waste packages prior to shipment, treatment, storage, and/or disposal begins by identifying the key waste categories. Waste Acceptance Criteria (WAC) are the key characterizing parameters which should be used in the identification step. These WACs are actually performance objectives against which waste packages are evaluated by both the generator and the treatment, storage and disposal (TSD) facility. The development of the WAC is based on regulatory requirements, facility design, technology limitations, and the need for accuracy and reliability in the waste characterization techniques. This paper will focus on the development of WACs in the generic sense.

WASTE ACCEPTANCE CRITERIA

The importance of the WAC in a performance based system is only apparent in the context of how it fits into the overall certification process. Figure 1 illustrates the overall certification process by showing the responsibilities of the waste generator versus those responsibilities assigned to the TSD. In general, the waste generator should categorize the waste, identify TSD options available for his waste, review the specific WAC for those chosen TSD facilities, and characterize the waste according to the accepting TSD's WAC. On the other hand, the TSD owner must design his facility to meet certain performance objectives, obtain all necessary permit and approvals to construct and operate the facility, and build and operate the facility to meet the defined objectives. In operating the TSD facility to meet the defined objectives, WACs need to be developed; and thus we come full circle with the waste generator needing to then meet these WACs.

The basic concerns for both the generator and the TSD are to address the following questions:

- What are the specific wastes or types of wastes?
- How do they need to be managed to meet safety and health concerns?
- What specific properties need to be monitored to ensure they are managed correctly?
- How will those specific properties be measured?

A waste generator meets his needs if the waste is accepted by a TSD, has satisfied its WAC, and is managed within acceptable health and safety limits. A TSD meets its needs when its operations are in compliance with regulations and permits and the facility operates within the limitations of the technologies used in its design and health and safety constraints.

The key properties which need to be monitored to assure that the waste management process does meet regulatory, permitting, health and safety, and technological concerns are termed performance limiting criteria. Without identification and quantification of those parameters, the performance of the TSD can not be assured. The performance limiting criteria must be the basis of the Waste Acceptance Criteria which each TSD facility must develop.

Development of Waste Acceptance Criteria

Suzanne T. Thomas, Sirrine Environmental Consultants, Inc.

TSD PERFORMANCE CRITERIA

The performance limiting criteria for a TSD should be based on evaluation of the following:

- facility design
- regulatory requirements i.e. air emissions standards, volume of material accepted, waste composition
- construction and operating permit limitations
- technological capabilities and limitations
- safety concerns for materials handling
- safety of treatment, storage, or disposal option
- accuracy and reliability of waste characterization process or of methods to gather data
- operability limitations

As much as possible, the criteria should be selected with knowledge of the critical operating parameters of the generating process and the known waste properties. Properties which red flag changes in the waste composition and other known regulatory criteria for the waste in question are also helpful.

Examples of these critical properties include chlorine concentration or heavy metal contamination for wastes to a combustion process, or the physical condition of a container, i.e. bulges and sweating which indicate some change has taken place.

For a given waste, the WAC is defined by physical, chemical, and radiological properties of the waste and associated containers. Some of the chemical parameters which should be considered include the specific chemical inventory, properties of the chemical constituents, properties of the composite waste form, any excluded materials, and such factors as corrosivity, reactivity, etc. Physical parameters should include the physical state, gross and net weights, density or specific gravity, volume, void fraction, waste container size, water content, pH, solids content, viscosity, flash point, and Btu content. Radiological parameters can include radionuclide inventory and concentrations, health physics surveys, fissile material content, and criticality limitations. Generally, if a waste package cannot meet the TSD's WAC, then it cannot be accepted.

DEVELOPMENT OF THE WASTE ACCEPTANCE CRITERIA

For a specific hazardous waste TSD, a step-wise process for developing the WAC can be described as follows:

Step 1 - Identify waste categories for acceptance i.e., ignitible(D001), corrosive (D002), reactives (D003), toxic, spent solvents (F001-etc.), spent sludges, discarded commercial chemicals, PCB waste, used oils, infectious waste, etc.

Step 2 - Define limits according to permit and regulatory stipulations i.e., PCBs less than 500 ppm for landfill disposal, allowable storage less than 90 days, etc.

Step 3 - Identify design or technology limitations i.e. wastes with light volatile fraction (greases) ought not be burned in a counter-current kiln, metal drums cannot be fed to non-slagging kilns, etc.

Step 4 - Evaluate operational constraints i.e., quantity of material (reactives in small quantities) or size of container (materials handling constraints).

Step 5 - Establish limiting criteria based on Steps 1 through 4.

The limiting criteria would then be very specific to the TSD's objectives. Examples of typical TSD limiting criteria and the resulting WACs are discussed below.

For a radioactive or mixed waste TSD, the process would be similar. For example, for radionuclide concentrations, the process would be:

Step 1 - Identify radionuclide categories to be accepted, i.e., low level waste, mixed, transuranics, etc.

Step 2 - Define regulatory or permit limits. For radionuclides this is especially critical. These include GTCC limits, TRU waste limits, CERCLA reporting requirements to minimize reporting, permit limits on radioactivity releases, and exclusion of RCRA and TSCA wastes.

Step 3 - Incorporate performance assessment of facility. The performance assessment of a facility includes potential release mechanisms, release quantities, and probable release pathways. Waste characteristics such as degradability and stability which define the potential release mechanism need to be included in the development of WAC. Other parameters include intruder scenarios, dose conversion factors (DCFs), etc.

Step 4 - Evaluate operational constraints. Consideration of routes of exposure to workers (inhalation, ingestion, and absorption) and fissile content to avoid criticality accidents are important to evaluate. In addition, the "as generated" versus "as disposed" issues need to be addressed when developing the WAC for the TSD.

Step 5 - Establish limiting concentrations. The most conservative limiting concentration for each radionuclide would then be used. Other limitations which need to be considered include the " sum of fractions" rule and exclusion conditions for certain radionuclides.

The limiting concentrations and criteria would again be very specific to the TSD's objectives. The two step-wise procedures given above are essentially the same. They represent a process of identification, evaluation of current and future constraints, and decision.

VARIOUS TREATMENT FACILITIES AND THEIR WACs

Some examples of WACs for various types of facilities can be discussed in light of the procedures described above.

In some cases, the specific waste stream necessitates a specific inclusion in the WAC. For example, for LDR waste, pre- treatment is normally required. The WAC should, therefore, include the pre-treatment reagents (reducing/oxidizing agents) along with the post-treatment analysis including the Toxicity Characteristic Leaching Procedure (TCLP) analysis. For reactives, pre-treatment with hydrogen peroxide, sodium or calcium hypochorite, chlorine, or other oxidizing agents will most likely be required. Therefore, the WAC needs to include test results for liquid waste compatibility. Total reactives concentrations are necessary but depend on the reactive of concern such as cyanide, free cyanide, or free sulfide.

Heavy metals will require treatment by chemical precipitation and sedimentation and/or filtration. Tests for compatibility, pH, heavy metals concentrations, temperature during bench scale reaction, and analyses of precipitated solids for leachability need to be performed. The WAC should identify waste stream compatibility, pH, heavy metals concentrations, and other chemical constituents. Stabilization and solidification are suitable for wastes which are ignitible, corrosive, reactive, and toxic. This includes PCB wastes, radioactive wastes and sanitary wastes. Parameters critical to the stabilization or solidification process include pyrophoric content, specific activity, metals content, water content, and particle size. For incineration or high-temperature oxidation, the WAC needs to include heating value (Btu), halogen content, sulfur content, and ash content.

The most critical part of the characterization process is to ensure that site conditions, permit conditions, and compatibility to system design and operating requirements are met. In addition, residual streams need to be evaluated for final disposition. This would include considering air emissions and their control, ash disposal, and container disposal. Other parameters which have appeared in some WACs, include percent acidity, total solids, specific gravity, byproduct streams, the Total Organic Carbon (TOC), pH, anions, metals, conductivity, and volatile organic concentrations.

Some major hazardous waste disposal firms have established standards for each of their facilities to use as the basic WAC data. These include physical descriptions such as odor, color, physical state, layering, weight and density, and state. Screening tests are included for pH, cyanide and sulfide, water reactivity, and flammability potential. Supplemental criteria include liquid waste compatibility, screening tests for solvent content, oxidizers, radiation, a test for suspended solids,a water acceptance test to determine miscibility and layering, and load bearing strength. For stabilized waste, tests to evaluate stabilization effectiveness, total residues, and quick leach extraction would be useful.

In the radioactive arena, suitable WACs have included the following. For radioactive land disposal, displacement volume criteria are critical. In addition, the waste classifications need to be specified. Class A, B, or C waste should be identified separately from other radwaste containing Special Nuclear Material (SNM) or mixed waste. Class A waste should be further identified a unstable or stable. Container requirements and visible characteristics are critical. Excluded types of containers need to be listed, and specific packaging requirements need to be given. In addition to the waste characteristics, special vehicle requirements into and out of the facility need to be part of the WAC.

Special requirements may be required for some materials. For example, biological material needs to be layered with a specific quality and quantity of absorbent and slaked lime. Formaldehyde will not be accepted. Gaseous waste may be limited to only specific radionuclides with radioactivity not exceeding certain limits and packaged in pre-specified containers or cylinders meeting certain pressure restrictions. TSDs handling radioactive waste actually specify containers to be used for ranges of radioactivity and half-lives. Liquid radioactive waste is not accepted for land disposal, but solidified liquid waste can be acceptable as long as it has been solidified with acceptable material. Organics are not usually accepted even if solidified. Oil may only be acceptable if it does not exceed a specific concentration. Pyrophoric materials need to be rendered non- pyrophoric prior to disposal. No water reactives can be land disposed. Toxic chemicals are usually only acceptable when the radioactivity hazard is greater than hazardous waste hazard. Transuranics are acceptable as long as concentrations don't exceed permit limitations and exhibit an even distribution of transuranic nuclides.

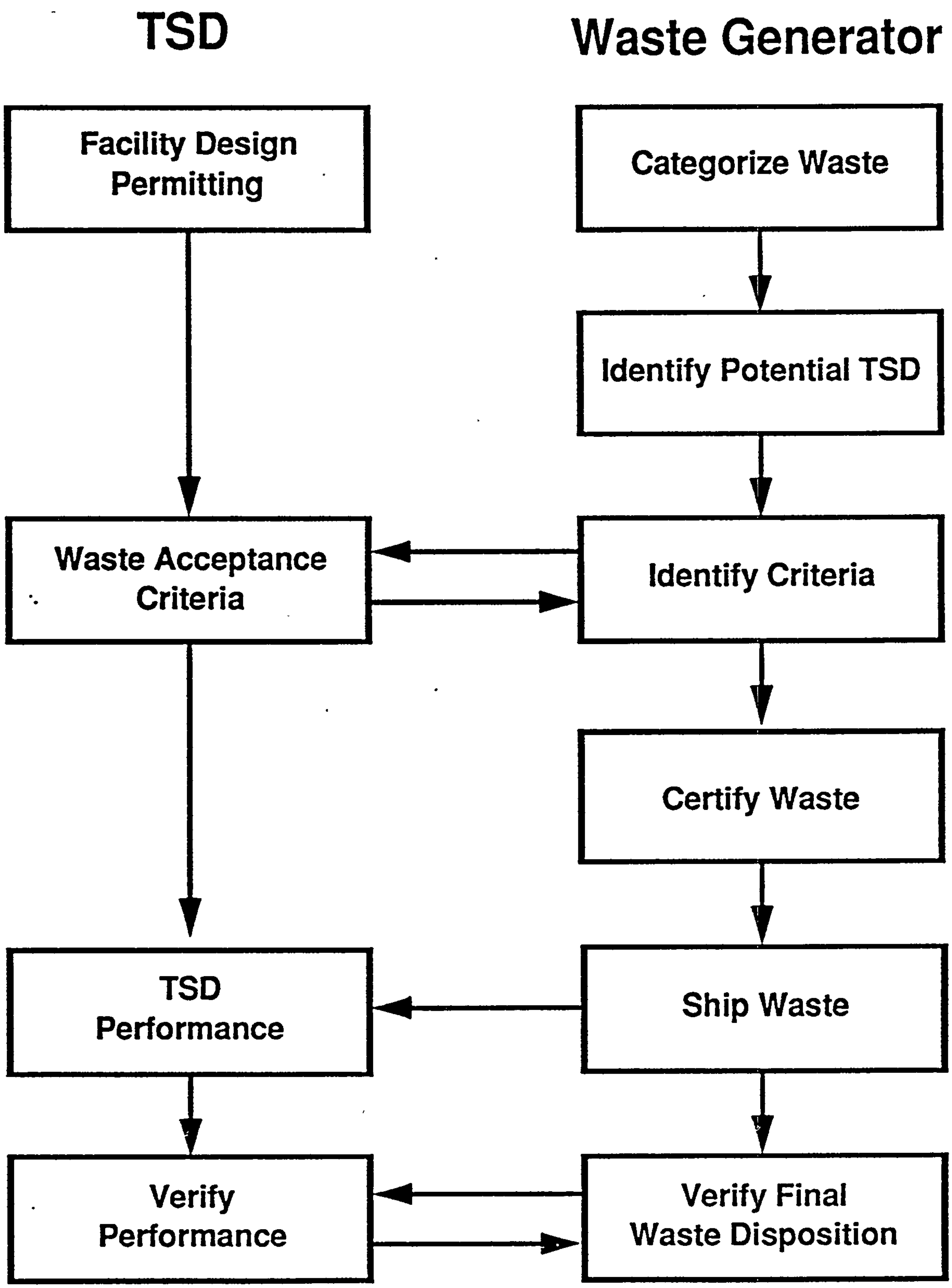
For specific treatment schemes of radioactive waste, other WACs may include component exclusions or concentration limitations based on the specific treatment as in the chlorine content for combustion processes.

The above examples have been extracted from the WAC for various types of TSDs and serve to illustrate the possible outcomes from the five-step procedure described above.

CONCLUSION

The development of the WAC is based on regulatory requirements, facility design, technology limitations and the need for accuracy and reliability in the waste characterization techniques. The five-step procedure described in this paper could apply to development of WACs in the generic sense. The procedure represents a process of identification, evaluation of current and future constraints, and decision.

Figure 1
Overall Certification Process



THE FIRST STEP IN WASTE CHARACTERIZATION IS IT RADIOACTIVE?

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I. INTRODUCTION

The characterization of potentially radioactive waste materials may include analyses and testing for radiological, chemical and physical parameters. The selection of the types of analyses to be performed may be driven by regulatory requirements, remedial alternatives, or disposal facility waste acceptance criteria. The determination that a waste is radioactive should be the first step in the characterization of the material since disposal and remedial options may depend on the material's radiological status. If process knowledge or screening methods can be utilized to determine that a waste is nonradioactive then further radiological characterization and subsequent disposal of the material as radioactive waste would be unnecessary. However, unlike characteristic wastes defined by the Resource Conservation and Recovery Act (RCRA), radioactive wastes do not have a concentration limit below which the materials are unregulated (Ref. 1). Since de minimis levels are not defined and due to the widespread occurrence of natural radioactivity, waste materials containing any radioactivity have the potential of being classified as radioactive waste.

II. CHARACTERIZATION QUANDARY

Current regulations define low-level radioactive wastes by exclusion but fail to define a quantity or concentration below which the material is considered to be nonradioactive. Low-level waste is defined as "radioactive material that (A) is not high-level radioactive waste, spent nuclear fuel, or byproduct material and (B) the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste" (Ref. 2). The lack of appropriate regulatory exemptions or de minimis concentrations has led to the use of inconsistent methodologies for determination of a waste materials radiological status. This in turn can lead to:

- inappropriate transfer of licensable quantities of radioactive material to unlicensed facilities;
- disposal at low-level radioactive waste disposal sites of waste materials that pose very little radiological risk;
- increased analytical costs to meet facility waste acceptance criteria; and
- generation of pseudo mixed waste for which there are no current disposal options.

In general, the methods currently used to classify a waste as nonradioactive are based on the generator's knowledge of the waste, assessment of radiological risk, radiological measurements, or some combination of the above.

III. NONRADIOACTIVE BY PROCESS KNOWLEDGE

Process knowledge is a method used to determine that a material is nonradioactive, based on information about the generation and storage of waste materials. Wastes that are generated outside of radiologically controlled areas and wastes to which radioactivity has not been added are often considered nonradioactive. For example, materials that never enter areas where regulated radioactive materials are used or stored and that are not exposed to radiation fields capable of activation may be considered nonradioactive based on process knowledge. This method of waste classification is based on the premise that radioactive waste constitutes waste materials to which radioactivity was added by the operations of the facility. This approach avoids the difficulty incumbent in the analytical method of waste classification, i.e. the absence of a standard with which to compare analytical results. Pitfalls in this approach include:

- the possibility of classifying wastes nonradioactive to which radioactive materials were inadvertently added;
- not accounting for radioactivity in materials as received; and
- not accounting for radioactive materials which may have been concentrated during processing.

This method requires a detailed knowledge of waste generation, waste tracking, and certification.

IV. NONRADIOACTIVE BY RISK EVALUATION

Another approach used is to exempt waste materials from regulatory control based on an evaluation of risk. Although this method does not attempt to define a material as nonradioactive, the effect is the same since the materials in question would be deregulated from a radioactive materials standpoint. Several problems appear when this method is employed:

- Risk Assessments must be based on specific materials containing known radionuclides with known fates;

- Consensus has not been established on what constitutes acceptable risk;

- The method does not address de minimis levels (i.e. levels of radioactivity below which the material would not need a specific risk evaluation).

Federal agencies are currently working on risk-based exemptions for waste. Although the Environmental Protection Agency (EPA) is responsible to provide guidance for all Federal agencies in the formulation of radiation standards, the EPA, the Department of Energy (DOE), and the Nuclear Regulatory Commission (NRC) have all proceeded with efforts to develop risk-based exemptions for wastes.

- The DOE has formed a Risk-based Work Group with the goal of determining the feasibility of developing regulatory exemptions for low-level waste materials to be disposed at RCRA and Toxic Substances Control Act (TSCA) facilities.

- The Below Regulatory Concern (BRC) Policy Statement (Ref. 3) issued in July of 1990 established a consistent risk framework under which exemptions would be granted by the NRC for certain practices involving small quantities of radioactive material. In July of 1991 the NRC announced deferral of actions on BRC petitions and the initiation of a consensus process regarding the Policy (Ref. 4). These actions were taken due to widespread public concern over the implications of the BRC Policy. One of the first steps in the consensus process was the formation of a core group of interested parties which is scheduled to convene late in 1991. Failure to obtain representation from all of the interested groups will result in the abandonment of the consensus process.

- Proposed EPA standards for low-level waste disposal include a BRC provision (Ref. 5). The EPA has been directed to resolve the disposal issue with the NRC and DOE. The EPA is receiving comments from other Federal agencies regarding this proposed standard.

V. NONRADIOACTIVE BY ANALYSIS

Waste materials that cannot be declared nonradioactive by process knowledge or for which risk assessments have not been performed and accepted are analyzed to determine their radiological status. This analysis or measurement of the material's activity may involve sampling and subsequent laboratory analysis of the material or it may simply involve surveys of the material/items with portable radiation survey meters. In either case, the analytical result/measurement or the method detection limit must be below the "nonradioactive" limit. Since a quantity or concentration below which a material is considered nonradioactive is not defined in the regulations, de facto limits are used. For example, if a waste material is sampled and analyzed to determine its radiological status, the analytical results (or the method detection limit) must be below some concentration or quantity limit in order to be classified as nonradioactive. De facto limits used in the absence of an appropriately defined regulatory limit include:

- Radioactive material as defined by the Department of Transportation;
- Maximum Permissible Concentrations of radionuclides in effluents released to unrestricted areas;
- Exempt quantities or exempt concentrations of radioactive materials; and
- Background.

The Department of Transportation (DOT) has defined radioactive material as any material having a specific activity greater than 0.002 microcuries per gram (Ref. 6). This definition is based on evaluation of risks from the transportation of materials in commerce and is applicable only to transportation. Although materials with a specific activity below 0.002 microcuries per gram are considered nonradioactive from a transportation standpoint, they are not necessarily excluded from licensing and radioactive waste disposal regulations.

The Nuclear Regulatory Commission (NRC) provides radioactive material concentration limits in effluents released to unrestricted areas for a number of radionuclides (Ref. 7). These effluent limits or maximum permissible concentrations (MPC) for air and water (only) are found in 10 CFR 20 Appendix B, Table II. These MPC values are often used as <u>de minimis</u> concentrations for unrestricted release of materials. Although the MPCs for most radionuclides are orders of magnitude below the DOT definition of radioactive material, transfer of waste containing radionuclides at or below the MPCs to an unlicensed disposal site may constitute a violation of NRC or state regulations unless the materials have been specifically exempted from licensing requirements.

Current NRC and State regulations provide quantity and concentration exemptions for certain radionuclides (Ref. 8). Materials or products containing "Exempt Concentrations" or "Exempt Quantities" of radioactive material may be received, possessed, used, transferred, owned, or acquired without a radioactive materials license. Problems associated with the use of these regulatory exemptions for classification of waste as nonradioactive include:

- Alpha emitting radionuclides are not included in the Exempt Concentration and Exempt Quantity Schedules[1];

- These exemptions are not generally considered to be applicable to waste disposal.

"Background", for purposes of this report, is a measurement of an instrument's response to the radioactivity present in an uncontaminated sample. For example, an uncontaminated soil sample may have a gross alpha activity "background" of 20 picocuries/gram (pCi/g) and a gross beta activity "background" of 30 pCi/g. Soils with gross alpha and gross beta activities less than these values would be considered nonradioactive using "background" as the release criteria. Problems are encountered with this approach due to the variability of background and the lack of suitable background measurements for waste materials.

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[1]The State of Tennessee has recently adopted an exempt quantity for alpha emitting radionuclides of 0.01 μCi, excluding transuranics.

VI. SUMMARY/CONCLUSIONS

Although the determination of the radiological status of waste materials is an important first step in waste characterization, it is complicated by the lack of appropriate regulatory guidance. Since all materials exhibit some degree of radioactivity, a variety of criteria, i.e. de facto limits, have been adopted by generators of low-level waste for classification of low activity waste materials as nonradioactive. Use of de facto limits can result in regulatory violations, increased disposal and analytical costs, and generation of waste with no disposal options.

Federal agencies are currently developing risk-based exemption policies which will make possible the exemption of waste containing low levels of radioactivity from some regulatory controls. Although this is a step in the right direction, broadly applicable concentration limits should be developed that would provide a means for consistent determination of a material's radiological status.

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2. The Low-Level Radioactive Waste Policy Amendments Act of 1985, H.R. 1083.

3. U.S. Nuclear Regulatory Commission, Below Regulatory Concern; Policy Statement, 55 FR 27522, July 3, 1990.

4. U.S. Nuclear Regulatory Commission, Below Regulatory Concern; Deferral of Action; Initiation of a Consensus Process, July 24, 1991.

5. U.S. Environmental Protection Agency, Advance Notice of Proposed Rulemaking for Low-Level Radioactive Waste Disposal, 48 FR 39563, August 31, 1978.

6. U.S. Department of Transportation, Code of Federal Regulations, Title 49, Part 173.403(y), 1990.

7. U.S. Nuclear Regulatory Commission, Code of Federal Regulations, Title 10, Part 20, Appendix B, 1990.

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CONTRACTING FOR ANALYTICAL SERVICES - REQUIRING DELIVERABLES FOR DATA VALIDATION

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The Environmental Restoration and Waste Management Division of the Department of Energy Nevada Field Office (DOE-NV) has recently revised the defense waste acceptance criteria for low-level radioactive waste disposal at the Nevada Test Site (NTS). The NTS currently accepts low-level radioactive waste (LLW) for disposal, but not low-level radioactive mixed waste (MW) or transuranic radioactive waste (TRU). The waste generator must demonstrate, either through process knowledge or sampling and analysis, that waste disposed of as LLW does not contain any hazardous constituents. Strict guidelines have been added to assure that data submitted in support of waste characterization meets acceptable standards of usability. The guidelines specify both the format and contents for data deliverables. Previous experience had shown that, in the absence of these guidelines, the quality of the data could not be verified using standard U.S. Environmental Protection Agency (EPA) data validation guidelines.

Data validation is the process of judging data quality and assigning usability levels to the data. Complete data validation should include components for sampling as well as for analysis. This paper deals only with the analysis portion of data validation.

The waste generators are required to analyze waste samples by using procedures mandated by the Resource Conservation and Recovery Act in "Test Methods for Evaluating Solid Waste" (RCRA SW-846). These methods specify both the analytical procedures and the required quality assurance (QA) which accompanies the analysis. Data validation is usually based on the laboratory meeting the QA requirements specified in the method. Three sets of criteria are usually employed. The primary criteria are the QA requirements specified in the analytical method. A second expanded set of criteria define data which is considered to be "estimated values." If the quality assurance results fall outside of both the primary and expanded criteria, the data are usually rejected as unusable. Both DOE and the EPA use a system of assigning data "flags" which alert the data user of when to use caution. Data which meet all associated QA requirements have no flags. If any QA requirements fall outside of the expanded criteria, "R" flags are assigned. If one or more QA requirement falls within expanded criteria, but none fall outside of the expanded criteria, "J" flags are assigned to the data. A "J" flag signifies estimated values and an "R" flag signifies unusable data. Data validation is a four step process: selecting which QA requirements will be examined; setting limits for primary and expanded criteria; comparing the associated QA results with the limits; and assigning usability flags to the data.

Figures 1 and 2 show examples of data validation based upon the quality assurance requirements associated with the use of internal standards in the volatile and semivolatile organic analysis (e.g., SW-846 methods 8240, 8280). These figures show a small portion of the overall data validation scheme for the methods. Internal standards are added to each sample prior to instrument analysis. The internal standards are used to quantify the analytes present in the sample. Each internal standard is associated with a group of analytes specified by the method.

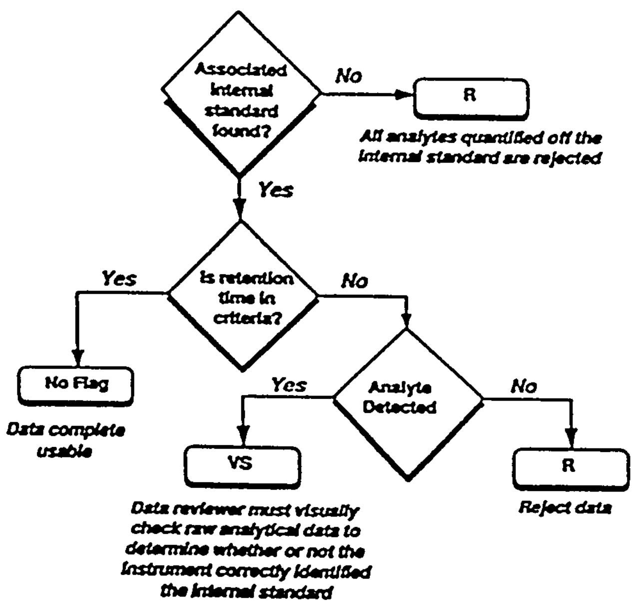

Figure 1 Organic Data Validation Scheme

There are two different QA requirements for internal standards. They are retention time (i.e., how long it takes the internal standard to elute from a chromatography column in the instrument) and instrument response (i.e., the peak area or peak height recorded by the instrument data system for the internal standard). The retention time and instrument response for each internal standard are measured by analyzing a standard solution run at the beginning of the day. The results are compared to the corresponding internal standard retention time and instrument response each time a sample is analyzed. In addition to meeting or failing the QA requirements, it is possible for the instrument to misidentify the internal standard when analyzing the sample. If the instrument operator fails to manually assign the correct

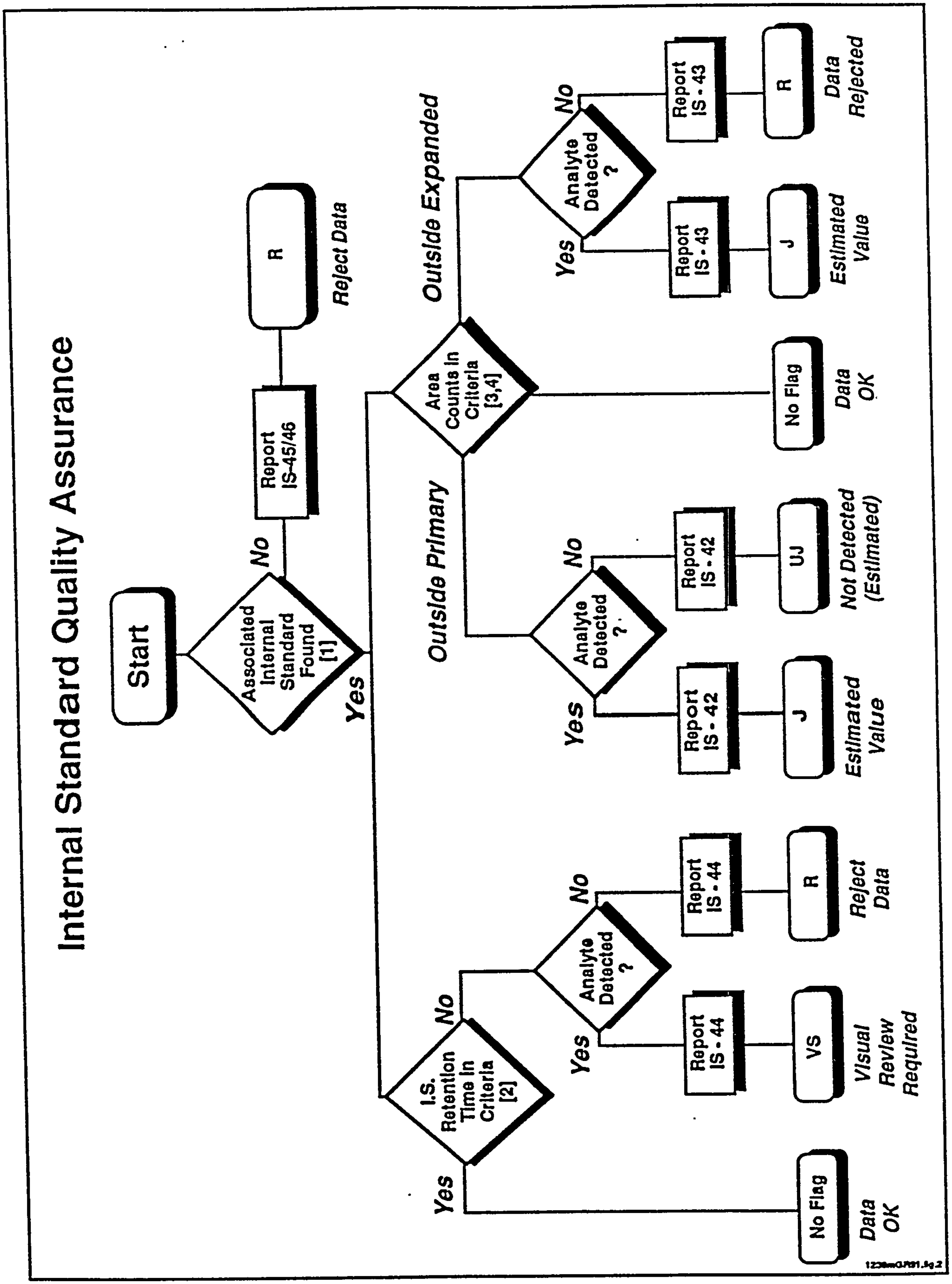

Figure 2. Computer Aided Data Review & Validation (CADRE)

internal standard, the instrument data system would misquantify all analytes associated with that internal standard. The data reviewer would reject the data.

Hand validation of data is a fairly labor intensive process. It is not unusual to have a data package for 20 samples require 40 hours for data validation. For the past several years the EPA has been working on a personal computer (PC) based expert system called Computer Aided Data Review and Evaluation (CADRE), which was developed at the EPA Environmental Systems Monitoring Laboratory in Las Vegas, NV for the EPA Contract Laboratory Program (CLP). This computer program can validate the same data package mentioned above in minutes. The scheme CADRE uses for validating data based upon internal standards is shown in Figure 4. While some technical interpretation is still required, the time savings are significant.

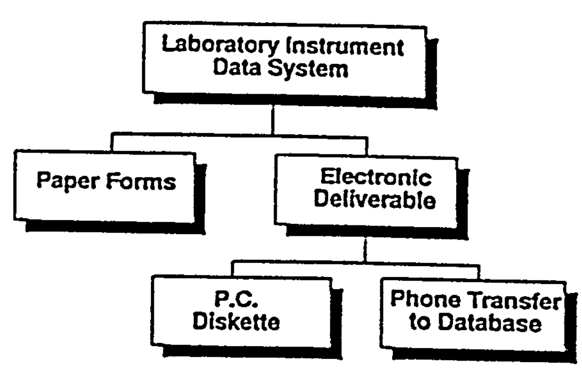

Figure 3. Data Production

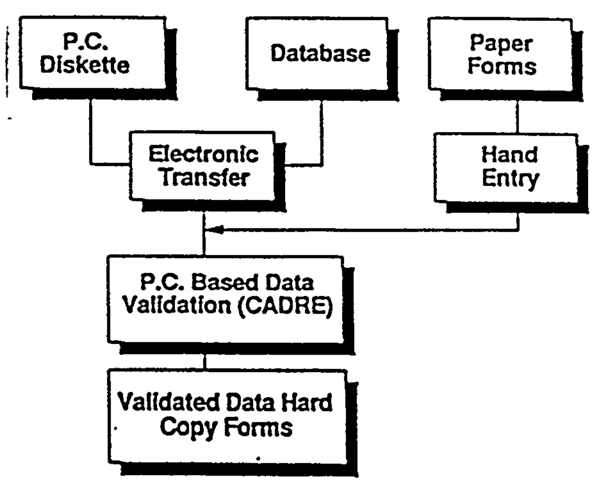

Figure 4. Automated Data Validation

This expert system takes advantage of the advances in laboratory instruments which allow the instrument data system to produce both paper forms and electronic deliverables (See Figure 3). CADRE is designed to work from hand entered data, from PC diskettes, or from data downloaded from a database. Figure 4 shows the logical flow of data for CADRE. Since CADRE was designed for use by the USEPA CLP, data must be in exact EPA format for the computer software to work. Fortunately, the RCRA SW-846 methods for volatile and semivolatile organic analysis and the corresponding CLP methods outlined in the February 1988 CLP Statement of Work are compatible. Therefore, CLP forms and diskette deliverables can be used to submit data from RCRA mandated analyses. The software to accomplish this task is widely available. All of the major gas chromatograph/mass spectrometer manufacturers support data system form generation for organic analysis. Most of the inorganic instrument manufacturers also have software available.

The NTS has chosen to designate the CLP forms as the format for all organic and inorganic data submitted in defense of waste characterization. The use of an instrument-generated forms in a standard format has been found to have several advantages. The use of a standard format assures consistency and completeness and eliminates transcription errors which arise when data are written or typed on reports. It mandates that the laboratory submit all the quality assurance results which are needed for data validation. In the long run, this should result in NTS receiving better data which is less costly to validate.

ANALYTICAL METHODS FOR CLASSIFYING LOW-LEVEL RADIOACTIVE WASTE

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Introduction

The purpose of this paper is to describe analytical procedures used to classify low level radioactive waste (LLRW) streams for disposal as either class A, B or C LLRW in accordance with 10 CFR 61. The 10 CFR 61 regulations require LLRW to be classified based on the content of specific radionuclides in waste streams collected from nuclear stations. Such analyses are performed at the University of Michigan. When 10 CFR 61 was implemented, there were few procedures specifically applicable to LLRW streams from reactors, which contain a diverse array of radionuclides, sometimes in high concentrations. Because of this, we chose to adapt analytical procedures used for low-level environmental monitoring for classifying LLRW to waste stream samples. The measurements enable the nuclear stations to establish correlation factors to compare to direct measurements.

Table 1. Waste Classification 10 CFR 61.55

	CONCENTRATION LIMIT		
Radionuclide	Class A	Class B	Class C
H-3	40 Ci/m^3	(2)	(2)
C-14	0.8 Ci/m^3	---	8 Ci/m^3
Ni-63	3.5 Ci/m^3	70 Ci/m^3	700 Ci/m^3
Sr-90	0.04 Ci/m^3	150 Ci/m^3	7000 Ci/m^3
Tc-99	0.02 Ci/m^3	---	0.2 Ci/m^3
I-129	0.008 Ci/m^3	---	0.08 Ci/m^3
Pu-241	350 nCi/g	---	3,500 nCi/g
Cm-242	2,000 nCi/g	---	20,000 nCi/g
Alpha-TRU's[1]	10 nCi/g	---	100 nCi/g
Cs-137	1 Ci/m^3	44 Ci/m^3	4600 Ci/m^3
Co-60	700 Ci/m^3	(2)	(2)

1 Half-lives greater than 5 years
2 There are no limits established for these radionuclides in Class B or C wastes.

Table 1 lists concentrations of radionuclides that must be determined in order to establish how the waste will be classified according to 10 CFR 61 regulations. The concentration of C-14, H-3, I-129, and Tc-99 must be listed on all LLRW manifests. They are all pure beta emitters. The other key nuclides used in classification determinations are also either pure beta emitters or pure alpha emitters; thus, they are difficult to measure especially for each waste stream that may be shipped. Because of this difficulty, a technique of correlating the classification nuclides with readily measurable gamma emitters is used (as allowed in the Branch Technical Position on waste classification). The indirect method (use of scaling factors) for determining concentration of a radionuclide relates an inferred concentration of a radionuclide to one that has actually been measured, and the concentration is averaged over the volume or the weight of waste being disposed of. Cobalt-60, cesium-137, and cerium-144, are used to provide correlation factors with the beta and alpha emitters. Cerium-144, when present, is commonly used as the scaling radionuclide for transuranics because of similar behavior in reactor systems (EPRI 1494).

The specific nuclides for analysis were determined by those listed in Table 1, which is summarized from section 61.55 of 10 CFR 61. The beta emitters analyzed for include tritium, carbon-14, nickel-63, technetium-99, strontium-90, and iodine-129. Alpha emitting transuranic nuclides include americium-241, plutonium-238, plutonium-239 and 240, curium-242, and curium-244. Plutonium-241 is essentially a pure beta emitter, and has a relatively high concentration. for classification because of its short half-life (14.4 years) even though it is the precursor for Am-241, a more important alpha emitting nuclide. At the University of Michigan, we analyze for all of the nuclides listed in Table 1 and also for iron-55, which decays by electron capture, because this radionuclide can be a significant contaminant in low-level radioactive waste. Most wastes streams contain mixtures of the radionuclides listed in Table 1; thus, the classification is determined by the usual sum of fractions rule found in 10 CFR 61.55 paragraph (a)(7). Source types vary considerably which can compound the difficulties already presented by measuring the pure beta and alpha emitters necessary for classification. Table 2 is a generalized listing of the types of samples collected by nuclear power plants, and illustrates the variations of sample types that must be analyzed.

Table 2. **Sample Types & Average Weights**

Sample Type	Average Weight (grams)
Evaporator Concentrate	500
Reactor Water	500
Primary Coolant	500
CUNO Filter	1.0
DAW Smear	0.5
Filter Crud	0.1
Resins	0.1
Trickling Filter	0.05

The approach to a sample set begins before its arrival. At the receiving laboratory we specify sample sizes and forms to optimize analysis for the various radionuclides. Several different methods have been used for the collection of aqueous samples. For example, plastic bottles containing various treatment reagents have been supplied in the past to preclude plate-out of technetium-99 on the container wall. This method causes complications in the sample collection, so we now use glass containers coated with plastic. These plastic-coated glass safety bottles are used for the collection of aqueous samples and they prevent the loss of Tc-99, which can be as much as fifty percent for plastic containers, even before the samples arrive. It has taken some effort to convince the plants not to use plastic containers because of concern that containers might break during shipment.

The samples are collected at the plants over extended periods of time and the dates of collection are recorded for back calculation of measured values to time of collection. Upon arrival, the sample set is logged-in and each sample is given an identification code to clearly identify each sample throughout all analyses. Sample sets typically have widely differing sizes because of radioactivity levels, availability of sample, and access for sampling. Sample weights can vary anywhere from 0.01 grams to 500 grams. Because of the widely differing sample sizes, the range of counting techniques, and variations in chemical recovery, the LLD's can vary significantly. Obtaining representative samples is another problem. For example a single smear may represent barrels of dry active waste, and when this sample is divided into the five separate sections required for the various analytical procedures, accuracy of representation is doubted. A similar situation exists for resin analyses which may be based on a few beads because of the radioactivity levels present. Radioactivity levels are yet another problem, first to have sufficient volume and activity to quantitate all the radionuclides, and second not to have so much that everything becomes contaminated which can require starting over.

General Processing

The characterization of the samples begins with gamma analysis. Gamma analysis is perfomed on the whole intact sample except for higher activity samples for which weighed aliquots are analyzed. An intrinsic germanium detector with a 8096 multi-channel analyzer interfaced to a computer with peak search software is used for the analysis. The counting efficiency for the various geometry configurations is calibrated using multi-energy gamma standards obtained from Amersham Corporation, Analytics, Inc. and the U.S. Environmental Protection Agency's quality assurance program (each is traceable to the National Institute of Standards and Technology).

Upon completion of the gamma analyses, each solid sample is divided into five representative sections as seen in Figure 1. This step is especially important if the sample is a smear with only one-half of the smear contaminated with the sample. One of the five sections is pretreated by first ashing in a muffle furnace, followed by wet-ashing the remaining residue with perchloric and hydrochloric acid Liquids that contain residues, such as evaporator concentrate, are evaporated and then pretreated with nitric acid; these fractions are dissolved in 20 ml of distilled, deionized water and analyzed for the strontium-90, nickel-63, iron-55, and the transuranics. Clear liquids (i.e. with no solid fraction) are analyzed using aliquots taken directly from the waste container. Samples for iodine-129, carbon-14, tritium and technetium-99 analyses cannot be pretreated because to do so would drive off the activity to be measured; thus, specific aliquots for each analysis must be available.

Analysis of Beta Emitters in LLRW

Carbon-14 is analyzed by placing a portion of the actual sample in a tube furnace at a high temperature (800°C) to volatilize any carbon present, as shown in Figure 2. The volatilized carbon from the sample is passed through a quartz tube packed with copper oxide wire and platinum coated beads which act as a catalyst to ensure conversion of any C-14 present to carbon dioxide. The gaseous stream is passed through two bubblers filled with a bubbler solution specific for carbon dioxide. The bubbler solution is counted directly by liquid scintillation analysis set to discriminate against potential tritium contamination on the low energy range and

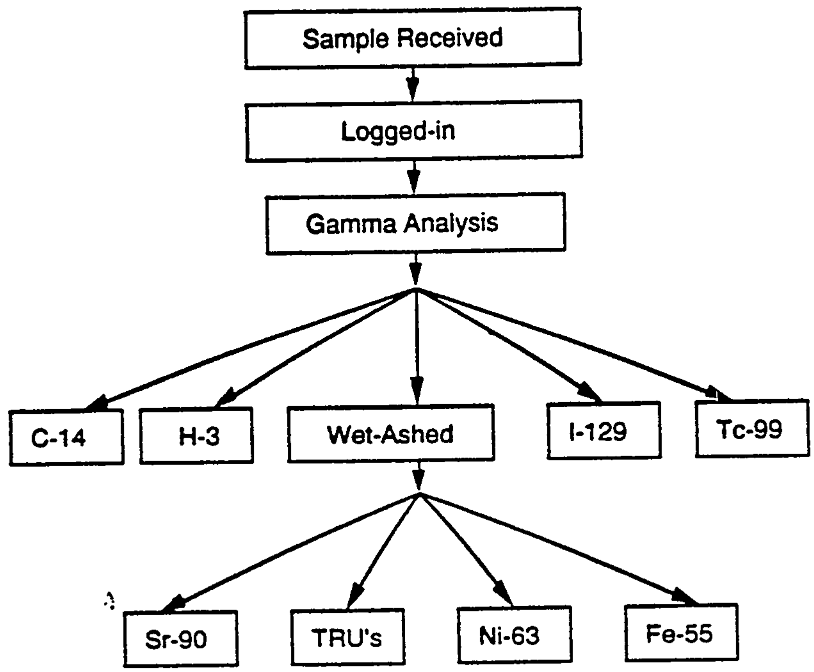

Figure 1. Flowchart of 10 CFR 61 Sample Analyses

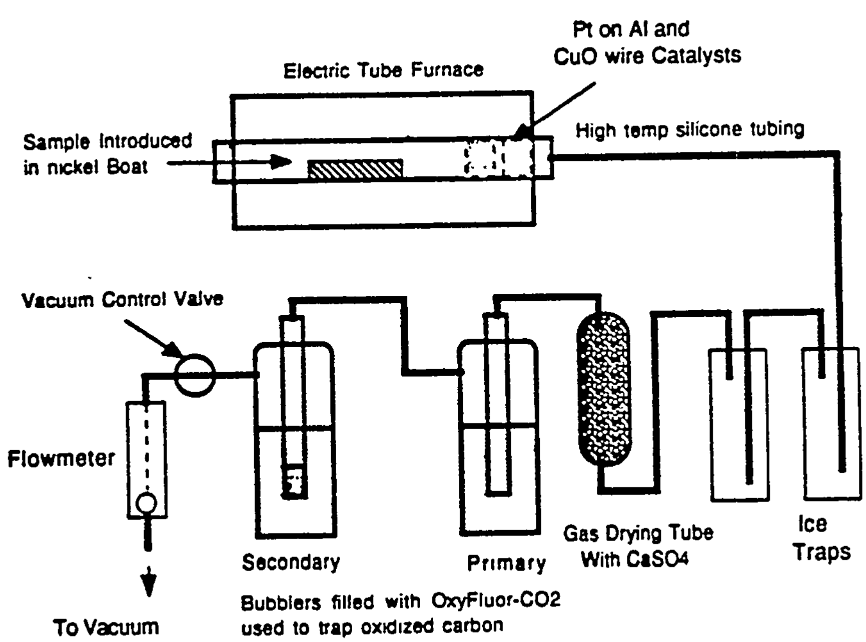

Figure 2. Diagram of the combustion furnace apparatus.

any other beta emitters with energy above the C-14 beta energy range. Counts in the upper energy window are used as a screening tool to indicate potential contaminants.

Resin analyses for C-14 can be difficult because of uncertainty in system recovery when resin beads are combusted in the tube furnace apparatus. Studies have been made of chemical recoveries for C-14 bound on resin beads available if C-14 is off-gased by the addition of 6M hydrochloric acid to regenerate the C-14. The regenerated gas is trapped in a cocktail specific for CO_2. This procedure was compared to that of oxidation of the resin sample in a high temperature tube furnace. The chemical recoveries for the off-gas procedure have proven reproducable and are comparable to or slightly higher than the tube furnace technique. (Grahn Masters thesis).

Tritium is analyzed by taking a weighed portion of the actual sample and preparing it for the separation from the other beta emitters by the complete distillation of the sample liquid. For solid samples water is added to absorb any tritium present prior to the distillation process. Figure 3 displays the actual apparatus utilized for this distillation. The distillate is combined with a water soluble liquid scintillation solution (Ultimagold-Packard Instruments) for counting in a liquid scintillation analyzer.

Technetium-99 is analyzed by ion exchangeseparation of Tc-99 from other interfering radionuclides. Technetium-99m is added for recovery determination. The recovery is based on counting an unprocessed standard and the processed sample for 10 minutes by a NaI MCA. The ratio of the two counts will be the chemical recovery. To determine the sample activity, the Tc-99m is allowed to decay so that it does not interfere with the Tc-99 counting, and the sample is counted for 50 minutes using a low-background gas-flow proportional counter.

Attempts to use methyl ethyl ketone (MEK) extraction have been unsuccessful both for replacing the ion exchange process and as a final cleanup step. A recent resin sample contained an unusual amount of activity which was determined to be contaminated with Cs-137 as well as Cs-134. These contaminants were carried over from the original sample and were not removed or separated by MEK extraction. Ion exchange also does not provide complete removal of contaminants; thus, it is necessary to use it with additional screening for the presence of contaminants by gamma spectroscopy and liquid scintillation beta spectra.

Strontium-90 is analyzed by a precipitation procedure with centrifugation to enhance precipitation of potential contaminants. Inactive carriers (strontium nitrate and barium nitrate in a solution of iron-yttrium carrier) are added to an acidic solution containing the actual sample. Barium is precipitated as barium chromate. The addition of iron hydroxide to the basic solution causes chromium, yttrium-90 and lanthanum-140 to be precipitated as hydroxides. In this method, all of the insoluble basic chromates and hydroxides are precipitated in one step following the initial centrifugation. This leaves only strontium in the form of strontium carbonate in the supernate. It is acidified with nitric acid to form an aqueous form of strontium nitrate which is transferred to a scintillation vial for liquid scintillation analysis using a water soluble liquid scintillation cocktail (Ultimagold).

The activity of strontium-90 is determined by measuring the ingrowth activity of yttrium-90 in the strontium precipitate and back-calculating the amount of strontium-90. Improvements that have been implemented in this procedure include the following: high percentages for chemical recovery, decreased analysis time, reduced volumes of mixed waste generated, a method for subtracting strontium-89 from the procedure and the removal of beta-emitting contaminants.

Nickel-63 is analyzed by extraction into chloroform after complexing with dimethylglyoxime in alkaline sodium citrate solution. Nickel is then back-extracted into HCl solution and transferred to a water soluble scintillation solution for LSA counting. The chemical recovery for nickel-63 is determined by performing the procedure on a set of standards of known activity.

Iron-55 is analyzed by radiochemical separation followed by photon counting. Since Fe-55 decays soley by electron capture, the only available radiations are characteristic x rays of 5.89, 5.90 and 6.49 keV emitted by the Mn-55 daughter. The samples can be counted with a germanium detector but there are some difficulties because of the low energy of the characteristic x rays emitted. This problem is dealt with by operating the germanium detector at high amplifier gain.

Samples are analyzed for iron-55 by complexing them with 20% triisooctylamine in xylene after washing with 6M hydrochloric acid. The iron is back-extracted into ammonium hydroxide and filtered. The filter is then placed onto a planchet, and the sample set directly on a high efficiency intrinsic germanium detector with the protective cap removed at high amplifier gain. The activity present is decay corrected to the date of sample collection.

Iron recovery is determined by performing the procedure with standards of Fe-55 of known activity A complication with this procedure has been that there has been contamination by Co-58. Since Co-58 emits characteristic x rays of essentially the same energy as those used to quantitate Fe-55, further research is being conducted to assure that the separation procedure is specific for Fe-55 (i.e. no Co-58 should be present as a contaminant). Samples are now screened by gamma counting for Co-58 contamination and the Fe-55 procedure will be run on cobalt standards to determine potential cross-contamination by the copious amounts of Co-58 generally present in the samples.

Iodine-129 is also performed by radiochemical separation and distillation (see Figure 4.) followed by neutron activation Natural iodine (100% I-127) is added for recovery determination. The iodine is distilled in air flow from an acidified aliquot of the sample and collected by bubbling through an alkaline solution in a receiver flask. The iodine is reduced and extracted into carbon tetrachloride. The iodine is then back extracted into H_2SO_3 solution. This is then irradiated in a neutron flux of 10^{13} n/cm^2-sec for five minutes. The natural iodine-127 captures a neutron to iodine-128 which decays with a 25 minute half life. The iodine-129 captures a neutron to iodine-130 which emits gamma rays with a 12 hour half life. The analysis of a beta emitter (I-129) is thus achieved by gamma analysis.

Analysis of Transuranium (TRU) Elements

Transuranic radionuclides in LLRW are analyzed by performing a series of extractions followed by measuring alpha spectra with a silicon surface barrier detector connected to a multichannel analyzer. Hydrofluoric acid is used to initiate the precipitation of the fluorides, and is precipitated by 0.5% sodium permanganate. The sample is filtered to separate the precipitates (containing americium, and other

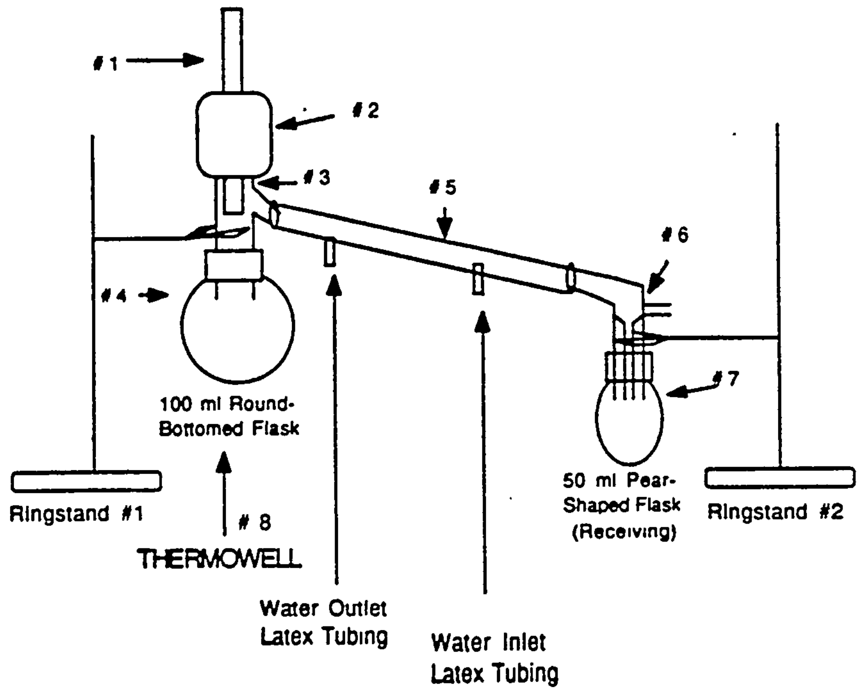

Figure 3. Tritium Distillation Apparatus

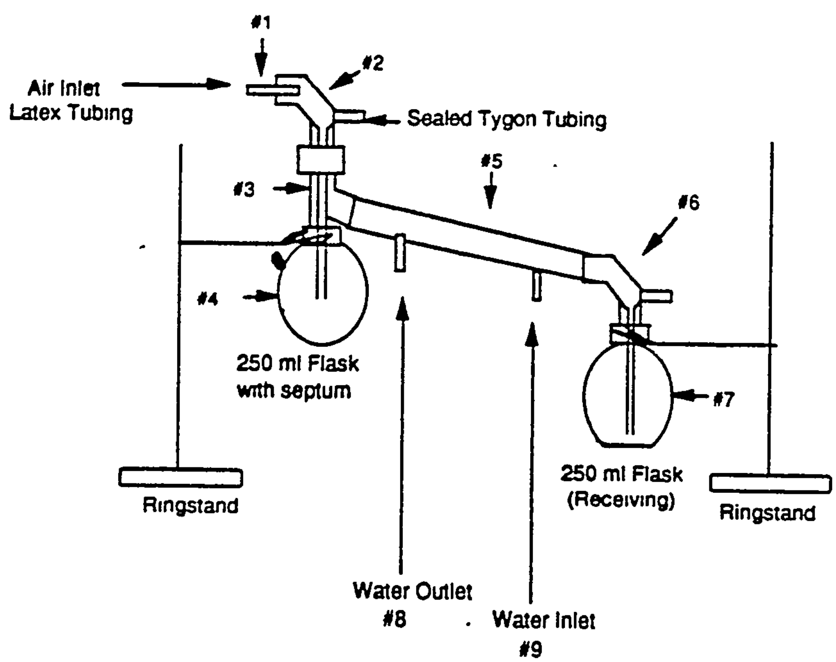

Figure 4. Distillation Apparatus for I-129 Analysis

non-oxidizable actinides, including curium) and the filtrate (which contains plutonium, protactinium, uranium, and neptunium.) The actinides in the filtrate (the "plutonium fraction") are oxidized by permanganate to the pentavalent or hexavalent states and do not form insoluble fluorides or carry isomorphously in the carrier lattice. Ferrous perchlorate is added to the filtrate to ensure complete reduction and precipitation of the plutonium and neptunium isotopes. The plutonium fraction is then precipitated with hydrofluoric acid and filtered. The recovery and detector efficiency are determined by performing the analysis on several known quantities of standard plutonium-239 and americium-241, and checked during sample processing by analyzing spiked "unknowns".

Plutonium-241 is analyzed by liquid scintillation counting of the plutonium separation fraction (of the transuranic separation for plutonium) since it is essentially a pure beta emitter. Because of potential contamination of the samples with Co-60, beta spectra are obtained with the liquid scintillation analyzer, and if present, that part of the Co-60 spectrum that overlapped the Pu-241 window is subtracted. This rarely happens now but was an earlier problem so we routinely screen for Co-60 to subtract it.

Sensitivity of Methods

Listed in Table 3. are the chemical recoveries and lower limits of detection (LLD) for a typical sample consisting of 4 grams counted for 1000 seconds. When it is possible, a sample larger than 4 grams is used; however, a much smaller sample size is generally the case in these analyses due to the size of sample that we receive. Furthermore, the counting time generally exceeds 1000 seconds because of the low sample activity present.

It is evident that the LLD's can vary significantly from one procedure to another, and this is especially true with the cesium, cobalt and cerium LLD's. The primary reason for the high gamma LLD levels is that the counting is conducted in a high background setting. On one side of the counting room is a research reactor and on the other is a powerful Co-60 source. The ideal setting for a germanium detector is in a well-shielded room free of excess background noise. Unfortunately, that is not an option for us at the present time.

Improvements and New Directions

The analytical techniques are sufficiently sensitive for classifying the wastes in the proper categories according to 10 CFR 61 because many of the techniques are adapted from environmental procedures. Our team at the University of Michigan is continuously working to improve the sensitivity and reliability of the techniques used. Research is ongoing with the C-14, Fe-55, Ni-63 and Tc-99 procedures. Because we handle such a broad range of sample types and activities, finding a suitable procedure that is reproducable and that is also capable of removing contaminants such as cesium and cobalt has proven to be quite challenging.

Quality Assurance

A top priority to our department and also to the nuclear stations that we service is that the characterization techniques for the analysis of low level radioactive waste sample be accurate, reliable and reproducible. To be able to accomplish this goal, the laboratory coordinator initiates a "paper trail" with each set of samples received. This documentation begins first by securing laboratory assistants that have been properly trained and are competent to perform the procedures necessary for a specific radionuclide identification; moreover, this training is validated by the use of NIST traceable standards and by the use of spiked samples which act as an unknown to measure chemical recovery and also to provide quality control. The use of blanks placed in a sample set is also frequently used to measure any contamination occurring during the course of analysis. The lab assistants are familiar with the specific procedure and the instrument(s) used enabling them to recognize when there are deviations from the expected behavior.

To perform these procedures satisfactorily, quality control programs have been initiated which document all analyses performed, when they are performed and by whom. All data sheets are reviewed and signed off by the laboratory coordinator and also the laboratory manager before any data is finalized. Because we are in a university setting with a small laboratory and limited financial resources, it is imperative that all personnel be well-trained and sensitive to the quality assurance aspects of all procedures performed. This sensitivity involves not only one's own data analyses, but keeping careful records of calibrations, defective instruments and instrument repairs, procedural updates, and any corrective action taken so that others in the lab benefit. Procedural and analytical changes must be well-documented from the arrival of a sample set to the completion of the final data report.

Table 3. Chemical Recoveries, LLD's

Radionuclide	Chemical Recovery	LLD (based on a 4 gm sample) pCi/g	Counting time (seconds)
Cs-137	100	350	1000
Co-60	100	560	1000
Ce-144	100	650	1000
H-3	86.1±0.22	1.2	1000
C-14	94.7±0.91	1.4	1000
I-129	22.0±3.30	50	1000
Tc-99	79.7±5.40	0.62	1000
Ni-63	7.50±0.04	8.7	1000
Sr-90	77.4±0.50	0.86	1000
Fe-55	96.6±0.69	39.4	1000
Am-241 & Cm-244 and Cm-242	88.1±2.50	.065	1000
Pu-239/40 and Pu-238	94.4±1.60	.034	1000
Pu-241	70.2±10.8	2.23	1000

Summary and Conclusions

An important concern to all utilities is cost. The complete analysis of a sample can cost from $2500-3000. Even though cost is an important factor in deciding how these analyses will be handled and by whom, the utilities themselves play an important role in obtaining representative data for the samples supplied. The importance of careful sampling technique cannot be overemphasized especially when a single smear will be representative of drums of dry active waste. Only by receiving proper training can nuclear employees fulfill their role in the cycle of 10 CFR 61 sampling.

From this paper, I hope you have gained insight as to why these chemical analyses are generally contracted off-site. The techniques are time and labor intensive, and in many cases an "art form". Meaning that procedural recoveries can vary significantly between lab assistants. To change a procedure from an art form to a reliable technique requires staff members to have adequate training and most importantly sensitivity to detail.

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PERFORMANCE ASSESSMENT

DEVELOPMENT OF REGULATORY GUIDANCE FOR PERFORMANCE ASSESSMENT OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES

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I. INTRODUCTION

A performance assessment (PA) analysis is needed to help demonstrate that a low-level radioactive waste (LLW) disposal facility will meet the performance objectives in Subpart C of 10 CFR Part 61, during the post-closure period. Given the long time frame covered by such an analysis and the complexity of the analysis, some amount of uncertainty is expected in the results. This is recognized in the 10 CFR Part 61 regulations. In particular, Part 61.23 states that an applicant must provide reasonable assurance that the performance objectives will be met.

Recognizing that uncertainties will exist in the results from PA analyses, the NRC has recommended that a reasonably conservative approach be taken in PA analyses (Starmer et. al., 1988, and Kozak et. al., 1990b). Incorporating conservativism into the analysis will help bound the results near the upper-end and thus provide greater assurance that the performance objectives will be met. This means that the results from any such analysis should not be taken as a prediction of the actual dose, but only as an indication of whether or not the performance objectives will be met. Overly conservative or worst case type analyses are not recommended as they will likely indicate that the performance objectives will be exceeded without providing meaningful information on the performance of the facility. The reasonably conservative analysis should have a sound technical basis to have confidence that the results truly represent the expected upper-bounds.

The NRC, through its Performance Assessment Working Group (PAWG), has established a Plan to develop guidance on undertaking a performance assessment of a LLW disposal facility. This guidance will address some key technical issues identified by the NRC which will likely have to be resolved by those undertaking PA of LLW disposal facilities. Suggested resolution of these technical issues and well-founded guidance on PA, will provide the framework for a sound technical basis for those undertaking PA analyses of LLW disposal facilities.

II. THE PLAN

The Plan established by the NRC PAWG can be broken into two phases as shown in Table 1. The phased approach has the advantage of allowing the incorporation of new scientific break-throughs in the study of PA. The PA area is still evolving as the scientific community gains better insight into the resolution of some difficult issues that still need to be resolved in PA, such as stochastic modeling, modeling radionuclide release, concrete performance, and validation of modeling results. Work in Phase I was initiated in 1991 and is projected to continue through fiscal year 1993 (FY-93). Work under Phase II will begin upon the completion of Phase I, and thus is not likely to begin until FY-94.

Table 1. NRC's PA PLAN

PHASE I	PHASE II
▪ Enhance NRC's PA capabilities - Mock PA exercise - Resolution of technical issues	▪ Resolution of additional issues ▪ Revision of guidance documents
▪ Development of PA guidance - Development of NUREG - Revisions to SRP - Development of TP - Development of REG-Guide	

A. Phase I

In the Plan, it is recognized that enhancement of NRC staff PA capabilities will best afford the NRC with the ability to provide guidance in the PA area. Therefore, the primary focus under Phase I of the Plan is to enhance NRC staff PA capabilities through the undertaking of a mock PA analysis. The mock exercise will provide NRC staff with a greater level of understanding of the phenomena and processes involved in LLW PA analyses, a greater understanding of the limitations of the various modeling approaches used in LLW PA, and a greater understanding of the sensitivity of key assumptions and variables used in PA analyses. The mock exercise will be carried out using actual site characterization data (to the extent possible) and actual inventory data, that are based on combined data from the three currently operating LLW disposal facilities. A hypothetical LLW facility consisting of vaults and trenches will be designed to accommodate the natural setting. Additional facility designs and settings will be incorporated into the analysis; this will allow a broader understanding of what needs to be considered in analyzing different types of facilities, in different types of natural settings.

During the exercise, only existing models and codes will be used; no new models or codes will be developed. Each of the submodeling areas identified in the Performance Assessment Methodology (PAM), developed by Sandia National Laboratories (SNL) under a technical assistance contract with the NRC, will be covered in the exercise (Kozak et. al., 1990b). The submodeling areas that will be covered, include: infiltration into the disposal facility, performance of the engineered barriers (i.e., cover and vault), source term (inventory and release), pathway transport (i.e., groundwater, surface water, and air), and dose calculations. The submodeling nature of the PAM requires the use of a multi-disciplinary team in its application. Therefore, the NRC, through its PAWG, will utilize a multi-disciplinary team approach.

The PAM developed by SNL is modular in that it allows the incorporation of different models to address each submodeling area. For example, either a one- or two-dimensional model can be used to analyze infiltration into the LLW facility. The modular approach gives the PAM robustness, which is needed to handle the various types of facility designs and geographical environments expected for LLW facilities. This modular nature requires a thorough understanding of the phenomena and processes involved with each submodeling area so that reasonable assumptions and limitations can be determined. It also requires an understanding of the integration of the various submodeling areas.

The PA exercise will be carried out, to the extent possible, to address the limitations of the PAM identified by SNL. Some of these limitations are: 1) infiltration modeling; 2) concrete/waste package degradation; and 3) radionuclide leaching (Kozak et. al., 1989a). It is recognized that the Phase I activities may be not capable of fully addressing all of these limitations, since only existing models and codes will be used; thus, some of these limitations will be more fully addressed in Phase II. An attempt will be made, through the PA exercise, to address some key technical issues identified by the NRC that will likely have to be considered by those undertaking PA analysis of LLW disposal facilities. Some of the technical issues identified by the NRC that may need to be considered, are questions relating to:

1. Conceptual model development.
2. The time-frame over which a PA analysis should be carried out.
3. Incorporation of the evolution of the site into the PA analysis.
4. Source term.
5. Dividing the source term among parallel pathways.
6. Accounting for uncertainty in the analysis.
7. Appropriate transfer coefficients to be used in dose models.
8. Performance of engineered barriers over time.

Again, full resolution of all of these technical issues is not expected during Phase I.

The second component of Phase I of the Plan is to develop guidance on PA. This guidance will be in the form of 1) development of a NUREG document; 2) revisions to the Standard Review Plan - NUREG-1200 (SRP); 3) development of a technical position document (TP); and 4) development of a regulatory guide (REG-Guide). This guidance will incorporate the NRC's position on resolving the technical issues previously identified. Limitations of the PAM addressed as part of the mock PA exercise will also be incorporated into the guidance documents.

Work on the SRP revisions and development of the TP will be undertaken simultaneously; this work is expected to be completed by the end of FY-92. Work on the REG-Guide development will begin upon the completion of the SRP revisions and the development of the TP.

NUREGs are documents published by the NRC. The NUREG, that will be published as part of this Plan, will document the mock PA exercise. It will serve as an example of the processes and considerations involved in undertaking a PA of LLW disposal facility.

The SRP provides guidance to NRC staff and Agreement State staff on the evaluation of license applications to construct and operate LLW disposal facilities. It also serves to improve license applicants and the public's understanding of the licensing process (U.S. NRC, 1988). Revisions to the SRP, as it relates to PA, will involve updating the subsections (i.e., 1-6) of Section 6.1. Section 6.1 covers safety assessment of radioactivity release from LLW facilities. Revision of Section 6.1 will provide improved guidance on analyzing a proposed LLW disposal facility to ensure that the performance objectives of 10 CFR 61 will be met.

The TP will provide a technical bases for the guidance provided in the revised SRP. It will also provide license applicants with acceptable criteria and technical bases for evaluating the performance of a proposed LLW disposal facility. The TP will also provide the foundation for the REG-Guide. The REG-Guide will be a more formalized version of the TP.

The guidance developed by the NRC will be based upon a wide range of sources to incorporate the latest and most technically sound information. All three guidance documents will utilize insight gained from the mock PA exercise. Results from research in the area of PA will also be utilized in development of this guidance. Table 2 shows a listing of the research that the NRC has or is currently funding in the area of PA. In addition, coordination efforts with other PA activities will also be used in the guidance formulation. Currently the NRC is coordinating with the DOE's PA activities and international programs PA activities (through the International Atomic Energy

Agency). These PA activities, along those currently being undertaking by several Agreement States may provide useful information which can be incorporated into the NRC guidance documents.

Table 2. NRC Funded PA Research

Research Group	Primary Area of focus
▪ Sandia National Laboratories	▪ Performance Assessment Methodology
▪ Pacific Northwest Laboratory	▪ Infiltration Evaluation ▪ Performance Assessment
▪ Idaho National Engineering Laboratory	▪ Performance of concrete ▪ Source term evaluation
▪ Brookhaven National Laboratory	▪ Source term evaluation
▪ Oak Ridge National Laboratory	▪ Dose Modeling
▪ National Institute of Standards and Technology	▪ Performance of concrete
▪ UC, Berkeley	▪ Performance of covers
▪ MIT	▪ Stochastic modeling
▪ U. of Arizona/New Mexico State University	▪ Las Cruces Trench Validation Study

B. Phase II

The full scope of activities for Phase II of the Plan has not been developed since it is anticipated that the results from the Phase I work will largely dictate what needs to be accomplished in Phase II. Currently, it is envisaged that work under Phase II will involve utilizing and developing more sophisticated models and codes (than those used in Phase I) to address those technical issues and limitations of the PAM not addressed in Phase I. As previously indicated it is anticipated that the Phase I activities will not fully address all of the technical issues identified by the NRC that will likely have to be considered by those undertaking PA analyses of LLW disposal facilities. Further, additional technical issues will likely be identified through the Phase I work.

During the Phase II work, current research in the areas of concrete performance, source term evaluation, and stochastic modeling should be at a point to help resolve or provide insight into the resolution of some of the more difficult issues not fully addressed during Phase I. New models and codes (particularly in the areas of infiltration evaluation, source term, and concrete performance) may have to be developed to address some of the limitations of the existing PAM.

The guidance documents developed under Phase I will be revised, during Phase II, to incorporate results and information from the Phase II activities. Section 6.1 of the SRP will again be revised to incorporate new NRC positions on resolving technical issues.

III. CONCLUSION

The NRC recommends that a reasonably conservative approach be taken in demonstrating that the performance objectives of Subpart C of 10 CFR Part 61 will be met. A reasonably conservative approach will provide greater assurance that the performance objectives will be met. However, even a conservative analysis should have a sound technical basis in order to have confidence that the performance objectives will indeed be met.

The NRC, through its PAWG, has developed a Plan for providing guidance to address some of the difficult technical issues which will need to be considered by those undertaking a PA of a LLW disposal facility. The guidance developed by the NRC will also address the limitations of the existing PAM. This guidance will help ensure that technically correct and credible results are obtained from PA analyses. And thus, provide greater assurance that the performance objectives will be met.

The Plan will be carried out in phases, which help ensure that guidance in the area of PA evolves with the evolving nature of the PA area.

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TREATMENT OF UNCERTAINTY IN LOW-LEVEL WASTE PERFORMANCE ASSESSMENT [1]

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ABSTRACT

Uncertainties arise from a number of different sources in low-level waste performance assessment. In this paper the types of uncertainty are reviewed, and existing methods for quantifying and reducing each type of uncertainty are discussed. These approaches are examined in the context of the current low-level radioactive waste regulatory performance objectives, which are deterministic. The types of uncertainty discussed in this paper are model uncertainty, uncertainty about future conditions, and parameter uncertainty. The advantages and disadvantages of available methods for addressing uncertainty in low-level waste performance assessment are presented.

INTRODUCTION

A low-level radioactive waste performance assessment methodology has been developed by Sandia National Laboratories (SNL) for use by the U.S. Nuclear Regulatory Commission (NRC) in evaluating license applications under 10 CFR Part 61 [Kozak *et al.*, 1990]. The purpose of the methodology is to allow NRC to conduct confirmatory analyses of a licensee's evaluation of postclosure impacts. This evaluation is meant to provide reasonable assurance that the performance objectives in 10 CFR Part 61.41 are not exceeded. These performance objectives specify that an offsite person may not receive a committed annual dose equivalent of more than 25 mrem whole body, 75 mrem thyroid, or 25 mrem to any other critical organ. The 25 mrem whole body objective has also been adopted by the U.S. Department of Energy (DOE) for low-level waste disposal under DOE Order 5820.2A, and has been proposed for the Environmental Protection Agency's (EPA) 40 CFR Part 193, which has not yet been promulgated. In order to assess compliance with the regulations, the performance assessment methodology developed by SNL consists of a set of models that are meant to represent a low-level waste disposal facility.

Uncertainties are an intrinsic part of any performance assessment. Uncertainty analysis is nothing more than an identification of how much or how little confidence the analyst has in his knowledge of the modeled system [Finkel, 1990]. The uncertainties in performance assessment have been classified as conceptual model uncertainty, mathematical model uncertainty, uncertainty about the future of the site, and parameter uncertainty [Davis *et al.*, 1990a]. The NRC's currently preferred approach to uncertainty in low-level waste performance assessment is to bound the uncertainties using conservative models and parameter values [Starmer *et al.*, 1988]. However, as part of our work to update, improve, and build confidence in the methodology, we are reassessing whether this approach to uncertainty analysis is appropriate and adequate.

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In the following sections, each type of uncertainty associated with performance assessment is discussed. For the sake of conciseness, we have lumped mathematical model and conceptual model uncertainty into the more general category of model uncertainty. For the sake of clarity, we have separated model and parameter uncertainty, although in some cases these two types of uncertainty cannot be completely distinguished.

MODEL UNCERTAINTY

The core of any model is its conceptual model. A conceptual model is a set of simplifying assumptions about the real system that can be used as the basis for a mathematical model, which in turn can be solved to estimate the variables of interest for a performance assessment. Simplification is necessary to represent the real system for the given well-defined purpose. The simplifying assumptions are derived from site-specific information and expert opinion, and include assumptions about the geometry of the system, spatial and temporal variability of parameters, isotropy of the system, and initial and boundary conditions.

Since models are simplifications of real systems, uncertainty is implicit in their definition. Many sources contribute to conceptual model uncertainty, including inadequacies in site-characterization data, misinterpretations of the data, and limitations of current models to describe the actual site adequately. In addition, models are most commonly developed by a single analyst or a small group of analysts using only their professional judgment to resolve available data into a model. The model is therefore often limited by the abilities and imagination of the developer, in addition to limitations in the available data. There may in general be a number of different models that are consistent with the data. In many cases, model uncertainty is the dominant type of uncertainty in a performance assessment: if an inadequate model is being used, uncertainty associated with the model input parameters becomes irrelevant.

Some have suggested that the formal elicitation of expert opinions may identify the initial uncertainties associated with the conceptual model [Kerl *et al.*, 1991; Kerl *et al.*, in press, Chhibber *et al.*, 1991a]. The primary advantage of this approach is the potential for developing an exhaustive number of possible alternative conceptual models that are consistent with available data. By broadening the base of expertise from which the conceptual models are developed, there is increased likelihood that a conceptual model will be included that captures some potentially adverse characteristic of the site, and to the extent possible, conceptual model uncertainty is addressed. The disadvantages of this approach include increases in cost and time and reduced flexibility associated with formalizing expert judgment [Bonano *et al.*, 1989].

An approach for the quantification of conceptual model uncertainty has also recently been proposed [Chhibber *et al.*, 1991a,b; Heger *et al.*, 1991]. The approach associates a probability with a given conceptual model, which is interpreted as a measure of the degree of belief that the conceptual model is appropriate for a given purpose. However, Chhibber *et al.* [1991a] recognize a number of difficulties in quantifying model uncertainty. Perhaps the most important constraint is that to apply probability theory, the models should be defined such that they are mutually exclusive, exhaustive, and independent. This difficulty seems insurmountable since all the conceptual models are based on the same site-specific data. Other difficulties arise when combining and aggregating expert opinion, and when incorporating new information into probability estimates. Given these problems, we conclude that this approach is an interesting area of research, but many significant issues need to be addressed before it can be considered for use in performance assessment.

Overall model uncertainty can be reduced, but not eliminated, by site-specific model validation. Site-specific data is the most defensible evidence for determining the reliability of a model, since it represents the real system to be modeled. However, as discussed by Davis *et al.* [1991], it is not practical to conduct validation experiments for the full range of conditions of interest in performance assessment because of time and funding constraints and because extensive testing at a site may interfere with the site's geologic integrity. Therefore, validation can be used to build confidence that the uncertainties are reduced to the extent practicable. In general, the appropriateness of any performance assessment model should always be determined based on site-specific validation.

Performance assessment models are often based on conservative assumptions. These assumptions are usually supported by rational arguments, or by modeling analyses that assume a specific conceptual model. However, the most convincing evidence of conservatism is site-specific observations, and such evidence should be sought at every opportunity.

Another approach to addressing conceptual model uncertainty is model intercomparison, which consists of comparing different models of the same processes. The models are different because they are based on different conceptual models (*i.e.*, they may not implement the physics or chemistry in an identical manner, or may have somewhat different assumptions). For instance, one might compare results from a one-dimensional, single layer transport analysis of radionuclide migration to results from a multidimensional, multilayer model. The intercomparison can be used to identify crucial assumptions in the two approaches to modeling radionuclide migration, and these assumptions can then be the focus of validation studies. Another example of intercomparison might be comparing a one-dimensional flow analysis with a multidimensional model. It should be noted that intercomparison is different from benchmarking, which is a comparison of computer codes that have the same conceptual model. Benchmarking provides confidence about the implementation of the model into a computer code, but does not provide any information about the appropriateness of the underlying conceptual model.

Model intercomparison does not provide as much confidence as model validation, since the comparison is between models, not between a model and experimental data. However, intercomparison can provide some confidence that the model is conservative compared to other possible models. This issue becomes important when there are multiple conceptual models that are equally consistent with available data. If the models cannot be distinguished from each other by acquiring additional site-specific data, then *each* of the models should be considered credible. The performance assessment must then be conducted using each model, and the results used to establish which model is most conservative. In general, it is not possible to establish conservatism of the model *a priori*. Conservatism among models can only be established by *a posteriori* comparisons of the calculated performance objective.

Besides the uncertainties associated with the underlying conceptual model, uncertainty in mathematical models arises from approximations required to arrive at a solution to the equations involved [Davis and Olague, 1991]. These approximations include truncations of mathematical infinite series, equation discretization, spatial discretization, and temporal discretization. Since numerical solutions are usually required that are implemented in the form of computer codes, there are also uncertainties associated with coding errors, computing limitations, and user errors. Both of these types of uncertainties are reduced with validation, since the complete model is being compared to the data. Benchmarking, verification, and quality assurance procedures can also be used to minimize uncertainties associated with implementing the models in the form of computer codes.

Current regulatory guidance on model uncertainty states that modeling must be defensible, and promotes the use of the appropriate amount of model detail that can be justified [Starmer *et al.*, 1988]. However, the current approach for determining defensibility is based on a blend of model intercomparison and expert opinion [Starmer *et al.*, 1988]. The blend of these approaches is informal, and the links between them are not completely clear. Furthermore, there has been very little discussion to date in low-level waste regulatory guidance about the use of validation to address model uncertainty. In our opinion, low-level waste performance assessments would benefit from a formal approach to addressing model uncertainty that includes the use of validation, model intercomparison, and expert opinion. Such a formal approach would increase the defensibility of analyses, and the consistency between analyses.

We recommend a process for reducing model uncertainty that includes five key aspects. First, a formal approach should be used to produce a broad spectrum of conceptual models that are consistent with data. At the present time, the only method available for this step is formal elicitation of expert opinion. Second, an iterative process of performance assessment modeling, data collection, and validation should be used to refine the model and to narrow the range of possible alternative models. Third, models that cannot be differentiated using available site-specific information should each be used in performance assessment analyses. Fourth, the conservatism of the performance assessment model(s) should be compared to real site behavior, if possible. Fifth, quality assurance procedures should be followed for code development and implementation.

We introduce a caution about this approach: the early steps should not be detached from the purpose of the performance assessment. The danger is that much effort may be expended toward processes that do not significantly affect the comparison with the regulatory performance objective. For instance, it may require much data to distinguish between two alternative models of unsaturated-zone flow, but if those models produce similar dose histories, it may not be necessary to distinguish between them. The solution to this problem is that performance assessment should be used at each step of the way to guide data collection, model refinement, and validation. By using performance assessment in this way, all efforts remain focused on the primary decision criterion: the regulatory performance objectives.

We also caution that this approach is not foolproof. Soliciting a broad range of opinion does not guarantee completeness in the resulting spectrum of models. Similarly, it is far easier during validation to reject a model than it is to accept one, and acquiring absolute confidence in a model from validation is impossible to achieve [Davis *et al.,* 1991]. However, since the purpose of performance assessment is to provide reasonable confidence, absolute confidence is unnecessary. Nevertheless, this overall approach is an improvement over current approaches, where little attention is paid to model uncertainty in low-level waste performance assessment.

UNCERTAINTY ABOUT THE FUTURE OF THE SITE

Uncertainty about the future of the site is the result of our inherent lack of knowledge about the future time evolution of the site. In the high-level waste arena this uncertainty is often accounted for by explicitly acknowledging possible alternative future scenarios. These possible scenarios are incorporated into performance assessment by assigning probabilities to each scenario. This approach was developed in response to the requirement in 40 CFR Part 191 that high-level waste performance assessment must include all significant events and processes over a period of 10,000 years. This requirement is not included in the low-level waste regulations (10 CFR Part 61 or DOE Order 5820.2A), and there is no regulatory guidance concerning the low-level waste performance assessment time period or how to account for future conditions at a low-level waste site. Hence, at the present time it is not clear what conditions need to be evaluated to meet the low-level waste regulations. Regulatory guidance is therefore necessary to identify conditions that need to be included low-level waste performance assessments. The guidance would promote consistency between analyses, which in turn will tend to make them more defensible.

Uncertainty about the future for low-level waste performance assessment is difficult to address because the regulation does not explicitly state a performance assessment time period or how to account for future conditions. Consequently, uncertainty about future conditions is not just a technical issue, but must be resolved by the regulators. The purpose of the following discussion is to provide possible approaches based on relevant technical information, from which regulatory decisions can be made.

In evaluating the proposed approaches, consider what the results of the performance assessment are intended to represent. The performance assessment is not a predictor of actual doses to an individual. Indeed, since the models tend to be deliberately conservative, the results are by definition not predictive. The results are therefore not to be taken as what *will* occur, but rather as an indicator of safety. This indicator should be optimized to evaluate the conditions of greatest concern.

One logical strategy would be to conduct the low-level waste performance assessment until the peak dose is obtained. Because low-level waste contains long-lived radionuclides (mainly ^{14}C, ^{129}I, ^{99}Tc, and the actinides), and because of the current emphasis on long-lived engineered barrier systems, this time period can become relatively long. Therefore, one approach would be to make assumptions about the long-term future and include these assumptions in the performance assessment modeling. The scenario approach mentioned above can be used to trace and justify assumptions about the future in a formal manner, and also addresses the uncertainty associated with the future by allowing for multiple scenarios.

There are two problems associated with using a scenario approach for low-level waste performance assessment. First, because most low-level waste sites are located near the land surface, surficial events and processes that could reasonably occur over long time periods may become important (*e.g.*, flooding, erosion, glaciation). Considering and modeling such processes would complicate low-level waste performance assessment significantly, and the main question becomes whether or not a near-surface facility can meet the regulations with these types of events and processes occurring. For instance, in many parts of the country, it is reasonable to assume that glaciation may occur within 10,000 years. Does that mean that glaciation should be included in a low-level waste performance assessment?

Second, since the scenario approach addresses uncertainty in the future, the result of applying scenario analysis is not a single dose, but rather a distribution of possible doses. The scenario approach identifies low probability events and processes that occur over long time periods. Because the occurrence of such events and processes is unlikely, the corresponding doses are also unlikely. Currently there is no guidance concerning how to compare a distribution of possible doses with the deterministic low-level waste regulations; therefore, the minimum that can be assumed is that the regulations cannot be exceeded. Consequently, the low probability doses are required to meet the low-level waste regulations. In other words, we must use the upper bound of the dose probability distribution function as the basis for comparison to the regulations. Including distant tails of the distribution results in focusing on low-probability events and processes, and the facility results in being designed for unlikely conditions, rather than more probable conditions. Viewed in the language of probability theory, to what extent do we want to include the tails of the probability distribution of doses when comparing to the deterministic regulation?

It is important to note that scenario definitions need to be self-consistent in evaluating the likelihood of human exposure. For instance, in the glaciation example above, there would clearly be a minimal probability of a well being drilled during the glacial period. The effect of these considerations will be to lower the probability of such exposure analyses, often to the point that they become so extreme that they can be eliminated from consideration.

The full scenario approach can be salvaged for use in low-level waste performance assessment by choosing an intermediate confidence limit for comparison with the deterministic performance objectives. For instance, the EPA provided guidance that suggested using the larger of the mean or median value of the probability curves for assessing compliance with the Individual Protection Requirement and Ground Water Protection Requirement in 40 CFR Part 191 [EPA, 1985]. Alternatively, the regulator may choose to use some higher confidence limit of the whole body dose probability curve to compare against the 25 mrem objective. This approach is self consistent, since all events and processes of possible importance are included, but it omits the low probability events, and focuses the decision maker's attention on more likely events. In light of all the immense uncertainties associated with performance assessment modeling, interpreting the deterministic regulation in this probabilistic manner, and explicitly acknowledging the associated uncertainties, seems to be the only viable way to assess compliance with the regulations.

Although this probabilistic interpretation of the deterministic standard overcomes the problems associated with including low probability events and processes, some near surface disposal facility will not be able to comply with the regulations for surficial events and process that may reasonably occur over long time periods. For such facilities, the regulator may then be constrained to limiting the inventories of the long-lived radionuclides that are permissible for disposal at the site.

Another possible approach to the time-frame issues associated with low-level waste performance assessment is to define an arbitrary, relatively short-term time period for determining events and processes to include in the performance assessment. This relatively short time period may not be sufficient for characterizing the peak dose because of the longevity of some constituents in low-level waste, as mentioned above. Also, because concrete barriers may last hundreds of years, use of concrete in low-level waste disposal facilities results in moving the peak dose past reasonably short time periods. This approach then becomes one of including events and processes that occur for an arbitrarily defined short time period, and extrapolating these conditions over long periods of time, for which it is not rigorously appropriate. However, analyses conducted in this way will be focused on events and processes that are likely to occur (*e.g.*, transport to a well), rather than highly uncertain events distant in the future. This approach is similar to the one suggested by EPA for assessing compliance with the Individual Protection Requirement and Ground Water Protection Requirement contained in 40 CFR Part 191: current conditions are assumed to exist for 1,000 years [EPA, 1985].

An example of this second approach would be to conduct the performance assessment using conditions that may be reasonably expected to occur during the first 100 years of the postclosure performance time period. This approach may be considered to be equivalent to modeling relatively minor perturbations about the current state of the site. Nevertheless, there arises the question of how large the perturbations should be. As an example, consider the rainfall at the site, which is important for assessing recharge, and hence, degradation rates of engineered barriers and release rates from the facility. There is an intrinsically probabilistic aspect in defining what rainfall will be included in the analysis, for rainfall is usually treated as being stochastically distributed in time. If the analyst decides to use the 100 year "maximum probable" precipitation year in the analysis, it should be understood that there will remain a finite probability that this value of maximum precipitation will be exceeded even during the first 100 years after closure, since the "maximum probable" event is actually based on some confidence limit that is less than 100 percent. If this value of precipitation is used as a basis for longer-term analyses, say for a 500 year analysis, the probability will increase that an actual annual precipitation will exceed this design basis precipitation. However, for the purpose of indicating safety, this may be adequate.

We conclude that there are two approaches that might be taken to quantify uncertainties about the site's future in the context of low-level waste regulations. The first approach is to conduct the performance assessment until peak dose, and to include possible future events and processes through a scenario evaluation. However, to use this approach in an appropriate way for decision making, the regulators must allow some low probability events that result in low probability dose estimates to exceed the performance objective. This approach would be completely self-consistent, and would focus attention on the appropriate (high probability, high consequence) issues. The choice of the particular value of the confidence limit for comparison with the low-level waste performance objectives is entirely a regulatory decision. Although the scenario approach provides a means for systematically treating future conditions at site and allowing for possible alternative scenarios, it is acknowledged that this type of analysis is not foolproof: any assumptions about the future are very uncertain.

The second approach is to define well-established design-basis conditions, in which only events and processes that are reasonable for a shorter time frame are included in the analysis. These conditions are then used to extrapolate to the longer time period needed to characterize peak dose. This approach has the advantage of focusing attention on the events and processes that are likely to occur in low-level waste performance assessment. It has the disadvantage that extrapolation of the design-basis conditions to longer time has progressively less physical meaning as the time period expands.

In closing this discussion, we again note that the resolution of these issues is entirely up to the regulator. The regulator may choose to follow either of these approaches, or an entirely different approach, depending on the particular regulatory philosophy applied. However, the most significant point is that some form of regulatory guidance is needed concerning uncertainty about the future state of the site for low-level waste performance assessment.

PARAMETER UNCERTAINTY

Parameter uncertainty relates to an incomplete knowledge of the model constitutive coefficients used in the performance assessment. In part, this uncertainty is identified with uncertainty in the actual values and the statistical and spatial distributions of data used to infer the model parameters. In addition, the parameters are not usually directly measurable, and, therefore, are commonly inextricably linked to a model. For instance, one cannot interpret an aquifer pumping test to evaluate hydraulic permeability without some assumptions about the geometry of the aquifer, or without an assumption about the constitutive behavior of the flow regime. Furthermore, one must also often invoke a complicated model to interpret the data. Therefore, while parameter uncertainty is frequently treated as being independent of other types of uncertainty, the types cannot be completely distinguished.

Extensive reviews of methods for propagating parameter uncertainty through models are given elsewhere [Doctor *et al.*, 1988; Doctor, 1989; Maheras and Kotecki, 1990; Zimmerman *et al.*, 1990]; hence, we will not provide elaborate details about them here. Instead, we focus on evaluating the approaches in the context of low-level waste performance assessment. That is, the information produced in the uncertainty analysis is to be compared against a fixed, deterministic performance objective.

To represent the effect of input parameter uncertainty on modeling results, the modeler must first quantify, then propagate the parameter uncertainty through the model to the model results. This may be accomplished in one of several ways. The most common approach is Monte Carlo analysis, which consists of selecting discrete sets of input parameter values from probability distribution functions of the input variables, running each set through the model, and constructing an output probability distribution function that quantifies the uncertainty associated with the input. Another approach is perturbation analysis (also called analytical stochastic models). This approach is similar to Monte Carlo analysis, where distributions in input parameters are used to estimate distributions in output parameters. However, based on simplifying assumptions, the model equations and solutions are derived with the probability distribution functions for the input and output parameters explicitly included. A third approach is to conduct "bounding" analyses, in which a clearly conservative set of parameter values is used to produce clearly conservative dose estimates.

The current NRC/SNL low-level waste performance assessment methodology is based on using bounding parameter values. In part, this approach was taken because of the intended use of the methodology. As mentioned previously, the purpose of the methodology was for the NRC to conduct confirmatory analyses of a license applicant's evaluation [Starmer *et al.*, 1988]. For this use, it may not always be necessary to conduct a full parameter uncertainty analysis, since the licensee should already have quantified the parameter uncertainty and identified a conservative set of model parameters.

Although bounding analysis was thought to be adequate for the NRC's purpose, in general there are several disadvantages associated with bounding analysis. First, to have confidence that a correct set of conservative input parameters is chosen, it must be compared with other likely sets of parameter values. In treating parameter uncertainty by a bounding analysis, it is assumed that the analyst can select the conservative combination of parameters *a priori*. In most cases, particularly for nonlinear models, this *a priori* identification of the bounding parameters cannot be done. Therefore, one would have to go through some analysis similar to Monte Carlo to estimate bounding parameters, and the advantage of bounding analysis (*i.e.*, simplicity) is lost.

A second drawback to bounding analysis is that using only a single realization of parameters reduces the amount of information available to the analyst and the decision maker. This can be illustrated by considering calculated dose distributions from two hypothetical sites, as shown in Figure 1. A bounding analysis would suggest that the two sites are similar: the standard is violated, and the maximum doses are comparable. However, there is clearly a distinction between the two cases. For Site A, there is a much higher probability that the standard has been violated, which suggests that many sets of possible parameters produce a violation. In contrast, fewer sets of parameters produce the violation at Site B. This suggests that more site characterization may be in order to attempt to narrow the input parameter distributions. Further site characterization is less likely to produce improvement in the analysis of Site A.

The goal of performance assessment should be to provide as much necessary information to the decision maker as possible. A model prediction should be provided along with an estimate of the associated uncertainty in order to maximize the information available to the decision maker [IAEA, 1989]. Furthermore, "no method based solely on point estimates provides the decision-maker with all the available information on the nature and extent of uncertainty, nor does it give decision-makers or other analysts a window into the process to identify and criticize the assumptions made therein" [Finkel, 1990]. Providing enough information so that it is easy to identify

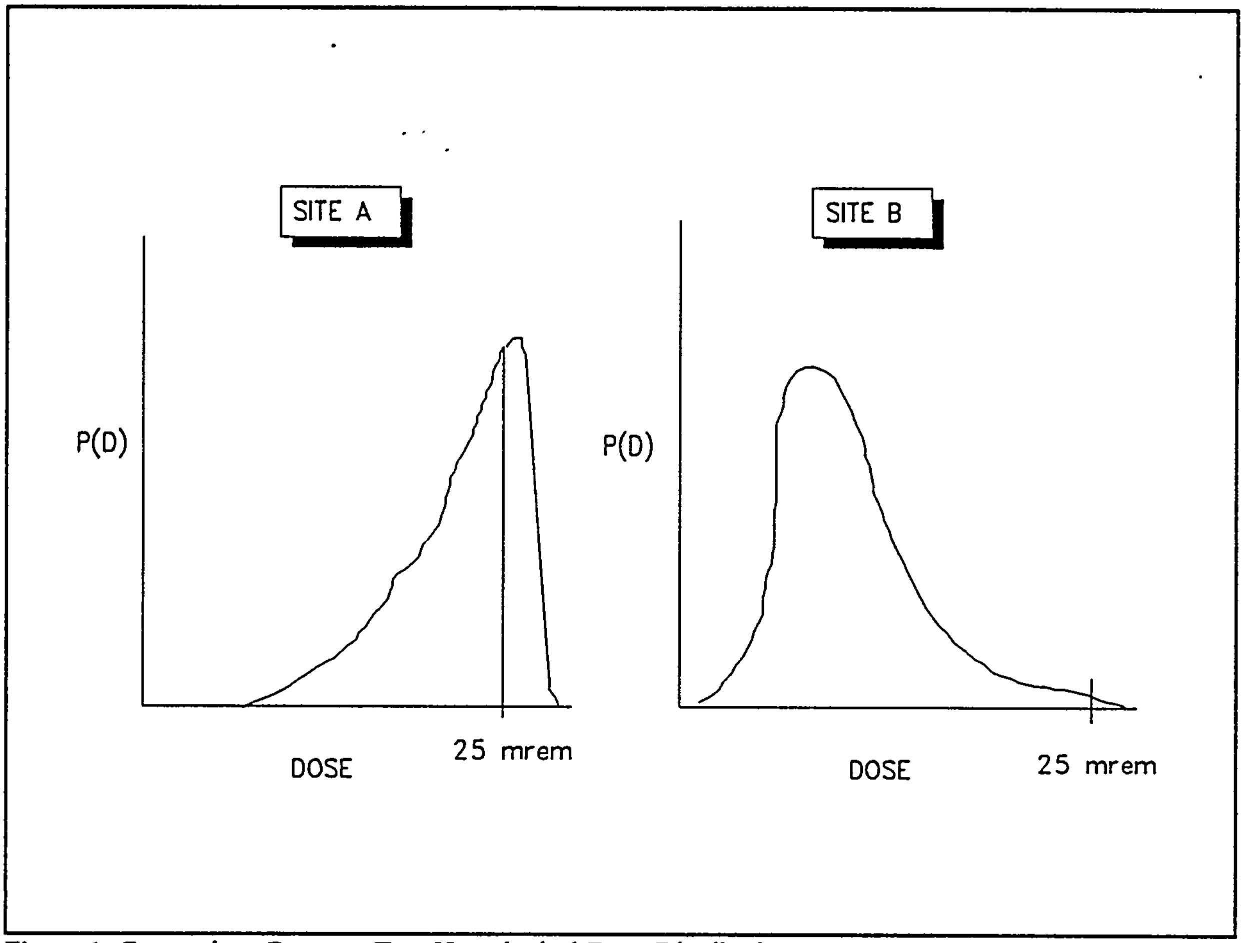

Figure 1: Comparison Between Two Hypothetical Dose Distributions

the modeling assumptions and associated uncertainties is important, since the ultimate goal is public acceptance. Not only is it important to present the decision-maker and the public with as much information as possible, but this information is also needed to guide data collection and validation efforts.

The above discussion suggests that while the use of bounding parameter values may be appropriate in some simple situations, in most practical cases the bounding parameter values cannot be specified *a priori*. Furthermore, the use of a bounding analysis limits the amount of information available to the analyst and decision maker. We therefore conclude that bounding analysis is *not* the best available method for parameter uncertainty analysis in low-level waste performance assessment.

As discussed by Zimmerman *et al.*, [1990], of the available techniques for parameter uncertainty analysis, Monte Carlo analysis is the most versatile because (1) it facilitates consistent propagation of uncertainties, (2) it can be easily applied to a series of linked models, such as are used in low-level waste performance assessment [Kozak *et al.*, 1990], (3) it does not require modifications to the original models; therefore, it is generally straightforward to use, (4) it is capable of dealing with large uncertainties in the input variables, since it allows full stratification over the variable ranges, and (5) it is appropriate for use with nonlinear models, in contrast to other popular techniques [Helton, 1990]. The primary advantage to conducting Monte Carlo analysis is that it provides model results from a large number of likely input parameter sets. Therefore, the output uncertainty is acknowledged, and there is some means for identifying whether the output uncertainty resulting from input parameter uncertainty has been bounded. Clearly, one has more confidence that the output has been bounded with increasing numbers of samples. Another advantage to this approach is that sensitivities of the model output to input parameter variations may be identified [Zimmerman *et al.*, 1990]; this allows the analyst to identify important model parameters for future data collection efforts. In this sense, it is consistent with our recommendation, given above, to use performance assessment to guide data collection.

The primary disadvantages that are usually cited for Monte Carlo analysis are that many realizations of the data are required to span the input data range, and that the parameters must be treated as uncorrelated [Harr, 1987]. However, both of these problems have been addressed. The required number of realizations can be greatly reduced through the use of a stratified sampling strategy, such as the Latin Hypercube Sampling method [Iman *et al.*, 1981]. Methods are also available that allow the analyst to introduce correlations among variables [Iman and Conover, 1982], and these methods are included in the computer implementation of Latin Hypercube Sampling [Iman *et al.*,1981].

An alternate approach to conducting parameter uncertainty analysis that has been proposed involves the use of analytical perturbation methods (analytical stochastic methods) for ground-water flow and transport calculations [Polmann *et al.*, 1988]. These models are often more numerically efficient than Monte Carlo analysis (i.e., require fewer realizations), although when Latin Hypercube sampling is used in conjunction with the Monte Carlo analysis, Monte Carlo analysis approaches the analytical perturbation methods in computational efficiency [Bonano *et al.*, 1987]. The available models contain a number of serious limitations (*e.g.*, normal input parameter distributions, small perturbations, highly uncertain correlation lengths, infinite domains), and we do not consider these models to be flexible enough or robust enough for use in performance assessment at this time.

As indicated above, the result of accounting for input parameter uncertainty, with the exception of bounding analysis, is a distribution of doses; therefore, the issues discussed in the previous section in relation to comparing a probabilistic answer with a deterministic regulation become relevant. As mentioned before, without any regulatory guidance, it is assumed that the fixed regulations cannot be exceeded. Therefore, the tail of the dose distribution obtained from accounting for parameter uncertainty must meet the deterministic regulations. An alternative approach, mentioned above, is to use some intermediate statistical measure of the dose distribution. This approach is comparable to the EPA's guidance that the basis for comparison between the deterministic Individual Protection Requirement (which is dose based) and Ground-Water Protection Requirement (which is concentration based) in 40 CFR Part 191 is the greater of the mean or median of the output variable distribution [EPA, 1985].

We recommend that for low-level waste performance assessment, parameter uncertainty analysis should be addressed using Monte Carlo analysis coupled with Latin Hypercube Sampling. This approach is used extensively, and has been recommended for high-level waste performance assessment [Davis *et al.*, 1990b]. Use of this approach will provide the decision maker with considerably more information relative to bounding analysis, and more importantly, it clearly acknowledges and communicates the large uncertainty associated with the model output variable due to input parameter uncertainty. It also provides some basis for assessing whether or not the model output distribution has been bounded. However, as discussed in the previous section, determining whether the complete dose history output distribution must fall below the regulatory performance measure, as opposed to some statistical measure of the distribution (*e.g.*, mean, median, 95 percent confidence limit) is entirely a regulatory decision.

SUMMARY AND CONCLUSIONS

Techniques for treating uncertainties associated with models, the future condition of the site, and parameters have been reviewed for applicability to low-level waste performance assessment. Special issues are introduced that relate to comparison of performance assessment results to a deterministic performance objective.

We recommend using a combination of expert opinion elicitation, validation, model intercomparison, and data collection to reduce model uncertainty. Model refinement should proceed by an iterative process of performance assessment modeling, data collection, and validation. It is recommended that, from a practical standpoint, the process be driven by performance assessment. In this way, resources will be efficiently allocated to the issues that most closely relate to the comparison with the regulatory performance objective.

Uncertainty about the future of the site poses peculiar problems in the context of current low-level waste regulations. These problems arise because of the indeterminate time scale for performance assessment and the deterministic performance objectives. To characterize the peak dose, the time scale may become fairly long. As the time scale expands, more processes become more likely, and fall into the category of "reasonable" events. One approach to quantifying these uncertainties is through the use of scenarios: this approach is used in high-level waste performance assessment. However, this approach requires consideration of events and processes that have a relatively low probability of occurring, and, therefore, produce dose estimates that have a low probability of occurring. A comparison against performance objectives that cannot be exceeded would require the facility to meet the regulation for these less likely events. This approach becomes more practical by using an intermediate confidence limit of the output distribution for comparison with the deterministic performance objectives. In this way, the low probability events are excluded, and the scenario approach becomes more appropriate for low-level waste performance assessment.

An alternative approach is to define a reasonable short-term time scale, and to incorporate only events and processes that may occur during that period, even if the analysis is carried out for longer times. Because of this extrapolation in time, this approach is not rigorous, but has the virtues of omitting highly uncertain events and processes that may occur in the distant future, and of focusing the analysis on more important assessment issues. However, there needs to be a clear limit established by the regulator on the magnitude of perturbations that are to be considered, even for relatively short term design-basis periods, to ensure consistency of treatment. This approach makes sense once one realizes that the performance assessment analysis is an indicator of safety, rather than a predictor of actual doses.

The decision about how to approach uncertainties about the future of the site must be resolved by the regulators because the issues are more closely related to regulatory philosophy than to definable technical concerns. We therefore make no recommendation about the appropriate approach.

To address input parameter uncertainty, we recommend using Monte Carlo analysis with Latin Hypercube Sampling. This approach acknowledges and communicates the uncertainty in model output due to model input, and provides a means for determining if the uncertainty in output has been bounded based on parameter uncertainty. The decision maker is provided with information about the distribution as well as the maximum dose from the analysis. The distribution may be used to identify qualitative differences between sites with comparable "bounding" behavior, to identify which may be suitable for further study, and should be used by the licensee to direct site characterization and validation efforts. Comparison of the model output distribution from parameter uncertainty with the deterministic low-level waste regulation is a strictly regulatory decision: the regulator may require the complete distribution to fall below the regulatory performance objectives, or may use some other statistical measure of the distribution as the basis for comparison.

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SOURCE INVENTORY FOR DEPARTMENT OF ENERGY SOLID LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES: WHAT IT MEANS AND HOW TO GET ONE OF YOUR OWN

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INTRODUCTION

In conducting a performance assessment for a low-level waste (LLW) disposal facility, one of the important considerations for determining the source term, which is defined as the amount of radioactivity being released from the facility, is the quantity of radioactive material present. [Reference 1] This quantity, which will be referred to as the source inventory, is generally estimated through a review of historical records and waste tracking systems at the LLW facility. In theory, estimating the total source inventory for Department of Energy (DOE) LLW disposal facilities should be possible by reviewing the national data base maintained for LLW operations, the Solid Waste Information Management System (SWIMS), or through the annual report that summarizes the SWIMS data, the Integrated Data Base (IDB) report. However, in practice, there are some difficulties in making this estimate. This is not unexpected, since the SWIMS and the IDB were not developed with the goal of developing a performance assessment source term in mind. The practical shortcomings using the existing data to develop a source term for DOE facilities will be discussed in this paper.

Two potential methods for arriving at a source inventory for DOE LLW disposal were investigated and rejected due to the unavailability of data. Originally, the intent was to investigate individual LLW production at several DOE sites and use the available data as a representation of the total source inventory. To calculate an effective dose equivalent from disposal facility operations, the individual radionuclides and the quantity of each must be identified. Due to differences in the environmental transport and in the dose conversion factors among the various radionuclides, summary reports of total activity are not particularly useful for a performance assessment. However, in investigating the potential for obtaining such data, it was discovered that, while the individual sites maintain tracking systems that differentiate among radionuclides, the are generally no comprehensive reports prepared that make the individual distinctions. Instead, the required annual reports are prepared from each data base, breaking the LLW activity into the SWIMS categories and not providing individual radionuclide distributions.

The other method of obtaining the source inventory information necessary for a performance assessment was to calculate, on a theoretical basis, the expected radionuclide distribution from DOE operations that generate LLW. Under this method, the probable radionuclide distribution in LLW from, for example, a plutonium or tritium production reactor, could be calculated, with the estimated activity used to develop ratios that could, in turn, be used to estimate the individual radionuclide activity from the reported total activity. The available information on solid LLW production, however, generally addresses commercial nuclear power plant operations, and not necessarily the type of production performed at DOE facilities. While some limited information is available through Safety Analysis Reports, Environmental Assessments, and similar documents, the level of detailed radionuclide distribution information necessary to conduct a performance assessment is not readily available.

Finally, the method chosen to report on the DOE LLW source inventory was to use the available data from the SWIMS and IDB, describing the type of information available for performance assessment purposes. The shortcomings of the available data for use in this particular application are also discussed, with emphasis on the activities that would be necessary to improve the data quality for performance assessment purposes.

HOW IS DOE LLW GENERATED?

There are some important differences between the DOE LLW streams and those expected from commercial nuclear power plant operation. Briefly reviewing the production of solid LLW in the DOE system may help to understand the development of a source inventory term.

One of the principal sources of LLW at DOE sites are the nuclear reactor operations. DOE reactors can be divided into two broad categories: production reactors and research reactors. While each of the two categories may be thought of as producing a distinctive radionuclide distribution, there are significant differences among the individual reactors within each category.

DOE production reactors are designed for the production of either plutonium or tritium. Due to the differences in the neutron environment inside production reactors as compared to nuclear power generating stations, the isotopic distribution in solid LLW generated from those facilities may be expected to be different from the more closely studied waste generated at commercial nuclear power reactors, particularly in terms of the presence and concentration of radionuclides expected to be significant in a performance assessment, such as transuranic isotopes. In addition, the relative yield of solid LLW from production reactors is different from that anticipated in commercial operations, and differs between reactors designed for production of tritium and those designed for plutonium. [Reference 2]

Research reactors have been operated by the DOE for a variety of research purposes, with various reactor core designs. The differences in design result in variations in the radionuclide distribution in LLW among the research reactors. For example, the High Flux Isotope Reactor at the Oak Ridge National Laboratory has been used to produce radionuclides that are not commonly available elsewhere, while experimental and gas cooled reactors have radionuclides in their LLW that are not commonly seen in commercial operations. With the plethora of reactor design and research purposes, defining a "generic" source inventory in LLW from research reactors for the purpose of conducting a performance assessment is not easily accomplished.

Other production operations in the DOE generate LLW streams with characteristics different from those normally encountered in commercial operations. Gaseous diffusion plant operations generate primarily uranium contaminated waste, weapons and components production operations generate alpha contaminated waste, and production of radioisotopes not commercially available generates unusual isotopic distributions, including radionuclides such as ^{153}Gd.

Research and development operations within DOE facilities also generate somewhat exotic radionuclide distributions, including projects such as the ^{233}U light water breeder reactor program, ^{252}Cf source production, and program for the production of isotopic power sources (e.g., power supplies using ^{144}Ce, ^{147}Pm, ^{228}Th, ^{232}U, etc.). In addition, the more routine fission products encountered in commercial operations may be produced in significant quantities, leading to more difficulty in meeting the performance objectives than would be expected at lower concentrations. These operations include the Waste Encapsulation Source Facility (WESF) operation at Hanford, which produced kilocurie quantities of ^{137}Cs and research and development in separations technology, which has produced megacurie quantities of ^{90}Sr in LLW.

Environmental restoration and decontamination activities generate wastes with varying radionuclide distributions, depending on location. Since all of the operations discussed above will eventually fall under some sort of decontamination or decommissioning function, each of the unusual waste streams will be encountered at least twice, once during routine operations and again during decontamination. The Formerly Utilized Sites Remedial Action Program, in which sites that processed uranium and thorium under the Manhattan Engineer District, is an example. From these sites, a significant quantity of uranium, radium, and thorium contaminated wastes will be generated. These wastes are not the typical fission product spectrum found in commercial or "routine" LLW. This can present difficulties in assessing the performance of disposal facilities, specifically in terms of environmental transport models and in dealing with background concentrations of the radionuclides.

DOE SOURCE INVENTORY

Prior to 1979, some DOE LLW was disposed of at commercial disposal facilities. Currently, LLW generated from DOE operations are disposed of on a DOE site, preferentially on the site at which the LLW was generated. For the purposes of estimating the DOE source inventory, the reported cumulative activity and volume of LLW disposed by DOE through 1989 was used. Estimates and projections are provided for the years following 1989. The small quantities of DOE LLW that have been disposed by sea dumping or by hydrofracture are not included in these summaries. Neither of these practices are currently in use. All data for this section was taken from the 1990 IDB report. [Reference 3]

The total volume of LLW disposed by DOE through 1989, summarized according to the facility at which the waste was disposed, is shown in Table 1. Figure 1 shows the same information, reported as percentages of the total activity disposed at each facility.

As a general rule, process knowledge plays an important part of all radioactive waste characterization, whether as the means whereby rough estimates of radionuclide distribution are made or as the mechanism for determining what radionuclides are likely to be present in the waste. Unfortunately in the DOE system, many of the processes, particularly the research and development functions, change radically over short time periods. This creates an additional uncertainty in determining the source inventory.

It should also be noted that the tracking systems on which performance assessments have been relying for radionuclide distributions do not include estimates of the uncertainty in estimating radionuclide concentrations. These uncertainties may be significant and could have a dramatic impact on the overall uncertainty analysis of a performance assessment.

Waste characterization is almost always an *a posteriori* evaluation, with the definition of radionuclide identity and concentration coming after the waste has been generated. Generally, documenting all, or more than 90%, of the activity in waste package is not systematically done. While operationally acceptable to do so, both from the perspective of the waste generator and the waste handler, the disposal facility operator must have somewhat more accurate and reliable data for a performance assessment.

ADDRESSING UNCERTAINTIES

For current inventories, or for the historical record of DOE LLW disposal, only a minimal amount of data validation is possible. In many instances, the operations that generated waste several few years ago have been altered or discontinued such that it is not particularly accurate to use the current waste characterization to estimate historic radionuclide distributions. Only limited quality assurance of the data base can be performed, since there are no reliable estimators to which it may be compared.

Reconstruction of original information for most waste packages is highly questionable, considering that many of the individuals who generated waste have since retired, left the DOE system, or have moved to other functions within the organizations. It would not be expected that an individual's memory of any specific waste package would provide more accurate information than is already available. However, it is possible that historic data may be supplemented through interviews with the waste generators, particularly in terms of estimating uncertainties and determining methods for improved radionuclide characterization.

The obvious conclusion is, therefore, that the existing source inventory data will essentially have to be used as it is. Limited improvements in the reliability may be achieved, and better estimates of the uncertainty in radionuclide characterization may be possible. However, significant improvements in the quality of the existing data should not be expected.

However, for LLW that is being generated now or will be generated in the future, there are several areas in which improvements could bring about a significantly better source inventory for performance assessment purposes. Waste certification programs are in various stages of development at DOE sites, and are being directed toward improving the accuracy, precision, and reliability of the source inventory for disposal facilities. A direct correlation between performance assessments and waste certification is required, starting with the development of performance based waste acceptance criteria and including evaluation and minimization of uncertainties in radionuclide characterization.

One common component of the various waste certification programs is that characterization is to be performed at the place and time the waste is generated and not after the fact. Some characterization and all verification will still be necessary through *a posteriori* waste characterization protocols, but the initial data must be generated at the location and time and preferably by the same individuals that are generating the waste.

To quantify the source inventory more accurately, some new methods for dealing with statistics are needed, particularly in dealing with uncertainties. More directly applicable methods, accounting for total uncertainty in the characterization data rather than assuming radioactive decay statistics dominate, are preferred. A few different approaches to developing such protocols are currently being developed. Other areas of statistics, such as hypothesis testing, also need to be more rigorously applied to LLW disposal in order to improve the reliability of the source inventory.

CONCLUSIONS

The source inventory for DOE LLW disposal facilities currently exists in a form that has been useful and appropriate to the operations of these facilities in the past. However, with the advent of performance assessments as an operational tool, more accurate and reliable estimates of the source inventory are required. Several activities have already been initiated to improve the identification and quantification of radionuclides in LLW, but more effort is needed, particularly in the areas of data management and concentration estimates.

REFERENCES

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2. J. E. Hammelman, et. al., Support Facilities Description for the New Production Reactor at Savannah River, (Draft), April 5, 1991

3. Oak Ridge National Laboratory, Integrated Data Base for 1990: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, October 1990

Table 1 Total Volume of Disposed DOE LLW through 1989

Site	Volume ($\times 10^4$ m^3)
Savannah River (SRS)	60
Hanford (HANF)	56
Oak Ridge (OR) Oak Ridge National Laboratory Y-12 Plant K-25 Site	43
Feed Materials Production Center (FMPC)	30
Nevada Test Site (NTS)	28
Los Alamos National Laboratory (LANL)	21
Idaho National Engineering Laboratory (INEL)	14
Others Pantex Plant Sandia National Laboratories - Albuquerque Lawrence Livermore National Laboratory Brookhaven National Laboratory Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant	3
TOTAL	255

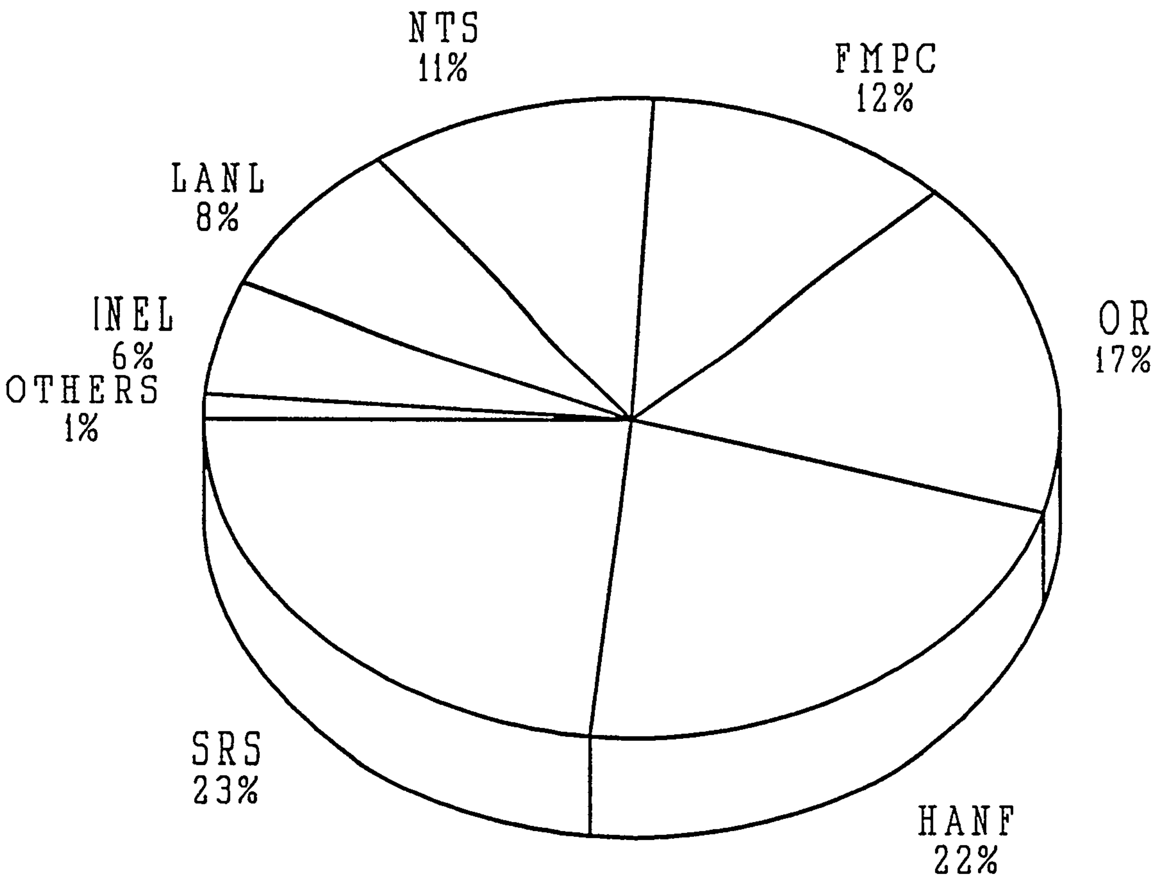
Figure 2 depicts the annual volume of solid LLW disposed since 1980 and the projected volumes through 2002. Note that these graphs are for the total reported volume of LLW disposal for the DOE system and are not summarized by facility.

The annual cumulative activity disposed at DOE sites is shown in Figure 3. This represents the total activity disposed and does not attempt to differentiate among radionuclides.

General radionuclide identification is available through the SWIMS, although the qualitative information is collected only according to the defined categories. In the data base, LLW is categorized as:

- **Uranium/thorium,** in which the principal radioactive contaminants are uranium, thorium, and other radionuclides with long half-lives,

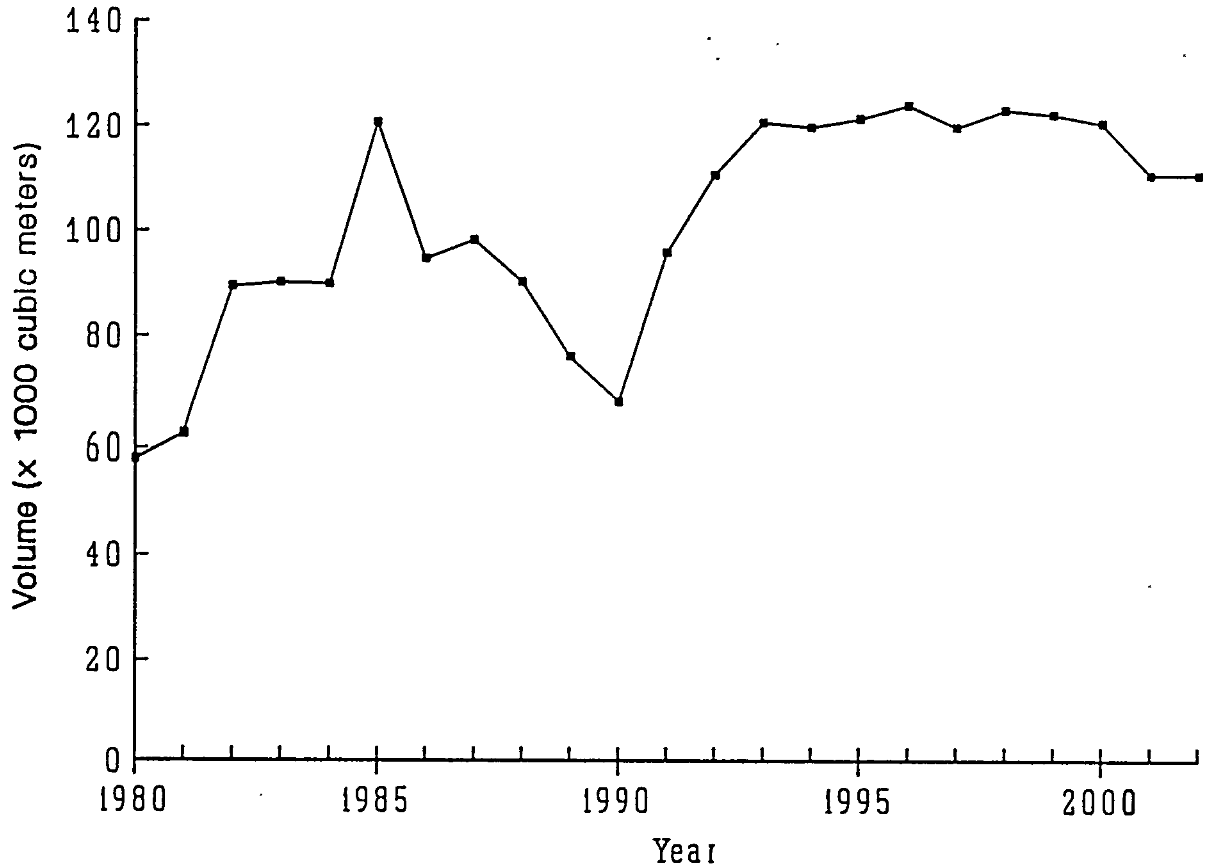
Figure 1 Total Volume of DOE LLW Disposed through 1989



- **fission product**, in which the principal radioactive contaminants are radionuclides with relatively short half-lives produced through uranium fission,
- **induced activity**, in which the principal radioactive contaminants are nuclides that have been made radioactive through activation, such as with neutrons,
- **alpha**, containing alpha-emitting radionuclides with atomic number greater than 92 and half-life greater than 20 years, and present in concentrations of 100 nCi/g or less (In effect, this category contains radionuclides that would make the waste transuranic waste if their concentration were greater.), and
- **other**, which are the LLW streams that do not fit into one of the other categories.

A representation of the radionuclide distribution in each of these categories is shown in Table 2, expressed as an activity percent for the particular category. These values are not empirically derived and are not necessarily precise and accurate. However, they have been used as a general estimate of the radionuclide distribution for the purposes of reporting disposed radioactivity.

Figure 2 Actual and Projected Annual Volume of DOE LLW Disposal



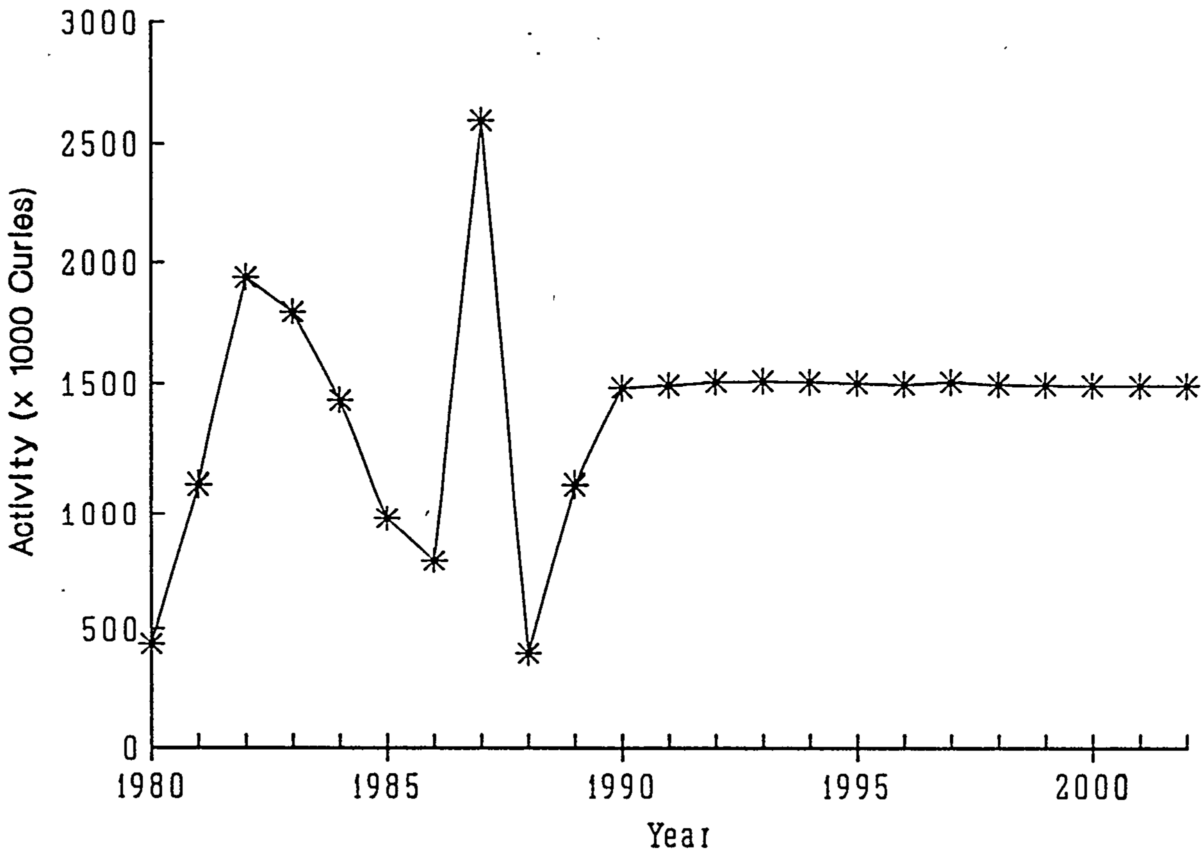
UNCERTAINTIES

Although the information presented above appears to be rather complete and relatively reliable, there are a significant number of uncertainties associated with this data in relation to attempting to establish a accurate, precise, and verifiable source inventory for use in a performance assessment of disposal facility operation.

Information for the SWIMS data base is generally collected by each site on a tracking form. Design and use of the individual forms is specific to each site, with many variations in format and content for the information collection process. The estimates of LLW volume disposed are likely to be reasonably accurate and reliable, since the volume estimates are usually based on the actual volume of the waste container. With effective methods of minimizing the void space within the package, the container volumes should be comparable to the net volume of waste.

In identifying the radionuclide constituents of a waste package, the information requested is couched in terms of the "principal (or major) radionuclides" present in the waste. There is no standard definition of "principal" radionuclides, although there are a few documents

Figure 3 Actual and Projected Annual Activity of DOE LLW Disposal



currently in the draft review cycle at some facilities that attempt to quantify the term. While this approach has been suitable for LLW disposal facility operation, it does not necessarily provide the level of information required to do a performance assessment. There are several radionuclides, such as ^{237}Np and ^{232}Th, that may not constitute the greater portion of a waste stream's contaminants, but may have a significant effect on estimating the potential effective dose equivalent resulting from the disposal facility operation. Because of their comparatively high dose conversion factors combined with increased environmental mobility, these radionuclides may alter the outcome of a performance assessment significantly, but may be missed in the reporting of "principal radionuclides."

Quantitation of the radionuclide content is problematic. Assuming that the radionuclides present can be effectively identified, determining their concentration within the waste package presents another set of uncertainties in establishing a source inventory for the disposal facilities. While nondestructive assay instruments are available for some waste forms and provide useful, reliable information under specified conditions, there are a great many radionuclides that are poorly characterized or not detected by nondestructive means. Sampling and analysis provides little improvement in reducing the uncertainty in

Table 2 Representative DOE LLW Radionuclide Distribution

Category	Radionuclide Contaminants					
Uranium/Thorium	^{234}Th	33%			Others	
	^{234m}Pa	33%			^{208}Tl, ^{212}Pb, ^{212}Bi,	<1%
	^{238}U	33%			^{212}Po, ^{216}Po, ^{224}Ra,	Total
					^{228}Ra, ^{228}Ac, ^{228}Th,	
					^{231}Th, ^{232}Th, ^{234}Pa,	
					^{235}U	
Fission Products	^{137}Cs	17%	^{106}Ru	6%	Others	<1%
	^{137m}Ba	16%	^{106}Rh	6%	^{60}Co, ^{99}Tc, ^{125m}Te,	Each
	^{144}Ce	15%	^{125}Sb	3%	^{134}Cs, ^{147}Pm, ^{151}Sm,	
	^{144}Pr	15%	^{95}Nb	3%	^{152}Eu, ^{154}Eu, ^{155}Eu	
	^{90}Sr	8%	^{95}Zr	1%		
	^{90}Y	8%				
Induced Activity	^{58}Co	55%	^{51}Cr	5%	Others	<1%
	^{54}Mn	38%			^{59}Fe, ^{60}Co, ^{65}Zn	Each
Alpha < 100 nCi/g	^{241}Pu	96%			Others	<1%
	^{238}Pu	3%			^{239}Pu, ^{240}Pu, ^{241}Am,	Total
					^{242}Cm, ^{244}Cm	
Other	^{137}Cs	18%	^{90}Sr	8%	Others	<1%
	^{60}Co	18%	^{90}Y	8%	^{238}U, ^{99}Tc, ^{14}C	Total
	^{137m}Ba	17%	^{54}Mn	7%		
	^{134}Cs	14%	^{58}Co	6%		
			^{3}H	1%		

for most wastes, since the most common solid LLW form is likely to be a heterogeneous accumulation of material that does not lend itself to representative sampling.

Some facilities use portable survey meters and dose-rate-to-activity conversion factors for quantitative estimates of radioactivity. These methods will not detect variations in certain radionuclides within the waste, particularly ^{3}H and ^{99}Tc, since there are no associated gamma emissions from those isotopes. In addition, radionuclides with a low specific activity and low activity wastes present a significant uncertainty with this technique, since the external exposure rate measurements are likely to be difficult to interpret in terms of the relationship to the total activity in the waste package.

EVALUATION OF THE DATA AVAILABLE FOR ESTIMATING RELEASE RATES FROM COMMERCIAL LOW-LEVEL WASTE PACKAGES*

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ABSTRACT

Information on the inventory, waste stream, waste form and containers used in LLW disposal has been obtained primarily from information compiled for the Nuclear Regulatory Commission (NRC) from shipping manifests which accompanied wastes disposed at the three currently operating commercial disposal sites (Barnwell, SC, Beatty, NV, and Richland, WA) during the period of 1987 - 1989. These data have been reviewed in order to determine the total activity distribution by waste class, waste stream and wasteform. The 1989 Richland shipping manifest data have been evaluated in more detail, including information on a radionuclide-specific basis. This Richland 1989 data have been compiled into a database that contains the waste stream, waste form, classification, half-life, annual limit for intake and activity for each radionuclide. Data from the other disposal sites and other years were insufficient for this grouping. This database has been compiled in terms of the distribution of activity for each radionuclide by waste stream and wasteform. This review evaluates these data in terms of the specific needs for improved modeling of releases from waste packages.

INTRODUCTION

Performance assessment of low-level waste (LLW) disposal facilities depends, among other things, on the ability to predict the rate of radionuclide release from the waste packages. For releases through the liquid pathway, modeling release rates requires knowledge of the length of time that the containers prevent water from contacting the waste form and on the waste form release characteristics which depend on the chemical form of the waste. Currently, most performance assessment methodologies treat release from the waste package in a general manner and take little account of the actual waste container/wasteform characteristics. To improve upon this, accurate data on the inventory, chemical form (i.e., waste stream and waste form), and container that comprise the waste packages are needed. This review evaluates the available inventory disposal data in terms of the specific needs for improved modeling of releases.

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Information on the inventory, waste stream, waste form and containers used in LLW disposal has been obtained primarily from information compiled for the Nuclear Regulatory Commission (NRC) from shipping manifests which accompanied wastes disposed at the three currently operating commercial disposal sites (Barnwell, SC, Beatty, NV, and Richland, WA) during the period of 1987 - 1989.[1] This NRC report provides a compilation showing the volume, activity, and radionuclide distributions of these wastes, and although some evaluation of the data is presented, the report was prepared primarily as a data source for use by others.

The 1989 Richland shipping manifest data[1] have been evaluated in more detail and compiled into a database that contains the waste stream, waste form, classification, half-life, annual limit for intake[2] and activity for each radionuclide. Data from the other disposal sites and other years were insufficiently detailed to permit such a grouping. This database has been evaluated in terms of the distribution of activity for each radionuclide by waste stream, wasteform and waste container.

In addition to reviewing existing manifest data, two other areas have been examined in terms of data sufficiency. These are: a) accuracy of the manifest inventory data for key radionuclides such as I-129 and Tc-99; and b) the availability of release rate parameters pertaining to cement solidification agents, sorbent materials, and key waste streams that frequently do not require a solidification/sorbent media.

In the next section of this paper, an overview of our findings concerning the distribution of activity within LLW will be presented. This will begin in a general fashion and consider the distribution of the total activity by each of the following: waste class, waste stream, wasteform, and waste container. A radionuclide specific breakdown by waste class and wasteform follows. The findings are reviewed in terms of performance assessment modeling needs. Finally, we present our conclusions.

DATA EVALUATION

After low-level waste has been generated it may be treated to, among other things, improve handling capabilities, remove free liquids, or provide radiation shielding. Some of the more widely used treatment options include stabilization in accordance with the stability criteria in the NRC's technical position on wasteforms,[3] solidification in an agent that is not required to have those stability properties, use of sorbents to remove free liquids, compaction and dewatering.

After treatment, the waste is placed in a container. For Class B and Class C wastes where the wasteform does not meet the NRC's stability criteria, a high integrity container (HIC) must be used. For other wastes, carbon steel drums or liners are typically used.

In reviewing the data from the three sites it became clear that the sites do not have a common manifest information system and they store data in different formats. The differences are discussed in detail elsewhere.[1,4] For this discussion, the two important differences that arise are:

Barnwell (operated by Chem-Nuclear Systems, Inc.) stores manifest information as summarized across entire shipments whereas Beatty and Richland (both of which are operated by U.S. Ecology, Inc.) record individual container information.

Waste streams are described differently, depending on the manifest specified by the disposal site operators. The U.S. Ecology sites have a more detailed breakdown on waste streams.

The net result of these differences is that considerably more detailed information is available on the waste delivered to the U.S. Ecology sites as compared to the Chem-Nuclear site. However, the Barnwell site received over 60% of the volume and 82% of the activity for the three year period under study. Consequently, some of the analysis discussed later on in this paper which are based only on the information at the Richland site in 1989 may not necessarily be representative of the nationwide data.

In reviewing the U.S. Ecology manifest forms it is noted that the wasteform is described by a numerical key to indicate if the waste stream is treated with a stabilization or sorbent media. Treatment of the waste is not typically required for several waste streams including equipment components, dewatered resins, dry active waste, and dry solids. In this case, the key indicates "none required" for the treatment option.

When treatment is used, ten different stabilization agents and twenty-three different sorbents were identified at the U.S. Ecology sites. To simplify the analyses, we have consolidated all of the cement-based stabilization agents into a single category which we call "cement." Similarly, the sorbents are all grouped into a category called "sorbents." Everything else is placed in the category "none required." For this analysis, the "cement" category does not include bitumen, gypsum cement, or vinyl ester styrene wasteforms. These three types of wasteform contributed much less than 1% of the total activity at the U.S. Ecology sites and have been included in the "none required" category.

Distribution of Activity and Volume by Waste Class

For the period of 1987 - 1989 the nationwide percentage of activity disposed of as Class C wastes was 73%. Class B wastes contained approximately 21% of the activity. Class A wastes contained the remaining 6%. Class A wastes were further categorized by whether the wasteform met the stabilization criteria in the NRC's technical position. 2.6% was classified as A-unstable and 3.4% was A-stable.

During this period, over 82% of the activity was disposed at Barnwell. Therefore, the Barnwell distribution is similar to the nationwide distribution. At the Richland and Beatty sites, the distribution was different. The majority of the activity was found in Class B wastes. Class A wastes were primarily A-unstable and accounted for 15% of the activity at Beatty and 8% at the Richland site.

In contrast, the majority of the volume (>96%) of the wastes are in Class A wastes. The volume of Class B wastes was 2.3% of the nationwide inventory and Class C wastes were contained in 0.75% of the volume.

A detailed breakdown of the volume and activity by waste class has been presented.[1] The distribution by activity for each site for the three year period is also presented in Table 1.

Table 1 Distribution of Activity by Waste Class at the Disposal sites for the years 1987 - 1989 (in Percent)

	Barnwell	Beatty	Richland	Total
A-Unstable	0.99	0.5	1.12	2.6
A-Stable	3.26	0.18	0.0005	3.4
A-Total	4.25	0.68	1.12	6.05
B	9.2	3.4	8.3	20.9
C	68.8	0.53	3.72	73.1
Total	82.2	4.6	13.2	100.0

Distribution of Activity by Waste Stream

One point one million curies were disposed at the Barnwell site from 1987 - 1989 in twelve different waste streams. Of these, only five contributed more than 1% of the activity. By far the most significant contribution (over 80%) to activity during this period came from waste described as "Equipment Components." Practically all of this waste stream was judged to be Class C. "Resin" wastes contributed over 12% of the total activity, but this activity was spread evenly over the three classifications, A, B, and C. Activity (principally Class B) of "Solid Non-Combustibles" comprised 4.7% of the total while another 1.4% was categorized as "Combustible plus Noncombustible" (again mostly Class B). "Filter media" contained about 1% of the activity. The other 7 waste streams contributed less than 1% of the total activity.

Sixty-two thousand curies were disposed at Beatty during the period 1987 - 1989 in twenty-one different waste streams. Over 81% of the activity was contained in waste described as "Dry Solid," 4% from "Non-Cartridge Filter Media," and 3.5% from "Solidified Resins." "Solidified Liquids" and "Evaporator Bottoms" each contributed about 3% of the activity but, for the latter, this was accumulated in just one year (1989). Other waste streams that comprised at least 1% of the activity were "Gas," "Activated Reactor Hardware" (1989 only), and "Compacted Dry Active Waste." Most of the "Dry Solid" was categorized as Class B; however, 10% of it qualified as Class C. All the "Activated Reactor Hardware" was Class C, as was about a third of the "Compacted Dry Active Waste" and "Solidified Liquids."

One hundred seventy eight thousand curies which came from twenty-two different waste streams were disposed at Richland over the same period. The major contributors to the activity were described as "Dry Solid" (45.9%), "Solidified Liquids" (24%), "Dewatered

Resins" (13.2%) and "Activated Reactor Hardware" (12.4%). The largest proportion of the combined activity of these four waste streams was Class B, but one of the waste streams ("Activated Reactor Hardware") was almost 100% Class C. "Filter Media," "Solidified Resins," and "Compacted Dry Active Waste" each contained between 1 and 2% of the total activity at the Richland site.

Normalizing the waste stream inventory information from each site to the nationwide inventory and combining activities from the three sites when appropriate (e.g., "Equipment Components" and "Activated Reactor Hardware") results in 67.5% of the activity in "Equipment Components," 12.3% in resins (Dewatered or Solidified), 9.8% in "Dry Solid," 3.9% in "Solid Non-Combustibles," 3.3% in "Solidified Liquids," and approximately 1% in each of "Filter Media," and "Combustibles and Non-Combustibles." This distribution by waste stream at the three sites is presented in Table 2. A detailed breakdown of the activity in each waste class, waste stream, and site can be found in Reference 4.

Table 2 Distribution of Activity by Waste Stream at the three disposal sites for the years 1987 - 1989 (in Percent)

	Barnwell	Beatty	Richland	Total
Equip. Comp[1]	65.8	0.08	1.6	67.5
Resins[2]	10.2	0.2	1.9	12.3
Dry Solids	-[3]	3.7	6.1	9.8
Solid Non-Comb	3.9	-	-	3.9
Solidified Liq	-	0.1	3.2	3.3
Filter Media	0.8	0.2	0.2	1.2
Comb + Non-Comb	1.1	-		1.1
Other				0.9
Total				100.0

[1] Includes Barnwell "Equipment Components" and Beatty and Richland "Activated Reactor Hardware" waste streams.
[2] Includes dewatered and solidified resins.
[3] A dash indicates that this waste stream identifier was not used at this site.

Distribution of Activity by Wasteform

Only limited information is available on the wasteforms disposed at the Barnwell site. That which is presented treats the waste in terms of volume disposed and not activity. A review of the data indicates that the volume percentage of wastes solidified in cement at Barnwell decreased from 14% in 1987 to 7% in 1989. "Solidified Liquids," "Resins," "Filter Media," and "Solid Non-combustibles" were the waste streams that had the most volume encased in cement. "Solidified Liquids" accounted for approximately 1/2 and "Resins" accounted for 1/3 of the volume in cement.

Approximately 80% of the activity disposed at Barnwell is in the form of "Equipment Components" and this waste stream does not typically require solidification. Therefore, less than 20% of the activity is solidified at Barnwell. Further, only 20% of the volume of "Resins" which contain 12.4% of the activity were solidified in cement. It is likely that less than 10% of the activity is disposed in cement-based material at Barnwell.

At the U.S. Ecology Sites information is available on the solidification and sorbents used to treat the wastes. Over 75% of the activity at Beatty was solidified in cement-based material during the period 1987 - 1989. 24% of the waste activity was in the category "none required" and 0.6% of the activity was treated with sorbents. At the Richland site, almost 71% of the material was contained in "none required," 27.7% was in "cement," and 1.5% was in "sorbent."

Assuming that 10% of the activity is stabilized in cement at the Barnwell site gives a nationwide average of 16% of the activity in cement. Approximately 1% of the activity is treated with a sorbent and the remaining 83% is in the category "none required."

Distribution of Activity by Waste Container

The Barnwell site records information by waste shipment and not container. Therefore, there is no information on the activity within each container.

At the U.S. Ecology sites the inventory is listed by container. However, the only information available on the container is the type (drums, boxes, cask liners, or others) and its volume. The container material and the thickness of the container wall are not listed. However, the manifest did specify if a HIC was used, but did not tell which type of HIC.

The number of containers received at the U.S. Ecology sites during 1987 - 1989 was 143,223. Over 75% of these had a volume of 7.5 ft^3, i.e., the volume of a 55 gallon drum. The range of container sizes was 0.02 - 1450 ft^3.

Although not reported in Reference 1, theoretically the manifest data could be used to determine the activity of each radionuclide within each container at the U.S. Ecology sites. The usefulness of this information is limited by the lack of knowledge on the container materials and thickness.

DISTRIBUTION OF INDIVIDUAL RADIONUCLIDES

During 1987 - 1989 almost 300 radionuclides were identified as being disposed of at the three disposal sites. Many of these have half-lives less than 1 year or have inventories less than 1 millicurie. In these cases, it is unlikely that the radionuclides will cause a significant dose to the general public. To prioritize the need to examine each of the 300 different radionuclides a screening criterion is needed. Such a criterion has been proposed.[4] This criterion takes the disposal inventory, multiplies it by a half life dependent factor, and divides the result by the maximum annual limit for intake recommended for radiation workers.[2] The exact expression is discussed in Reference 4.

For this paper, we will divide the radionuclides into two classes according to their half-life. The dividing point for the classes will be the half-life of Cs-137. Radionuclides with a half-life less than or equal to that of Cs-137 will form one class. The reason for this distinction is that the shorter half-life class will undergo substantial decay during the 300 year period required for structural stability of the wasteform/container system. Further, as we will show, the distribution of radionuclides with a long half-life is markedly different than for those with a short half-life.

In this analysis, the screening criterion was applied to the Richland, 1989 data as this was the only data that contained a detailed breakdown of the inventory by waste stream and wasteform. The following radionuclides were determined to have the highest ranking for the short half-life class: Sr-90, Cs-137, Co-60, Cs-134, Fe-55, and H-3. These radionuclides contain more than 94% of the activity. It is interesting to note that tritium had over 60% of the inventory at Richland during 1989, yet it ranks sixth on the list due to its higher maximum annual limit for intake. For the long half-life class, Th-232, U-238, Ra-226, C-14, Am-241, Pu-239, I-129, and Tc-99 were identified as radionuclides with a potential for a large impact on performance assessment. The activity of all of these nuclides comprise 0.5% of the inventory. Ni-63 which contains the bulk of the long half-life group activity, approximately 2% of the total inventory at this site, did not make the list because of its relatively high annual limit for intake.

Distribution of Radionuclides by Waste Class

In 1989 at Richland, 6.6% of the activity was class A-unstable waste. For the short half-life group, this distribution was approximately followed. The percentage amount of 5 of the 6 radionuclides identified earlier ranged between 2 and 8%. There was no Class A Sr-90. In contrast, for the long half-life group, most of the activity is Class A-unstable. 100% of the Th-232 and U-238 are in this category. 74% of the I-129, 62% of the C-14, 43% of the Ra-226, and 38% of the Tc-99 are also Class A-unstable.

Distribution of Radionuclides by Wasteform

As previously discussed, a review of the data indicated three major classes of wasteform: "cement," "sorbent," and "none required." The distribution by wasteform follows.

At the Richland disposal site in 1989, only 3% of the activity was solidified in cement. This contrasts markedly with the previous two years when over 50% of the activity was contained in cement. For the short half-life group, with the exception of Cs-134 which had 8% solidified in cement, the others had less than 4% in cement. The distribution of the long half-life group was markedly different. Over 60% of the Ra-226, 40% of the C-14 and Am-241, and 27% of the U-238 are in cement.

The amount of wastes treated with sorbent amounted to 1.6% of the activity in 1989 at Richland. Essentially none of the short half-life radionuclides considered received this treatment. Fe-55 had 0.9% in sorbents and all of the rest had less than 0.5% treated with sorbents. The opposite was true for the long half-life group. Over 80% of the Th-232 was treated with sorbents, as were 15% of the I-129, 6% of the U-238 and C-14, and 4% of the Tc-99 and Am-241.

The amount of activity in "none required" wasteforms was greater than 95% during 1989 at the Richland site. For the short half-life group, Cs-134 had 92% of its activity in this category while all others had more than 95%. Most of the long half-life group also had the majority of their wastes in the "none required" category. However, most were far less than 95% and only 14% of the Th-232 was in this category.

The distribution of these fourteen radionuclides by waste class and wasteform is presented in Table 3. For each nuclide, the final three columns total 100%. For this data set, wastes that are not Class A-unstable are either Class B or Class C.

Table 3 Distribution of Radionuclides disposed at Richland in 1989 by Class and Wasteform (in Percent)

Long half-life group	A-Unstable	Cement	Sorbent	None
C-14	62.4	43.3	5.9	50.8
Tc-99	37.6	0.0	3.9	96.1
I-129	73.8	0.4	15	84.6
Ra-226	42.8	62.4	3.6	33.9
Th-232	100	5.0	80.5	14.5
U-238	100	27.3	6.1	66.6
Pu-239	12	2.6	3.5	93.9
Am-241	32.8	41.3	4.6	54.1
Short half-life group	**A-Unstable**	**Cement**	**Sorbent**	**None**
H-3	4.0	4.0	0.4	95.6
Fe-55	7.3	1.6	0.9	97.5
Co-60	7.8	3.3	0.5	96.2
Sr-90	0.0	0.0	0.0	100
Cs-134	4.7	8.1	0.1	91.8
Cs-137	2.0	2.0	0.0	98.0

DISCUSSION

Availability of Release Rate Data

The fact that 83% of the commercial waste disposed of in the U.S.A. for the three-year period is in the form "none required" indicates that information is needed on the release characteristics of the waste streams. The waste streams that typically do not require treatment include "Equipment Components," "Dewatered Resins," "Dry Solids," "Solid Non-Combustibles," and "Combustibles and Non-Combustibles." Each of these waste streams contribute more than 1% of the nationwide inventory.

Unfortunately, there is very little information on the release rate from any of the above waste streams. Therefore, the modeler is left to guess this key parameter. In some cases, the release rates are expected to be quite low and their value may be estimated from other systems. For example, "Equipment Components," which contain over 67% of the nationwide activity, are often made of stainless steel which is known to corrode slowly in soil systems. Similarly, the release rate of stainless steels in concrete vaults characterized by high pH may be estimated by rebar corrosion data. However, there will be a high degree of uncertainty in applying corrosion data taken from one system to another system because of all of the uncontrolled variables that may influence corrosion. Further, the possibility of preferential release of constituents has not been examined.

Other waste streams, e.g., "Dry Solids," "Solid Non-Combustibles," and "Combustibles and Non-Combustibles," are poorly defined at this time. These waste stream descriptions are inadequate for modeling purposes because they do not define the physical and chemical form of the waste. Therefore, the modeler is left with the need to conservatively estimate their release rates. These waste streams contain approximately 15% of the nationwide inventory.

For waste streams treated with sorbents, once again there is little information on release rates from these wasteforms. Many sorbents are essentially inert fillers, e.g., diatomaceous earth and silicates, and will have only a minor effect on the release of radionuclides. However, this question has not been experimentally addressed. Although only 1% of the total inventory is treated with sorbents, knowledge of release rates may be important because many of the long-lived radionuclides are treated with sorbents. For example, 80% of the Th-232 disposed at Richland in 1989 was treated with a sorbent and was Class A-unstable.

For waste streams solidified in cement, approximately 16% of the nationwide activity, there have been a large number of leaching experiments conducted. This experimental database is heavily focused on Cs, Sr, and Co. Unfortunately, as shown previously, only a small fraction of their inventory is solidified in cement. Furthermore, performance assessment calculations indicate that these nuclides generally do not significantly contribute to the dose to man. The long-lived nuclides which often contribute to the dose to man and were contained in significant fractions (at Richland in 1989) in cement include C-14, Ra-226, U-238, and Am-241. However, there is very little information on the release rates of these elements from cement waste forms.

Even though there is a substantial database for leaching of several radionuclides from cement, there may be a high degree of uncertainty in the release rate parameters. Typically, diffusion is believed to be the rate controlling process from cements. The measured apparent diffusion coefficients for a single nuclide in different cement formulations may vary by several orders of magnitude depending on the cement aggregate, water-to-cement ratio, the presence of chelating agents or other factors.[5] Therefore, care must be exercised if the modeler uses diffusion coefficient values taken from the literature on a system that differs from the one under study.

Inventory

The inventory data presented in this report are from the shipping manifests received at each of the three disposal sites. These data have been taken to be exact and no attempt has been made to determine the actual accuracy.

In practice, it is likely that the activity level of the radionuclides that are major contributors to total activity (e.g., Cs-137, Sr-90, Co-60, H-3, etc.) are measured with a reasonable degree of accuracy. These radionuclides are usually detected directly and occur at substantial levels. However, the activity of minor radionuclides such as Tc-99 and I-129 have a large degree of uncertainty in their measurement. The activity level of these radionuclides are often near or at detection limits and are often estimated by scaling ratios with other radionuclides.

These scaling ratios for Tc-99 and I-129 from power plant ion exchange resin wastes are believed to be at least 2 - 4 orders of magnitude too large.[6] Therefore, their estimated inventory in these wastes are 2-4 orders of magnitude larger than their actual inventory. During the period 1987 - 1989 over 95% of the I-129 and 66% of the Tc-99 came from power plant wastes. Much of this activity was contained on resins.

I-129 and Tc-99 are important contributors to the dose to man for many release scenarios from LLW disposal sites because of their high mobility and long half-lives. In many scenarios, I-129 is the leading contributor to the dose to man. If their inventories are incorrectly overestimated by a few orders of magnitude, as believed for power plant wastes, the predicted dose will be overestimated by a similar amount. For this reason it is crucial to obtain accurate measurements of the activity levels for these isotopes from all sources.

Container Lifetime

As a minimum, the container thickness and material, e.g., carbon steel, stainless steel, HDPE, etc., must be known before an estimate on container life time can be made. This information is not available from the shipping manifests. Therefore, estimates on container lifetime are at best educated guesses.

Distribution of Activity by Waste Container

In general, a HIC is expected to prevent radionuclide release for a longer time period than a carbon steel drum. Therefore, when modeling releases, it would be appropriate to know the distribution of radionuclides by container. The activity in a particular container is reported on the U.S. Ecology manifests, however, it is not available in Reference 1.

To portion the radionuclides into containers with the available information, the modeler must make assumptions for everything. For example, a) Class A wastes could be assumed to be in carbon steel containers; b) Class B and C wastes with a waste treatment option of "none required" could be assumed to be stored in HIC's in order to meet the structural stability requirements in 10 CFR 61; and c) Class B and C wastes with stabilized wasteforms could be assumed to be placed in carbon steel liners, etc. However, the usefulness of these assumptions is limited by lack of information pertinent to estimating container lifetime.

CONCLUSIONS

The available radionuclide data for 1987 - 1989 inventory received at the three commercial disposal sites have been evaluated in terms of the distribution by waste stream, wasteform, and waste container. These data were reviewed in an attempt to determine data needs for performance assessment modeling.

The distribution of activity by waste stream and wasteform differ dramatically from site to site and year to year. For this reason, whenever possible, the three-year average for all three sites was used in determining the distribution of the radionuclides. This was not possible for the detailed breakdown of each radionuclide by wasteform and waste stream. In this case, only the Richland 1989 data were sufficiently detailed.

Based on our review the following improvements to the database are needed to improve performance assessment:

a) There is a need for an improved shipping manifest. The manifest should include more information on the container, e.g., the container material and thickness. The information provided is insufficient for estimating the time that the container prevents moisture from contacting the wasteform. Also, the distribution of radionuclides within each container should be available. Currently, any attempt to determine the distribution of radionuclides within a class of containers (e.g., HIC, carbon steel drum, etc.) requires significant assumptions. This information could be obtained through better record keeping on the shipping manifest.

b) Better characterization of the wasteform is required. Over 83% of the activity of wastes in this country are disposed in "none required" wasteforms. When treatment of the wastes are not required, once the container is breached, the untreated waste becomes the barrier to release. There is little information on the release parameters appropriate for untreated wastes, e.g., "Equipment Components," "Dewatered Resins," "Dry Solids," and "Combustibles and Non-Combustibles."

c) Better characterization of the inventory is needed for minor constituents with long half-lives and the potential to cause relatively high predicted doses to the general public, e.g., I-129 and Tc-99. These radionuclides are difficult to measure directly and are often conservatively estimated using scaling factors.

Two other important observations are:

d) The distribution of long half-life radionuclides is markedly different than for short half-life radionuclides. Based on the Richland 1989 data, the long half-life radionuclides are primarily in Class A wastes and are often found in sorbents or cements in higher proportions than average. Short half-life radionuclides tend to be Class B and C, typically are not treated with sorbents.

e) Resources should be focused on obtaining relevant release information from the wastes containing radionuclides that provide the largest risk to the public. These nuclides are typically long-lived and have a distribution within the wastes as discussed in d).

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LICENSING AND DOCUMENTATION

THE USE OF NUREGs 1199 AND 1200 IN THE ILLINOIS LLW LICENSING PROGRAM

by

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ABSTRACT

This paper will describe how the LLW licensing staff of the Illinois Department of Nuclear Safety used NRC's NUREG 1199, NUREG 1200, NUREG 1300 and Regulatory Guide 4.18 in its licensing program for reviewing and evaluating a LLW disposal facility license application. The paper will discuss how Illinois guidance documents were prepared based on modifications made to these NRC documents which were necessary to take into account site and facility specific considerations, as well as changes required by Illinois statutes and regulatory codes. The paper will review the recent revisions (January 1991) to NUREG 1199 and 1200 and the importance of these revisions. The paper will also discuss recommended modifications to these NRC documents and provide an update on the status of the Department's review and evaluation of an application for a license to site, construct and operate a LLW disposal facility in Illinois.

INTRODUCTION

The purpose of this paper is to describe how the licensing staff of the Illinois Department of Nuclear Safety used NRC's NUREG 1199 (Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility), NUREG 1200 (Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility), NUREG 1300 (Environmental Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility) and Regulatory Guide 4.18 (Standard Format and Content of Environmental Reports for Near Surface Disposal of Radioactive Waste) in conjunction with the review and evaluation of an application for a license to site, construct and operate a low-level radioactive waste (LLW) disposal facility. Prior to describing the use of these documents, however, information on the structure and responsibilities of IDNS and Illinois codes and regulations will be discussed.

In 1987 the State of Illinois entered into an Agreement with the U. S. Nuclear Regulatory Commission whereby the State assumed the responsibility for regulating source, byproduct and special nuclear materials in Illinois under the federal Atomic Energy Act (AEA). Under this Agreement, the State also assumed regulatory authority over the disposal of LLW. The agency responsible for regulating the possession, use and disposal of radioactive materials in Illinois is the Illinois Department of Nuclear Safety (IDNS). IDNS also has the responsibility for locating and characterizing a LLW site in Illinois as well as the responsibility for the development of a facility.

As shown in Figure 1, IDNS has an organizational structure capable of coordinating both the siting and licensing of a LLW disposal facility. Within

IDNS, the Office of Environmental Safety (OES) has responsibility for siting and developing a LLW disposal facility and the Division of Radioactive Materials (DRM) of the Office of Radiation Safety (ORS) has responsibility for processing license applications authorizing the disposal of radioactive materials. Accordingly, DRM has the lead responsibility for independently evaluating a license application for a LLW disposal facility and recommending to the IDNS director whether a license should be issued or denied. The organizational structure of IDNS for the review and evaluation of a license application is shown in Figure 2.

LICENSING PLAN

The first task undertaken after the LLW licensing staff was established in June of 1988 was to prepare a written plan for reviewing and evaluating a license application for a LLW disposal facility. The purpose of the plan was fourfold:

1. To provide a detailed description of the specific process that the licensing staff would follow when evaluating an application for a license to construct and operate a LLW disposal facility. The plan identified specific tasks to be accomplished, set forth the milestones and schedules in the licensing process and provided for continuity in the event of staff or organizational changes;
2. To provide a management approved program to be used for evaluating the status and performance of licensing reviews;

3. To facilitate public understanding of regulatory requirements and functional tasks involved in the overall process of licensing a LLW disposal facility in Illinois; and
4. To serve as a vehicle for obtaining public involvement in the licensing program.

GUIDELINES

The second task the LLW licensing staff undertook was to prepare "guidelines" for preparing a license application for a LLW disposal facility in Illinois. The purpose of these guidelines was to provide detailed guidance and suggestions on the format and content of an application for a license to site, construct and operate a LLW disposal facility. The guidelines, which were published for public comments, were also intended to serve as an additional mechanism for obtaining public input into the overall licensing process. These guidelines were based primarily on NUREG 1199 (Rev. 1) and Regulatory Guide 4.18 as will be described below following a brief review of Illinois code requirements.

The primary Illinois codes governing the disposal of LLW are 32 IAC Parts 601 and 606. Part 601 essentially duplicates NRC's Title 10, Code of Federal Regulations, Part 61 and was adopted in conjunction with the NRC agreement state program. Part 606 provides additional requirements for design, construction, operation, monitoring and maintenance of a LLW disposal facility. These additional requirements are over and above those found in 10 CFR Part 61. They were promulgated as required by Section 6 of the Illinois

Low-Level Radioactive Waste Management Act. The regulations in Part 606 require the disposal facility to be designed and constructed utilizing the best available technology that is economically reasonable, technologically feasible and environmentally sound. Additionally, these regulations, among other things: prohibit shallow land burial or underground injection wells; require the disposal facility to be designed and constructed for the complete containment of waste and waste constituents; require the facility to be designed to accept waste for a period of at least 50 years; and require the facility to be operated so that no person outside the facility boundary will receive a radiation dose in excess of 1 millirem per year to the whole body as a result of facility operations.

The general information that must be contained in an application for a IDNS license to construct and operate a LLW disposal facility is contained in 32 IAC Sections 601.50 through 601.100. The wording of these sections is essentially identical to Sections 61.10 through 61.16 of 10 CFR Part 61 except that subsection 601.70(c) of the Illinois Part 601 additionally requires an applicant to provide, "an environmental assessment describing the impacts that the disposal site will have on the environment." Therefore, an evaluation of the potential environmental impact of the facility will be performed in conjunction with the review and evaluation of a license application under Illinois codes.

Recognizing that more specific guidance on the format and content of an application was desirable (both from the standpoints of IDNS staff and the applicant) and also recognizing that the use of NUREG 1199 (Rev. 1) and Reg. Guide 4.18 were too generic and primarily applicable to shallow land burial, the IDNS licensing staff developed specific guidelines as identified above. This was achieved by significantly editing and combining NUREG 1199 (Rev. 1) and Regulatory Guide 4.18 into a single document specific to Illinois siting plans and IDNS statutes and regulations. This approach eliminates the need to submit redundant information in two separate documents as required by NRC.

The major changes and differences in the NRC documents and IDNS guidelines are summarized in Figure 3. The IDNS guidelines essentially follow the same format as NUREG 1199 (Rev. 1) except that Chapter 6 of the IDNS guidelines includes the environmental assessment information and analyses that should be included in an application for an IDNS license. Furthermore, the scope of the materials addressed in the guidelines is essentially equivalent to the materials addressed in both NUREG 1199 (Rev. 1) and Reg. Guide 4.18. Important differences in the IDNS guidelines include the elimination of the NEPA requirements for consideration of alternatives which are limited by Illinois statutes. The guidelines also eliminate the need for identification of land uses and populations within a 10 km radius and substitutes a request for information on these items within a 2 mile radius. These variances appear justified knowing the specific sites in Illinois that were characterized.

ACCEPTANCE RATIONALE

Following development of the IDNS guidelines, the LLW licensing staff developed "acceptance rationale" for use in reviewing an application. The term "acceptance rationale" as used by the IDNS licensing staff means the procedures, criteria and/or bases used for judging, determining or verifying from the information contained in an application for a LLW facility license, that there is reasonable assurance that IDNS regulations will be met. The purpose for developing written acceptance rationale is to provide guidance to reviewers, enhance uniform rule interpretations, minimize misunderstandings and ensure completeness of the overall review and evaluation of the license application in a timely manner. The "acceptance rationale" do not constitute additional requirements for applicants. Rather, "acceptance rationale" are viewed as the Department's guidance on acceptance procedures and methods for determining and/or verifying that regulatory requirements have been met.

The format for the acceptance rationale was organized by individual regulation contained in the IDNS codes as follows:

1. Each REGULATION is reprinted;
2. INTERPRETATION is given when necessary;
3. The Department's COORDINATOR for reviewing that regulation is listed;
4. A listing of RELATED REGULATIONS is included. These are other regulations that deal with the same topic or a topic that is closely associated with the listed regulation;
5. The ACCEPTANCE RATIONALE is presented;
6. The REVIEW PROCEDURE is outlined; and
7. GUIDANCE DOCUMENTS are listed.

Acceptance rationale for IDNS code Part 601 (including acceptance rationale relative to the environmental assessment required by Section 601.70(c) of Part 601) extensively use and follow the information contained in NUREGs 1200 and 1300. However, since IDNS code Part 606 requirements are over and above those found in 10 CFR Part 61, it was necessary to develop acceptance rationale for Part 606, which are unique to the Illinois regulatory program. Some of these rationale were simple to develop. For example, personnel qualifications contained in Part 606 are detailed and exact requiring little, if any, guidance for determining acceptability. The development of acceptance rationale for other unique requirements in Part 606 was more difficult. An example of an acceptance rationale relative to the IDNS one millirem per year exposure is shown in Figure 4.

As noted above, IDNS guidelines on the format and content of a license application were primarily based on Revision 1 of NUREG 1199 and Reg. Guide 4.18. In January 1991 the NRC distributed Revision 2 to NUREG 1199 and 1200. The changes contained in Revision 2 of these documents were primarily editorial and "housekeeping" in nature. For example, many of the changes merely changed the words "must" and "requirements" to "should" and "recommendations," respectively. In addition, Revision 2 of NUREG 1199 suggests that an applicant, "establish a quality assurance (QA) program as an expansion of the quality control program required by 10 CFR 61.12(j)." Since similar editorial changes were incorporated into the IDNS guidelines when originally prepared, revisions to the IDNS guidelines to take into account the 1991 NRC revisions to NUREGs 1199 and 1200 are not considered necessary.

The IDNS LLW licensing staff considers NUREGs 1199, 1200, and 1300 as extremely helpful in its overall program for at least three important reasons. Firstly, these documents provided a substantial base for developing State specific guidelines in a timely manner. An important factor in this regard is the fact that NUREGs 1199, 1200, and 1300 had already undergone extensive peer and public reviews thereby providing confidence in their use by the IDNS staff. Secondly, these NUREG documents were useful in providing a national perspective in the training of IDNS staff and consultants who were selected to assist in the review and evaluation of a license application. Thirdly, the documents were very useful in explaining the bases of the IDNS guidelines to an applicant, members of the public and IDNS citizens' and technical advisory groups.

In an effort to determine the usefulness of the IDNS guidelines to an applicant, IDNS licensing staff contacted members of the Chem-Nuclear Systems, Inc. (CNSI) licensing staff and requested their views on the helpfulness of the guidelines. The CNSI licensing staff indicated that the IDNS guidelines were generally useful and helpful to an actual applicant in expediting the preparation of a license application for a LLW disposal facility license.

The IDNS licensing staff recognizes that 10 CFR Part 61 and the NRC NUREG documents were primarily promulgated to accommodate shallow land burial. As noted above, this approach to waste disposal in Illinois is prohibited by statutes. Furthermore, it appears that shallow land burial disposal will not be an acceptable technique for the majority of potential host states who have selected engineered structures as the preferred technique for LLW disposal. Therefore, it appears that modifications to NUREGs 1199 and 1200 to emphasize this disposal technique are warranted. Of particular importance is the question of how much credit an engineered facility should be given in the long-term, overall performance of both a facility and site to isolate LLW from the accessible environment.

On May 15, 1991, CNSI filed an application with IDNS for a license to site, construct, operate and close a LLW disposal facility near Martinsville Illinois. As noted above, the format and content of this application followed those requested in IDNS guidelines. Following the review and evaluation of the application by the IDNS licensing staff and its consultants, and examination of staff's interrogatories by an IDNS management review group, finalized interrogatories were transmitted to the applicant on November 13, 1991.

SUMMARY

In summary, the IDNS licensing staff used NRC NUREG 1199 and Regulatory Guide 4.18 as the bases for preparing Illinois guidelines for the content and format for an application for an IDNS license to authorize the siting, construction and operation of a LLW disposal facility. NUREGs 1200 and 1300 were used in developing acceptance rationale relative to 32 IAC 601, which is the Illinois equivalent to 10 CFR Part 61. Thus, NUREGs 1199, 1200, and 1300 and Regualtory Guide 4.18 served as important bases for documents used by the IDNS staff in its LLW licensing program.

Figure 1

ILLINOIS DEPARTMENT OF NUCLEAR SAFETY

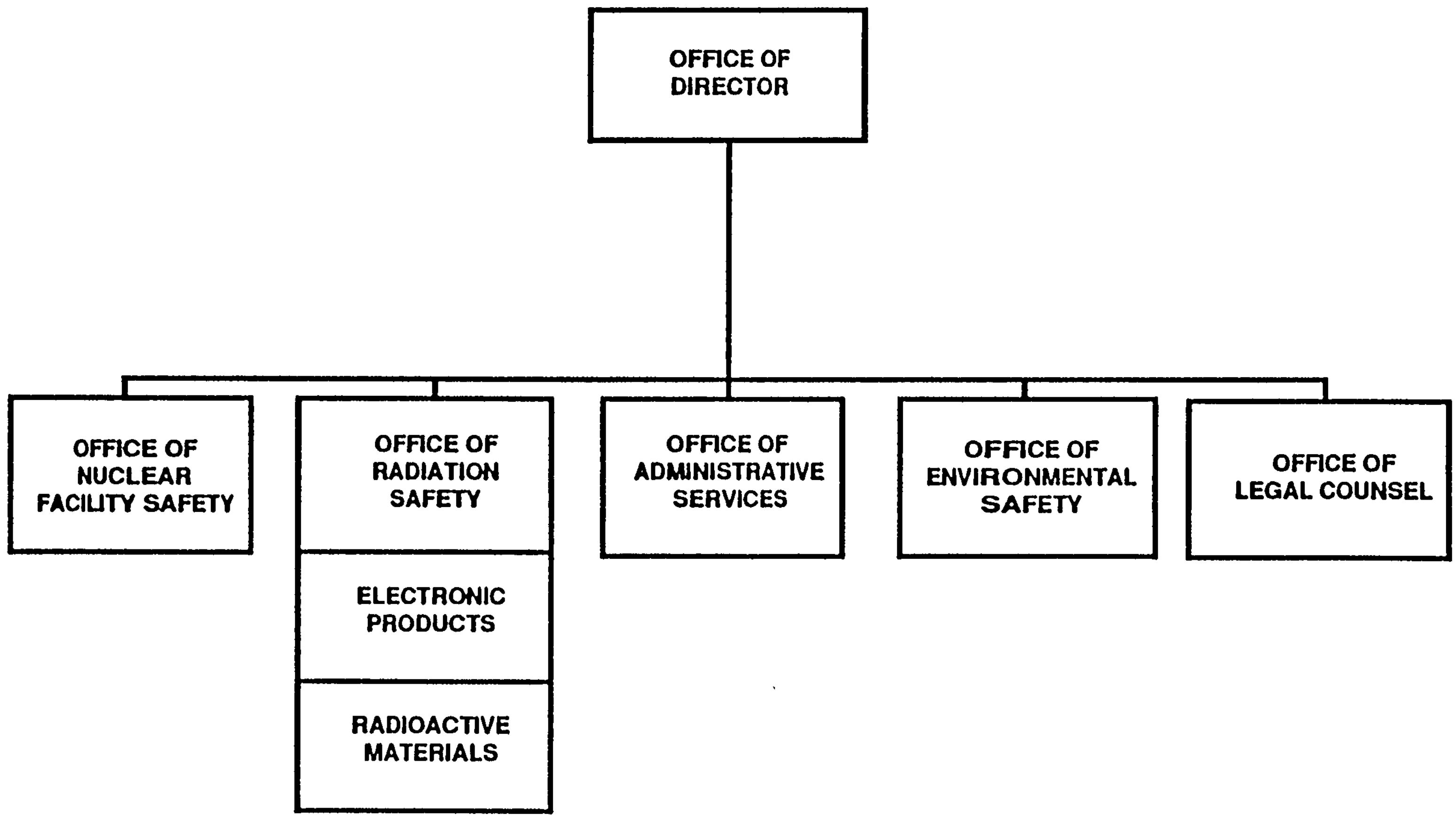

Figure 2

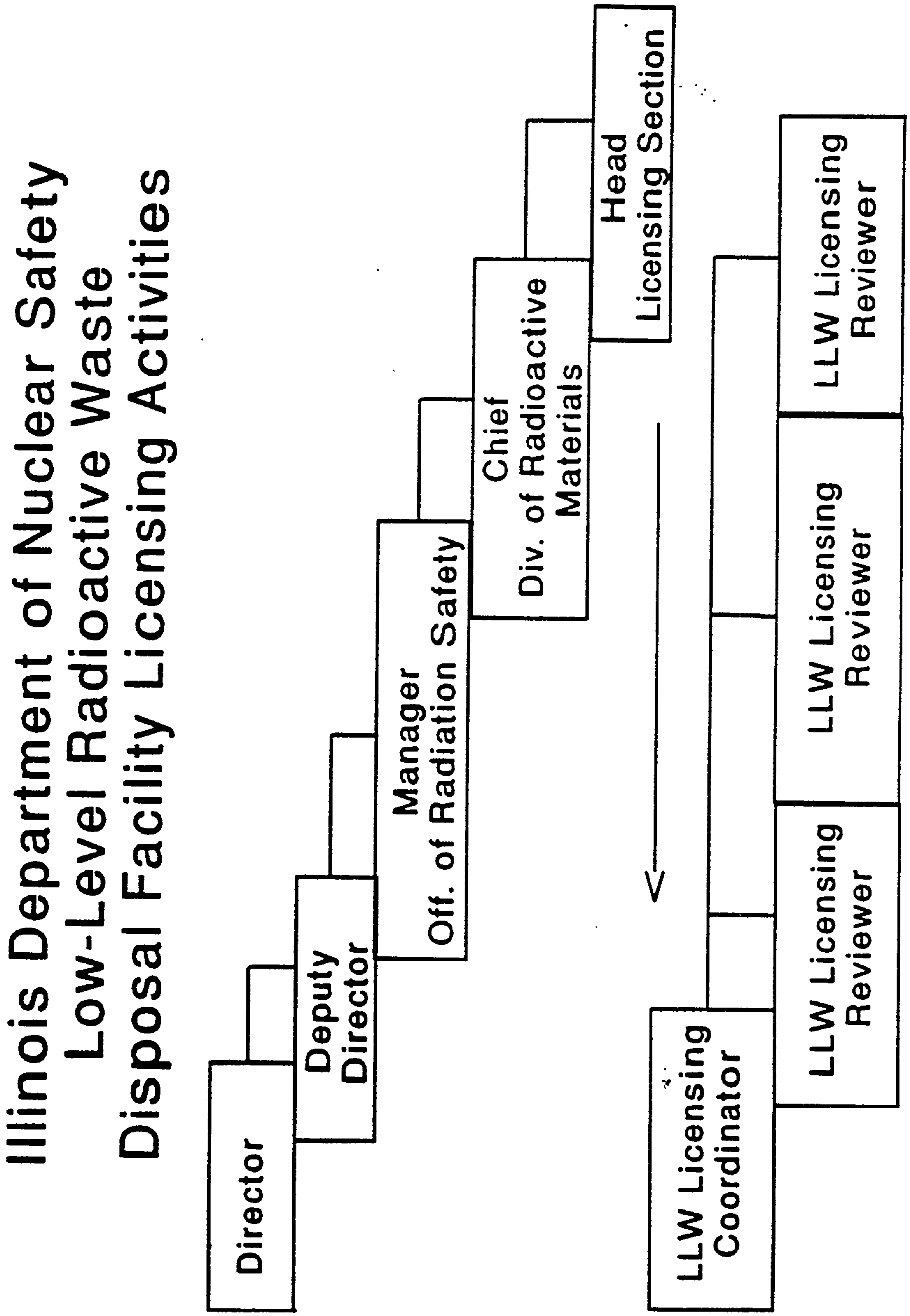
Illinois Department of Nuclear Safety
Low-Level Radioactive Waste
Disposal Facility Licensing Activities
Director
Deputy Director
Manager Off. of Radiation Safety
Chief Div. of Radioactive Materials
Head Licensing Section
LLW Licensing Coordinator
LLW Licensing Reviewer
LLW Licensing Reviewer
LLW Licensing Reviewer
LLW Licensing Reviewer

Figure 3
IDNS "GUIDELINES FOR PREPARING A LICENSE APPLICATION FOR A LLW DISPOSAL FACILITY IN ILLINOIS". COMPARED TO THE NRC'S NUREG 1199 (REV. 1) AND REG GUIDE 4.18

1. COMBINES THE TWO NRC DOCUMENTS INTO ONE GUIDANCE DOCUMENT.
2. ELIMINATED ALL REFERENCES TO SHALLOW LAND BURIAL FACILITIES.
3. IDENTIFIED SPECIFIC PARTS OF ILLINOIS REGULATIONS AND ELIMINATED ALL REFERENCES TO 10 CFR 61.
4. ELIMINATED SUBMISSION OF REDUNDANT INFORMATION IN THE TWO SEPARATE FEDERAL DOCUMENTS THAT WAS INCLUDED TO FULFILL BOTH NEPA AND AEA REQUIREMENTS.
5. ALLOWS THE ILLINOIS APPLICANT TO SUBMIT ONE DOCUMENT RATHER THAN THE TWO DOCUMENTS REQUESTED BY THE NRC.
6. REVISED TO REFLECT SPECIFIC KNOWLEDGE OF THE SITES BEING CHARACTERIZED (E.G., DELETED INVESTIGATION OF THE UNSATURATED ZONE).
7. ELIMINATED THE NEED TO COLLECT UNNECESSARY DATA (SUCH AS, LAND USE WITHIN 2 MILES AS OPPOSED TO THE NRC'S 6.2 MILES).
8. ELIMINATED THE NEPA REQUIREMENTS FOR CONSIDERATION OF ALTERNATIVES AND SUBSTITUTED ILLINOIS REQUIREMENTS SUCH AS BEST AVAILABLE TECHNOLOGY, CHARACTERIZATIONS OF AT LEAST TWO SITES, ETC.
9. REVISED TO ENSURE APPLICATION CONTAINS ALL INFORMATION REQUIRED BY ILLINOIS CODES (I.E., ENGINEERING CODES, PERSONNEL QUALIFICATIONS, ETC.) NOT CONTAINED IN FEDERAL GUIDELINES.
10. REVISED TO REFLECT THE FINANCIAL ASSURANCE PROVISIONS THAT ARE SPECIFIC TO ILLINOIS.

Figure 4

Regulation: 606.30(d)(4)

DRAFT

1. REGULATION:

Section 606.30 Requirements for Design, Construction, Operation, Monitoring, and Maintenance of the Low-Level Radioactive Waste Disposal Facility

d) Operation and Maintenance - Requirements

4) The facility shall be operated so that no person outside the facility boundary receives a radiation dose in excess of 1 millirem per year to the whole body as a result of the facility operations.

2. INTERPRETATION:

This requirement applies only to gamma-ray exposure from all sources in the restricted area during disposal and closure operations. See Figure 1 in the Illinois Department of Nuclear Safety's publication entitled, "Guidelines for Preparing a License Application for a Low-Level Radioactive Material Waste Disposal Facility in Illinois."

3. COORDINATOR: DAVID SCHERER REVIEWER:

4. RELATED REGULATIONS:

601.70(g)
601.80(c)
601.210
606.30(b)(6)(B,I),(c),(d)(1-3,5-8)

5. ACCEPTANCE RATIONALE:

This regulation should be satisfied if the whole body external dose to the maximally exposed member of the public located outside the facility buffer zone boundary should not exceed 1 millirem per year from all operations. The dose analysis should consider the maximum inventory of waste and in the facility at anyone time outside of the disposal modules, as well as the path the waste follows after receipt at the facility, including inspection, processing, storage, transport, and disposal. The analysis should provide enough information so that the staff can conclude or draw a reasonable assurance that the requirements are met.

6. REVIEW PROCEDURE:

The staff should review information provided in the license application regarding the inventory and operating procedures employed. In its review, the staff should ensure that the assumptions used in the analysis of dose to the general public should be consistent with statements made elsewhere in the application. In addition, the staff should review the accuracy and appropriateness of the analytical techniques employed. Independent calculations should be prepared by the staff to confirm that these requirements will be met.

7. GUIDANCE DOCUMENTS: None required

NUCLEAR REGULATORY COMMISSION ACTIVITIES TO PREPARE FOR REVIEWING LICENSE APPLICATIONS AND ISSUING LICENSES

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and
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1. INTRODUCTION

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) assigned States the responsibility to provide for disposal of commercial low-level radioactive waste (LLRW) by 1993. The LLRWPAA also required the U.S. Nuclear Regulatory Commission (NRC) to establish procedures and develop the technical review capability to process license applications for new LLRW disposal facilities. Under the LLRWPAA, NRC is required, to the extent practicable, to complete its review of an LLRW disposal facility license application within 15 months of its submittal by a State. This provision of the LLRWPAA helps ensure that NRC, in addition to protecting public health and safety and the environment, facilitates States' achievement of LLRWPAA milestones for new facility development. A timely NRC review is needed for States to accomplish their objective of having new disposal facilities in operation on the dates prescribed in the LLRWPAA.

To help assure NRC and States' compliance with the provisions of the LLRWPAA, NRC has developed a licensing review strategy that includes: (1) the further development of regulatory guidance, (2) enhancement of licensing review capability, and (3) prelicensing regulatory consultation with potential applicants.

2. REGULATORY GUIDANCE

NRC has developed numerous regulatory guidance documents to carry out the shared responsibilities of licensing of LLRW disposal facilities. This regulatory guidance defines acceptable approaches for meeting NRC regulations and, if adopted by applicants, will result in expedited reviews of applications. NRC staff (staff) has developed guidance documents applicable to the license application (the safety analysis report (SAR)) and the environmental report (ER), which must accompany the license application.

2.1 Safety Analysis Report Guidance

Two key SAR-related guidance documents issued by NRC are: (1) NUREG-1199, "Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility", and (2) NUREG-1200, "Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility." NUREG-1199 (Standard Format and Content for the SAR) provides guidance to the applicant on the type of information that should be included in the SAR in order to address the regulatory requirements of 10 CFR Part 61. The purpose of NUREG-1199 is to explain in more detail the information that should be provided in the SAR and to establish a standard format for presenting the information. Use of the standard format will: (1) help ensure that the SAR contains the information required by Part 61; (2) aid the applicant and NRC staff in ensuring that the information is complete; (3) help persons reading the SAR to locate information; and (4) contribute to reducing the time needed for the review process.

NUREG-1200, the Standard Review Plan (SRP) for the SAR, provides guidance to staff reviewers in the Office of Nuclear Material Safety and Safeguards (NMSS), on how to perform safety reviews of applications to construct and operate LLRW disposal facilities and provides implicit guidance to licensees and applicants. Although this document has been produced for the NMSS staff to use in conducting its reviews, Agreement States and interested parties responsible for conducting their own licensing reviews or developing license applications can also use the SRP. The principal purpose of the SRP is to ensure the quality and uniformity of staff reviews and to present a well-defined base from which to evaluate proposed changes in the scope and requirements of reviews. Other important purposes of the SRP are to make information about regulatory matters widely available and to help the nuclear industry and interested members of the public to better understand the NRC's review process. Each individual SRP identifies what organizations within NRC will perform the review, the matters that are reviewed, the Commission's regulations and acceptance criteria necessary for the review, how the review is to be accomplished, the types of conclusions that are appropriate, and the implementation requirements.

An important part of each individual SRP is the section on acceptance criteria. This section contains statements regarding applicable NRC regulatory requirements as well as related guidance, and the technical bases for determining the acceptability of the design or the programs within the scope of review of the SRP. The technical bases support specific criteria that may also be called out in NRC regulatory guides, industry codes and standards, and branch technical positions.

The technical bases for some individual SRPs are provided in branch technical positions or appendices that are included in the SRP. These ancilary documents typically set forth the solutions and approaches that the staff has determined to be acceptable for dealing with a specific problem or design area. These solutions and approaches are codified in this form so that staff reviewers can take consistent positions on similar problems as they arise. Branch technical positions and appendices present solutions and approaches that are acceptable to the staff, but that are not considered as the only possible solutions and approaches. However, applicants proposing solutions and approaches other than those described in the branch technical positions may expect longer review times and possibly more extensive questioning than those using suggested solutions and approaches.

The current version of the SRP and NUREG-1199 are primarily directed toward traditional near-surface LLRW disposal methods. To further ensure that our shared NRC-State objectives are met, NRC is continually improving this guidance through updates and revisions to the SRP to provide greater clarification and more information for applicants and NRC reviewers. States, industry groups, licensees, and others have been helpful in developing and revising this guidance.

NRC staff is currently developing Revision 3 to NUREG-1200. Current revisions, to be finalized in 1992, are proposed in several areas, including the licensing process, floodplain criteria, soil cover systems, waste disposal operations, and radiation protection design features among others. Future planned revisions to the SRP include topics on the use of geosynthetics in LLRW disposal, performance assessment (PA) methodology and decontamination of facility structures.

2.2 Environmental Report Guidance

NRC, in an effort parallel to SAR guidance, has also issued two key ER-related guidance documents. These are: (1) Regulatory Guide 4.18, "Standard Format and Content of Environmental Reports for Near-Surface Disposal of Radioactive Waste," and (2) NUREG-1300, "Environmental Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility." Regulatory Guide 4.18 provides guidance to the applicant on the type of information that should be included in the ER in order to address the regulatory requirements of 10 CFR Part 51 and the National Environmental Policy Act (NEPA).

NUREG-1300 (the Environmental Standard Review Plan (ESRP) for the ER) provides guidance to NMSS staff reviewers on performing environmental reviews in support of license applications to construct and operate LLRW disposal facilities. Each individual ESRP includes applicable references to related Federal agency regulations, guidelines, or acts that will affect the staff's environmental review. This document's organization was developed to be consistent with the Commission's 1984 revisions to Part 51. Provisions have been made for periodic revisions of the ESRP to respond to future regulations, guidelines, or acts affecting NRC's environmental review responsibilities.

2.3 Other Technical and Procedural Guidance

NRC has also developed many other guidance documents related to licensing LLRW disposal facilities under Part 61. Most of this guidance is referenced in NUREG-1200 and NUREG-1300. Examples of NRC technical guidance developed specifically for the LLRW program include: NUREG-0902, "Site Suitability, Selection and Characterization"; NUREG-3774, Vols. 1 to 6, "Alternative Methods for Disposal of Low-Level Radioactive Wastes"; NUREG/CR-2700, "Parameters for Characterizing Sites for Disposal of Low-Level Radioactive Waste"; and NUREG/CR-5432, Vols. 1 to 3, "Recommendations to the NRC for Soil Cover Systems over Uranium Mill Tailings and Low-Level Radioactive Wastes."

NRC has also developed guidance on procedural matters relating to LLRW disposal facility license preparation and review. Examples of this guidance include: NUREG-1274, "Review Process for Low-Level Radioactive Waste Disposal License Application under Low-Level Radioactive Waste Policy Amendments Act"; NUREG-1383, "Guidance on the Application of Quality Assurance for Characterizing a Low-Level Radioactive Waste Disposal Site"; and NUREG-1293, "Quality Assurance Guidance for a Low-level Radioactive Waste Disposal Facility."

In developing NRC guidance documents, NRC staff has used -- and referenced in NUREG-1200, NUREG-1300 and other NRC LLRW guidance -- industry standards, regulatory guides, and general guidance of other programs and organizations that are applicable to licensing an LLRW disposal facility under Part 61. Examples of these include: ASTM C998-83, American Society for Testing and Materials, "Standard Method for Sampling Surface Soil for Radionuclides"; NUREG-1298, "Qualification of Existing Data for High-Level Nuclear Waste Repositories"; EPA Report 600/4-79-019, "Handbook for Analytical Quality Control in Water and Wastewater Laboratories"; and DOE/LLW-13Tg, "Low-Level Radioactive Waste Management Handbook Series, Environmental Monitoring for Low-Level Waste Disposal Sites."

3. LICENSING REVIEW CAPABILITY

The second element of our licensing review strategy is the continuing enhancement of our overall licensing review capability. Since promulgation of Part 61 in 1982, NRC's activities and capabilities in the area of LLRW disposal have increased substantially. Several recent activities demonstrate NRC's commitment to maintaining and enhancing the staff's license review capability. These include the review of prototype license applications and the enhancement of staff's PA capability to evaluate license applications.

3.1 Review of Prototype License Applications

NMSS staff (and support consultants) reviewed two Prototype License Application Safety Analysis Reports (PLASARs) submitted by the U.S. Department of Energy (DOE) for the earth-mounded concrete bunker (EMCB) and belowground vault (BGV) alternative methods of LLRW disposal. For these two "mock licensing reviews," the NRC reviewers relied extensively on the SRP for evaluating the acceptability of the information provided in the EMCB and BGV PLASARs. The staff selected certain review areas in the PLASARs for development of safety evaluation report input to provide examples of safety assessments that are necessary as part of a licensing review. Staff concentrated its review on the design and construction and operations-related portions of the PLASARs. The results of the NRC reviews are presented in two volumes of NUREG-1375. Volume 1, "Safety Evaluation Status Report for the Prototype License Application Safety Analysis Report," July 1989, is the staff review of the EMCB PLASAR. Volume 2, "Safety Evaluation Review of the Prototype License Application Safety Analysis Report," August 1991, contains the staff review of the BGV PLASAR.

The primary objective of the staff's review of the PLASARs was to provide assistance to the States and regional compacts by (1) identifying acceptable and unacceptable alternative design features, and (2) demonstrating the staff's use of the SRP. The review of the PLASARs also provided the staff valuable licensing experience and enabled identification of SRP weaknesses. In recognition of those weaknesses, the NRC staff is revising both the SRP and the Standard Format and Content for the SAR to improve the agency's regulatory guidance, particularly in the areas of PA and occupational radiation protection.

3.2 Performance Assessment Capability

NRC, through its Performance Assessment Working Group (PAWG), has established a plan to develop guidance on undertaking a PA of an LLRW disposal facility. This guidance will address some key technical issues identified by NRC and States, which will likely have to be resolved by those undertaking PA of LLRW disposal facilities. Suggested resolution of these technical issues and well-founded guidance on PA will provide the framework for a sound technical basis for those undertaking PA analyses of LLRW disposal facilities.

In the PAWG plan, it is recognized that enhancement of NRC staff PA capabilities will best afford the NRC with the ability to provide guidance in the PA area. Therefore, the initial focus under the plan is to enhance staff PA capabilities through the undertaking of a mock PA "sample problem". The mock PA exercise will provide staff with a greater level of understanding of the phenomena and processes involved in LLRW PA analyses, a greater understanding of the limitations of the various modeling approaches used in LLRW PA, and a greater understanding of the sensitivity of key assumptions and variables used in PA analyses. The initial set of input parameters for the PA sample problem will utilize real site characterization data (to the extent pratical) and inventory data that are based on information currently available from operating LLRW disposal facilities. For the initial set of input conditions for the sample problem, a hypothetical LLRW facility consisting of vaults and trenches will be designed to accommodate the natural setting. The initial facility input conditions will be modified for sensitivity calculations. This will allow a broader understanding of what needs to be considered in analyzing different types of facilities in different types of natural settings.

The mock PA analysis will provide NRC staff the opportunity to address some key technical issues, identified by NRC, that will likely have to be considered by those undertaking PA analysis of LLRW disposal facilities during license review. These include questions on conceptual model development, the time-frame over which a PA analysis should be carried out, source-term characterization, parallel pathways analyses, and performance of engineered barriers over time.

The second focus of the PAWG plan is to develop guidance on PA. This guidance will derive from the results and experience obtained from the mock PA analysis. It is anticipated that the guidance may include a new NUREG document on PA, revisions to the Plan (NUREG-1200), a technical position document, and a regulatory guide. This guidance will incorporate the NRC's position on resolving the technical issues identified previously. It is anticipated that the PAWG will continue to address additional issues and revise PA guidance documents as necessary to adequately support license reviews.

4. PRELICENSING REGULATORY CONSULTATION

The third element of NRC's licensing review strategy is our prelicensing interaction with potential applicants. To help States fulfill the objectives of the LLRWPAA for the development of new LLRW disposal facilities, the States and NRC consult with one another before a license application is submitted. This prelicensing consultation facilitates preparation of a license application that NRC can review in a timely manner. This consultation also enables NRC staff to identify concerns with the site characterization program, disposal facility design, and other licensing matters early in the process, so they can be addressed early in the licensing process.

Prelicensing interactions can yield many significant benefits. Prelicensing consultation can be undertaken on proposed site characterization plans, the ongoing site characterization program, PA, facility design, facility operations, and other licensing matters, up through the formal submittal and docketing of a license application. Some of the benefits of prelicensing consultation with NRC staff include:

- Identifying licensing issues early in the LLRW program.
- Helping focus NRC technical reviews and the development of review capability for specific projects.
- Focusing applicant investigations on critical issues.
- Helping ensure that applicants submit an acceptable license application for docketing and conducting the license review and licensing proceedings.
- Helping ensure an adequate preoperational environmental monitoring program.
- Establishing a preliminary framework of licensing issues to be fully reviewed in the formal license review.
- Expediting the overall licensing process.

4.1 Prelicensing Regulatory Consultation on Site Characterization Plans (SCPs)

Since site characterization is a very important activity to support an LLRW disposal facility license application, it is useful to describe the general framework of how NRC would likely review a proposed SCP for a specific site. Assume that the SCP contains the program of investigations and tests that the applicant intends to conduct at the preferred site and the identification of the disciplines and data types needed to satisfy regulatory requirements to support an LLRW disposal facility license application under Part 61. The NRC review would then proceed as follows.

The overall objectives of our review would be to provide comments on the SCP that can be applied to the site characterization program and to identify potential licensing issues so that the applicant may address them early in the licensing process.

The NRC staff would review the adequacy of the applicant's planned site characterization activities, as presented in the SCP, to investigate the characteristics of a potential disposal site to the extent needed to: (1) support a license application (i.e., the SAR) and an ER, and (2) permit an independent NRC staff evaluation of the proposed near-surface disposal facility. This independent evaluation would include both consideration of public health and safety (Part 61) and compliance with NEPA (as implemented by 10 CFR Part 51). Further, the NRC staff review of a potential applicant's site characterization program proposed in the SCP would consider the following for a near-surface disposal facility:

- Statutes, regulations, and regulatory guidance referenced in the SCP, as they relate to NRC regulations in Parts 61 and 51.

- Tests and investigations planned for characterizing candidate sites, including the level of detail described in the SCP.

- The applicant's plan for using existing site data in developing planned tests and investigations.

- Disposal facility concepts (for example, EMCBs or BGVs) so that site-specific parameters that may affect design criteria and environmental analyses can be investigated during site characterization.

- Plans and approaches for assessing how the site will perform. These preliminary PAs will help focus site investigations on areas of significance, and will help define the kinds and amounts of data needed to determine whether there is reasonable assurance that a site will meet the requirements in NRC regulations.

- Plans to identify the kinds and amounts of radioactive waste materials anticipated to be received for disposal at the site. Identification of the waste characteristics will help to determine whether limits should be imposed on waste inventory at the site. It also permits a preliminary PA of the sites, that is, whether a particular site is capable of meeting the dose limits prescribed in Part 61.

The staff review of the SCP would be based on requirements of NRC regulations as well as site-specific conditions that may affect radiological safety or environmental effects of a proposed LLRW disposal facility. Staff review of the SCP would typically be conducted primarily on the basis of the following specific NRC regulations and guidance documents: Parts 61 and 51, NUREG-0902, NUREG-1199, NUREG-1200 (SRP), Regulatory Guide 4.18, and NUREG-1300 (ESRP).

The NRC staff review should be performed in a timely manner to meet applicant needs. Typically our review comments would be transmitted in written form. Applicant meetings, telephone discussions, and site visits with the NRC review team would be held as necessary to complete the review. Further, NRC staff and the applicant may have additional interactions, after NRC comments are provided to the applicant to clarify and resolve issues and to plan for future NRC-applicant interactions during the licensing process.

NRC staff in the Division of Low-Level Waste Management and Decommissioning, NMSS, has already provided a variety of regulatory consultation and technical assistance to States involved in licensing LLRW disposal facilities.

For example, at the request of the respective States, staff completed reviews on the SCP for the Vernon/Vermont Yankee Site in Vermont and the generic SCP for the State of Connecticut. Staff has also completed reviews of quality assurance plans, environmental impact study plans, and other LLRW disposal facility related documents prepared by various States.

In addition to the reviews just described NRC staff in NMSS and other offices provide ongoing regulatory consultation and technical assistance to States in several other ways. These include: assistance during NRC Agreement State program reviews and visits; participation in the quarterly Low-Level Waste Forum meeting and the LLRW Regulators' Workshop held annually by NRC; and other interactions between NRC staff, regulators, and other interested parties.

5. SUMMARY

The NRC is prepared to review license applications and issue licenses for LLRW disposal facilities under Part 61. NRC NMSS staff has the primary responsibility for licensing facilities under Part 61 and has developed a comprehensive licensing review strategy. Staff has developed numerous regulatory guidance documents for reviewing license applications, including a Standard Format and Content and SRP for both the SAR and the ER required under Part 61. NRC is continuing to enhance staff review capability through review of prototype license applications and enhanced technical capabilities in PA and other technical areas. Further, NRC staff is providing prelicensing regulatory consultation to potential applicants and States, not only to facilitate the preparation of license applications, but also to enable staff to focus technical reviews and the further development of staff review capability on specific projects. NRC is committed to the continuing enhancement of licensing review capabilities for LLRW disposal facility projects now in progress and for new projects and disposal technologies of the future.

THE CONTRACTOR'S ROLE IN LOW-LEVEL WASTE DISPOSAL FACILITY APPLICATION REVIEW AND LICENSING

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INTRODUCTION

The California Department of Health Services will soon reach a licensing decision on the proposed Ward Valley low-level radioactive waste disposal facility. As the first regulatory agency in the country to address the 10 CFR Part 61 requirements for a new disposal facility, California's program has broken new ground in its approach. Throughout the review process, the Department has relied on contractor support to augment its technical and administrative staff. A team consisting of Roy F. Weston, Inc., supported by ERM-Program Management Corp., Environmental Issues Management, Inc., and Rogers and Associates Engineering Corporation, has worked closely with the Department in a staff extension role. The authors have been involved with the project in contractor project management roles since 1987, and continue to support the Department's program as it proceeds to finalize its licensing process.

This paper describes the selection process used to identify a contractor team with the needed skills and experience, and the makeup of team capabilities. It outlines the management, communication, and technical approaches used to assure a smooth agency-contractor function and relationship. It describes the techniques used to ensure that decisions and documents represented the Department credibly in its role as the regulatory and licensing agency under the Nuclear Regulatory Commission (NRC) Agreement State program. The paper outlines the license application review process and activities, through preparation of licensing documentation and responses to public comments. Lessons learned in coordination of an agency-contractor team effort to review and license a low-level waste disposal facility are reviewed and suggestions made for approaching a similar license application review and licensing situation.

STRUCTURING THE LICENSE REVIEW TEAM - CALIFORNIA EXPERIENCE

The Department of Health Services, faced with receiving the country's first application for a new low-level waste disposal facility, recognized that there was a need to augment its permanent staff. The license review process is a unique and resource-intensive effort, with substantial complexity and the need for an intensive, focused program. But it only happens one time, so creating a full complement of staff capabilities is not necessarily practical.

A wide range of expertise is required for the license review process, ranging from engineers and health physicists to cultural resource specialists and biologists with specific expertise in local ecological features. Also helpful to the process is background and expertise in the low-level waste regulatory field, highlighting the individuals who have been actively involved in development of low-level waste regulations and regulatory guidance over the years. At the same time, some of the expertise required is employed only briefly, sometimes only for a few days during the approximately two-year process. Use of contractor support can address this situation as well.

Whatever the level of contractor support needed, however, it is critical that the licensing decisions be made by the regulatory agency itself. This calls for using contractor support as an extension of agency staff, rather than any sort of turn-key contract situation. Active, day-to-day involvement of the Department's managers and staff in the contractor's efforts proved to be essential.

A competitive procurement process was used to select the appropriate contractors to support the Department's program. Three separate procurements were made, including the following:

- Contractor to review site selection and characterization, Roy F. Weston, Inc., later selected to review the license application and support the licensing process

- Contractor to support the Department in facility design and quality assurance, Ebasco Environmental

- Contractor to prepare the environmental impact report/statement, Dames & Moore

This paper focuses on the Weston contract to review site selection and characterization, and to support the Department in the license review and licensing process.

EARLY INVOLVEMENT SHAPES LICENSE REVIEW PROCESS

The key element of success in California's use of contractor support was having its contractor team involved early. By bringing the team together early enough to work together on reviewing preliminary data and plans, and to structure the license review process in advance, significant progress was made. California's contract required a project work plan be developed as the first deliverable, defining project schedules, staffing, communication, work products, and other relevant information. This created a clear understanding from the start about how the support project would proceed, eliminating potential misunderstandings.

The first major technical effort was review of the applicant's site characterization plan, site characterization procedures, and the data resulting from site characterization activities. This allowed the Department to hold informal licensing consultation sessions with the applicant long before an application was received. At the same time, and in an ongoing effort, the separate quality assurance support contractor was reviewing the applicant's quality assurance program and procedures. The Weston team reviewed the performance assessment models and accompanying assumptions and scenarios before they were used by the applicant, and reviewed initial results of applying the performance assessment approach. Any needed guidance for the applicant was also prepared during this pre-application period.

PREPARATION FOR LICENSE APPLICATION REVIEW

As the time approached for receipt of a formal application, the team and the Department prepared for the review. The review process was designed in detail through preparation of a license review plan. The plan incorporated NRC guidance and process plans as appropriate, and included approaches specific to California's regulatory regime. A quality assurance program for the review team and the Department's activities was also put in place in advance of receiving the application.

This time of preparation allowed commitment of all needed staff and contractor resources, as well as putting in place the coordination mechanisms needed to review the different parts of the application and integrate the safety evaluation review with the parallel environmental review process. A detailed roadmap of the entire review and approval cycle was prepared that laid out how all activities would be conducted, scheduled, and coordinated. It included provision for site visits, clarification meetings, conference calls, and other coordination mechanisms needed throughout the process.

CONDUCTING THE LICENSING REVIEW

The application for the proposed Ward Valley disposal facility was received in late 1989. Its size and complexity reinforced that it had been wise to spend time preparing the team for the review process, including completing quality assurance training and systems, orienting the project team, and working closely with the Department to prepare for the first application review steps.

Completeness review of the application needed to be completed immediately, as the January 1, 1990, milestone called for a certification of receipt of a complete application. The contractor team assigned section leaders to each section of the application according to the format of NUREG 1200, the standard review plan. The application, which had been prepared as directed in accordance with NUREG 1199, the standard format and content document, was easily separated into sections for preliminary completeness review.

Each section leader reviewed the application information to determine whether all regulatory guidance headings were addressed, whether analysis and results were presented in all regulatory areas, and whether justification had been provided for the application material. With the addition of some supplementary material, the application was deemed complete by the Department in compliance with the 1990 milestone.

Detailed technical review followed, with each section leader calling on appropriate technical experts to review all elements of the application. A small integration team of senior regulatory specialists reviewed the entire application, assured that section leaders were addressing all applicable regulatory requirements, and served as the cross-cutting body that integrated all portions of the applications to reach the needed regulatory findings of 10 CFR Part 61, as adopted by California. Department staff also reviewed the application, focusing on the areas of monitoring, radiation safety, and design. All reviewers understood that their efforts were aimed at reaching the findings needed in the safety evaluation report, based both on the framework of NUREG 1200 guidance and of the regulation itself.

A four-round interrogatory process was both necessary and helpful to the license review. Interrogatories were generated both by the Department staff and the contractor team, and were integrated into a computerized tracking system. Special issues that arose, such as trench cover design, were addressed through special efforts of the review team augmented by outside expertise from other agencies and sources. An ad hoc panel was formed, for example, to examine comments by the U.S. Environmental Protection Agency related to use of a synthetic liner in the disposal units and development of a sufficient vadose zone monitoring system. The panel included various experts in the topic, and was able to reach an advisory position that addressed the concerns of all involved.

The Department was at the same time involved in reviewing the applicant's detailed operating procedures, determining how to establish its own regulatory programs (e.g., permitting facility users), and coordinating the license review with the environmental review process.

Preparation of the safety evaluation report (SER) was the major deliverable for the contractor and Department team. The SER was started early, as it helped define what additional information was needed through the interrogatory process from the applicant. The contractor team prepared draft sections for review by the contractor integration team and for the Department's review. A decision was made to use a two-volume SER in order to address the applicant's compliance in light of the NUREG 1200 guidance, but also to reach the findings required in the regulation itself.

As the SER evolved, the license was prepared, including license conditions that reflected commitments made in the application, California-specific conditions (e.g., the compact's waste streams), and concerns of the public. The Department worked closely with the contractor team to draft and finalize the license conditions.

SUPPORTING CONTRACTOR ACTIVITIES

Other activities were either completed by contractor support organizations or could be in another state's situation. As noted, the environmental review process was a separate activity requiring coordination with the safety evaluation review. The Department served in that coordination role, ensuring that information and conclusions reflected a coordinated approach.

Public involvement support was provided by the contractor team, working closely with the Department. This involved reviewing thousands of comments received during a public comment period and through public hearings, and assisting the Department in preparing a responsiveness summary to the public concerns.

Expert witness testimony is available to the Department from the contractor team, if required, as is potential future support for regulatory oversight, review of amendment requests, closure plans, financial updates, etc.

CONCLUSIONS

The lessons learned from the California experience in using contractor support for license review include the following:

- A team approach and close coordination are critical. As the regulator, the Department must issue all guidance, request all additional information, and reach all licensing decisions. To use a contractor team effectively, there must be no gap in the team approach. This also provides for flexibility to address emerging issues, which proved to be very helpful.

- Advance planning before receipt of a license application is invaluable. In California's case, the early review role in conjunction with advance planning resulted in a team that was well prepared and ready to begin review immediately.

- Keeping a "big picture" perspective on the overall process is essential, as the entire team proceeds toward the final objective of reaching a defensible licensing decision. Scheduling, tracking, and organizing the overall process is a formidable challenge and is key to keeping the overall program on track.

License Restrictions at Barnwell

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ABSTRACT

The State of South Carolina was delegated the authority by the U.S. Nuclear Regulatory Commission to regulate the receipt, possession, use and disposal of radioactive material as an Agreement State. Since 1970, the state has been the principal regulatory authority for the Barnwell Low-Level Waste Disposal Facility operated by Chem-Nuclear Systems, Inc. (CNSI).

The radioactive material license issued authorizing the receipt and disposal of low-level waste contains numerous restrictions to ensure environmental protection and compliance with shallow land disposal performance criteria. Low-Level waste has evolved from minimally contaminated items to complex waste streams containing high concentrations of radionuclides and processing chemicals which necessitated these restrictions. Additionally, some waste with their specific radionuclides and concentration levels, many classified as low-level radioactive waste, are not appropriate for shallow land disposal unless additional precautions are taken. This paper will represent a number of these restrictions, the rationale for them, and how they are being dealt with at the Barnwell disposal facility.

Barnwell Licensing Background

In August 1969, CNSI, formerly Chem-Nuclear Services, submitted a license application to the South Carolina Board of Health for the disposal of commercial low level radioactive waste on property they had acquired near Barnwell, South Carolina. This property is adjacent to the Savannah River Site and the Allied General Nuclear Fuel Services (AGNS) processing facility which was under construction at that time. AGNS has since been decommissioned before it began operations.

The application for low level waste disposal was prompted in part by the Atomic Energy Commission's (AEC) moratorium placed on sea disposal of waste in the early sixties, and its closing of burial grounds at Oak Ridge, Tennessee and the National Reactor Test Site in Idaho to commercial waste later in that decade. Although there were other commercial sites operating throughout the country, the State of South Carolina initially supported a commercial facility in the state since it was becoming heavily involved in the commercial Atomic Nuclear industry. It was perceived from an economic standpoint that this site would serve the state and surrounding states in the Southeast who were also developing commercial nuclear power. Little did we know at that time Barnwell would become the nation's number one commercial disposal facility. This prompted numerous political actions such as the Low Level Waste Policy Amendments Act of 1985 requiring all states to assume the responsibility for low level waste management and disposal.

An initial license was issued to CNSI on November 6, 1969. However, this license restricted them to receipt and possession of prepackaged waste for transfer to other authorized disposal facilities throughout the country. Twenty months later, following a lengthy review process by numerous state agencies and commissions, the AEC, and the U.S. Geological Survey, exchanging numerous documents and information in support of land disposal, and holding one public hearing on March 4, 1971, an amended license was issued to CNSI on April 13, 1971, authorizing disposal of waste at the Barnwell site. Also in April of that year, the land acquired by CNSI was deeded to the State of South Carolina and subsequently leased back to them. The original perpetual maintenance fee was 8 cents per cubic foot, later raised to 16 cents, and is currently $2.80 per cubic foot. There is over 40 Million Dollars in this interest bearing account to provide long term care and maintenance for the site.

Evolution of Waste

The original license issued to CNSI authorized the above ground receipt and possession of 5000 curies of By-Product Material, 5000 pounds of Source Material, and Special Nuclear Material (U-235, U-233 and Pu) in quantities not to exceed unity. Due to the increased concentrations of waste and irradiated metal components, the license now allows the above ground possession of 50,000 curies, 60,000 pounds of Source Material and 3500 grams of Special Nuclear Material. Transuranic waste with half-lives greater than 5 years is limited to less than 10 nanocuries per gram for Class A waste, and less than 100 nanocuries per gram for Class C waste, and only if the transuranics are incidental to the total radionuclide inventory. Radium waste is excluded unless in discrete concentrations. The exclusion of transuranic and radium waste has caused disposal problems for generators with these waste steams.

In addition, restrictions have been imposed on waste with concentrations above Class C limits. Above Class C waste such as sealed sources are only allowed to be received following a case-by-case review and approval process. Irradiated metal components above Class C are prohibited since the Department of Energy is responsible for their disposition; these waste forms are not appropriate for shallow land disposal. In earlier years of operations the facility received waste with low to moderate concentrations. In fact, in the original submittal for a license, waste containers were not to exceed 100 millirems per hour on contact. Today, stainless steel liners containing irradiated components have demonstrated 50,000 rems per hour on contact. Radiation levels are restricted to the shielding capacity of the transportation casks and operational limits imposed by the facility operator.

Low level waste received at the Barnwell site has evolved over the years from minimally contaminated dry active waste, evaporator concentrates, ion exchange resins and filter media. As the operational life-time of the commercial reactors grew, the waste stream loadings began to increase in radionuclide concentrations. Replacement of metal reactor components, power level monitors, poison curtains, and other metal fixtures, also contributed to a new waste stream of high activity radionuclides such as Cobalt-60 with extremely high radiation levels. Due to these increased concentrations, and high activity components, new restrictions were required to provide enhanced protection of the burial environment from migration of radionuclides, transportation and protection of site workers. Some of these restrictions were administrative in nature for better management controls, but others required innovative measures on the part of waste generators and their contractors to meet these new regulatory requirements. For the most part, generators had the ability to comply with the requirements. Some took longer than others to affect changes in their waste programs. Eventually all generators complied, although some of them did so "kicking and screaming" during the process of change. However, the S.C. Department of Health and Environmental Control (DHEC) Bureau of Radiological Health worked very closely with the burial facility operator, the waste generators, and the NRC to formulate these requirements. 10 CFR Part 61 reflects many of these restrictions which were vanguarded by the State of South Carolina.

Chronological History of Major Restrictions

1. October 1974 - During the period May 1972 to October 1974, CNSI was authorized to receive bulk shipments of liquids for on site solidification prior to disposal. This allowance was made due to the under design of evaporators at most of the regional reactor sites. During that era, many waste generators did not have the capability to solidify large volumes of water which were slightly contaminated. Therefore, they were allowed to ship these liquids in large tankers for processing at the burial site. This concept became quite controversial from a transportation standpoint and would have severe repercussions if an accident occurred and large quantities of liquids were released. This

practice was reviewed and determined not to be in the best interest of the state from a public health standpoint, thus the requirement to solidify liquids at the point of origin was initiated.

The reactor sites vehemently objected to this decision. However, mobile solidification units were designed and put into operation at the reactors, and permanent solidification units eventually built. The generators were able to comply with this restriction although it was expensive through the use of contractors. Urea formaldehyde was selected as the media of choice and was eventually disallowed as a solidification media due to its extensive hazardous and corrosive properties.

2. April 1979 - Following the accident at Three Mile Island (TMI) a public statement was made that in effect said "any waste resulting from the accident would probably be disposed at Barnwell." This evoked a public and political outcry. Little was known at that time about the amounts of waste, what the waste would contain, and the concentrations. Therefore, an immediate ban was imposed to prevent any waste from this facility from being disposed at Barnwell. This decision was later supported by the analysis of certain waste that contained large concentrations of fission products and transuranics. This action also caused a rethinking of low level waste, and that stricter requirements would be necessary. Since then however, TMI waste has been accepted at Barnwell on a selective and qualified basis. The ability for TMI to comply with their restriction is still being evaluated.

3. May 1979 - The ban on organic liquids such as scintillation fluids containing hazardous chemicals was imposed to avoid environmental consequences from their chemical properties and mobility. It was also to reinforce the long standing restriction that the radioactive hazard had to outweigh the chemical hazard to be acceptable for disposal. Clearly, scintillation fluids with slight quantities of tritium and Carbon-14 were overwhelmingly, chemically hazardous. This proved to be a major decision because later, mixed wastes under the provisions of the Resource Conservation and Recovery Act (RCRA) were prohibited from disposal at all sites. This decision was not taken well by a number of generators performing research using these compounds. However, new regulations were promulgated which allowed disposal of these fluids by other methods. It also brought about the use of nonhazardous fluids and recycling of the hazardous "cocktail" mixtures.

4. October 1979 - Through DHEC's inspection efforts, it was determined that many waste forms arriving at the burial facility contained large quantities of freestanding liquids, and occasionally these liquids were found to be corrosive to the carbon steel burial containers. Not only did this cause concern

for the potential of radionuclide migration, it presented a problem during transportation due to leaking containers. Therefore, a freestanding liquid restriction of no more than 0.5% non-corrosive liquids by waste volume was imposed. Further, due to the increased concentrations of radionuclide in ion exchange resins and other filter media, all waste containing radionuclides with half-lives greater than five (5) years having a specific activity of one (1) microcurie per cubic centimeter or greater required stabilization by an approved solidification media. Previous to this, ion exchange resins were allowed to be "dewatered"; however, this earlier process left large amounts of residual liquids in the containers.

These new restrictions caused considerable controversy throughout the nuclear industry and DHEC was besieged with concerns of the ability of generators to meet these new sanctions. Even the NRC expressed their concerns. DHEC considered these objections and formulated a phase-in schedule to allow the generators time to comply and acquire the equipment and/or services. For those utilities who failed to make progress, they were prohibited from shipping their waste. The results of these restrictions were quite profound, and went a long way to provide credibility for shallow land disposal. By January 1, 1981, these restrictions were fully implemented.

5. November 1979 - It was becoming increasingly evident that the Barnwell site had become the major commercial low level waste site in the nation accepting over 75% of waste transferred for disposal (not generated). This was viewed by the political leaders of the state as an unacceptable situation. Therefore, Governor Richard Riley requested DHEC to impose a volume limitation on Barnwell. This decision was twofold; not only was there concern about the public's health from the impact of increased transportation, but the capacity for South Carolina generated waste was being jeopardized. Earlier, in January 1978, a volume restriction had been imposed not to exceed 2.4 million cubic feet per year. The November 1979 restriction established a declining schedule that limited the site to no more than 189,000 cubic feet per month and by October 1981, the site could only receive 100,000 cubic feet per month. This is now the permanent restriction of 1.2 million cubic feet per year.

This plan also required a prior notification condition and an allocation scheme to insure that South Carolina's interests were preserved and its waste given priority. CNSI was responsible to administer the allocation program based on the historical waste disposals made by all the generators.

The volume limit restrictions had a considerable impact on the nuclear industry, and almost created a panic situation; more so than the present eventuality that the Barnwell site will close at the end of 1992. However, waste generators again took innovative measures to solve this problem confronting them. Better waste management practices were devised such as segregation and compaction. Advancements were made in waste processing such as extrusion, evaporation, and solidification. Ion exchange resins were regenerated and loadings became heavier. However, there were some negative consequences to this. Waste became higher in radionuclides and more hazardous from a handling, transportation, and disposal standpoint. This required further restrictions concerning containment of waste, and improving handling techniques during disposal operations.

6. October 22, 1980 - Due to increased concentrations of radionuclides in waste forms such as ion exchange resins and other filter media, certain utilities were having problems meeting the stabilization requirements previously established. In order to allow an alternative to solidification, DHEC conceived the idea to allow disposal in containers that could act as a secondary barrier within the disposal trench, and contain waste in a manner superior to solidification. There has always been controversy concerning solidification, and the various media and their processing problems. Therefore, DHEC issued its criteria for the High Integrity Container (HIC). This caused serious repercussions from vendors supplying solidification services for the utilities because they viewed this as an encroachment on their business interest. On June 1, 1981, the first HIC was approved and a 90 day allowance was granted to phase out carbon steel dewatering liners for Class A Stable and Class B and C wastes.

The use of HIC's proved to be a successful alternative to solidification and went far to improve ALARA at the reactors and the disposal site. However, a controversy arose in the late 80's from the use of polyethylene as a HIC material. It was the position of the NRC that this material did not meet the stability criteria and that the containers would deform under the trench backfill and crack, causing the release of radionuclides. Although DHEC did not totally agree with this postulation, concrete overpacks are now used for the emplacement of polyethylene HIC's in the burial trenches to provide stability. This of course increased burial expenses significantly, but it did provide a reasonable solution to the perceived problem.

7. December 27, 1983 - 10 CRF Part 61 conditions were implemented at the Barnwell Site. This had a significant impact on waste generators concerning the proper classification of their waste streams. Prior to the implementation however, DHEC required all waste streams to be properly quantified and qualified, and accurately account for the radionuclide concentrations. Therefore, the generators had established data bases and formalized their process control programs to assure proper classification. Many generators were assisted by vendors who developed elaborate computer codes. The impact of 10CRF Part 61

on burial facility operations was somewhat minimal due to the fact that many of the restrictions had been put in to affect in phases by the state previously, and it was not a tremendous problem for the generators to comply with the new restrictions.

Legislative Restrictions

On July 1, 1980, the State of South Carolina's Low Level Waste Transportation and Disposal Act was enacted. This state legislation was very unique and somewhat controversial to waste generators. For the first time in regulatory history, persons transporting waste were required to secure a transport permit, provide financial liability, and give three day advance notice of their shipments. This legislation also subjected them to enforcement sanctions by the state in the form of civil penalties and permit suspensions for noncompliance with federal and state regulations. In an effort to minimize the impact on waste generators, the state devised a permitting and notification system that was reasonable and somewhat simplified. This program has been extremely effective in the management of low level waste and regulatory compliance.

Examples of LLW Restrictions at Barnwell

1. Liquid radioactive waste in any form. ALL liquids must be solidified in approved media. Allowances made for incidental free-standing liquids in solidified waste forms and dewatered resins. There are no liquid allowances for other waste forms. Absorbants may not be used as a substitute for solidification. Absorbants only allowed for incidental liquids such as condensation.

2. Scintillation fluids, e.g. toluene, xylene, dioxane, or other similar organic liquids or solids to include empty vials, bottles, glassware, etc. which have contained these fluids.

3. Unsolidified sludge, aqueous filters, filter sludges, evaporator bottoms, and ion exchange resins. Allowances made for dewatered resins less than 1 uCi/cc.

4. Radium, except for small quantities in biological waste, dials of instruments, compasses, watches, etc. NO technologically enhanced radium sources, contaminated soil, rubble, unless specifically approved by the Department on a case-by-case basis.

5. Transuranic waste (Pu-239, AM-241, etc.) Limited to mixed radionuclides: 10nCi/gr. - Class A, 100 nCi/gr. - Class C. Waste primarily contaminated with transuranic at or below limits is prohibited.

6. Waste containing chelating agents with concentration greater than 8% weight by volume.

7. Radioactive waste containing toxic or hazardous chemicals where an evaluation has determined that the hazard posed by the chemical or chemicals exceeds that of the radioactive constituents.

8. Radioactive waste capable of producing toxic gases, vapors, or fumes.

9. Pyrophoric radioactive waste and reactive materials.

10. Contaminated oil or pertroleum based material in any form. Allowances made for incidental absorbed oil less than 1% by waste volume.

11. Untreated or improperly packaged waste containing biological, pathogenic, or infectious material.

12. Any dispersable radioactive waste such as incinerator ash, residuals or powders unless solidified or specifically approved packaging.

13. Uncontained or bulk radioactive waste. ALL waste must be packaged in acceptable closed containers.

14. Waste which exceeds Class C limits. Sealed source with concentrations that exceed Class C limits are reviewed on a case-by-case basis.

15. Gaseous radioactive material other than Krypton 85 and Xenon 133.

16. Unencapsulated sealed sources or special form radioactive materials greater than 5 curies.

Additional Requirements

1. Solidification media must have an approved topical report by the NRC and final approval by state. All solidified waste must meet NRC's Branch Technical Position On Waste Forms and stability requirements of the license.

2. High integrity containers (HICs) used as an alternative to solidification or encapsulation must be approved by state. As of March 1, 1986, all HICs received must have passive vent system, approved by the Department.

3. Waste with concentrations at or greater than 1 uCi/cc total with half-lives greater than 5 years must meet stability requirements of Class B-C waste.

Conclusion

Low level waste has experienced a considerable evolution over the past twenty years requiring numerous restrictions for shallow land disposal. The ability of waste generators to comply with these restrictions has been quite extensive and costly, but there was a workable solution to each problem that arose. This is due in part to the cooperation throughout the nuclear industry and a reasonable approach taken by the regulatory agencies.

Today we are faced with even more challenges under the Low Level Waste Policy Amendments Act of 1985. It is yet too early to predict the outcome of this major restriction.

<u>References</u>

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2. Memorandum of May 18, 1971 from H.G. Shealy, Chief, BRH, DHEC to L.E. Priester, Jr. Ph.D., DHEC.

3. Legal Notice of Public Hearing, E. Kenneth Aycock, M.D., S.C. State Health Officer.

4. Letter of October 26, 1979, From Governor Richard R. Riley of South Carolina to Malcolm Dantzler, M.D., DHEC Commissioner.

5. Letter of November 2, 1979, from David M. Reid, Executive Assistant to Governor Riley to H.G. Shealy, Chief, BRH, DHEC.

6. Letter of March 11, 1980 from L. B. Hubbard, CNSI to H.G. Shealy.

7. Letter of October 30, 1979, from H.G. Shealy, to Bruce W. Johnson, President, CNSI.

8. Letter of February 2,1 982 from H.G. Shealy to J. Purvis, CNSI

10. Interview between V.R. Autry and H.G. Shealy on August 15, 1990.

11. High Integrity Container Criteria, SC DHEC October 22, 1979.

12. S.C. Radioactive Material License 097, issued to CNSI.

13. 10 CFR Part 61, U.S. Nuclear Regulatory Commission.

14. Part VII, DHEC Regulation 61-63, Radioactive Material (Title A).

15. DHEC Regulation 61-83, Transportation of Radioactive Waste Into or Within South Carolina.

EMERGING LOW-LEVEL WASTE TECHNOLOGIES

Emerging Technologies in Low-Level Waste

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Abstract

There appear to be three types of new or emerging technologies in Low-Level Waste Management:

1) Technologies developed a number of years ago, but still not commercially used;
2) Existing technologies that are newly applied to LLW Management, and
3) Newly developed technologies that are gaining acceptance in the Radwaste community.

This paper provides a brief update on technologies from each of the areas listed above. However, emerging coating materials for LLW containers is the focus of this paper.

NOTE: The author is not endorsing the vendors identified with the technologies listed in this paper. The list of technologies presented is not exclusive and EPRI would be pleased to hear of other emerging technologies.

INTRODUCTION

There appear to be three types of new or emerging technologies in Low-Level Waste Management:

1) Technologies developed a number of years ago, but still not commercially used;
2) Existing technologies that are newly applied to LLW Management, and
3) Newly developed technologies that are gaining acceptance in the Radwaste community.

The following is at best a partial listing new and emerging technologies.

New Technologies Not Commercially Used	Available Technologies Newly Applied to LLW	Newly Emerging Technologies
1) In-situ Waste Vitrification	1) Fiberglass HIC	1) 3R-STAT
2) Soil Conditioning with Andisols	2) Concrete HIC	2) Sludge Drying
	3) Container Coatings	3) NOREM
	4) Carbon Dioxide Blasting	4) Steel and Liner Coating
	5) Electrochemical Ion Exchange of Decon Solutions	
	6) Smelting for V.R.	
	7) Hollow Fiber Filters	
	8) Cation Fiber	

NEW TECHNOLOGIES NOT COMMERCIALLY USED

1) In-situ Waste Vitrification

NEW TECHNOLOGIES NOT COMMERCIALLY USED

1) In-situ Waste Vitrification

Vitrifying waste in the disposal unit through the use of electrical energy which super heats the waste to a molten form. The molten waste when it cools results in a glass like substance. Off gases from this process are controlled and treated prior to release to the environment. The technology has been successfully tested and is available.

Contacts: EG&G Idaho, Idaho Falls, ID
Battelle Pacific Northwest Labs Richland, WA

2) Soil Conditioning with Andisols

Conditioning the near field environment around waste packages and disposal units with agents to bind up anionic forms of radionuclides particularly long-lived ones such as Tc-99 and I-129 can be achieved through the use of andisols. These are soils formed from volcanic parent material in the Western United States. They can be used as backfill around waste packages, around and under disposal units.

Reports: "Anion Retention in Soil: Possible Application to Reduce Migration of Buried Technetium and Iodine—a Review," by B. Gu and R. K. Schulz, U.S. Nuclear Regulatory Commission NUREG/CR 5464.

Contact: Dr. Robert K. Schulz, Department of Soil Science, University of California Berkeley, Berkeley, California 94720. Telephone 415-642-2205.

AVAILABLE TECHNOLOGIES; NEW TO LLW

1) Fiberglass High Integrity Containers (HICs)

The EG-series containers have a material that is a glass fiber-reinforced plastic (FRP) formed by filament winding, hand lay-up, and chopped-strand construction methods using E-glass and a vinyl-ester thermosetting resin. For further corrosion resistance, the inner surface is a formed synthetic barrier. The vendor has reported test data to demonstrate 300-year integrity for this container. NRC's review is expected to be completed in January 1992.

Contacts: Pacific Nuclear Corp , Colombia, SC

2) Concrete HICS

Fiber-reinforced polymer impregnated concrete-lined steel container produced in Japan - CHICHIBU.

Contacts: CHICHIBU Cement Company, Japan

Precast concrete lining for insert into a liner.

Contacts: Scientific Ecology Group, Inc., Oak Ridge, TN

In Europe, reinforced and impregnated concrete for container material is used primarily. These containers are lined with epoxy resin paints or butyl rubber.

Contacts: Not available at this time.

3) Container Coatings (Discussed in detail p.4)

4) Carbon Dioxide Blasting

Dry ice pellets, up to 1/4" in length and up to 1/16"in diameter are introduced into a high velocity stream. This propels the pellets at subsonic, sonic and higher speeds. The dry ice particles are directed at a surface to be decontaminated. On impact the dry ice particles sublime, leaving only the contaminant for disposal.

Contact: Waste Minimization & Contaminant Services, Inc., Cleveland, OH

5) Electrochemical Ion Exchange of Decontamination Solutions
"In its simplest form the ELOMIX cell consists of three compartments, (anode, cathode and resins) separated by cation permeable membranes. In the resin compartment, radioactive and chemical components are removed from the flowing solution in the resin compartment." NP-7277, May 1991 Westinghouse has the license for this technology.

Reports: "Electrochemical Ion Exchange of LOMI Decontamination Solutions." NP-7277, May 1991

Contacts: Westinghouse

6) Smelting for VR
Iron smelting technology is being pursued by one company and will be used on contaminated iron pipes, etc. from nuclear facilities. The resultant material can be efficiently turned into solid blocks for disposal or turned into containers for waste handling. The use of the material depends upon the level of contamination.

Contacts: Scientific Ecology Group, Inc., Oak Ridge, TN

7) Hollow Fiber Filters
Hollow Fiber Filters (HFF) are used in place of conventional precoat filter in dual condensate purification systems. The HFF is made of macaroni-like annular fibers. It has an extremely large surface (filtration) area per unit volume. Its filtration area is 10 to 100 times as much as a conventional membrane or precoat because the diameter of each fiber used is extremely small. The result is more efficient processing, thereby producing less waste for disposal.

Reference: "Operational Experience of Hollow Fiber Filter For Condensate of BWR" Hirahara, Y., Mochizuki, H. Tajima, F, Saskai, N. and Shirai, T. Toshiba Corporation and Tokyo Electric Power Company, Inc.
"The Application of Hollow Fiber Filter Membrane Filtration to the Power Industry" Peter E. Down (Romicon, Inc.) EPRI Conference 1991 Filtration of Particulates in LWR Systems

Contact: EPRI, Tom Passell, (415) 855-2070
Toshiba Corporation, Japan

8) Cation Fiber
Precoating with powdered resin and fiber mix. Fibers are stiff which prevents the powdered resin from compressing, resulting in less resin surface available for capturing contaminants. The stiff fibers improve the porosity of the resins increasing their life and efficiency. This results in more effective resin use and less resin for disposal.

Reference: "Step Precoating with Powdered Resins and Cation Fiber" Richard P. Gerdus, Vermont Yankee Nuclear Power Corporation. EPRI Workshop on Filtration of Particulates in LWR Systems, September 1991.

Contacts: EPRI, Tom Passell, (415) 855-2070

EMERGING TECHNOLOGIES

1) 3R-STAT
A computer code that assesses fuel conditions and from these assessments, the model provides estimates of the release rates of I-129 and Tc-99 over the specified reactor operating period. The model has been verified at over 15 facilities and is being used by six Compacts/States to project the Iodine-129 source term of their proposed LLW disposal facility. The I-129 source term developed using this technology can be a 1,000 to 10,000 fold improvement in accuracy over other more commonly used methods. This source term is necessary for accurately calculating the site's performance assessment i.e., dose to humans.

Reports: "Iodine-129 and Technetium-99 in Low Low Level Waste from New York State Reactors" EP 89-45 ESEERCO July 1991
Contact: Vance & Associates, Ruidoso, NM

2) Sludge Digestion and Drying

This Sludge drying technique uses a proprietary pretreatment, centrifugal concentration and indirect drying of the concentrate. This drying process then results in the formation of dried pellets which can be incinerated.
Contact: WasteMaster, Inc., Charlotte, NC

3) NOREM

Cobalt-free, wear-resistant alloys, designated NOREM, have been developed for nuclear valve and turbine applications. Laboratory evaluations and component (valve) tests show that these alloys perform better than the long-established cobalt-base Stellites typically used in nuclear plant valves. Weld wire and welding procedures have been developed for valve repair and refurbishing. Four organizations have executed nonexclusive licenses with EPRI to produce and market these alloys.

3) NOREM (contd)

Reports: "NOREM Wear-Resistant, Iron-Based Hardfacing Alloys," EPRI NP-6466-SD, July 1989
"Qualification Loop Tests of Cobalt-Free Hardfacing Alloys - PWR Phase 1989-1990 Progress," EPRI-7030-D, November, 1990
Contact: EPRI, Howard Ocken, (415) 855-2055

4) Steel Drum Coating (Detailed discussion p.6)

CONTAINER COATINGS

Because most of the new disposal sites will not be available as of January 1,1993 and existing disposal sites can stop accepting out of state wastes as of that date, issues associated with interim on-site storage of LLW are of growing importance. One factor crucial to the extended storage of wastes is container integrity. Container life can be extended by the use of coatings.

Coatings can be applied either internally or externally, or both to metallic waste containers. Internal coatings are applied to protect the containers against corrosion from contact with waste or waste products. External coatings protect the container from the outside environment. In order to accomplish this protection coating function in one of three ways:

1) inhibit corrosion of the steel,
2) protect the steel by being a sacrificial material, or
3) act as a barrier to any reaction with the steel.

Inhibitive coatings work by releasing ionic material from the pigments in the coatings in the presence of penetrating water. Often the ionic materials are chromates or molybdates. The result of this interaction slows down the corrosion process.

Sacrificial coatings, on the other hand, contain pigments such as zinc. These coatings produce a bi-metal electrical corrosive cell where the zinc becomes the anode and the steel is the cathode. The anode material when interacting with liquid (either in the waste or on the outside of the container) slowly dissolves leaving a protective layer on the cathode i.e., steel. (When the zinc dissolves in the liquid the liquid becomes the electrolyte, i.e., a pathway for the ions to move through and be deposited on the steel. This is the same kind of reaction that occurs in a battery.)

Finally, barrier coatings provide the steel a tighter cohesive film type coating with a low permeability to water, oxygen and ionic material.

Coatings used on radwaste containers today are the barrier type. These coatings are primarily alkyd primers, enamel, melamine-alkyd resin and epoxy resin paints. These materials are usually sprayed on with thickness of at least 0.005 inches. The metal surfaces should be freshly sand blasted prior to applying the barrier material for best results. Better protection is achieved when four light coats are applied rather than one or two heavier coats.

The following discussion addresses commercially available container coatings not frequently used in the industry but which are worthy of further investigation and assessment relative to future use.. Each of the coating materials discussed is a barrier type coating.

Container Coatings

Auto Oxidizing Resins

This type of coating dries and ultimately cross links by reacting with available oxygen. This group of coatings also contain drying oils which form films though oxidative drying. In these resin coatings, oil (usually a vegetable oil) is combined with the resin which adds toughness and chemical resistance. This improves the resins overall weather and moisture resistance. The amount of oil added to the resin affects the characteristics of the product. For example, adding more oil results in less chemical resistance but higher penetrability of the coating and better protection of uncleaned surfaces. Where as adding less oil results in having to apply the resin to a clean surface, but the resin then has good chemical and moisture resistance.

These resins ar very resistant to water vapor. However, their properties do not hold up well in the presence of strong organics, basics or acids. Modified akyl resins, i.e., adding melamine-formaldehyde, improves their resistance to acids and bases. Still these coatings are not considered good in the presence of strong acids or bases. In addition they still do not exhibit the properties necessary to protect the container from organics.

As you are aware, enamel paints are regularly used on 55 gallon drums (17H containers), B25 Boxes and sometimes on liners. Though modified (melamine-) alkyd resin and epoxy-resin paints are commercially available they are not consistently used in the US nuclear industry. Japanese studies using melamine-alhyl paint on the outside of 17H containers with epoxy paint on the inside have shown this coating application increases the life expectancy of these containers considerably. The study results projected an 80 year life when continuously immersed in either river or sea water.

Thermoplastic Resins

Thermoplastic resins soften at elevated temperatures. The molecular structure of these resins are not cross-linked into a rigid molecule.

Examples of this type of resin are:

1) vinyl coatings, which are derived from solvents such as ketones or glycol ethers. Most vinyls include a UV scattering material enhancing their resistance to UV. These coatings have excellent resistance to water and moisture.

2) chlorinated rubber coatings are non-flammable and have excellent resistance to acid, alkali, and oxidizing agents. In addition they have very low water vapor transmission rates.

3) polyethylene coatings consist of polymers and copolymers from acrylic and acrylic acid. These resins have excellent UV stability and chemical and moisture resistance to weathering. However in strong chemical environments they are not recommended.

4) bituminous resins such as asphalt and coal tar are the most useful thremoplastics for corrosion control. In addition they have superior resistance to moisture, acids and alkalis as well as excellent weathering properties. One draw back is, they will redissolve in their original solvent i.e., toluene, benzine, etc. (depending on what they're made of). For this reason thermoplastic resins are not normally used for high concentrations of organic liquids.

Though commercially available, these coatings are not extensively used in the US nuclear industry except as liners in some stainless-steel containers. However due to their unique properties they are being evaluated relative to their potential use for extended storage of wastes.

Thermosetting Resins

Thermosetting resins refer to a class of material whose final coating properties result from chemical reactions with a copolymer (an organic compound) or moisture. The result is a cross-linked polymer i.e., any epoxy resin. The chemical cross linking that occurs during their formation creates large three-dimensional molecular structures. These structures are what make these materials tough, flexible and a highly chemical-resistant barrier which protects the metal surface to which it is applied.

Materials in this chemical reaction group include 1) epoxies, 2) unsaturated polyesters, 3) urethanes, 4) high-temperature curing silicones and 5) phenolics (i.e., polyurethanes and zinc laden organics). Coatings resulting from these materials, except the phenolics, can have excellent resistance to acids, alkalis and moisture. In addition they resist abrasion, degradation from UV and heat. Again, a key feature of these resins are their flexibility.

Once more, though these materials are commercially available, readily recognized as epoxy resins, coal-tar resins and urethane coatings, they are not currently used by the US nuclear industry. However, they are under evaluation relative to their applicability to extended storage of LLW.

Steel and Liner Coating

Finally, a topical report is being reviewed by the NRC to evaluate a product that would be applied to 17H containers (55 gallon drums), boxes or liners to qualify the container as a High Integrity Container (HIC). The product is a combination of thermoplastic and polyamide thermosetting resins that combines the superior properties of both materials to provide a flexible, tough barrier coating. Because of proprietary considerations major portions of the topical report submitted to NRC are not available for public review.

Reports: NRC Topical Report
Contact: Avancer, Charlotte NC

CONCLUSIONS

These are just a few examples of coatings which are being investigated by the industry. Further evaluation is necessary to determine which type of coating material and/or in what combination is best for specific waste types and waste forms for extended storage. EPRI will be publishing a report in the spring of '92 which will provide information on coatings and wastes to improve our ability to match the correct coating to meet the storage situation at hand.

Clearly, when we talk about new and emerging technologies, there are a significant number that can and will impact the many facets of LLW management. Keeping up with these technical developments is complicated by the fact that their original development was not in response to a low level waste management need. However, successful use of these technologies depends upon correctly matching the technology with the need. It is imperative that the potential user understand exactly what is to be accomplish and determine whether implementing a new technology is going to ultimately accomplish the defined objective. Sophisticated use of new and emerging technologies is the most difficult but provocative goal we can set for ourselves. The next most challenging task is sharing what we've learned.

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Office of Environmental Restoration and Waste Management (EM)

How Technology Transfer Issues Are Managed

by Claire H. Sink, Technology Integration Division, DOE
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Introduction

Since the Manhattan Project in the 1940s, the United States has been engaged in producing nuclear weapons for national security. However, with the recent breakup of the Soviet Union, the Cold War appears to have ended and the potential for continued improvement in superpower relations is more promising than ever. With this turn of events, there is a growing belief within the Administration and among the American public that future nuclear weapons production should be reduced. Accordingly, DOE is downsizing and reconfiguring the nuclear weapons complex (the Complex) to respond to substantially revised mission requirements.

In 1989, Secretary of Energy James Watkins made a commitment to accelerate DOE compliance with all applicable laws and standards aimed at protecting human health and the environment. At a minimum, this pledge requires the remediation of the 1989 inventory of chemical, radioactive, and mixed wastes at DOE production sites by 2019. The 1989 Complex inventory consisted of more than 3,700 sites, encompassing more than 26,000 acres contaminated with radioactive, hazardous, and mixed wastes. In addition, over 500 surplus sites are awaiting decontamination and decommissioning (D&D), and approximately 5,000 peripheral properties have contaminated soils (e.g., uranium tailings). Moreover, these problems exist at both inactive sites, where the primary focus is on environmental restoration, and at active sites, where the major emphasis is on improved waste management techniques.

Although some of DOE's problems are considered unique due to radioactivity, most forms of contamination resident in the Complex are not; rather, contaminants such as waste chemicals (e.g., inorganics), organics (e.g., fuels and solvents), halogenated organics (e.g., PCBs), and heavy metals commonly result in conventional industrial processes. Although certain other forms of contamination are more unique to DOE operations (e.g, radioactive materials, explosives, and pyrophorics), they are not exclusive to DOE. As DOE develops innovative solutions to these and related waste problems, it is imperative that technology systems and "lessons learned" be transferred from DOE sites and its R&D laboratories to private industry to maximize the nation's return on environmental management technology investments.

The EM Organizational Structure

Central to the Department's newly established thirty-year environmental cleanup mission, Secretary Watkins authorized the formation of the Office of Environmental Restoration and Waste Management (EM). Within EM, the Office of Technology Development (OTD) was concurrently formed to establish and maintain an aggressive national program for applied research and development, resolve major technical issues, and rapidly advance beyond current technologies for environmental restoration and waste operations. Under the aegis of OTD, the Technology Integration Division (TID) facilitates the infusion, adoption, and diffusion of innovative environmental management technologies to foster enhanced environmental restoration and waste management capabilities within the DOE Complex and among private industry, universities, and other governmental entities.

To uphold this thirty-year commitment, the EM strategy is to use the best available technologies (BATs) developed by industry, universities, Federal agencies, and other organizations engaged in the practice of research and development (R&D) to achieve regulatory compliance, remediate contaminated DOE sites, and successfully manage waste streams. Unfortunately, in many instances BATs are incapable of satisfying current and future regulatory requirements. Without the requisite public and political backing (e.g., Congressional funding commitments), OTD efforts to develop innovative suites of environmental management technologies will be severely constrained.

To ensure environmental stewardship, progress towards environmental compliance, and achieve cleanup goals by the year 2019, EM must first reduce the enormous costs and lengthy and rigorous compliance schedules associated with cleanup. In addition, EM has estimated that future waste generation must be reduced by as much as 80 per cent. If the thirty-year mission is to be achieved, EM programs and personnel must serve as catalysts for change within the DOE Complex. The Secretary indicates this "new culture will emphasize an open door philosophy ... wherein constructive criticism from any source, external as well as internal, is encouraged and rewarded."

To promote the requisite cultural changes, EM has developed a comprehensive strategy that encompasses the following activities: ensuring the treatment and/or disposal of stored wastes; developing and deploying innovative technology solutions to environmental problems; structuring program activities to support regulatory reform; communicating with stakeholder publics; expanding the human resource base; practicing pollution prevention; training and/or retraining current staff as well as new hires; and integrating and institutionalizing EM activities (i.e., environmental restoration, waste management, and technology integration) into current and future Departmental activities.

EM's Technology Development Mission

OTD has established and is currently maintaining an aggressive national research, development, demonstration, test and evaluation (RDDT&E) program to deliver technology which ensures *faster, better, safer, and cheaper* attainment of environmental restoration and waste management goals. For this to occur, OTD must attract and sustain a qualified environmental work force that is responsive to increasingly complex regulatory requirements. OTD also must transfer innovative technologies and "lessons learned" to appropriate points of contact within the user community. Industry is encouraged to participate during RDDT&E to ensure innovative technologies and generic solutions are transferred to the commercial marketplace to assist private industry in satisfying relevant statutory and regulatory requirements.

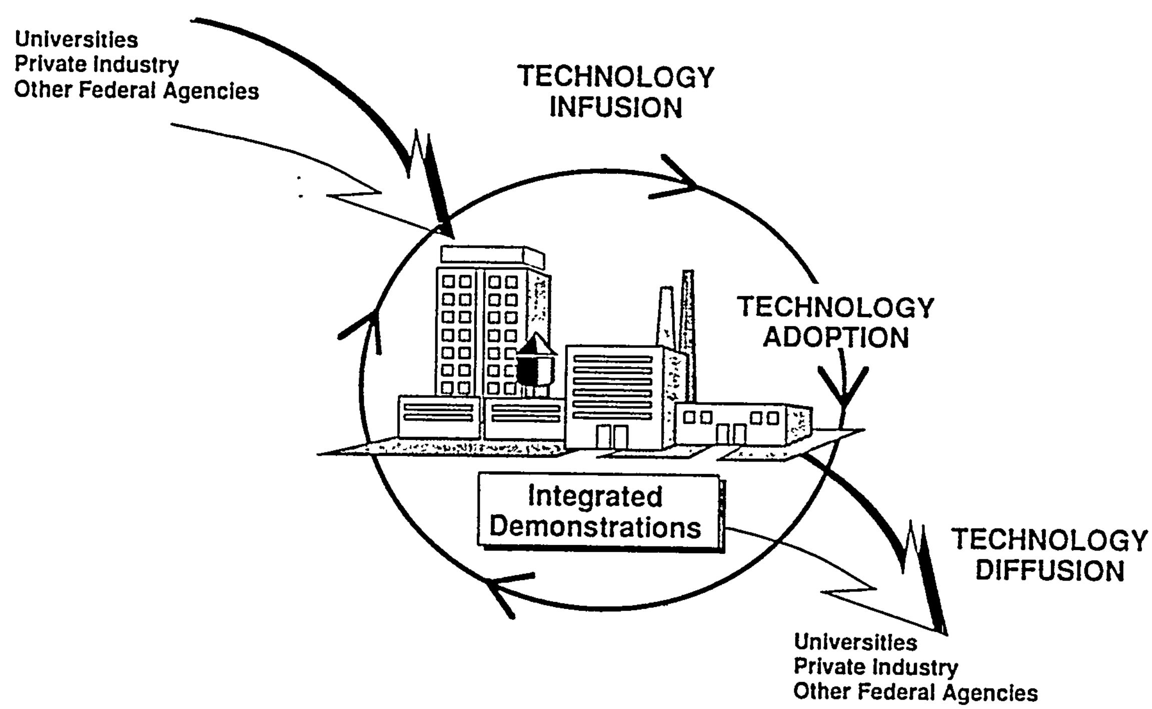

Figure 1

Technology integration encompasses the infusion, adoption, and diffusion of innovative environmental technologies, and is largely the province of TID. The goal of technology infusion is to facilitate the transfer of outside technology into DOE for environmental restoration, waste management, and technology integration evaluation. Technology adoption activities are focused on the transfer of technologies successfully demonstrated at one DOE site to other sites with similar EM technical issues. Technology diffusion activities facilitate the transfer of successfully demonstrated environmental technologies from the DOE Complex to industry, academia, and other governmental entities confronted with similar environmental challenges (See Figure 1).

Since 1990, TID has succeeded in establishing collaborative partnerships with U.S. industry, the National laboratories, other Federal agencies, universities, and certain international participants to facilitate timely and effective applications of generic technologies to satisfy a growing array of Federal, State, and local environmental requirements. TID also supplements OTD's systems approach to developing integrated solutions to EM problems, one that capitalizes on the cross-cutting relationship between Integrated Demonstrations (IDs), which investigate potential "end-to-end" solutions for DOE site problems, and Integrated Programs (IPs), which undertake a set of RDDT&E activities that are responsive to an individual problem category (e.g., waste minimization, characterization, treatment, storage, and disposal) commonly encountered throughout DOE sites and facilities. Whereas IDs are structured to solve problems common to particular sites, IPs develop specific technologies to solve waste stream problems (See Figure 2).

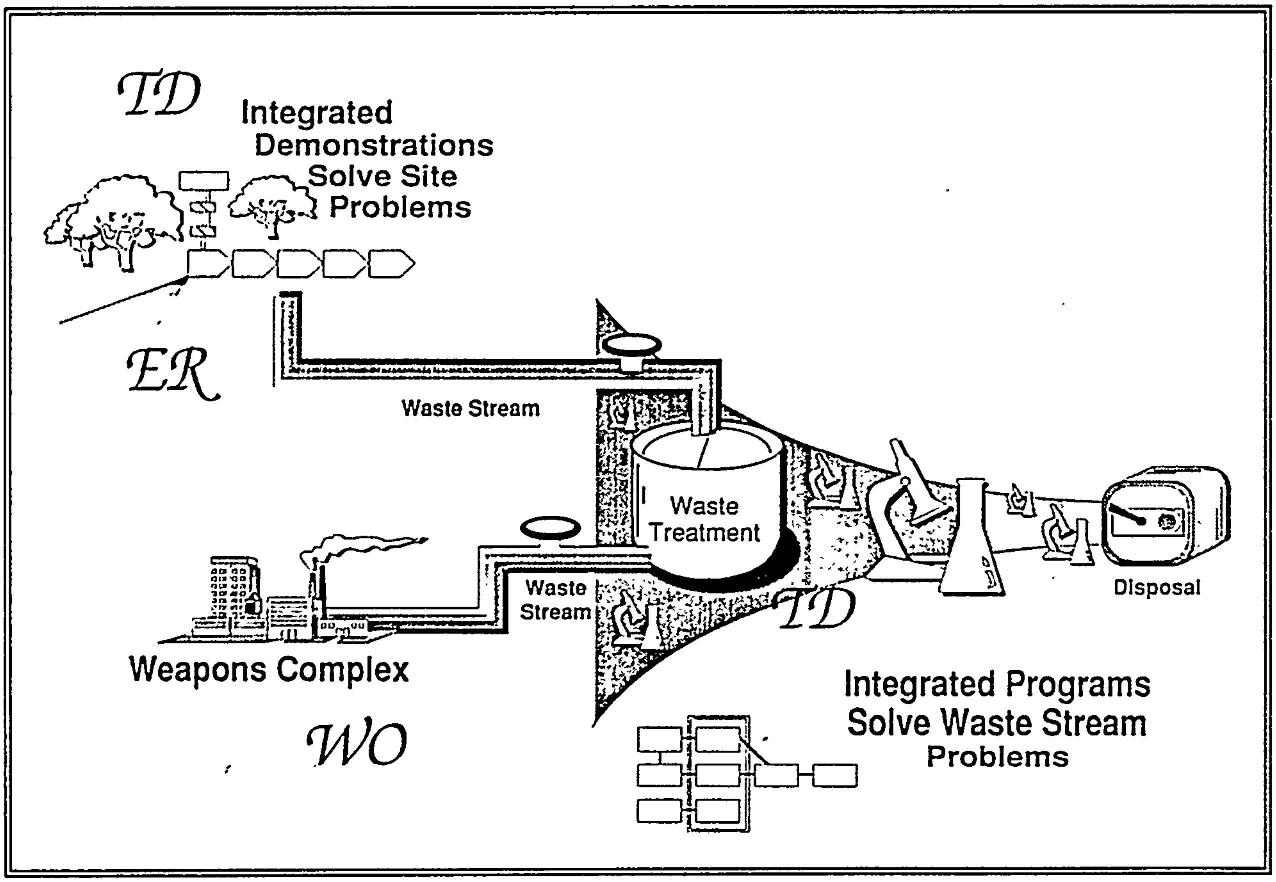

Figure 2

Environmental Restoration IDs proceed through various characterization, assessment, remediation, and monitoring phases, and are designed as full-scale technology evaluation projects. These projects are implemented concurrently so alternative technical solutions to specific environmental restoration problems can be examined and evaluated in parallel. In addition, they are planned and executed in a context that considers pertinent factors associated with full-scale environmental restoration (e.g., planning, regulatory permitting, and public acceptance). Waste Operations IDs, like their environmental restoration counterparts, involve the parallel testing of multiple technologies so the advantages of one technology versus another, as well as potential combinations of technologies, can be weighed accordingly.

Because IDs are conducted on a systems basis, relevant determinations (e.g., cost, efficiency, and technical merit) can be made regarding a technology's ability to proceed beyond bench-scale tests toward commercial application. However, before innovative suites of technologies are demonstrated in an ID, they are carefully screened. Those with a limited probability for commercial success are typically dropped from further consideration. An exception might involve a technology which has marginal commercial applicability but is uniquely capable of solving problems unique to DOE sites. Similarly, potential costs and benefits associated with these technologies are analyzed and evaluated. In each case, a determination is made regarding potential risks to human health and the environment, and necessary precautions are taken to ensure the minimization of risk and likelihood for success.

The three primary components of the ID are operational, technology filtering, and technology integration. Operational concerns are addressed in the "end-to-end" phases of an ID previously addressed. Technology filtering requires the evaluation and selection of those technologies that successfully navigate the RDDT&E process and satisfy criteria established in the pursuit of faster, better, cheaper, and safer technologies. Technology integration necessitates early and constant interaction among Federal and State regulatory authorities and affected stakeholders (e.g., neighboring communities around DOE sites) to ensure expedited regulatory and public acceptance of innovative environmental technologies.

IPs are centrally managed, though not necessarily centrally located, to provide a focal point for the development of the scientific knowledge base required to satisfy EM goals and objectives. In addition, applied research activities with the highest probability for success are assembled and further coordinated to maximize their synergistic probability. IPs provide a continuing mechanism to focus R&D activities, direct them toward the development of innovative technologies, enable evaluations of their suitability and applicability to existing or planned IDs, and expedite the transfer of results to the DT&E phase. OTD management also ensures that IPs focus on customer needs and avoid redundancy. Furthermore, IPs are coordinated among multiple laboratories and/or participants so that potential solutions to generic problems are broadly disseminated throughout the DOE Complex.

As a complement to the systems approach and programmatic framework of the IDs and IPs described above, OTD engages in joint efforts and cooperative ventures with other government agencies and the private sector to leverage resources and facilitate technology integration (i.e., infusion, adoption, and diffusion). These public-private partnerships serve as a vehicle to increase industrial participation and foster entrepreneurial innovation. They also provide access to the best available environmental technologies developed by industry, universities, the National laboratories, other government agencies, and international parties. In addition, TID identifies eligible technology for testing and evaluation in the IDs and by communicating, coordinating, and transferring results of OTD activities to interested constituencies. This requires not only program outreach but "inreach" to other EM offices, Field Offices, contractor managers, and Integrated Demonstration Coordinators. As a result of these efforts, the potential for duplication is being reduced or eliminated.

Public-private partnerships that tie RDDT&E activities to DOE Site remediation are critical to the success of the IDs. Such win-win arrangements can provide the necessary foundation for a new U.S. environmental management technology base, one that will be increasingly responsive to both domestic and international environmental restoration and waste management needs. In addition to making OTD successes available to private industry, TID is committed to working with State and local organizations to make DOE-funded environmental management technology available for use in various economic development initiatives that create jobs and increase regional economic conditions. By focusing the overall RDDT&E effort on generic, user-identified needs, OTD is able to develop innovative technologies that both outperform conventional technologies and can benefit public-private remediation efforts.

Various TID programmatic mechanisms are employed to ensure goals and objectives are realized. For example, collaborations are funded as cooperative agreements, grants, interagency agreements (IAGs), subcontracts, DOE "Work for Others" (WFOs), and cooperative research and development agreements (CRADAs). In acting as a broker in matching suppliers with end-users of environmental management technologies, TID works as a facilitator to streamline government procedures and overcome bureaucratic inertia. TID is developing a consistent operational philosophy to enhance interactions with current and potential private-sector partners for predictability externally. In addition, TID is working to jointly determine user/market needs and identify and overcome the following barriers to successful collaboration and commercialization: handling of proprietary data; management of potential conflicts of interest; delays in procurement; and distribution of intellectual property rights (IPR).

Overview of Technology Integration Models

Presently, TID is supporting a number of technology integration activities that will provide several program benefits integral to the future success of the EM mission. At the Ames Laboratory, technologists are working in conjunction with TID to develop a technology maturation and derisking model. The first application of this model is a mobile heavy metal sampling, screening, and analysis system. This system will perform two major roles. First, it will enable efficient site characterizations by rapidly identifying concentrations and locations of radioactive contaminants. Second, it will function in a quality assurance/quality control (QA/QC) role in support of environmental remediation activities. By sampling post-remediation contaminant levels on a real-time basis, remediation effectiveness and efficiency levels can be assessed. Furthermore, modifications can be made to current operational parameters of cleanup systems to ensure maximum efficiency. If such mobile sampling technology were not developed, conventional laboratory sampling practices would require between 45 and 90 days per sample.

Using the mobile system capability, it has been estimated that the total time elapsed per sample can be reduced from about 90 days to about 15 minutes. Translated into dollar figures, relevant costs per sample can be reduced from about $4,000 to approximately $500.

In addition, the typical system lifetime will range from 6 to 8 years, with capital costs ranging from $500,000 to $750,000 per system. Assuming a conservative operational level of 50 per cent, each mobile system could analyze up to 5,000 samples per year. Given the number of sites and acreage contaminated with heavy metals within the Complex, at least 10 mobile systems could be deployed effectively at DOE environmental restoration sites over the next 5 to 10 years, thus yielding aggregate cost savings in excess of $100 million from an initial investment of $5 to $7 million.

The Ames Technology Maturation and Derisking capability is structured to leverage U.S. Department of Commerce funding to provide innovative sampling and analysis technology to the IDs. In FY 1992, site liaison activities are scheduled for Savannah River, Rocky Flats, Idaho National Engineering Laboratory (INEL), Hanford, the Nevada Test Site, Oak Ridge, and Fernald. As successes are achieved, technology derisking should continue to produce substantial dollar savings and help ensure the availability of innovative environmental technologies to enable EM to achieve remediation schedules and satisfy compliance agreements.

The Oak Ridge Technology and Software Licensing Model is built around existing Martin Marietta Energy Systems (MMES) technology applications business development and licensing programs. In FY 1992, potential environmental and waste management applications of inorganic membrane technology for in-situ remediation of mixed wastes is being investigated, and its suitability as a cleanable, high-efficiency air filter will be explored. In support of this activity, collaborative projects with industry are being formed to address: remediation of industrial wastes; the development of metal working fluids and environmentally benign solvents to be used in manufacturing applications; and the suitability of reuse/recycling as an integral part of EM waste management efforts.

TID has also initiated a cooperative agreement between EM and the Environmental Protection Agency (EPA) Office of Research and Development (ORD) which has lead to the establishment of the EPA-National Environmental Technology Applications Corporation (NETAC) Private Capital Model. This model is being designed to assist in the cost-effectiveness evaluation of private sector funding in cost-shared arrangements to support evaluation and accelerated development of near-term environmental restoration technologies. Current efforts are focused on determining the feasibility of public-private investment collaboration and establishing a detailed model to facilitate future interactions and agreements.

At Argonne National Laboratory (ANL), an ANL/ARCH Development Corporation is developing the Assesstek New Enterprise Development Model to enhance the potential for technology integration success through public-private interactions and cost-shared arrangements. ARCH, a not-for-profit corporation that is an affiliate of the University of Chicago, will support the formation of a new corporate entity whose fundamental purpose is to provide enhanced environmental systems and services. Licensing of technology and developing new enterprises are two major strengths of this model.

The Colorado Center for Environmental Management (CCEM), a multi-disciplinary consortium established by the State of Colorado to address major environmental issues, has initiated a project that is charged with the development of a comprehensive prototype to address public participation and regulatory compliance issues within the ID framework. As with most environmental initiatives, public participation is a vital element of the EM program because it promotes inputs from stakeholder publics (e.g., Indian Tribes) near DOE sites. Established in FY 1991, the CCEM Technology-Regulatory Integration Project is a regulatory compliance and public involvement prototype for Federal, State, and local governments that influence DOE selection and deployment of innovative technological systems to remediate DOE hazardous waste sites. This prototype is expected to provide an example for encouraging industry, university, regulatory, and public participants to work in conjunction with EM to develop and demonstrate innovative technological systems.

Summary: What TID Will Do For Industry

TID is a support program which locates, assesses, and acquires innovative technologies from other DOE research programs, other Federal agencies, private industry, and academia. In addition, public participation and regulator integration activities central to the success of the IDs are two other major TID thrusts. Whereas two-way communications with stakeholder publics foster public awareness and support for EM activities, regulatory integration helps to accelerate regulatory permitting to facilitate the demonstration and testing of promising innovations. Ultimately, these efforts foster applications of innovative environmental management technology through Records of Decision (RODs) for cleanup of DOE sites.

The TID mission is to transfer information, knowledge, concepts, and technology in, out, and among interested users. TID supports Technology Development activities by infusing, adopting, and diffusing innovative environmental management technologies from industry, academia, and other government agencies to support public and private environmental restoration and waste management activities. As technologies are infused into the DOE Complex, they are moved among the IDs to ensure the broadest possible applicability. Modifications can be made (i.e., technology preparation and adaptation) to accommodate increasingly specific applications of environmental technology unique to a specific site or facility. This may involve either differing combinations of suites of technologies as well as downscaling or upscaling for modularity.

Technologies are intended to be cooperatively developed with industry and sister agencies to ensure successful demonstration and diffusion to the private sector. Tools which enhance technology integration include: industrial workshops to identify mutual technical needs; personnel exchanges between public and private participants; broad public announcement of technology solicitations; and publications that describe ways of doing business with EM. TID also designs "win-win" partnership agreements with other government agencies, academia, and industry, ensures public-private cooperation, and facilitates effective program coordination throughout EM Technology Development and across the IDs. The sum of the technology integration effort contributes to the development of a new environmental technology base to address DOE's thirty-year mission as well as other Federal agency and industry remediation needs.

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WASTE MINIMIZATION

CULTURAL CHANGE AND SUPPORT OF WASTE MINIMIZATION[a]

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INTRODUCTION

Regulations, consumer demands, corporate conscience: for whatever reason, "environmental green" is rapidly becoming the color of choice for American industry. Whether steered toward waste prevention by choice or driven by regulations, the benefits of preventing waste are becoming more and more apparent.

But while bottom line issues are convincing top level managers, pollution prevention requires active participation by the front-line employees actually operating the waste-generating processes. Pollution prevention requires more than just management commitment, but also conscious forethought by purchasing and procurement staffs, design engineers, and mid-level managers; all of whom directly influence an organization's waste generation for well or for ill.

The process of bringing a subject like pollution prevention to top of mind awareness, where designing to prevent waste becomes part of "business as usual," is called *cultural change*.

With Department of Energy orders and management waste minimization commitment statements on file, the REAL work is just beginning at the Idaho National Engineering Laboratory (INEL): shaping the attitudes of 11,000+ employees. The difficulties of such a task are daunting. The 890 square mile INEL site and in-town support offices mean a huge diversity of employee jobs and waste streams; from cafeteria and auto maintenance wastes to high-level nuclear waste casks. The range of employee interests, attitudes, and levels of knowledge are similarly broad. "Feel good" employee programs like recycling must be operated with an eye toward management "bottom line" realities. "Go forth and do good" statements play well with many front line employees but not with results-oriented, measurement-minded managers.

INEL is pursuing a three component cultural change strategy: training, publicity, and public outreach. To meet the intent of DOE orders, all INEL employees are slated to receive

a. Work sponsored by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, under DOE Idaho Field Office, Contract No. DE-AC07-76ID01570.

"pollution prevention orientation" training. More technical training is given to targeted groups like purchasing and design engineering. To keep newly learned pollution prevention concepts top-of-mind, extensive site-wide publicity is being developed and conducted, culminating in the April "Pollution Prevention Awareness Week" coinciding with Earth Day 1992. Finally, news of INEL pollution prevention successes is shared with the public to increase their overall environmental awareness and their knowledge of INEL activities. An important added benefit is the sense of pride the program instills in INEL employees to have their successes displayed so publicly.

WHAT IS CULTURAL CHANGE?

Culture change is the process of bringing a subject to top-of-mind-awareness so that it becomes a normal part of "business as usual." While culture change is achieved partially through publicity and awareness, it is more than just that.

Publicity/awareness campaigns tend to be an "external stimulus" and commonly cause short-term changes in employee behavior usually without changing the root cause of that behavior. A change in *culture* not only changes behavior but it also changes root causes leading to behavior.

Consider a common culture change topic: safety. Safety publicity campaigns commonly encourage employees to remember to don protective equipment like safety glasses. Often such campaigns will run their course and the use of safety equipment improves. Sometimes improvement is short-lived and gains are lost when the campaign ends. While publicity can remind employees to work safely, *only when employees decide to take personal responsibility* for their safety has the culture changed. A true change in the work culture would mean employees would consciously don the equipment without further need for reminders and publicity. In short, in a workplace with a "safety culture," an employee considers it a natural part of his/her job to work safely and *takes the personal initiative* to do so, regardless of reminders. (In fact, in a work area with a safety culture, constant reminders can be seen by employees as an affront to their professionalism: they may feel "talked down to.")

So while publicity has its place, it's important to realize that publicity alone will not necessarily lead to employee acceptance of the personal responsibility so vital for culture change.

STRUCTURAL BARRIERS TO CULTURE CHANGE

Pollution prevention/waste minimization culture development faces hurdles similar to those of safety programs, but faces added difficulties as well. The biggest obstacle faced by waste minimization culture change programs is the lack of *infrastructure* such as company policies and procedures, measurement systems, and incentive and training programs.

For example, most companies have policies and procedures regarding the use of safety equipment like eye protection. Culture change might mean reminding employees of the need for such protection and to embrace safety procedures. Often, training materials are easily available to assist.

In the case of waste minimization programs, procedures may be non-existent or, at a minimum, they may be untested over time. Employees may have no conception of the value of waste prevention. Company training materials and programs may be weak or absent. Even when procedures and training are available, other important systems may not be. For example, adequate waste prevention measurement systems are difficult to design and must be integrated throughout a company's procurement and material/waste tracking systems... an imposing task.

In addition, safety, security, and legal procedures and policies may be inadequate to embrace the concept of "waste prevention" and may need to be modified or rewritten. Perhaps the most surprising barrier to waste prevention is a company's smoothly operating system of waste *management*. Although waste management is likely far more expensive than prevention would be, employees and managers may take the hard-to-argue-with position that if it ain't broken, why are we fixing it?

All of these challenges contribute to the difficulty of changing a culture to embrace waste prevention: a company faces a "chicken and egg" scenario where culture change is needed to drive infrastructure development and infrastructure must be developed before employees can put to work their newfound waste prevention ethic.

Thus for the purposes of this paper, infrastructure development will be assumed to be either ongoing or completed and will not be addressed further. A good discussion of the necessary infrastructure is available in the papers of other presenters in the Waste Minimization/Pollution Prevention session.

In addition, justifications for pollution prevention/waste minimization will not be discussed here. If a reader is not convinced of the economic, environmental, and social benefits of waste prevention, it is far too early to be contemplating a change in the culture of your company or facility.

ATTITUDINAL BARRIERS TO CULTURE CHANGE

We all hate change. This is true regardless of how sincerely others assure us that the change will benefit us in the long run. Waste prevention is no different. The thought of avoiding 6,000 barrels of waste is very scary to those people employed in handling, tracking, and trucking the 6,000 barrels.

The following is a list, in no particular order, of some of the statements encountered by the author while introducing pollution prevention concepts to employees. Readers familiar with formal debate or speech argument analysis will recognize several "logical fallacy" sorts of statements. They are presented here to alert a reader to the very real resistance which can be expected while attempting to bring about a cultural change to waste *prevention* instead of *management.*

We've always done it this way.

The classic argument against change. To many workers, a change in procedures is an unspoken insinuation that they were wrong to follow the procedures for so many years. This is especially true if they were the people who developed the procedures. In addition, procedure changes often mean extra work; in training, re-tooling, and even rewriting of supporting or intersecting procedures.

Pollution Prevention is Communist.

A "kill the messenger" argument (actually once directed at the author). Despite convincing evidence to the contrary, many employees are convinced that preventing waste is the brainchild of radical environmentalists and has no place in American industry where the "real work" is done. The corollary to this argument is that the very act of suggesting such broad change is ruining America's international competitiveness.

You're still producing waste so any reduction is worthless.

The argument suggests that if preventing waste can't solve 100% of a problem then the concept of waste prevention is inherently flawed. After demonstrations to employees of a particular equipment modification which cuts process costs by 90% and waste by 60%, the author is often reminded by skeptical audience members of the remaining 10% cost and 40% waste.

Adds to R&D, implementation time.

The argument suggests, probably rightly, that taking the time to design for waste prevention adds to research/design and implementation time. However, one of the keys to waste prevention is to look at *total* time and *total* costs. Thus, designing for waste prevention may (or may not) add time to the front end of a process but can drastically reduce time and money spent on the back end, such as waste management and environmental restoration/cleanup of poorly managed wastes.

Preventing wastes doesn't apply to me.

Pollution prevention is generally seen to apply to any and all who generate waste. While some waste streams may be more important to target for a variety of reasons, almost anyone can apply pollution prevention principles to their waste generating processes.

Sorry, I do IMPORTANT work.

The suggestion here is that the work of some people or programs is too important to bother with waste prevention. One audience member explained to the author that he worked with "solvents to clean airplanes, and if the solvents don't work, people die." The man was evidently unaware of the extensive waste prevention program at Boeing in Seattle, Washington, where the goal is to try to reduce hazardous solvent use by as much as 90%.

Are your overheads biodegradable?

One of the most difficult problems faced in presenting pollution prevention concepts to people is to undo some of the "environmental" things they think they know, such as the belief that biodegradability is the ultimate test of environmental friendliness. Often such beliefs are couched in a "greener than thou" attitude, which makes them doubly difficult to discuss with their holder. The statement constantly used by the author is that "the best way to manage waste is to prevent it." In the case of the overheads, they were designed to be reused for several years for hundreds of presentations. Biodegradability would actually inhibit their long term or permanent use. In short, biodegradability would cause a waste where there need be none.

CULTURE CHANGE THEMES

Attitudinal and structural barriers can be overcome. In the case of waste minimization, one of the best ways to do this is to tie the "new" concept of preventing waste into existing, accepted programs within a facility or organization.

Many organizations have ongoing quality, safety, productivity, and environmental stewardship programs. Often the very infrastructure not established for waste minimization is not only firmly established for these programs, but it is also fine-tuned and fully accepted by management and employees.

Thus some of the best waste minimization culture change themes are those which reiterate safety, productivity, and other existing themes. For example, if a waste is prevented, a company eliminates worker exposure and environmental hazard potential as well as storage and disposal costs. In this case, waste prevention could be promoted as a natural part of worker safety, environmental stewardship, or good economics.

Thus when waste minimization is tied to existing, accepted themes and programs, the "resistance to new ideas" factor is minimized and use of existing infrastructure is maximized.

Several themes present themselves as possibilities. Many may be healthily operating in your company or facility already:

Safety
Cost savings/economics
Quality/productivity
Employee empowerment
Environmental sensibility/stewardship
National/international competitiveness
Required!

The last item deserves mention. Managers sometimes find that a few of their employees, for whatever reason, are simply not moved by even the most persuasive positive arguments for waste prevention... or for safety or quality for that matter. In those cases, a manager may have no choice but to advance the hard-line argument that waste prevention is now *required* in many companies, state and federal government offices and facilities, and for government contractors. In addition, present requirements will likely become more and more severe as local, state and national waste minimization regulations and legislation continue to be enacted. While enforcing adherence to requirements is a more coercive method of developing a waste minimization culture, it is a last resort which has found success in safety and other programs.

WASTE MINIMIZATION AWARENESS ACTIVITIES

One of the cornerstone components of culture change is interaction with employees. There are numerous ways that the tenets of a waste minimization program can be shared with the employees who it is hoped will embrace them:

Training/Education
Publicity
Public Outreach
Incentives

Training/Education

The first step in preparing waste minimization training is to determine which sections of the employee population need specific training. There are many ways to divide employee populations, but with regard to waste minimization, five categories seem to naturally present themselves.

Management. Management education, involvement, and support is absolutely vital for a waste prevention program to succeed. While managers, like the rest of us, tend to resist change, they are also among the easiest to convince of the benefits of waste prevention. This is especially true when management fiscal incentives are tied to the meeting of company goals: when a program can help a manager meet safety, environmental compliance, and cost goals while increasing the size of his/her bonus, a manager's cooperation and support is usually gained. Cooperative managers applying proven management techniques to waste minimization challenges is also one of the best opportunities to develop waste minimization infrastructure: short and long term planning, ongoing budgeting, goal setting, tracking, etc.

Waste generators. Process owners and others who actually generate waste are very important targets for waste minimization education, since they are where "theory" collides with "reality." A process owner can be a waste minimization program's best friend or worst enemy depending on many factors, including the generator's input into new procedures and goals; the degree to which the generator's salary is tied to waste management instead of prevention (presently, more waste often means a bigger budget!); and even things as simple as contact between those promoting prevention and the "front line" waste generators. Generators must be shown why waste prevention is better than management and how important their role is in meeting facility or company goals.

Design Engineers. Often, the engineer who designed a system is the *only* person in a facility who knows how an entire system works, including raw material consumption and waste generation. Design engineers *must* be educated that their design decisions permanently define a system's waste generation properties for good or for ill. Good design means less waste generation.

Purchasing/Procurement. The people who purchase the goods and materials used in a company bring a new meaning to the computer term "garbage in, garbage out." Procurement staffs must understand that the purchase of hazardous materials directly leads to the generation of hazardous waste, with all the subsequent waste management expense. The place to ensure the purchase of non-toxic alternatives and recycled goods is the company purchasing staff. Technical staffers must be available to help generally non-technical buyers purchase materials which will not impact quality, cost, and productivity but which will reduce waste generation.

Employees/New Employees. Broad-based education is a must to let employees know of management commitment, existing programs, and opportunities for them to contribute their ideas.

Publicity

A number of publicity avenues can be used to inform "target groups" of employees about waste minimization themes, programs, policies, and events. Some suggestions:

Posters
Brochures
Presentations
Displays
Events
Newsletter articles
Videos
Miscellaneous: time sheets, computer start-up screens

The *types* of publicity activities which can be used to promote waste minimization are limited only by imagination. The *content* in such activities, however, should stem from a combination of the waste minimization culture change themes discussed earlier, the target audience, and the particular message to be delivered to the target audience. Here are several examples:

How/what/where to recycle
How to use the company incentive program
How to use the surplus materials system
Cutting waste cuts costs
Where to go for help
Preventing waste is required
Teamwork is needed to prevent waste
Preventing waste is the right/environmental thing to do

Each of these examples could spawn publicity activities all their own, like a large scale campaign with the sole intent to encourage recycling. Likewise, each of these examples could be used in combination with others, such as showing how the company incentive program financially rewards employees who find ways to cut costs through waste prevention.

Public Outreach

While not vital for a company/facility waste minimization culture change program, public outreach nonetheless has a valuable role. In general, such a campaign informs the public about the environmentally/financially sound waste minimization activities taking place within the organization. Waste minimization is almost always a positive step for an organization, especially for one with any history of poor environmental management. Positive environmental steps are always welcomed by the public.

Spreading the positive word about your good waste minimization activities can be done in a number of ways. Information given to the press is one way, but don't overlook opportunities to speak directly to key members of the public, such as seminars attended by educators or forums for business and industry. Local, state, and federal government offices often have programs where success stories would be welcomed and broadly publicized. Technology transfer programs also exist, which share your good ideas with other organizations with similar problems.

Incentives

Remember, true culture change requires that employees "take to heart" waste minimization goals and find ways to apply them to their own work. Incentive programs are one of the best ways to encourage employees to take such steps, since most incentive programs offer the employee direct financial or other benefits as a reward for personal initiative.

Incentive programs can be tailored to any employee or group of employees depending on the needs of the program. If more management support is needed, incentives can reward managers for meeting or exceeding waste minimization goals. Perhaps environmental managers or coordinators need to be better rewarded for their work. Regardless of the incentive system established, it should encourage innovative, creative thinking; long term solutions; and teamwork... which may mean incentives directed at programs instead of individual employees.

BIGGEST HEADACHES

While the culture change strategy outlined above is fairly straightforward, it only hints at the difficulties encountered when trying to shape the attitudes of a large number of employees with diverse educations, beliefs, and backgrounds. As a friendly warning to those who will be attempting such a task, the author presents the following examples of some of his biggest programmatic headaches.

Apathy. The chronic curse of anyone with an important message. You can lead an employee to a staff meeting but you can't make him care.

Hostility. Whether from ignorance, frustration, fear, or plain orneriness, people hostile to your message will take any opportunity to let you know their feelings and find flaws in your arguments.

Over-enthusiastic support. A surprising problem with surprising manifestations. In one instance, an enthusiastic employee eager to avoid waste generation loaded hazardous chemicals into her car to personally transport them from one facility building to another for recycling, violating company safety procedures and federal transportation laws. Her heart was in the right place but her mind was not.

Lack of success reporting. Once culture change starts to take hold and employees start to take personal initiative, one of the biggest problems is getting them to tell you what is going on in what used to be your program. It is a happy but vexing problem to discover what fine waste prevention ideas have been thought of and implemented without news of the success story getting to you.

Desire for instant gratification. In a business culture where results are expected quickly, it is often difficult to convince your superiors of the need for patience. Especially in a system in the process of developing the appropriate infrastructure, results will simply not happen overnight.

Mismatched enthusiasm. A common complaint heard from employees enthused about preventing waste is the lack of support from their managers. In defense, even sympathetic managers often have a full plate of problems demanding immediate attention and simply have no time for new, untested ideas like "waste prevention." Another common complaint is heard from managers, enthused about the possibility of waste and thus cost prevention (and the personal financial incentives that result), who simply cannot get their employees interested in the idea. In defense, often employees don't share in the bonuses awarded to highly productive managers. In both cases, the enthusiasm of one group did not match the enthusiasm of the other important group. A headache.

Misinformation. Waste minimization suffers from the curse of new ideas: no standardization of terms. Take the question of what legally constitutes "recycled" paper. Most papers, even recycled, use some amount of virgin paper fibers. But how much recycled fiber content makes paper "recycled?" One state may define "recycled" paper as containing at least 10% paper recycled from any source, including paper factory scraps. Another may define it as having at least 50% paper recycled from consumer waste: a BIG difference. Some states have no definition at all.

Even the terms "waste prevention," "waste minimization," "pollution prevention," and "source reduction," while used virtually interchangeably in this paper, have different meanings in different states, regulations, and policies.

Confusion and misinformation will exist as long as terms have not been agreed upon. The lack-of-standardized-terms problem presents itself immediately when a company embarks on writing waste minimization policies and procedures: yet another difficulty to overcome when a waste minimization infrastructure is absent.

TIPS

While a good waste minimization culture is vital to waste prevention, development of such a culture is a long process with the most significant results to be found over the long term. However, certain activities will yield quick, highly visible results to encourage employee interest and management patience.

Get early successes, like recycling. It's important to show observers that immediate, positive results are possible, and recycling is a relatively easy, highly visible activity.

Integrate waste minimization into existing programs. As discussed earlier, the lack of waste minimization infrastructure virtually requires that existing programs be used wherever possible. For example, existing employee incentive programs can be expanded to include incentive distribution for waste prevention ideas.

Ensure employee input, involvement, and responsibility. Perhaps more than most company programs, waste minimization relies almost entirely on an individual's knowledge of his/her own processes. That means employee involvement is vital, since they will be the people discovering many of the best waste prevention opportunities.

Stress the long-term nature of waste minimization. As shown earlier, waste minimization requires culture change since the major goal is continuing results over the long term. Culture change is not, nor can it be accomplished by, a "quick fix."

Follow applicable policies and procedures. Waste prevention may be a "miracle cure" to some people, offering many more solutions than problems, but that doesn't mean there aren't other valid competing issues. Safety, security, productivity, and quality are legitimate issues that must be considered when developing a program to prevent waste. Could paper recycling from a "classified" work area potentially compromise security? Do recycling bins meet fire codes? Remember: all the rules still apply. Follow the procedures. Get the right approvals. Doing it right the first time is just another way of preventing waste.

Make it fun. When a concept is as universally positive as waste prevention, make it fun. Why not? In the waste minimization educational/publicity program run by the author, posters feature monsters and amazing mechanical gizmos, and the employee training video and display are built around a "magic" theme. Even in the most conservative business atmosphere it's possible to be creative and humorous. Your message will get across better and your audience will appreciate the extra effort you made to keep them interested.

CONCLUSION

Preventing waste makes plain economic, environmental, safety, and quality sense. Waste prevention, simply put, prevents problems.

But at the most basic level, individual employees at their work stations are the front line troops in the battle against waste. Only if *they* decide to prevent waste will waste get prevented. That's why every effort must be made to implement a waste minimization culture, where employees consider waste prevention a fundamental part of their job.

It sounds like a lot of work and it is. But success breeds success and once the culture starts taking hold, successes will come quickly and have a momentum of their own. Good luck.

WASTE MINIMIZATION BARRIERS
Michael R. Wilcox

Since Pollution Prevention is considered an ultimate form of Waste Minimization, the presentation focused on barriers to Pollution Prevention.

The Pollution Prevention Act was passed by Congress on 27 October 1990 in response to the large amounts of money being spent on pollution control. We must prevent pollution instead of spending money on problems generated by the pollution we could have prevented.

The Pollution Prevention Act requires the EPA to develop a Biennial Report to Congress outlining industry trends, areas requiring multimedia priority, incentive recommendations, and research and development priorities for source reduction and technologies. This Biennial Report appears to be separate from the RCRA-generator Biennial Report.

One can break down Pollution Prevention Barriers into five categories: Regulatory, Economic and Financial, Institutional, Technical, and Educational.

Regulatory:

Traditionally, the regulatory system has had an "end-of pipe focus". Policies such as Best Available Control Technology (BACT) for air quality and Best Demonstrated Available Technology (BDAT) for hazardous waste have not recognized potential waste minimization gain.

Many of us are familiar with remediation and the millions of dollars spent cleaning up old sites. Energy in this area is necessary and regulations will only grow.

While enforcing effluent or emission levels, perhaps equal time should be spent examining how each media relates to each other in a way such that pollution is minimized. The regulatory emphasis has been on specific contaminants in specific waste stream media with minimal consideration to other media. Multi-media focus centralizes pollution prevention strategy and heightens the awareness of how a given pollutant relates both in mass-balance and regulatory scope such that an environmental solution is maximized.

Proper management of waste under RCRA, TSCA, etc, consumes an incredible amount of money and management commitment. When one considers time spent on waste sampling and analysis, handling, manifesting, certifying, shipping, training, potential spillage, and potential cradle to grave liability, one may elect a comprehensive look at pollution prevention for their entire organization. This may be aided or even enhanced should future regulation dictate.

Some people see an uncertain regulatory future. They may not be sure where or how to devote dollars for "tentative" regulation(s). Pollution Prevention certainly makes sense, but some people may only be triggered through enforceable regulation that requires pollution prevention documentation. The community is not always given advanced notice of potential regulatory action.

Some organizations may question whether voluntary efforts under the 33/50 Industrial Toxics Project (ITP) will be worth it. If some type of pollution prevention "credit" or "incentive" is established by regulation in the future, the question arises as to whether past volunteering organizations will receive any "back credit".

Economic and Financial:

Some corporate managers may favor end-of-pipe control. Some managers may fail to fully account costs associated with each unit of pollution generated. Costs incurred are not just disposal costs. Detailed waste management costs such as sampling, handling, manifesting, training, etc, can be "hidden costs" which are difficult to calculate. Other less identifiable costs include man-hours needed for performing State and EPA notification, permitting, and reporting (Biennial Reporting, Toxic Release Inventory reporting, spill releases, etc). There also exists potential future liability, penalties, and fines. These items may be more obscure than capital costs and operation and maintenance costs; and may slant cost analysis in favor of no substantial capital outlay for pollution prevention.

Pollution Prevention may entail changing processes, triggering a short term view of capital investment. Management may not be very excited about changing processes that both are profitable and in full environmental compliance. Pollution Prevention technologies may require a large initial capital outlay. Small businesses may have insufficient capital relative to large businesses; though there exists grants of up to 25,000 dollars through the EPA and Small Business Association. Loans may not be granted to big businesses in debt.

Institutional:

Large organizations all have complex organizational rules, procedures, and practices. Changing these guidelines takes time and is costly. Pollution Prevention requires new ways to look at processes and perform operations.

Because of this, numerous company procedures, pamphlets, technical orders, policies, etc, will probably have to be rewritten. Many guidelines are related and must not contradict each other. This takes considerable time and money.

Old organizational guidelines may very well prevent experimentation in new ways of doing business. Many of these guidelines are proven and have been around for years. Changing the status quo may be a hurdle to pollution prevention.

Some organizations may not have strong commitment required from upper management for acceptance, promotion, and implementation. It is absolutely essential that pollution prevention objectives be realized and practiced throughout all organizational levels in order to become effective.

Front-line employees (shop, maintenance personnel, etc) may resist adopting and implementing pollution prevention even though they may support the concept. Many people perform old operations out of habit. Some people take pride in the way their craft is performed and resist changing in fear of compromised quality.

Technical:

Some pollution prevention can be achieved administratively such as improved housekeeping, inventory/procurement practices, and material exchange programs. However, other cases demand sophisticated pollution prevention methodologies and technologies. For certain industry-standard processes, practical pollution prevention technological limits exist.

There is less certainty in pollution prevention technologies than known traditional end-of-pipe treatment technologies for environmental compliance. Treatment Technologies are known risks for compliance but Pollution Prevention risks are higher and may not give the same product quality and profits as the initial process.

Industry lacks experience in pollution prevention as it is a relatively new culture. Existing technologies will find new homes and be modified and new technologies will most likely be developed.

Educational:

Incorporation of pollution prevention into the educational curriculum in design of products and manufacturing processes is paramount. Environmental engineers have primarily focused on end-of-pipe treatment technologies and not on the processes that generate waste. Industrial engineers (industrial, mechanical, civil, etc) have been taught how to design new or modify existing processes, but not necessarily with a pollution prevention state of mind.

Actually, identifying barriers is an important part of the waste reduction process. What often appears as a barrier can help direct a facility to a better solution. A barrier can mean a trip back to the drawing board to a more long term solution. Here are three case study summaries to support this:

<u>Hytek Facility</u> at Kent, WA

Products: Open mold fiberglass plant making tub and shower stalls

Issue: Air Release

Waste Reduction Problem: Looking at recycling acetone using distillation and recycling still bottoms into a filler and putty. Tub and shower manufacturer use inert filler. Substitute 5% of the filler with ground still bottoms. Eliminate need for still bottom disposal.

The Challenge: RCRA inspectors did not allow open air drying of still bottoms. Hytek could not dry still bottoms and pursue that waste reduction.

Positive Side: Incident resurrected Acetone Substitution Program. Implemented an acetone substitute. Changed gun cleaning process by sending through clean resin and applying to less critical molding function. Implemented procedures at six facilities.

Results: Reduced need for acetone by 90%. Stimulated new ideas.

Jorgeson Steel at Seattle, WA

Products: Coating Surfaces

Issue: Toxicity Classification

Waste Reduction Opportunity: Using bicarbonate soda blasting to clean and prepare surface to accept coating.

Challenge: Sodium Bicarbonate fails WA hazardous waste laws

Positive Side: Causing agency to look at toxicity classification of sodium bicarbonate and process the exemption.

Summary: Running into barriers should not impede the process of making waste minimization changes.

Tiz's Door at Everett, WA

Products: High quality doors and cabinets

Issue: Air Release from using HVLP guns

Waste Reduction Opportunity: Facility identified HVLP guns as a way to reduce waste and increase transfer efficiency in their coatings procedure. Local air quality agency determined the guns, because of their high solids mixture were causing an air release.

Challenge: Identify tool that will produce the best quality with the lowest environmental impact.

Positive Side: Company is sponsoring a transfer efficiency study with the University of WA, the Pacific Northwest Pollution Prevention Research Center, EPA, and the Washington Department of Ecology. The study will help company and other coatings operations determine how best to comply. It may also help agencies regulate these industries better.

Process Waste Stream Assessments in a Pollution Prevention Program

Terry Foecke

Waste Reduction Institute
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Introduction

The job of a process wastestream assessment team will be to • identify and understand the use of hazardous and toxic materials in processes and operations, and • identify sources of waste. Two questions are used to guide the assessment:

Why is the process/operation done this way?

What are the consequences?

The following four steps are often referenced as essential components of a good assessment:

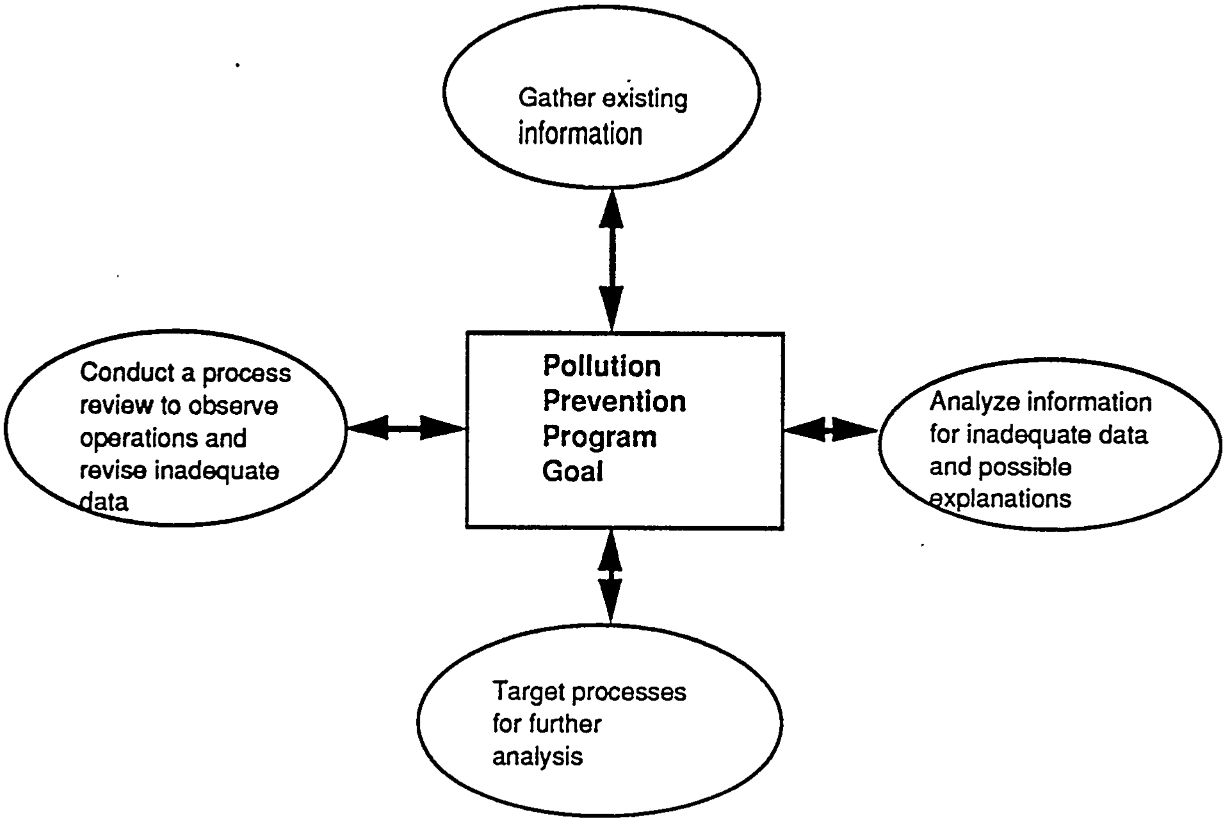
√ Gather existing information

√ Analyze that information for possible gaps and clues for further assessment

√ Use that analysis to target processes and operations for further analysis

√ Conduct a walk-through to observe the targeted processes and operations and fill information gaps

This is not a linear process, however. The following diagram illustrates the flow of ideas and information, and also shows that an assessment can begin at any point.



The first step in the analysis is to gather existing information on production procedures and other activities. Before you gather this information, determine what information you need to complete your analysis. Then determine which information is readily available and which information requires further development. This will simplify your search and make the analysis more efficient. The following table suggests the kinds of information you might gather.

Some of the information collected may not be current and therefore inaccurately reflect the facility's current operations or procedures. The process review step of the process analysis is used to update this information and to explore further options for pollution prevention. This effort to understand what enters and leaves a process may identify good pollution prevention options. To provide a complete picture of material use, wastes, and releases in a facility, however, the information should also be used to answer the questions in the next section.

Process Records and Information

Type of facility record	Use in process analysis
Environmental records: • Form R for submissions under SARA Title III, Section 313 • permits • reports from previous evaluations • waste manifests or other shipping documents • disclosure forms submitted to regulatory agencies	• Acceptability of current use/process • Set priorities • Provide quantities of use/waste/release • Describe current management practice
Diagrams, blueprints and other schematics of products, processes and facility	• Explain current use of space • Understand use/functions of products and processes • Identify possible limitations on change
Process and operation information • process description • quality control guidebook • customer certifications • history of deliveries • history of process changes • purchasing records • inventory records standard operating procedures	• Understand processes • Set priorities for facility inspection • Possible limitations on changes • Understand reasons for use • Understand waste generation • Document volumes of use
Product information and specifications	• Possible limitations on changes • Understand processes and procedures
Technical literature • Material Safety Data Sheets • equipment specifications • product data sheets • advertisements	• Understand processes and procedures
Economic information • departmental cost accounting reports • operating costs for wastes • costs for products, utilities, raw materials, labor	• Understand reasons for use • Priorities for further analysis • Identify cost parameters • Establish conditions for cost/benefit analysis

Relating process information to toxic and hazardous uses, wastes, and releases

- What toxic chemicals are listed on the facility's TRI report?

- What processes and operations use toxic chemicals or hazardous materials?
  --Why are those chemicals or materials used?
  --How much of those chemicals or materials are purchased, used, and consumed?*
  --What do those chemicals or materials cost?
  --Can processes be done differently in order to reduce the use,waste, or release of toxic chemicals or hazardous materials?

- What are the hazardous properties of those chemicals or materials?
  --Do those chemicals have potential environmental, workplace safety, and public health liabilities? **
  --Is the facility in compliance with current and anticipated regulations for the use and management of these chemicals and associated releases?

- Which processes are sources of wastes and other releases?
  --What is the quantity of wastes/releases?*
  --What are the management, treatment and disposal costs for wastes/releases?
  --Can those processes be done differently in order to reduce wastes/releases?

- What are the hazardous properties of wastes/releases?
  --Do wastes/releases have potential environmental, workplace safety and public health liabilities?**
  --Is the facility in compliance with current and anticipated regulations for the management of wastes/releases?

- What is the available budget for the pollution prevention program?

** Materials use and waste generation rates should be related to production volumes to determine when changes are solely the result of variation in production rates.*

*** While it is difficult to predict the potential liability related to a material, waste, or release, team members should consider the possible fines, penalties or lawsuits related to violation of environmental regulations, long-term liability for disposal choices and employee safety.*

A use, waste, or release may be targeted for elimination or modification for any or all of the following reasons:

- Purchase or disposal costs are high
- High risks to human health or the environment
- Potential liabilities from endangering the environment, workers or public health
- High use or release rates
- High potential for successful implementation of pollution prevention options

Once a process or operation is selected for further analysis, a review must be conducted to see how well the actual processes correspond to the recorded information collected earlier. A special team (which is probably different from the facility's overall pollution prevention team) can be a useful approach. While the size of the team will vary depending on plant size and industry, the team should include people with direct responsibility for and knowledge of the particular process or area of the plant to be reviewed.

An agenda or checklist should be prepared before the review to guide the team through the facility and to ensure that all necessary information is collected. The checklist should be specific to the facility and include, at a minimum:

- A list of all chemical or material uses to be verified.

- A list of all waste and release sources to be verified.

- A list of all environmental protection efforts being made.

- A list of all pollution prevention practices already in place and a preliminary list of pollution prevention options to be evaluated.

- Other questions to be answered or issues to be resolved during the inspection.

A checklist will facilitate the process and operations review by verifying existing information and assumptions and identifying all uses, wastes, and releases of concern. The review should be scheduled when all, or most, of the targeted processes are operating. Since production, cleaning, maintenance, and product preparation processes may vary between shifts, reviews may need to be repeated during other shifts. New reviews should also be scheduled periodically, since reviewing processes over an extended period of time corrects for variation in production scheduling, and irregular or seasonal production. Repeat reviews also allow new uses, wastes, and releases to be identified.

CASE STUDY
Acme Computer Supply

Acme's review team was to review the processes which generated wastes at the facility, prioritize them for reduction, and discover and select reduction options. The review team consisted of:

-a process engineer
-a product engineer
-a mid-level manager
-the painting area supervisor.

Analysis of Processes

Step 1: Gathering Information

The first step in the review was to assemble as much data as possible on the operations using toxic chemicals or generating hazardous waste. Much of the existing documentation originated in the painting supervisor's area. Additional efforts concentrated on identifying incoming raw materials and outgoing products, wastes, and emissions. Volumes and costs were identified for each of the streams. Information sources for this review included purchasing records, manifests, material safety data sheets (MSDS), technical specifications, SARA reports, and conversations with paint area workers.

Documentation revealed that the facility generated 82,420 pounds of hazardous wastes. The wastes generated included 45,936 pounds of paint waste, 18,460 pounds of paint booth filters and 18,024 pounds of trichloroethane. Nonhazardous industrial waste was limited to 5,026 pounds of rancid coolant.

This information was assembled into a series of flow diagrams. The flow diagrams presented a clear visual representation of each process and how those processes were related.

Step 2: Analyzing the Gathered Information

The flow diagrams showed that: •The facility was emitting almost 60,000 pounds of trichloroethane, as much as 77 percent of the trichloroethane purchased. •The disposed paint accounted for approximately 48 percent of the paint purchased. Also, paint solvent emissions amounted to over 19,000 pounds annually. Approximately 15 percent of the paint waste came from the plastic housing coating operation. •Only 37 percent of the coolant concentrate could be accounted for as a waste material. It was assumed that the remaining coolant was being lost to drag-out on parts or was being absorbed by the Floor-Dri around the machine tools.

Step 3: Targeting Processes for Further Study

In prioritizing future source reduction efforts, the review team considered a number of factors: volume of wastes generated, toxicity of the materials used, and amount released to the environment. Using these criteria the review team put together several basic facts regarding each process area.

Cleaning

-Trichloroethane emissions were 60,000 pounds annually.
-Waste trichloroethane amounted to 18,000 pounds per year.
-Trichloroethane is a relatively toxic substance and appears on the SARA 313 list.

Frame and Panel Painting

-Paint solvent emissions from this process were 19,000 pounds annually.
-Paint wastes from this process accounted for two-thirds of the hazardous waste generated.
-While individual solvent components appeared on the SARA list, no individual component was of sufficient quantity to trigger reporting requirements.
-The chromic acid in the chromate wash primer was the only known carcinogen listed on all of the MSDSs studied.

Housing Painting

-The emissions and hazardous wastes generated from this process were significantly less than the frame and panel painting operation.
-While individual solvent components appeared on the SARA list, no individual component was of sufficient quantity to trigger reporting requirements.

Machining

- No hazardous wastes or toxic emissions resulted from this process.

At first the review team considered listing the frame and panel painting operation as their number one priority due to the large volumes of hazardous wastes and solvent emissions generated and the use of the chromate wash primer. However, further consideration established that inadequacies in the cleaning process mandated use of the chromate wash primer in painting. Addressing the cleaning system <u>first</u> would solve part of the painting problem. The metal frame and panel painting process would be considered <u>second</u> and the plastic housing paint process addressed <u>third</u>. The machining area was dropped from any further consideration under this program.

Step 4: Conducting a Process and Operations Review

Priority One: Cleaning

With these priorities in place, the review team then conducted a Process and Operations Review, taking a closer look at trichloroethane use in the vapor degreaser. The degreaser was an older model with little documentation. Only after taking out a tape and measuring was the review team able to determine that the degreaser's freeboard-to-width ratio was 0.5, less than the current standard of 0.75. Compounding the lack of freeboard in the design was a fan near the degreaser. The degreaser operator used this fan when the paint room became too warm. The fan blew across the degreaser opening, disturbing the vapor layer and increasing solvent losses.

Using a stopwatch, the review team determined that the chain hoist used to feed parts and baskets into the degreaser operated at a speed of 12 feet per minute. This speed was slightly faster than desired, but in light of the larger problems, this was not a major concern. Drag-out was not considered a major contributor to solvent loss due to the simple part geometries of the metal panel and frame parts. Then, the review team questioned the need for the degreaser as it was functioning in the production process. Examination and interviews revealed that the soils removed by the degreaser included light oils, coolants and particulate. Flash rust, which was a problem on some parts, was not (and could not be) removed by the vapor degreaser.

Painting

The second phase of the process and operations review took the review team through the painting area to examine processes that were inefficient or that generated wastes. Recall that the painting area had two sections: one for painting the metal frames and panels and one for painting the plastic housings. •Painting for both sections was being done in a total of four paint booths. •One specially-designed booth was dedicated to the one-pass painting of the plastic housings, while the other three were used for painting the metal panels. On any given day, each of the three booths might handle all three paint operations: chromate primer, base coat, and final coat. Depending on down-time or production runs, the use and function of the three booths would vary widely from day to day. •In all booths, filters were on a monthly change schedule, regardless of process.

Priority Two: Metal Frame and Panel Painting

The metal painting process involved a chromate-based wash primer, a base coat and a final textured coat •95 percent of the frames and panels were painted with two standard colors, 5 percent was custom work. The review team's study of this section revealed that the base and texture paint being used was a two-part polyurethane formulation. The paint was mixed in five-gallon pressure pots. Because the paint was catalyst cured, the pot life was limited to approximately four hours. After four hours of use, one to three gallons might still be left in the pot. This unused paint was discarded along with the solvent used to clean out the pot. The facility had changed to the polyurethane paint about five years earlier when they experienced problems with adhesion.

All coats of paint were applied by operators using hand-held air-atomizing spray-guns. Overspray was collected on pads which were shipped off-site for disposal. Depending on production runs, operators would change over between different paint colors throughout the day. Each booth had a separate container of blow-back and clean-up solvent for each of the two standard paint colors. Periodically (usually after a weekend), operators would decant the clean-up solvent into a new container and put the settled-out solids in a waste paint drum. The review team noted that every time there was a changeover between paint colors or types, the mixed paint remaining in the 5-gallon pressure pots would be poured into the waste paint drum, since it would not survive the layover to the next use. They observed that waste paint from each booth could go as high as 10 gallons a day, and total booth waste was rarely less than 5 gallons a day.

Priority Three: Plastic Housing Painting

The plastic housings were painted with a high gloss coating in a special enclosed, dust-controlled paint booth. The paint used was a non-catalyzed formulation, using a high concentration of methyl ethyl ketone (MEK) as a solvent. The housings were allowed to air dry after painting. Only one color was applied in this section.

Wastes (overspray, rags, filters, clean-up solvent, unused paint) from the plastic housing booth were combined with the other paint wastes, and all procedures and schedules for clean-up were similar to those in place in the metal frame section. The review team found that <u>overall</u>, the non-catalyzed MEK paint used in the plastic housing booth saved on the amount of paint waste generated. On the plus side, pot life was almost indefinite since the paint could be thinned if the viscosity became too high. The down side was that using this paint required frequent use of solvent for gun clean-up.

<u>Identifying Pollution Prevention Options</u>

Step 1: Examine the Product

The review team decided that the first area to look for options was far back in their manufacturing process; at the product and process design for the computer frames, panels, and housings. The review team questioned why some internal aluminum panels needed to be painted. Since the aluminum would not rust and did not require painting for aesthetic purposes, they proposed discontinuing the painting of these parts. It was also proposed that if the plastic housings were injection molded in the color desired, this would eliminate the secondary process of painting. Investigation of this option revealed that custom formulation of the plastic color might (at the time) be prohibitively expensive, but that it merited further consideration.

Step 2: Examine Fabrication/Formulation

The next step was to examine the fabrication process for its impact on secondary processing.

Machining

The review team raised a question which they decided would require some research and further study. They wondered if the existing fabrication process for the metal parts could be done differently: •using the very lightest oils available for machining •changing these oils differently or filtering them to reduce the buildup of particulate on the parts •instituting new, more frequent schedules for machine maintenance to insure tramp machine lubricating oils didn't mix with process oils. These were seen as other avenues towards reduced use, or even elimination of trichloroethane as a cleaning agent in the finishing process.

Step 3: Examine Secondary Processes (Finishing)

A secondary process (finishing) and its materials had been assigned highest priority due to their toxicity and volume and it was viewed as an area for detailed, immediate action on a number of levels. One of the Review Team's concerns affecting both sections of the paint area was the amount of paint which was ending up as a hazardous waste from paint cleanup. The Review Team was able to develop a number of options to the current cleaning and painting operations. These options ranged from the simple which could be instituted immediately to the more complex which would require additional study.

Cleaning

A very simple option for cleaning processes was to remove the fan from the vapor degreasing area. The review team also suggested more complex options for the vapor degreaser, including: •retrofitting the current degreaser to bring it up to the current standard •purchasing a new degreaser •converting to an alternative solvent or •changing to an aqueous cleaning system.

Painting

A simple option for both painting sections was reducing the amount of paint mixed to match the expected workload. To reduce paint cleanup wastes, complex options proposed for the frame and panel painting section included: •converting to a water-borne coating •using electrostatic or other improved application equipment and •converting to powder coating.

An initial area of concern following the process and operations review was why a chromate-based wash primer was required for painting the frames and panels. Based on their first round of information-gathering and analysis, the review team's preliminary conclusion was that all painting of aluminum, including the chromate primer, might be eliminated from the process. When the review team tested that idea with workers, however, they learned that the wash primer was needed on aluminum substrates to improve adhesion. In addition, flash rust appearing on the steel parts during periods of high humidity also led to poor paint adhesion.

Recognizing that they were stuck with the chromate for the short-term, the review team came back with a simple option: •to restrict the use of the chromate primer to one, or under unusual conditions, two booths, thereby reducing the generation of hazardous paint filters by 25 to 50 percent. This change could be successfully implemented after the next change of filters. Two of the booths could be restricted from using the wash primer, and the nonchrome filters could be segregated, tested and disposed of as nonhazardous if tests reported no hazardous constituents. A more complex short-term option was: •to come up with a substitute for the chromate primer.

In a long-term approach that fits into Step 1: Examining the Product, the review team decide to research the possibility that a brushed aluminum panel might provide a satisfactory aesthetic appearance, eliminating the need for painting.

For the housing painting section, complex options for reducing cleanup wastes included: •changing to high solids coatings •changing to water-borne coatings. Pollution control options identified included the use of carbon canisters to capture solvent vapors ar a fume incinerator to destroy the vapor emissions. (Both of these options were ultimately rejected as prohibitively capital-intensive with no hope for a payback.) The more complex options proposed by the review team were to be used as a foundation for further discussions of source reduction efforts, tying back into their examination of the product design and fabrication. Because implementing these solutions would require significant amounts of capital investment, research and development time, and possibly changes in the product design or quality, it was decided that other individuals within the facility needed to be brought onto the review team from upper-level management, finance, and quality control.

Analysis of Options

Acme Computer Supply's review team addressed the long range solutions to waste reduction by studying both technical and economic considerations. Project goals were developed to narrow the technically viable options; these goals were: •to achieve a significant reduction in the generation of hazardous waste •to improve the health and safety aspects of the work place •to maintain product quality •to sustain the facility's 10% per year growth for a 5-year period •to meet the corporation's economic requirements.

Acme's review team now consisted of: •a process engineer •a product engineer •a mid-level manager •the painting area supervisor •a vice-president •their purchasing agent •a quality control engineer.

The review team examined a number of different cleaning and painting technologies and compared each technology to the project goals. Through extensive testing and process evaluations, the review team's favored approach was the use of a three-stage aqueous cleaning/iron phosphating and powder coating system that they believed would best meet the first four project goals stated above.

To determine if the proposed aqueous cleaning/iron phosphating and powder coating system met the corporate economic criteria the review team contacted a number of equipment manufacturers. Each of these manufacturers was asked for a client list and to provide budgetary quotations on supply and installation of a three stage aqueous cleaning/iron phosphating spray washer and powder coating system, performance data, and utility usages. From this information, the anticipated operating, maintenance and capital costs of the proposed system were developed and compared to the costs of the current cleaning and painting methods. These costs are shown in Figure 1. In all, the facility anticipated an annual pretax savings of $368,000 from implementation of the new system. The capital cost of the proposed system was $397,000.

Figure 1
Operating and Maintenance Costs

		Current System	Proposed System
Raw Materials			
	Paint - liquid	$241,788	$9,672
	- powder	-	80,065
	Filters	4,692	235
	Trichloroethane	47,870	-
	Paint cleanup solvents	11,739	-
	Phosphate/cleaner	-	2,570
	Nonchrome sealer	-	215
		306,089	**92,757**
Disposal Costs			
	Trichloroethane	3,480	-
	Paint related wastes	10,440	522
	Paint filters	23,075	
		36,995	**522**
Labor Costs			
	Degreaser	39,936	-
	Material handling	26,624	39,936
	Painters - liquid	159,744	42,598
	- powder	-	21,299
	Silk screening	51,916	51,916
	Packing	26,624	-
	Overtime	59,593	-
		364,437	**155,749**
Utility Costs (Changes)			
	Liquid cure ovens	10,911	2,538
	Dry-off/powder cure oven	-	26,597
	Spray washer	-	26,828
	Bake-off oven	-	4,728
	Conveyor & parts heat loss	-	624
	Electric	-	5,114
		10,911	**66,429**
Contingency 10% of Total		-	5,051
Total Annual Operating Costs		**718,432**	**350,508**
Anticipated Annual Pretax Savings		**$367,924**	

Then, using the annual pretax savings, the capital costs, and the company's prescribed tax, interest and depreciation rates, a cash flow analysis and Internal Rate of Return (IRR) were determined. The cash flow analysis is shown in Figure 2. The payback calculated was 2.4 years with an IRR of 49.2 percent over six years. This cash flow analysis met the company's requirement for a three year payback and a six year IRR of 35 percent.

Cash Flow Analysis

	Capital Profit	Deprec. Profit[1]	Pretax Flow	Pretax	After Tax		Cash	Year	Invest.	@ 95%	Savings
0	$397,288										(397,288)
1			56,614	367,924		311,310		152,542		209,156	
2			83,033	367,924		284,891		139,597		222,630	
3			79,259	367,924		288,665		141,446		220,705	
4			79,259	367,924		288,665		141,446		220,705	
5			79,259	367,924		288,665		141,446		220,705	
6					367,924		367,924		180,283		180,283
	$397,288	377,424		2,207,544	1,830,120		896,760		370,640		

Year	Present Value[2]	Net Present Value
0	(397,288)	(397,288)
1	178,766	(218,522)
2	162,634	(5,888)
3	137,802	81,914
4	117,779	199,693
5	100,666	300,359
6	70,281	370,640
	370,640	

Payback: 2.4 Years
ROI: 49.2%
Salvage Value: $19,864

(1) A tax rate of 51% was used
(2) An interest rate of 17% was used

Simple Economic Evaluation

A manufacturer of hardware products, while implementing a plant-wide pollution prevention program, was able to realize some unexpected economic benefits. Initially, the program focused on eliminating a 1,1,1-trichloroethane vapor degreasing operation. The vapor degreaser was used to remove heavy stamping and cutting oils from brass and steel parts. The plant also had an aqueous cleaning system that could be used in place of the vapor degreaser but the aqueous system was not as effective at removing the heavy oils.

It was decided that the best way to eliminate the vapor degreaser would be to completely convert the plant over to a single water-soluble coolant which could be removed effectively from the parts in the aqueous cleaning system. This would eliminate the fugitive release of 1,1,1-trichloroethane to the atmosphere and the generation of hazardous solvent wastes that were the result of operating the vapor degreaser. In addition, the water-soluble coolant could be recycled, thus reducing the quantity of oil wastes generated and the overall operating costs.

Plant management knew that converting all of the plant's processes to a water-soluble coolant would not be a simple task. Although committed to plant-wide pollution prevention, plant management wanted any capital equipment purchases to provide an economic payback. A simple economic evaluation was done to determine the number of years for the investment payback of converting to and recycling a water-soluble coolant. The economic evaluation is outlined below.

Installed Equipment Cost

The installed equipment necessary for recycling a water-soluble coolant includes the recycling equipment and a mobil sump cleaner. The recycling equipment consists of solids filtration and a coalescing filter to remove tramp oils. The sump cleaner is necessary to remove the dirty coolant from the numerous machine sumps and transport it to the recycling equipment. The clean recycled coolant is to be supplied to the machines through overhead piping. This piping is the major contributor to the mechanical/piping installation and materials cost.

Equipment cost		
-Coolant recycling equipment	$15,000	
-Sump cleaner		$10,000
Mechanical/piping installation and materials	$7,500	
Electrical installation and materials	$2,000	
Total installed cost		$34,500

Annual Operating Cost

Costs for the operation of the coolant recycling system include labor, raw materials, maintenance and replacement parts. Labor costs are incurred for cleaning and refilling machine sumps and monitoring the coolant recycling equipment. The raw material cost is for the anticipated annual coolant usage. The maintenance and replacement parts costs are for the proper operation of the purchased equipment.

Labor	$60,000
Raw materials	$42,350
Maintenance	$5,000
Replacement parts	$1,000
Total annual operating cost	$108,350

Annual Savings

Savings are realized through the conversion to a single coolant and the recycling of the coolant. The conversion to a single coolant reduces the cost for material handling of both raw materials and wastes. Recycling the coolant reduces the raw material purchase cost and the disposal cost of oil wastes.

Material handling	$50,000
Raw material	$36,056
Waste disposal	$54,154
Total annual savings	$140,210

Economic Payback

$$\text{Years to payback investment} = \frac{\text{Installed equipment cost}}{\text{Savings - operating cost}} = \frac{34{,}000}{140{,}210 - 108{,}350} = 1.1 \text{ years}$$

Plant management believed that a 1.1-year payback was excellent and approved the project. Now, in addition to the reduced operating cost, the plant no longer assumes the liability associated with using 1,1,1-trichloroethane.

CASE STUDY 2
Cleaning operation

Good planning reaps benefits without changing the necessary process requirements or finished product quality. In this instance, as part of a new plant startup, planning included careful selection of an aqueous-based cleaning method. Its sister plant used vapor degreasers for similar cleaning.

This case involves manufacturers of buffed brass hardware. In the cleaning operation at the other plant, brass fixtures are punch pressed into shape, buffed with tripoli and rouge-based compounds, vapor degreased, and clear coated with a powder coating for aesthetics and tarnish protection. To achieve high luster on the fixture, liberal amounts of buffing compounds are applied during buffing. In the course of application, the compound compacts in recessed areas of the fixture. This presents a cleaning problem for the vapor degreaser and necessitates additional work prior to powder coating. Annual consumption of vapor degreasing solvent in this plant is 130,000 pounds with disposal costs in excess of $14,000 (1989 figures). Because of the tenacious nature of the buffing compound and the importance of removing it all prior to powder coating, special attention was paid to selecting an alternative cleaning method for the new plant. Extensive laboratory testing with engineering pre-design was conducted in order to establish workable process parameters. Once completed, the process was transferred full-scale to the new plant.

The new cleaning process utilizes an aqueous ultrasonic and spray cleaning approach. To complement the system, a new cleaner also was developed. After forming and application of the buffing compound, the fixtures are positioned in specially designed racks which are in turn stacked in the tank containing the cleaner. The fixtures are then ultrasonically cleaned. The cleaning solution is heated to help fluidize the compound. Cleaner concentration and contaminant levels are monitored on a regular basis and tight control is maintained. Depending on workload and contaminant levels, the cleaning tank is dumped, cleaned and recharged every one to two weeks. The entire contents of the tank are transferred to a waste clarifier prior to disposal. The cleaner and buffing compounds do not present problems in the wastewater treatment system.

Following cleaning, the fixtures are unloaded and given an immediate deionized water (DI) mist rinse to avoid dry-down and water spotting. This is an important step since residues and water spots cannot be tolerated on the finished fixture. Owing to the poor water quality in the area, DI water is used. At this point, the fixtures, which are still basket racked, enter a multi-stage belt washer consisting of two well water spray rinses followed by two DI spray rinses and an oven dry off. Spray rinsing is required to help dislodge heavier compound deposits. All of the rinses are recirculated and are used at room temperature. The well water rinses are overflowed and counterflowed to minimize contaminant carryover and corrosive water. The DI rinses, which are not overflowed, receive constant fresh makeup to adjust for displacement loss. All rinses are dumped and recharged on a weekly basis. After final rinsing and dry off, the fixtures are re-racked on an overhead conveyor line, powder coated, cured and packaged for shipment to final assembly.

Installation of this cleaning method in the new plant has brought about improved cleaning performance and a corresponding drop in reject levels. Compared to the plant using vapor degreasing, overall process costs have been reduced. Further cost reduction was later realized through cleaner reformulation which allowed for a 70 percent reduction in applied cleaner concentration without any loss in cleaning performance. In addition, improvement in rack design enabled better cleaning of a particularly difficult-to-clean fixture. The new plant is now considering a closed loop cartridge/coalescing filtration system to reduce the volume of water sent to waste treatment. In effect this will extend the cleaner life by reducing the dampening effect posed by contaminants on cleaning energy in the ultrasonic tank.

In summary, the pollution prevention program at the new plant has proven successful. Added benefits in the way of improved cleaning at reduced cost were made possible as a result of good planning. Finished product quality remained uncompromised with essentially no change to basic process requirements.

The Role of Top Management Commitment in Establishing a Pollution Prevention Program

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DP-644
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Today, we will discuss leadership and how it differs from and complements management. We will address why leadership is key to implementing a viable pollution prevention awareness and waste minimization program.

Why Pollution Prevention?

The Hazardous and Solid Waste Amendment (HSWA) added section 1003(b) to RCRA, which states: ". . . it to be the national policy of the United States that, eliminated as expeditiously as possible." HSWA further states that . . . "Waste that is nevertheless generated should be treated, stored, or disposed of so as to minimize present and future threat to human health and the environment."

Pollution Prevention is becoming the focus of our national waste management strategy.

What is Pollution Prevention?

Everyone you talk to has a different definition of what pollution prevention is or what it is supposed to mean. In defense Programs, we are using the holistic definition for pollution prevention:

"All the actions necessary to keep pollutants from being released to the environment."

This encompasses a hierarchy of practices:

- Source Reduction
- Recycle
- Treatment
- Disposal

The emphasis is on <u>source reduction</u> and recycle to <u>prevent the creation of wastes</u>.

But to have a effective pollution prevention program requires a culture change in the organization. Issues associated with pollution prevention are varied, complex, and in many cases poorly defined. People comprising that organization are being asked to change their way of doing things. Therefore, unless the boss forces a change, it will not happen. So when establishing a pollution prevention program top management commitment is vital to accomplish the culture change. Top management cannot just be involved, they must be committed to this culture change. Commitment is necessary because in supporting and adopting the program, top management must understand that resources will be required and be willing to provide the resources.

As J. P. Kotter states in "A Force for Change," change always demands more leadership. He goes on to state that the 1990s demand that in order to successfully implement a pollution prevention program, an organization needs a catalyst and leaders. The leader is the sparkplug. Without leadership, a pollution prevention program in a particular organization will fall into the category of just another well meaning activity that attempts to meet current prescribed standards.

Management and leadership are not necessarily one in the same. We need to establish the difference between management and leadership because the definition of the two are important to understand—yet poorly understood.

Management sets the direction and brings a degree of order and consistency to a product or activity.

President Eisenhower defined leadership best when he said "Leadership is the art of getting someone else to do something you want done because he wants to do it."

In "A Force for Change" the difference between management and leadership is described as follows:

Management VS Leadership

	Management: Organizing and staffing	Leadership: Aligning People
PRIMARY FUNCTION	Creating an organization that can implement plans, and thus help produce predictable results on important dimensions (i.e., cost, delivery schedules, product quality)	Getting people lined up behind a vision and set of strategies so as to help produce the change need to cope with a changing environment.
BRIEF DESCRIPTION OF THE ACTIVITY	A process of organizational design involving judgements about fit.	Getting people to understand and believe the vision and strategies by communicating.

Once leadership is understood, responsibilities become clear. You, as Pollution Prevention Coordinator for your organization, are the catalyst—the sparkplug—the leader. You are the quarterback—management is the coach. You are the leader on the field. You call the plays. Built, in order to do your job successfully, you need to gain the coach's confidence. The success of the team as well as the coach's job are dependent on your ability to successfully guide the offense to score. He has committed the offense to your leadership. It's that way in business. You need to give top management a reason for committing themselves, their organization to a Pollution Prevention Program.

This is done in three steps:

First, GET THEIR ATTENTION;

Make It Clear to Top Management That:

- It is everyone's responsibility to carry out the mission of the organization with maximum efficiency and meet environmental compliance.

- Pollution Prevention is Fundamental to achieving maximum efficiency and environmental compliance.

Next, <u>GET THEIR INTEREST</u>:

Emphasize the incentives for Pollution Prevention:

- Better use of dollars in a tight budget environment
- Comply with regulatory requirements
- Reduce potential future liability
- Demonstrate organization and employee commitment to the community
- Improve product quality.

Therefore, let management know that you intend to do in the area of pollution prevention (in football, it's referred to as "play calling"). Set goals (score a touchdown); set milestones - time lines (get first down and keep the ball away from the opposition).

<u>Publicize Accomplishments</u> by showing how the program is:

- Meeting regulatory requirements
- Reducing future liability
- Improving product quality
- Demonstrate commitment to the community
- COST SAVINGS

<u>PROMOTE PROGRAM</u> by:

- Widest possible exposure
- Newsletters - Articles - Brochures
- Videos
- Seminars - Workshops
- Recognition - Awards.

Then, <u>GET THEIR COMMITMENT</u>:

this Calls for Total Commitment Not Just Involvement. (it's Just Like the Story of the Chicken and the Pig: to Be Committed, We Need to Be Pigs. the Example i Always Used to Explain <u>Commitment</u> to My Athletes at the Beginning of Summer Practice Was—the pig, the pig was committed!)

Once committed, top management must:

<u>AUTHORIZE</u> The Pollution Prevention Program

And

<u>PROVIDE ENTHUSIASTIC</u> Support to Ensure its Success!

MIXED WASTE

Mixed Waste Management Options[a]

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Abstract

Disposal fees for mixed waste at proposed commercial disposal sites have been estimated to be $15,000 to $40,000 per cubic foot. If such high disposal fees are imposed, generators may be willing to apply extraordinary treatment or regulatory approaches to properly dispose of their mixed waste. This paper explores the feasibility of several waste management scenarios and attempts to answer the question: "Can mixed waste be managed out of existence?"

Existing data on commercially generated mixed waste streams are used to identify the realm of mixed waste known to be generated. Each waste stream is evaluated from both a regulatory and technical perspective in order to convert the waste into a strictly low-level radioactive or a hazardous waste. Alternative regulatory approaches evaluated in this paper include a delisting petition, no migration petition, and a treatability variance. For each waste stream, potentially available treatment options are identified that could lead to these variances. Waste minimization methodology and storage for decay are also considered. Economic feasibility of each option is discussed broadly.

Introduction

There currently is no mixed waste disposal, and treatment facilities do not yet exist to manage much of the nation's mixed waste in accordance with 40 CFR 268 requirements. Because of the low volume projections for this special type of low-level waste, one State has reported that the potential disposal cost of a single cubic foot of Class A mixed waste could be on the order of $15,000, exclusive of treatment. This estimated cost is approximately 100 times higher than the cost of disposing of nonhazardous Class A low-level radioactive waste at a similar location. This discrepancy has prompted at least one State to question whether generators of mixed waste will likely find less expensive ways to manage their mixed waste, thereby avoiding land disposal of the waste entirely. By evaluating regulatory constraints, mixed waste inventory, mixed waste minimization options, and potential treatment options and their costs, this paper helps identify what mixed wastes cannot be managed out of existence.

Regulatory Constraints

Classification of low-level radioactive waste is described in 10 CFR 61. Low-level radioactive waste contains source, special nuclear, or byproduct material that is not classified as high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act (AEA). Regulations given in 40 CFR 260 and 261 provide guidance to the regulated community and authorized State representatives on the definitions of solid and hazardous waste. The regulatory definition of hazardous waste is derived from Congress' definition in

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a. Work sponsored by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, DOE Idaho Field Office, under DOE Contract No. DE-AC07-76ID01570.

Resource Conservation and Recovery Act (RCRA) Section 1004(5). Mixed waste is low-level radioactive waste regulated under the AEA that also contains a hazardous waste component regulated under the RCRA.

Disposal of this waste must satisfy both sets of requirements unless the waste can be treated or justified to fall under one or the other set of requirements. For example, if mixed waste can be treated to remove the radioactive portion of the waste, the waste is no longer classified as a mixed waste and can be disposed of in a hazardous waste facility.

EPA developed and published criteria to identify characteristics of hazardous waste and to list wastes to be regulated. In developing these criteria, EPA had to consider the toxicity, persistence, biodegradability, and potential for bioaccumulation of waste material. Waste listed under 40 CFR 261 (3) can be "delisted" under certain requirements and be disposed of as low-level radioactive waste.

Methodology

Two studies will be outlined in this paper. The purpose of the first study, *Mixed Waste Management Options,*[b] was to evaluate the feasibility of managing all mixed waste as either hazardous waste or radioactive waste. Regulatory options such as delisting, no migration petition, and treatability variances were considered. Technical options such as treatment and waste avoidance were also considered.

For this study it was assumed that no land disposal facility was available for the management of commercial mixed waste. Therefore, if the waste were to be disposed of, all types and classes of mixed waste would need to be converted to either solely low-level radioactive waste or solely hazardous waste.

Two compact regions having relatively recent and complete information on mixed waste generation were selected to provide a representative cross-section of the types of mixed waste requiring disposal. The National Institutes of Health mixed waste streams were also used to provide more comprehensive data on medical research waste.

Each waste stream was categorized by EPA waste code and radioactive waste class. Additional information, such as waste form or radionuclide concentration, was also used to categorize the existing waste types. The evaluation generally followed the steps outlined in Figure 1.

Feasibility of Regulatory Options

The hazardous component of the characteristic mixed waste can be removed through treatment of the characteristic of the waste by complying with the mandatory requirements imposed through RCRA's land disposal restrictions. This waste can be disposed of in a low-level radioactive waste disposal facility because the characteristic portion of the mixed waste has been eliminated.

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b. N. Kirner, G. Faison, and C. Owens, *Mixed Waste Management Options*, DOE/LLW-134, December 1991.

Listed waste, however, remains listed even after mandated treatment under RCRA's land disposal restrictions. This listed waste must still be disposed of as listed waste under RCRA, regardless of the effectiveness of such treatment. For listed waste to be disposed of as solely radioactive waste, it must first be "delisted," as prescribed in 40 CFR 260.20 and 40 CFR 260.22.

EPA has recognized that a listed waste from a particular facility may not actually be hazardous. This situation may occur if

- The waste does not contain the components or exhibit the characteristics for which it was originally listed

- The waste contains the components at relatively low levels
- The listed components are present in an immobile form.

The regulations pertaining to delisting require demonstrations that the treated waste is no longer hazardous and therefore, is not required to be managed in a land-based unit meeting RCRA standards. Requirements for delisting include the following:

- Detailed description of the manufacturing process or other operations that produced the listed waste

- A description of the waste and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration

- Test results on representative samples

- A list of all materials used in the manufacturing or other operating processes that produce the waste (examples include raw materials, intermediate products, by-products, products, oils and hydraulic fluids, and surface preparation materials)

- Groundwater monitoring data.

The cost of delisting averages $100,000 to $350,000 per petition. The time to process a delisting petition is approximately two years. At the present time, there have been no mixed waste delisting petitions submitted and the success rate of delisting petitions overall is 12%. In addition to the cost and time involved in developing a delisting petition, the petition must be site and waste specific. Extensive waste analysis must be performed. If a waste stream changes in any way, the existing petition cannot be used.

One waste treatment facility has expressed the interest in developing a delisting petition for certain representative mixed waste streams. This will decrease the cost of individual mixed waste generators delisting their waste streams.

The regulations provide other options for waste management. A no migration variance is a formal decision that can be rendered by EPA to allow land disposal at a particular facility of specific, prohibited wastes (including mixed wastes) that do not meet the treatment standards established by EPA under 40 CFR 268. For example, if a disposal facility could qualify for a "no migration" variance [40 CFR 264.301 (d)], the disposal facility would not be required to have a dual liner, leachate collection system. These minimum technical facility requirements cause much of the additional cost of mixed waste disposal. Similarly, if the untreated waste could be demonstrated not to migrate from the disposal facility, it may be exempted from treatment requirements (40 CFR 268.6). Additionally, a treatability variance may be used to provide treatment better suited to a unique or hard-to-treat waste.

Information requirements for obtaining a successful no migration variance will vary considerably depending on the type of facility and the approach chosen to demonstrate that migration will not occur. The critical components that should be included in the application include:

- Waste description
- Facility description
- Site Characterization
- Monitoring plans
- Waste mobility monitoring
- Assessment of environmental impacts
- Prediction of infrequent events
- Quality assurance and quality control plans.

To qualify for a no migration petition, it is estimated that the cost will range from $100,000 to $500,000 and will take a minimum of two years to gain approval. One no migration petition that has been approved for mixed waste is at the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

The third type of regulatory option is a treatability variance under 40 CFR 268. It allows alternative or customized methods of treatment for certain types of mixed waste streams. For example, wastes with a complex matrix, such as mixed waste, may be difficult to treat either to the acceptable level or by the required treatment method, because the waste is significantly different from the wastes considered when EPA established the standards.

The regulations allow a generator or owner/operator of a treatment, storage, or disposal facility to submit a petition requesting a variance that will establish an alternative treatment standard. Variance submittal requirements include the following:

- Description of the processes and feed materials involved in the generation of the waste and an evaluation of whether they may produce a waste that is not covered by the demonstration

- A waste description, including the same characteristics that EPA used to develop the best demonstrated available technology

- A description of the system used to treat the waste

- A description of any other treatment systems investigated by the petitioner, the treatment system believed by the petitioner to be appropriate for the waste, and the concentrations in the treatment residue that can be achieved by using the preferred treatment techniques

- Descriptions of all sample handling preparation and test methods used to obtain data indicating that the treatment standards are not achievable

- A certification that all of the information submitted in the petition is accurate.

The cost for a treatability variance is about $40,000 and takes 4 months to 1 year for approval.

In addition to treating the hazardous waste component to 40 CFR 268 requirements, it is also possible to deregulate the radioactive waste component. The most common method of "treatment" for radioactive waste is storage for decay. This treatment has been used for materials with relatively short half-lives (half-lives of up to two months); however, the projected cost of mixed waste disposal could make this treatment concept economical for much longer-lived radionuclides (half-lives on the order of five years). Alternatively, a waste may qualify for the exemption under 10 CFR 20.306.

Analysis of Mixed Waste Streams

A summary table of preferred management options for mixed wasted is found in Table 1.

The comparison of waste management options is build on several assumptions which may change as more information on cost of treatment becomes available. First, incineration and stabilization were preferred mixed waste treatment strategies. Biological treatment was not used in any of these treatment strategies because it appeared that the wastes were in highly concentrated form, more suitable to incineration. Where dilution of the waste is possible, then the less expensive biological treatments may show promise. Second, the cost of incinerating mixed waste quoted by a single company formed the basis for all calculations involving incineration. It was assumed that some treatment services will include delisting as part of the treatment service and that delisting would at least double the normal cost of incineration. It should be noted that although treatment technologies are listed int he matrix, and mixed waste may be eliminated because of the treatment, some of those treatment technologies are not presently available.

Minimization Options

The purpose of the second study, *Mixed Waste Minimization Plan*,[c] is to determine potential commercially generated mixed waste streams that may benefit from minimization techniques.

This study is divided into two phases. Phase One is a document for State policymakers so that mixed waste minimization programs can be encouraged for generators. Phase Two informs generators how to identify mixed waste streams and how to identify processes that can be implemented to eliminate mixed waste on a waste stream basis.

Mixed waste minimization options include the following:

- Substitution of nonhazardous or nonradioactive inputs
- Reformulation or redesign of end products
- Modification or redesign of production process
- Change in material usage, handling, and storage practices

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c. National Low-level Waste Management Program, *Mixed Waste Management Plan*, draft, EGG-LLW-10097, January 1992.

- Use of closed loop reclamation, reuse, or recycling

- Use of onsite or offsite recycling processes

- Modification or redesign or processes, technologies, equipment, or maintenance practices.

Mixed waste minimization methodology is shown in Figure 2.

Several features determine the success of a mixed waste minimization program. Some of the most important are:

- Management commitment at all levels
- Employee training to recognize waste minimization opportunities
- Method for tracking waste generation
- Process definition and development
- Design and implementation
- Documentation of results and lessons learned

Taking into account the varied sources of mixed wastes, not all waste minimization programs will use all of these features. Mixed waste minimization should only be considered when there is reduced risk to employees, the public, and the environment. Another consideration is that the ethical problem of the impact of the waste minimization effort may be worse than if no waste minimization were done at all. For example, if an effort to reduce mixed waste required a reduction in medical diagnostic tests, would there be an unacceptable increase in deaths as a result?

Long term cost savings associated with incorporating an option include some easily measured savings on the following: raw material costs, disposal costs, permitting costs, storage cots, shipping costs, and any utilities or labor costs.

Conclusions

Most, but not all, mixed waste can be managed to avoid disposal in jointly regulated disposal facilities. Wastes that will require jointly regulated disposal fall into two categories: (a) characteristic waste having a technology-based treatment standard other than contaminated elemental mercury and lead solids that cannot be decontaminated and (b) treatment facility equipment and process wastes that were derived from treating listed mixed wastes requiring jointly regulated disposal.

The volumes of these wastes are expected to be very small. However, they still will require mixed waste disposal. HEPA filters from incinerator facilities may also require disposal in jointly regulated facilities. The incinerator facilities treat listed and other bulky wastes from secondary waste streams. These secondary wastes are extremely difficult to predict because their production will vary with the number of treatment facilities, and with types and volumes of waste treated.

Some mixed waste streams in certain processes can be successfully minimized. The up-front elimination of these wastes through waste minimization, process change, and product substitution programs also provides alternatives to disposal. However, there are certain mixed waste streams that are either necessary for university and hospital research, the hazardous component cannot be substituted, or the process cannot be modified to eliminate the waste.

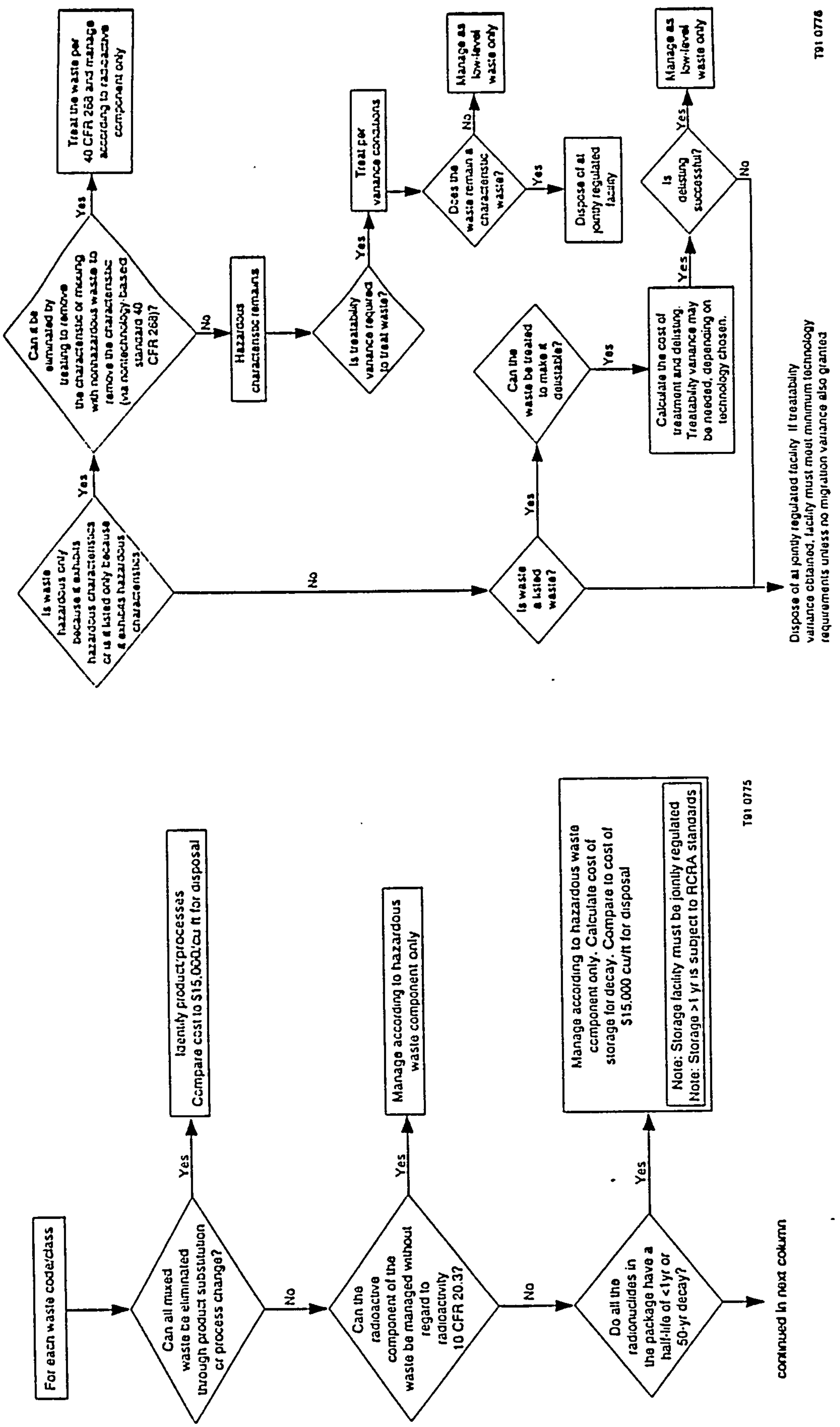

Figure 1. Mixed waste management schematic.

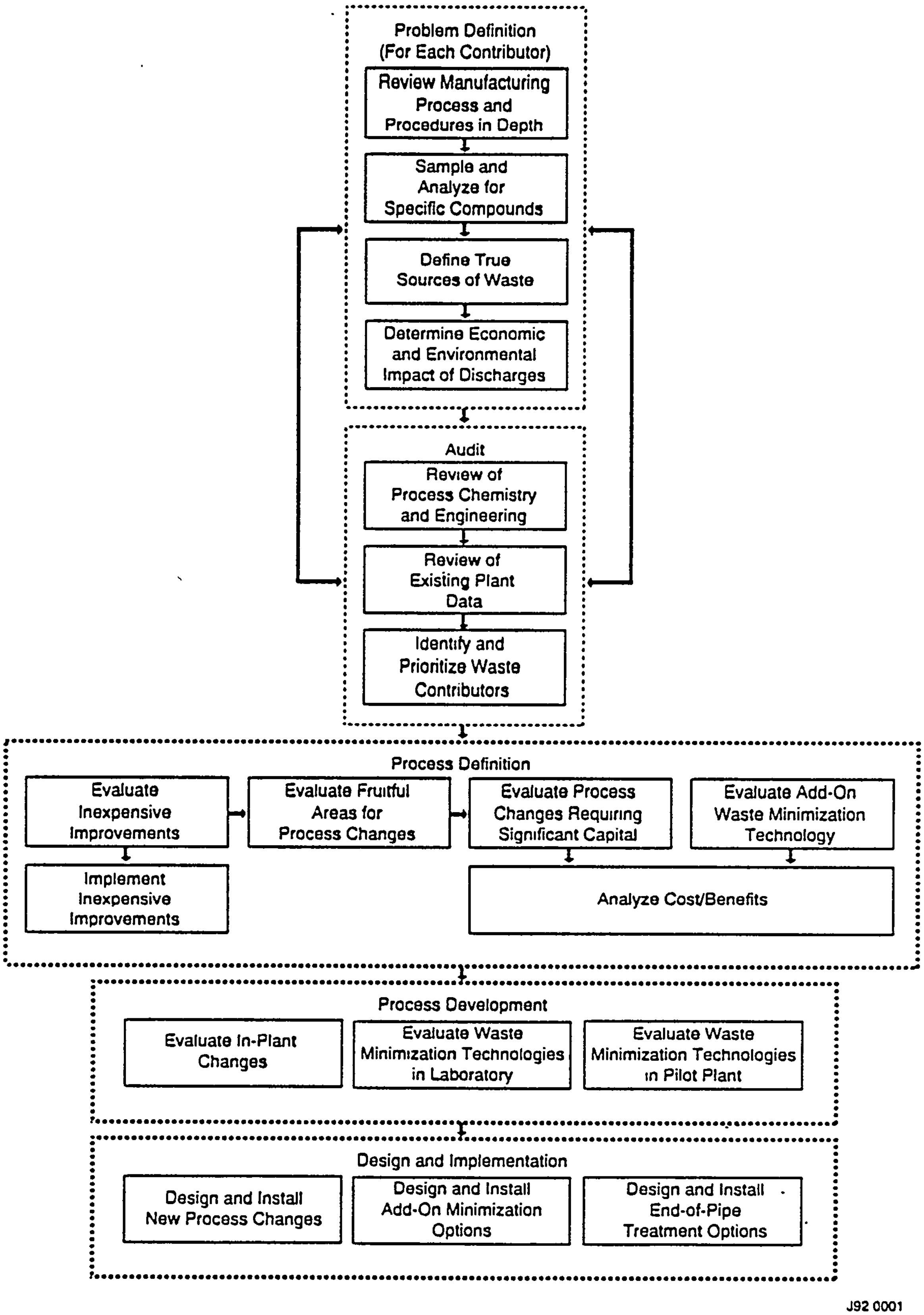

Figure 2. Mixed waste minimization methodology.

Table 1. Preferred Options for Mixed Wastes

Waste Description/Form	Waste Code/Class	Appropriate Treatment Approach	Residue Management
Organic Solvents—Liquid ignitable wastes	D001/A	Treat for characteristic (INCIN), dispose of in AEA facility	LLW
Organic Solvents—Absorbed liquid, ignitable wastes	D001/A	Deactivate to remove characteristic, stabilize, dispose of in AEA facility	LLW
Acid	D002	Neutralize acid	LLW
Lead acid battery	D002/D008/A	Internally contaminated: deactivate to remove characteristics, decontaminate lead plates, submit treatability variance for radioactive lead core, dispose of in AEA/RCRA facility	Mixed Waste
		Not internally contaminated: deactivate to remove characteristic, decontaminate lead plates, thermal recovery in lead smelter, dispose of in AEA facility	LLW
Magnesium, thorium chips	D003/A	Deactivate to remove characteristic, stabilize, dispose of in AEA facility	LLW
Liquid chromium—corrosion-inhibiting chromates, incidental corrosion products, Cr-51 carrier, other chromium	D007/A	Precipitation/filtration to remove characteristic, dispose of filtrate in sewer, stabilize filter	LLW
Aqueous lead wastes	D008/A	Same as above	LLW
Absorbed liquid chromium or resins—corrosion-inhibiting chromates, incidental corrosion products, Cr-51 carrier, other chromium	D007/A	Reduction and precipitation to remove characteristic, stabilize, dispose of in AEA facility	LLW
Radioactive lead solids, activated lead, contaminated lead containers	D008/A,B,C	Treat to remove lead characteristic, decontaminate radioactive lead solids, stabilize, dispose of in AEA facility	LLW
Aqueous mercury	D009/A	Precipitation/filtration to remove characteristic, dispose of filtrate in sewer, stabilize filter	LLW
Elemental mercury	D009/A	Treat by amalgamation, dispose of in AEA/RCRA facility	Mixed waste
Unknown mercury	D009/A	Chemical precipitation to remove characteristic, stabilize and dispose of in AEA facility	LLW
Solvents using freon, distillation bottoms and filters	F001/A	Incinerate, delist residue, dispose of in AEA facility	LLW
Absorbed solvent liquids, spent solvents using freon	F001/A	Incinerate, delist residue, dispose of in AEA facility	LLW

Table 1. (continued)

Waste Description/Form	Waste Code/Class	Appropriate Treatment Approach	Residue Management
Liquid solvents, scintillation fluids, other organic fluids			
- Spent solvents			
	F002/A	Incinerate, delist residue, dispose of in AEA facility	LLW
- Methylene chloride		Same as above	
- Toluene	F002/A	Same as above	LLW
- Benzene	F005/A	Same as above	LLW
- Paint solvents	F005/A	Same as above	LLW
- Semivolatiles	F005/A	Same as above	LLW
- Toluene	F005/C	Same as above	LLW
- Acetonitrile	F005/B,C	Same as above	LLW
- Chloroform	U003/A	Same as above	LLW
- DDT	U044/A	Same as above	LLW
- Methylene chloride	U061/A	Same as above	LLW
- 1,4-Dioxane	U080/A	Same as above	LLW
- Phenol	U108/A	Same as above	LLW
- Dioxin	U188/A	Same as above	LLW
	F027		LLW
Absorbed liquid spent solvents			
- Spent solvents	F002/A	Incinerate, delist residue, dispose of in AEA facility	LLW
		Same as above	
- Methylene chloride	F002/A	Same as above	LLW
- Toluene	F005/A	Same as above	LLW
- Benzene	F005/A	Same as above	LLW
- Paint solvents	F005/A	Same as above	LLW
- Semivolatiles	F005/C	Same as above	LLW
- Toluene	F005/B,C	Same as above	LLW
- Acetonitrile	U003/A	Same as above	LLW
- Chloroform	U044/A	Same as above	LLW
- DDT	U061/A	Same as above	LLW
- Methylene chloride	U080/A	Same as above	LLW
- 1,4-Dioxane	U108/A	Same as above	LLW
- Phenol	U188/A		LLW

Table 1. (continued)

Waste Description/Form	Waste Code/Class	Appropriate Treatment Approach	Residue Management
Organic solvents, scintillation fluids with xylene			
- Xylene			
	F003/A	Incinerate to remove characteristic, dispose of in AEA facility	LLW
- Acetone		Same as above	
- Ethyl acetate	F003/A	Same as above	LLW
- Ethyl benzene	F003/A	Same as above	LLW
- Ethyl ether	F003/A	Same as above	LLW
- Methanol	F003/A	Same as above	LLW
- Ethyl acetate	F003/A	Same as above	LLW
- Methanol—^{14}C, ^{3}H	U112/A	Same as above	LLW
	F003/B		LLW
Absorbed organic solvents, scintillation fluids with xylene			
	F003/A	Stabilize (resin-based agents meet concentration-based standards) dispose of in	LLW
- Xylene			
		AEA facility	
- Acetone	F003/A	Same as above	LLW
- Ethyl acetate	F003/A	Same as above	LLW
- Ethyl benzene	F003/A	Same as above	LLW
- Ethyl ether	F003/A	Same as above	LLW
- Methanol	F003/A	Same as above	LLW
- Ethyl acetate	U112/A	Same as above	LLW
- Methanol—^{14}C, ^{3}H	F003/B	Same as above	LLW
Solvents, acetonitrile, formaldehyde, methanol			
- Acetonitrile			
	U003/A	Incinerate, delist residue, dispose of in AEA facility	LLW
- Formaldehyde		Same as above	
- Methanol	U122/A	Same as above	LLW
	U154/A		LLW
Absorbed solvents, acetonitrile, formaldehyde, methanol			
- Acetonitrile			
	U003/A	Incinerate, delist residue, dispose of in AEA facility	LLW
- Formaldehyde		Same as above	
- Methanol	U122/A	Same as above	LLW
	U154/A		LLW
California-only and other state-only wastes			
- Oil/A,B,C—Liquid			
	N/A	Incinerate, delist residue, dispose of in AEA facility	LLW
California-only and other state-only wastes			
- Oil/A,B,C—Absorbed liquid			
	N/A	Incinerate, delist residue, dispose of in AEA facility	LLW
Secondary waste from treatment of listed waste.	Varies	Varies	Mixed waste

TRI-CITIES ENVIRONMENTAL ANALYSIS AND TREATMENT COMPLEX (TREAT)

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Summary

Chemical Waste Management (CWM) is proposing to privately fund the design, construction, and operation of an analytical laboratory, a commercial hazardous waste treatment facility, and a mixed waste treatment facility. The analytical laboratory will be located in Richland, Washington, and the hazardous treatment facility and the mixed waste treatment facility are proposed to be located at the Department of Energy's (DOE's) Hanford site in eastern Washington state. These locations are shown on Figure 1. This complex is the Tri-Cities Environmental Analysis and Treatment Complex (TREAT). The investment is expected to be approximately $100 million over the next five years with commercial and government customers paying only for direct services received from TREAT.

Chemical Waste Management is a member of the Waste Management, Inc., family of companies along with Waste Management of North America, Waste Management International, Inc., and Wheelabrator Technologies, Inc. (Wheelabrator, Rust, Sirrine Environmental, Donahue). This relationship is shown in Figure 2.

Analytical Facility

The analytical laboratory, located in Richland, Washington, will provide laboratory analysis of waste containing both hazardous and radioactive contaminants. The analytical facility will also accommodate TREAT management staff and other CWM personnel who plan to participate in joint education and technology programs with local entities. Land for the analytical facility has been identified in the City of Richland at the Port of Benton's Richland Airport. Negotiations are underway for the property.

The laboratory will initially be a 22,000 square foot facility with capacity for processing a minimum of 4,000-8,000 samples per year. The TREAT laboratory will service the U.S. Department of Energy's Hanford reservation. It is expected that services can also be provided to other DOE facilities such as those at Idaho and Rocky Flats. The facility will include capability for environmental, radiochemical, and geotechnical work. The laboratory will be configured for expansion in both environmental capacity and processing of RCRA and mixed waste samples. There will be segregation of sample preparation and dual equipment for "clean" and "dirty" samples. This complies with CWM's philosophy of such separation to prevent or reduce the occurrence of cross contamination and false positive results.

The TREAT analytical laboratory is expected to have ground breaking in 1992 and be in operation in 1993.

Treatment Facility

The TREAT treatment facility will conduct incineration of both hazardous commercial waste and mixed waste at two separate units. Processing of hazardous and mixed wastes will not be commingled. The services provided at the treatment facilities will include separation, sampling, incineration, stabilization, repackaging, and transportation operations.

The hazardous commercial waste incineration will be sized to support the waste stream generators in the states of Washington, Oregon, Idaho, and Alaska. This waste stream is expected to comprise 30-50,000 tons per year of incinerables. The incinerator will be a rotary kiln unit with secondary combustion. The cleanup train is expected to be a dry scrubber and baghouse system. Ash will be transported to a permitted landfill in Arlington, Oregon.

The design basis for the mixed waste incinerator is currently under development. Initial volumes of mixed waste from Hanford and the commercial markets within Washington, Oregon, Idaho, and Alaska are expected to be small with substantial growth in later years from the DOE Hanford restoration and decommissioning programs. Therefore, the initial incinerator design under evaluation is a small unit of 5-10 million BTU/hr and will be either a dual chamber or a rotary kiln configuration. The cleanup train is expected to be a dry scrubber, baghouse, HEPA filter system. A larger unit will be developed as growth in mixed waste volumes occurs. Radioactive ash will be returned to the generator. Waste landfilling/disposal will not be a part of the TREAT Complex.

The proposed site for these incinerator facilities is in the center of the 560 square mile controlled nuclear reservation and is a considerable distance (8 miles) from the Columbia River and agricultural areas of the Columbia Basin.

A Notice of Intent has been filed with the state of Washington for the incinerator complex and a permit application will be filed with the Washington Department of Ecology in the spring of 1992. A 20-month permit schedule will allow operation to begin in 1995 for both the hazardous and mixed waste incinerators.

TREAT is part of the answer to managing the current and future hazardous and mixed wastes generated in other parts of the state and the Pacific Northwest. These wastes would now be able to be treated in the Northwest, eliminating the need for excessive transport. Serving these dual markets is part of the key to the financial viability of the TREAT Complex. Serving more than one customer justifies this significant corporate investment.

Figure 1. Hanford Nuclear Reservation

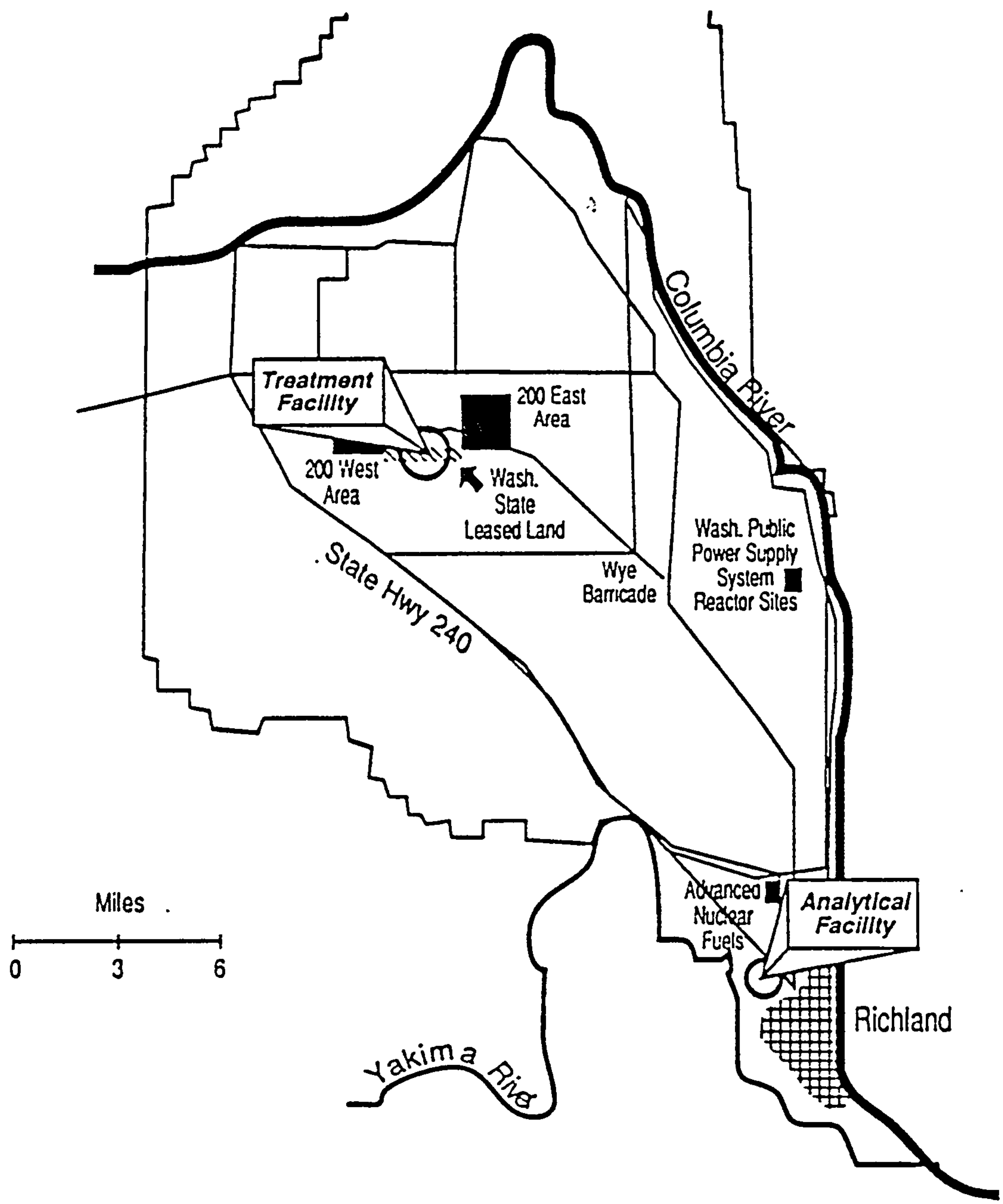
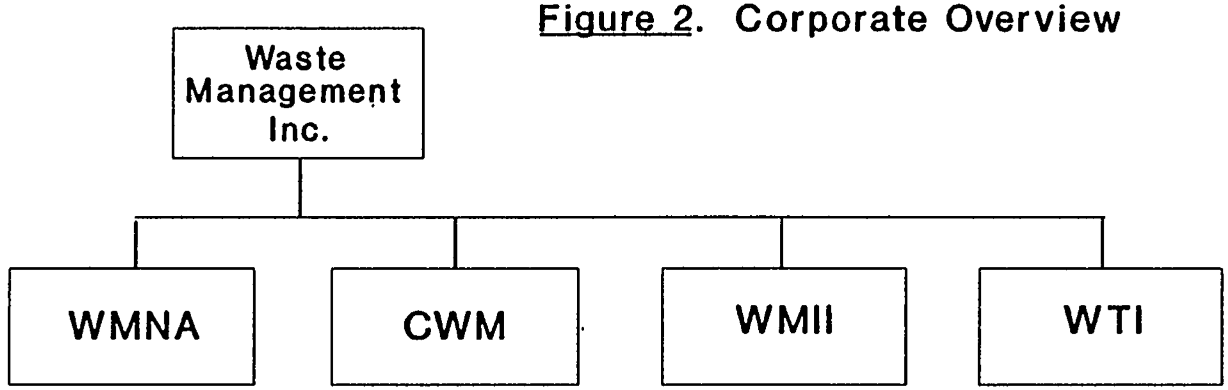


Figure 2. Corporate Overview



Waste Management of North America, Inc. (WMNA) provides collection, recycling, and disposal of municipal solid waste and management of medical wastes;

Chemical Waste Management, Inc. (CWM) manages industrial and hazardous wastes and provides remediation services for Superfund and other contaminated sites;

Waste Management International, Inc. (WMII) provides comprehensive waste management services internationally; and

Wheelabrator Technologies Inc. (WTI) owns and operates trash-to-energy and wastewater treatment plants, manufactures air pollution control devices and provides environmental and construction engineering services.

- Rust
- Sirrine Environmental
- Donahue

TRACKING AND TRANSPORTATION

A STATE'S PERSPECTIVE ON TRACKING LOW-LEVEL RADIOACTIVE WASTE

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I was asked to share with you today some of my thoughts and experiences on the tracking of low-level radioactive waste. I suppose I was asked because Illinois, as part of the Central Midwest Interstate Low-Level Radioactive Waste Compact has been involved in developing a tracking system for well over a year now. I should say two things up front, however. First, for the past five months, I have been working and living out of the Martinsville, Illinois, High School Gym and American Legion Hall while attending the public hearings surrounding the selection of Martinsville as the site for the CMC disposal facility. This experience may have deadened my senses, jaundiced my views on things a bit and, if nothing else, it may cause me to speak louder than I need to. Second, let me point out quickly that I do not profess to be an expert on the tracking of low-level waste, but, as Yogi Berra once put it, "you can observe a lot by just watching." So what I would like to share with you are some of my observations and some of the things we in Illinois and the CMC have learned about the difficulties and tough issues involved in the development of a tracking system.

In some ways, things we have done and accomplished have been simple. But, as H.L. Menken once said, "for every problem, there is a solution which is simple, neat and wrong." As Menken projected, some of the things we thought were or would be simple turned into really heady problems or critical policy matters. I can best share these experiences with you by first giving you a brief description of the tracking system as we see it.

To do this I will take a quote from one of our consultants' reports which quickly summarizes the system. The consultants envisioned the following capabilities and components for the system: "... Information would be gathered from shipment manifests to track LLW from "cradle to grave", that is, from generator shipment to disposal." The tracking process is to begin with prenotification to the Illinois Department of Nuclear Safety of an impending shipment of LLW by a generator or processor. Summary information obtained from the prenotification would be entered into the tracking system creating a record. The system would then generate and assign a manifest number to serve as identification to track the shipment and accumulate additional pertinent information to a particular shipment.

Entering additional detailed information to the "summary information file" is to be completed at the time of shipment. The combined summary and detail data would then be stored on the tracking system to enable the Commission and the Department to track the shipment of LLW into, through, or outside of the compact region. "Active" tracking of the LLW would end when the shipment has either been stored for decay or has reached a disposal site. The data from the stored for decay or disposed shipment would be retained on the tracking system for statistical analysis and reporting purposes.

Wishing to track the waste from cradle to grave raised, from the outset, a number of issues, some of which continue to beg resolution. Some of the issues are related to legal and technical concerns. Some of the issues were imbedded in political relations and questions of jurisdiction between and among the party states and the commission itself. I would like to talk about both but begin with the latter one.

Clearly, the development of any system which has implications across state boundaries invites a certain politics. I'm not, however, suggesting that this is bad or that the politics is of a dirty nature but it is politics nonetheless: politics which requires good diplomatic skills for all involved. I should note here, and I hope without sounding cynical, that the great sage Will Rogers once defined diplomacy as "the art of saying nice doggie while you're tryin' to find a rock." Well we've spent a lot of time on the nice doggie part but honestly had little need to go looking for rocks.

The political issues which have arisen include the need to ensure that the laws which govern the transport of low-level waste have symmetry between and among the party states and that the states have the necessary provisions within their satutes to afford proper authority for approving, monitoring, and otherwise regulating the shipment of low-level waste into, through and out of the state. I should note here that this aspect of the system's development was somewhat simple since the CMCC has only two states--Illinois and Kentucky. This was also made easy because by far the lion's share of waste in the compact region is generated within the borders of Illinois. As a result, the most detailed and demanding statutes are found in Illinois.

Since implementation of the tracking system implies the possible denial of access to facilities within the Compact region, concern was also raised regarding the possible interference with the Constitution's "Commerce Clause" should Illinois refuse access to Illinois and Compact treatment facilities to out-of-state shippers. The basic question here was, does Illinois have the legal authority to deny access. We have concluded that we do, providing that the permitting system which will be the basis for such a denial is both designed and administered fairly and in a way which is blind to the permitted person's geographical location.

Another area of political concern has arisen in our having made the decision to develop one tracking system which meets the needs of all three entities involved--the Compact Commission, Illinois and Kentucky. As we worked on the design of the system, the consultants worked with officials from each entity through a consensus building exercise from which the purposes and goals of the system were developed. While there was considerable overlap and consensus found among the three tracking system goal statements, there were some differences as well.

These differences have led to questions by one or two of the parties about the need for certain aspects of the actual design which meet a stated goal or need of the third party. Working out these differences has, again, dredged up the need for keen diplomatic skills. The results of the discussions surrounding these differences have, however, been productive and have led to somewhat easy resolution of differences.

Among the technical problems we have faced are the following:

First, if the statutes provide authority to track waste, can articles shipped for treatment, the results of which will create waste, be themselves tracked as waste? In other words, can the tracking of items shipped as material for treatment be required, given that the statute only authorizes the tracking of waste? This issue ties directly to another issue which surrounds the definition of waste which I identify and discuss in some detail in just a minute.

Second, can or should some items be tracked with less information about them than is required for other items? For example, should the same amount of information be required of items shipped from outside of the region for treatment as those shipped within the region? At the root of this issue is the idea that items shipped into the region for treatment will be required to be returned to the region of origin for final disposal. Since they will not be disposed of within the CMCC region, it was suggested that less information than that required in a detailed manifest might be adequate for tracking purposes. We have resolved the issue by requiring the same amount of detail for all shipments regardless of their location of origin. One bit of supporting information for this decision is that all out-of-region shippers are currently required to provide the detailed information. As such, the tracking system requirements simply extend the current reporting environment. No new costs to the shipper are engendered by the tracking system.

Third, for tracking purposes, how should waste be defined? I should note that at one point, to proceed with the system's development and to get around the semantic difficulties of classifying items typically shipped as radioactive materials as waste, I suggested that an item simply be classified and manifested as "radioactive stuff" and tracked as such. While I did so somewhat tongue in cheek, for a fleeting moment I actually thought that it was going to catch on and actually be used. However, on a more serious note, there is a segment of the regulating community that is trying to classify a broad range of radioactive material as LLW for purposes of exercising compact control of interregional shipments. This has been probably the most significant hurdle in defining the tracking system. Trying to establish a coherent policy framework to include certain limited categories and not others has been extremely difficult. From my perspective, states must be willing to realize that certain facilities such as nuclear laundries, sealed source manufacturers and distributors and radiopharmaceutical companies are generators of waste, not treatment facilities. As such, states must be willing to accept those wastes irrespective if the laundry, sealed sources or radio-pharmaceuticals were used in another state. The same holds true for non-allocatable residual waste from treatment facilities.

Fourth, a question was raised early on regarding the appropriateness of the use of a tracking system in providing information used in the assessment of user fees to cover the cost of the implementation and administration of the tracking system. We have decided to design the system to provide the needed information. The system is also being designed to provide for an annual validation of the level of the fee being assessed.

One other area of technical concern to us ties to one of the goals set for the development of the tracking system, and that is that the system was to be designed to have the smallest possible economic impact on small generators and shippers. This goal has translated into concern for the particular means by which generators, processors, shippers and brokers "feed" information into the system. Clearly, the larger users of the system will have micro-computer capabilities to communicate with the tracking system and be able to purchase the required software for the system interface without a sizable impact on their operations. The system is being designed to allow smaller operators to access the system and meet its reporting requirements by the use of faxcimile communications equipment. Information received in this form will be put into the system by staff of the department. This reduces the direct cost to the smaller user for the purchase of computer hardware and software and thus reduces the cost impact.

While there are other political and technical issues which arose during all of our developmental efforts to date, these are the ones which have presented the more major hurdles.

Overall our system is being designed:

1. To provide for the monitoring and authorization of the export and import of waste and certain specific categories of radioactive material,
2. To assist in responding to emergency circumstances which threaten the public safety and health or the environment, and
3. To provide information to monitor trends in waste types shipped, the volume, mass and activity of the waste shipped, treatment processes used, and to assist in the assessment of fees.

So, what have we learned from all of this?

a. What appears to be simple can, in fact, be very complex and full of policy "pot holes" that must be filled.
b. A tracking system can be a very useful tool in meeting statutory requirements and planning needs in ensuring the public health and

safety, in ensuring environmental safety and in monitoring the interstate and intercompact flow of low-level radioactive waste, and

c. That we're all in this together and as such, we need to maintain perspective, be optimistic and above all, maintain a sense of humor. As the cosmic philosopher Casey Stingel once said, "they say it can't be done, but sometimes that just don't work."

NRC'S PROPOSED RULEMAKING ON THE DOCUMENTATION AND REPORTING OF LOW-LEVEL RADIOACTIVE WASTE SHIPMENT MANIFEST INFORMATION

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Background

Since the 1982 promulgation of regulations for the land disposal of low-level radioactive waste (LLW), requirements have been in place to control transfers of LLW intended for disposal at licensed land disposal facilities. These requirements established a manifest tracking system and defined processes to control transfers of LLW intended for disposal at a land disposal facility. The information to be provided on the shipment manifest included physical, chemical and radiological descriptions of the waste, the waste's classification (i.e., class A, B, or C), and the total quantities of certain long-lived radioisotopes.

Because the regulations did not specify the format for the LLW shipment manifests, it was not unexpected that the two operators of the three currently operating disposal sites should each have developed their own manifest forms. The forms have many similarities and the collected information, in many cases, is identical; however, these manifests incorporate unique operator preferences and also reflect the needs of the Agreement State regulatory authority in the States where the disposal sites are located. This Agreement State regulation, authorized under Section 274 of the Atomic Energy Act, as amended, will apply at most of the approximately 14 disposal facilities being sited by individual States or Regional State Compacts as a result of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA). Since Agreement State regulations must be compatible with, but need not always be identical to, those of the Nuclear Regulatory Commission (NRC), the possibility of a proliferation of different manifest forms containing variations in collected information could be envisioned. If these manifests were also to serve a shipping paper purpose, effective integration of the Department of Transportations' (DOT) requirements would also have to addressed.

This wide diversity in uses of manifest information by Federal and State regulatory authorities, other State or Compact entities, and disposal site operators, suggested a single consolidated approach to develop a uniform manifest format with a "baseline" information content and to define recordkeeping requirements. This approach could: (1) impact the quality of regulatory, operational, and administrative decisions based on manifest information, (2) reduce the information processing burden for LLW shipments which could transverse Compact or State boundaries (e.g., for processing prior to disposal) and (3) improve the tracking of waste from generation to disposal.

The NRC, in 1989, had embarked on a rulemaking activity to establish a base set of manifest information needs for regulatory purposes. In response to requests from State and Regional Compact organizations who are attempting to design, develop and operate LLW disposal facilities, and with the general support of Agreement State regulatory authorities, this orginal data base rulemaking was expanded to include development of a uniform low-level radioactive waste manifest.

Overall Purpose of Uniform Low-Level Radioactive Waste Manifest

As alluded to above, there are a number of purposes which can be served by the information reported on a low-level radioactive waste manifest. These are listed in Table 1, in which the regulatory or other entity most likely to use and/or require the manifested information is indicated.

Table 1 Purposes Served by Uniform Low-Level Radioactive Waste Manifest Information

	Purpose	Principal entities served
1.	Assist in selection of appropriate emergency response actions in the event of transportation incident	DOT (Emergency Responders)
2.	Shipment tracking	NRC, Agreement States, States, Compact Commissions, Shippers
3.	Safe shipment and handling	DOT, States
4.	Safe and efficient LLW management	NRC, Agreement States, States, Compact Commissions, Site Operators
5.	Site performance assessments	NRC, Agreement States, States, Compact Commissions, Site Operators
6.	Confirm effectiveness of existing regulations	NRC
7.	Assess significance of problem wastes	NRC, Agreement States, States, Compact Commissions, Site Operators

Information Needs

In specifying the information that should be reported and stored for NRC regulatory purposes, a review was undertaken of the performance assessment models under development for disposal facility licensing. The goal has been to ensure that reasonable and prudent amounts and types of information are collected and stored so that possible movements of radioactivity from disposed LLW can be adequately predicted.

Each shipment of LLW to a disposal facility is currently accompanied by a multi-page manifest that describes the shipment's contents. These manifests have been developed by each of the existing LLW disposal facility operators, Chem-Nuclear Systems, Inc. and U.S. Ecology, Inc., and typically contain most of the information currently considered appropriate for NRC regulatory purposes. The existing manifests, in their unique ways, also contain information intended to comply with DOT requirements and could be modified to be generally responsive to waste tracking and other needs of the States and Compact Commissions. As a result, the proposed rulemaking, for the most part, is attempting to set a minimum standard in terms of data needs and data specificity, and to format this information in a manner that not only meets regulatory needs (e.g., DOT requirements for shipping papers) but minimizes the information collection and transfer burdens.

Approach to the Design of the Uniform Low-Level Radioactive Waste Manifest

In order to initially satisfy stated DOT regulatory requirements, the design of the proposed uniform low-level radioactive waste manifest has focused on a segregated approach to capture the needed manifest information. Specifically, coordination efforts with the DOT solicited the view that information required for potential incident response purposes should not be commingled with other manifest-supplied information and should not unnecessarily be pushed back to continuation pages in a large manifest document. As a result, a three form manifest document with general instructions has been proposed.

The forms are shown in Figures 1 through 3. The first form, NRC Form 540, is principally directed at DOT requirements but may also serve the waste shipment acknowledgement purpose required in NRC regulations. This form has been developed to reflect anticipated changes to DOT regulations which were proposed in the Federal Register on November 14, 1989. The second form, NRC Form 541, gathers information which may be particularly useful in defining LLW and disposal container characteristics so that reasonable disposal site performance assessments can be made. Finally, NRC Form 542, allows the tracking of LLW back through processors or collectors to the initial waste generator. States and Compacts need to identify the generators of LLW so as to establish whether the waste has been generated in the State or Compact in which the LLW disposal facility is located. When new disposal capacity is available, the LLRWPAA grants the authority to Compacts/States to bar waste from outside the Compact/State.

Development of individual manifest forms in this manner opens up the possibility that the entire uniform manifest would not have to physically accompany a LLW shipment. Instead, only NRC Form 540 would be used to meet DOT shipping paper requirements, and this form would also be the vehicle used to satisfy NRC's LLW shipment control and tracking requirements. The remaining information on NRC Forms 541 and 542 could be transmitted electronically or by some other suitable means. This approach could significantly reduce the amount of paperwork which currently accompanies LLW shipments.

All three forms shown in the figures will be designed for potential use in computer printers and each form will be provided as an original and 5 copies. Continuation sheets have also been developed for each form and are respectively numbered as NRC Forms 540A, 541A and 542A.

A comparison of the proposed manifest forms with those currently being used by the two disposal facility operators will indicate not only a number of format similarities but also some significant differences. On Form 541, the reliance on descriptive codes has been extended to cover the disposal containers and to indicate through a lettered suffix whether disposal requires use of an approved structural overpack. In like manner, a letter suffix, "-s," is used to indicate that a waste form or solidification media meets the structural stability requirements required at a particular disposal site.

On both Forms 540 and 541, the columnar space provided for information on individual isotopes and their respective activities has been widened to allow reporting in two adjacent columns. This feature was incorporated into these forms after finding that the single column listing on existing manifests resulted in a considerable amount of unused space across the remaining width of the manifests.

Recordkeeping and Reporting

The principal rulemaking issues on the subject of recordkeeping and reporting have been related to NRC's requirements on the storage of manifest information in licensee's recordkeeping systems and the reporting of this information or subsets of this information by the licensee to the NRC. Similar to the manner in which information is stored at the existing disposal sites, licensees could be required to store LLW and disposal container information using some subset of the over 150 different descriptors included on the manifest forms. The potential regulatory needs to sort this disposal container and waste data into a variety of data fields appears to clearly warrant the need for an electronic data storage/sorting system. One approach could (1) require electronic data storage by the licensees, (2) provide for transfer of this information to regulatory authorities, and (3) allow the regulators to develop programs to sort this data to accommodate their particular purposes. A second possibility could be to require licensees to store the data on a computer system so that the data could be manipulated in certain generally prescribed ways.

On this alternative, the question is whether NRC can justify, on public health and safety grounds, the need for licensees to have a computerized recordkeeping system. If required, the regulation could also require that the system be developed and used in accordance with a quality assurance program. This quality assurance program would address system development, verification, operation, maintenance, and modification activities.

A similar rulemaking issue is applicable to information reporting; specifically, should NRC require the transfer of manifest information between a disposal facility licensee and NRC in an electronic format. Certainly, timeliness, efficiency and the goal of error-free transfer of data would be enhanced, but again the significance of this requirement in terms of public health and safety must be considered.

On both these recordkeeping and reporting issues, it should be pointed out that licensees would not only have to meet NRC regulatory requirements but also address the needs of State/Compact authorities.

Interface Issues

The proposed use of an NRC-developed uniform low-level radioactive waste manifest has led to the need to address a number of interface issues. One of the most important involves the matter of Agreement State compatibility. As currently envisioned, the uniform low-level radioactive waste manifest, or facsimile, would be used by all shippers of low-level radioactive waste: that is, by waste generators, waste collectors, and waste processors. To serve the intended purpose, both NRC and Agreement State licensees would be required to use and record the minimal information as called for on the applicable manifest forms. However, it is recognized that a particular Agreement State may require additional information for their unique regulatory purposes and that disposal site operators may require further information to satisfy operational and administrative considerations. Therefore, the uniform low-level radioactive waste manifest allows Agreement States or disposal site operators to impose additional manifest requirements which may be transmitted as additional pages to the proposed uniform manifest, as indicated on Form 540, Figure 1. Serious consideration, however, should be given to the need for specific additional information via-a-vis the advantages in maintaining a "uniform" manifesting system. Furthermore, caution must be taken to ensure that any additional requirements for information are reported in a format which does not conflict with DOT regulations for shipping papers.

A second interface issue results from the need to determine which licensees must use the manifest and to prescribe the method used to attribute manifested waste back to original generators. The importance of this issue has been recognized by the Low-Level Radioactive Waste Forum, who have had a working group developing consensus guidelines for defining when shipments of radioactive material should be classified as radioactive waste. To address this issue, a licensee who is a processor or collector of LLW would be required to identify on Forms 541 and 542 the licensee to whom waste should be attributed. In this context, the licensee is defined by referencing the intent of the Low-Level Radioactive Waste Policy Amendments Act of 1985. In this manner, it is believed that the uniform manifest can be used to attribute radioactive waste to the proper generators, including those situations involving shipments of radioactive material or items for decontamination, potential recycle, or sorting and separating (i.e., situations in which an identifiable low-level radioactive waste component occurs as a result of these processes). This approach is also viewed as one that provides flexibility to States and Compacts in controlling and tracking of the radioactivity which may be treated, processed or disposed of in their respective State or Compact facilities.

Status and Plans for Rule Finalization

A draft of the proposed rule was issued for Agreement and Non-Agreement State comment in March 1991. Based on these comments, a revised package was prepared and sent to DOT for their approval in May. This package was also submitted to the formal NRC review process. DOT approved this package in July and the expectations are that the Commission will consider the entire rulemaking package around the first of the year. A positive Commission view could result in publication for public comment early in 1992. If and when the proposed rule is published in the Federal Register, an active review process involving interactions with generators, collectors, processors, and disposal facility operators, as well as States and Compacts is envisioned. Since the manifest forms and instructions for their completion will be referenced but will not be embodied in the proposed regulation, the review process on these elements of the rulemaking has already been initiated through this and other forums. Although content and format issues have been and will undoubtedly continue to be raised as the rulemaking process unfolds, the goal is to issue a final rule in CY 1992.

Conclusion

The NRC is seriously considering a Low-Level Radioactive Waste Shipment Manifest Information and Reporting rulemaking which includes development of a uniform manifest. This rulemaking approach is seen as accomplishing NRC's primary objectives to clarify, standardize, and expand, in a limited manner, the existing NRC requirements for the collection, recording, and reporting of manifest information. At the same time, the development of a uniform manifest, approved by DOT, will standardize the format for complying with shipping paper requirements. This standardization should not only reduce the paperwork physically accompanying LLW shipments but also provide for more effective use of shipping paper information in the event of a potential transportation incident. Finally, the uniform manifest recognizes the need to properly attribute waste in the context of the LLRWPAA, yet provides the States and Compacts considerable flexibility in determining how to use the manifest "generator" information to accomplish their particular LLW attribution and tracking goals.

APPROVED BY OMB NO 3150 EXPIRES

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714) U.S. NUCLEAR REGULATORY COMMISSION WASHINGTON DC 20555 AND TO THE PAPERWORK REDUCTION PROJECT (3150) OFFICE OF MANAGEMENT AND BUDGET WASHINGTON DC 20503

NRC FORM 540 U.S. NUCLEAR REGULATORY COMMISSION

UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST

SHIPPING PAPER

1. EMERGENCY TELEPHONE NUMBER ( )

ORGANIZATION

2. IS THIS AN "EXCLUSIVE USE" SHIPMENT? YES / NO

3. TOTAL NUMBER OF PACKAGES IDENTIFIED ON THIS MANIFEST

4. DOES EPA REGULATED WASTE REQUIRING A MANIFEST ACCOMPANY THIS SHIPMENT? YES / NO

If "Yes," provide Manifest Number →

EPA MANIFEST NUMBER

5. SHIPPER – Name and Facility Address

SHIPPER I.D. NUMBER

USER PERMIT NUMBER | SHIPMENT NUMBER | COLLECTOR | PROCESSER | GENERATOR TYPE (Specify)

CONTACT | TELEPHONE NUMBER ( )

6. CARRIER – Name and Address

EPA I.D. NUMBER

SHIPPING DATE

CONTACT | TELEPHONE NUMBER ( )

SIGNATURE – Authorized carrier acknowledging waste receipt | DATE

7. NRC FORM 540 and 540A Page 1 of ____ Pages
NRC FORM 541 and 541A ____ Pages
NRC FORM 542 and 542A ____ Pages
ADDITIONAL HOST STATE (OR OTHER) INFORMATION ____ Pages

8. MANIFEST NUMBER (Use this number on all continuation pages)

9. CONSIGNEE – Name and Facility Address

CONTACT

TELEPHONE NUMBER ( )

SIGNATURE – Authorized receiver acknowledging waste receipt | DATE

10. CERTIFICATION

This is to certify that the herein named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation. This also certifies that the materials are classified, packaged, marked and labeled and are in proper condition for transportation and disposal as described in accordance with the requirements of 10 CFR, Parts 20 and 61, or equivalent state regulations.

AUTHORIZED SIGNATURE | TITLE | DATE

11. U.S. DEPARTMENT OF TRANSPORTATION DESCRIPTION (Including proper shipping name, hazard class, UN ID Number, and any additional information)	12. DOT LABEL "RADIOACTIVE"	13. TRANSPORT INDEX	14. PHYSICAL AND CHEMICAL FORM	15. INDIVIDUAL RADIONUCLIDES AND ACTIVITY IN SI UNITS (CUSTOMARY UNITS)	16. LSA/SCO CLASS	17. TOTAL WEIGHT OR VOLUME (use appropriate units)	18. IDENTIFICATION NUMBER OF PACKAGE

FOR CONSIGNEE USE ONLY

NRC FORM 540

Figure 1. Uniform Manifest - Form 540
(actual size 8 1/2 x 14 in.)

APPROVED BY OMB NO 3150
EXPIRES

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST ... U.S. NUCLEAR REGULATORY COMMISSION WASHINGTON DC 20555, AND TO THE PAPERWORK REDUCTION PROJECT (3150 ...), OFFICE OF MANAGEMENT AND BUDGET WASHINGTON DC 20503

NRC FORM 541 — U.S. NUCLEAR REGULATORY COMMISSION

UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST

CONTAINER AND WASTE DESCRIPTION

Additional Nuclear Regulatory Commission (NRC) Requirements for Control, Transfer and Disposal of Radioactive Waste

1. MANIFEST TOTALS

NUMBER OF CONTAINERS	DISPOSAL VOLUME (cu ft)	DISPOSAL WEIGHT (lbs)	ACTIVITY (10 CFR Part 20) Millicuries: ALL ISOTOPES	TRITIUM	C 14	Tc 99	I 129	SOURCE (kg)

SNM: ISOTOPE	GRAMS	NO OF CONTAINERS
U 233		
U 235		
PLUTONIUM		
TOTAL		

2. MANIFEST NUMBER

3. Page 1 of Page(s)

4. SHIPPER NAME

SHIPPER ID NUMBER

DISPOSAL CONTAINER DESCRIPTION							WASTE DESCRIPTION FOR EACH WASTE TYPE IN DISPOSAL CONTAINER						
							PHYSICAL DESCRIPTION			CHEMICAL DESCRIPTION		RADIOLOGICAL DESCRIPTION	
5 DISPOSAL CONTAINER IDENTIFICATION NUMBER/ GENERATOR ID NUMBER(S)	6 CONTAINER DESCRIPTION AND MFG OR MODEL NO OF NRC OR CERTIFICATE OF COMPLIANCE NUMBER (See Note 1)	7 VOLUME (cu ft)	8 WASTE AND CONTAINER WEIGHT (lbs)	9 SURFACE RADIATION LEVEL (mR/hr) (R/hr)	10 SURFACE CONTAMINATION dpm/100cm²: ALPHA	BETA GAMMA	11. WASTE DESCRIPTOR (See Note 2)	12 WASTE VOLUME IN CONTAINER (cu ft)	13 SORBENT SOLIDIFICATION STABILIZATION MEDIA (See Note 3)	14 CHEMICAL FORM/ CHELATING AGENT	WEIGHT % CHELATING AGENT IF > 0.1%	15 INDIVIDUAL RADIONUCLIDES AND ACTIVITY (mCi) AND CONTAINER TOTAL, OR CONTAINER TOTAL ACTIVITY AND RADIONUCLIDE PERCENT	16 WASTE CLASSIFICATION AS Class A Stable; AU Class A Unstable; B Class B; C Class C

NOTE 1. Container Description Codes. For containers/waste requiring disposal in approved structural overpacks, the numerical code must be followed by "OP."

1 Wooden Box or Crate
2 Metal Box
3 Plastic Drum or Pail
4 Metal Drum or Pail
5 Metal Tank or Liner
6 Concrete Tank or Liner
7 Polyethylene Tank or Liner
8 Fiberglass Tank or Liner
9 Demineralizer
10 Gas Cylinder
11 Bulk Unpackaged Waste
12 Unpackaged Components
13 Sealand Container
14 High Integrity Container
18 Other. Describe in item 6 or additional page

Note 2. Waste Descriptor Code (Choose up to three which predominate by volume)

20 Charcoal
21 Incinerator Ash
22 Soil
23 Gas
24 Oil
25 Aqueous Liquid
26 Filter Media
27 Mechanical Filter
28 EPA Hazardous
29 Demolition Rubble
30 Cation Ion exchange Media
31 Anion Ion exchange Media
32 Mixed Bed Ion exchange Media
33 Contaminated Equipment
34 Organic Liquid (except oil)
35 Glassware or Labware
36 Sealed Source/Device
37 Paint or Plating
38 Evaporator Bottoms/Sludges/Concentrates
39 Compactable Trash
40 Noncompactible Trash
41 Animal Carcass
42 Biological Material (except animal carcass)
43 Activated Material
58 Other. Describe in item 11, or additional page

Note 3. Sorption, Solidification, Stabilization Media Codes (Choose up to three which predominate by volume.) For solidification media meeting disposal site structural stability requirements, the numerical code must be followed by "S" and the media vendor and brand name must also be identified in item 13. Code 100-NONE REQUIRED

Sorption
60 Speedi Dri
61 Celetom
62 Floor Dry/Superfine
63 Hi Dri
64 Safe T Sorb
65 Safe N Dri
66 Florco
67 Florco X
68 Solid A Sorb
69 Chemsil 30
70 Chemsil 50
71 Chemsil 3030
72 Dicaperl HP200
73 Dicaperl HP500
74 Zonolite Gd4
75 Perlnet
76 Perlnet II
77 Aquaset
78 Aquaset II
81 Other. Describe in item 13 or additional page

Solidification
90 Cement
91 Concrete (encapsulation)
92 Bitumen
93 Vinyl Toluene
94 Vinyl Ester Styrene
98 Other. Describe in item 13 or additional page

Figure 2. Uniform Manifest - Form 541
(actual size 8 1/2 x 14 in.)

APPROVED BY OMB NO 3150-
EXPIRES

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714) U.S. NUCLEAR REGULATORY COMMISSION WASHINGTON DC 20555 AND TO THE PAPERWORK REDUCTION PROJECT (3150-) OFFICE OF MANAGEMENT AND BUDGET WASHINGTON DC 20503

NRC FORM 542 — U.S. NUCLEAR REGULATORY COMMISSION

UNIFORM LOW-LEVEL RADIOACTIVE WASTE MANIFEST

MANIFEST INDEX AND REGIONAL COMPACT TABULATION

List all original "PROCESSED WASTE" generators (if any) before "COLLECTED WASTE" generators.

1. WASTE COLLECTOR/PROCESSOR

NAME

IDENTIFICATION NUMBER

SHIPPING DATE

SHIPPER USE ONLY

2 MANIFEST NUMBER

3 Page 1 of Page(s)

4 GENERATOR IDENTIFICATION NUMBER	5 GENERATOR NAME, PERMIT NUMBER (IF APPLICABLE) AND TELEPHONE NUMBER	6 GENERATOR FACILITY ADDRESS	7 PREPROCESSED WASTE VOLUME (cu ft)	8 MANIFEST NUMBER(S) UNDER WHICH WASTE (OR MATERIAL) RECEIVED AND DATE OF RECEIPT	9 WASTE CODE P = PROCESSED C = COLLECTED	10 ORIGINATING COMPACT REGION OR STATE	11 AS PROCESSED/COLLECTED TOTAL: A SOURCE MATERIAL (kg)	B SNM (g)	C ACTIVITY (mCi)	D VOLUME (cu ft)
TOTALS OF ALL (NRC FORMS 542 AND 542A) PAGES										

NRC FORM 542

Figure 3. Uniform Manifest - Form 542
(actual size 8 1/2 x 14 in.)

U.S. DEPARTMENT OF ENERGY AUTOMATED TRANSPORTATION MANAGEMENT SYSTEM

J. H. Portsmouth

The U.S. Department of Energy (DOE) has approximately 80 transportation facilities throughout the nation that specialize in science, engineering, technology, production, and waste management activities. These facilities vary in size from small laboratories to large industrial research plants. The DOE differs from other government agencies in that its facilities are government owned and contractor operated. At the DOE facilities, each contractor's transportation management operation have different internal and site specific procedures, and reports to a DOE regional Field Office Traffic Manager (FOTM).

The DOE Transportation Management Program (TMP) has the responsibility to manage a transportation program for safe, efficient, and economical transportation of DOE-owned materials. The DOE Headquarters TMP, provides oversight responsibility, formulates policy, and conducts site appraisals to ascertain that DOE policies and procedures are being adhered to at the contractor level. The TMP develops and administers transportation/ traffic operations management policies and programs for materials; including radioactive materials, other hazardous materials, hazardous substances, and hazardous wastes, pursuant to applicable federal regulations, such as the Code of Federal Register, Sections 40 and 49.

In recent years, transportation management has become an increasingly critical and integral part of the DOE's operations. This is primarily because of transportation issues regarding the shipment of radioactive materials and hazardous wastes that are frequently the focus of public concerns. To efficiently manage the DOE transportation management functions in the 1990's, the TMP will require an increase in its automation capabilities. A large nationwide organization such as the DOE with approximately 400,000 annual shipments and requiring millions of business transactions necessitates the establishment of automated systems, programs, procedures, and controls to ensure that the transportation management process in being handled in a safe, efficient, and economical manner. As the mission of many DOE facilities changes from production of special nuclear materials for defense purposes to environmental restoration and waste management, the role of transportation management will become even more important to the safe and efficient movement of waste materials to prescribed locations.

In support of this role, the Automated Transportation Management System (ATMS) was conceived to assist the DOE and its contractors in the performance of their day-to-day transportation management activities. The ATMS utilizes the latest in technology and will supply state-of-the-art automated transportation management for current and future DOE transportation requirements.

The thrust for developing an ATMS program for the DOE comes from two directions. First, the developments in computer technology during the last decade made it possible for transportation managers to use powerful technologies to build and maintain current sophisticated, transportation information databases. This technology helped transportation managers to track shipments of high-level radioactive waste from origin to destination through the use of satellites. The use of electronic data interchange (EDI), also makes it possible for the electronic, paperless exchange of shipping information, such as bills of lading and freight bills. This technology can eliminate the need to reformat or reenter data received from different organizations because of computer compatibility problems.

Secondly, the DOE has been criticized (e.g., DOE Inspector General and DOE Tiger Teams) for not having an integrated, automated freight transportation management program; particularly in the hazardous materials handling, freight bill payment, and auditing functions. In a recent DOE-IG finding on the subject of automated transportation systems, the following finding was stated. "Consistent use of low-cost carriers and verifying carrier invoice charges prior to payment would save DOE an estimated $3.2 million dollars annually." The ATMS program currently under development by the TMP is an integrated systems-engineered approach aimed at correcting these findings.

Recently, many government agencies including the DOE have been taking the lead from their civilian counterparts, and the industry in studying the feasibility of automating various transportation management operations. Agencies within the Department of Defense (DOD) and the General Services Administration (GSA) are among the governmental institutions studying the feasibility of automating their transportation business transactions. Additionally, the automation of other transportation management applications such as the use of EDI in the private sector (particularly among many fortune 200 companies), has increased significantly since the Motor Carrier Deregulation Act of 1980. The U.S. Congress has also mandated in Public Law 99-627 that became effective November 7, 1986, that all government agencies consider automating their transportation management activities. This law directed the GSA to establish an interagency task force for the purpose of studying the feasibility of developing an integrated automated transportation management system, that could be used by the various federal agencies.

Through the collection and effective analysis of data describing shipment activities of the DOE, the ATMS will enable TMP executives and DOE field offices and contractor's traffic managers to take advantage of opportunities that were unavailable to them in the past. They will be able to:

- Perform more effective rates negotiations with carriers
- Better understand where the DOEs transportation dollars are spent
- Track hazardous materials shipments more effectively
- Analyze transportation patterns and carrier usage
- Provide specific shipment information for emergency response
- Track inventory and maintenance status of radioactive material (RAM) and hazmat packagings.

The objective of the ATMS program is to effectively integrate existing and future planned DOE and contractor computer capabilities and applications into a DOE-wide transportation information system. Although, automated transportation management capabilities are currently available within the DOE, this endeavor has suffered from fragmented contractor efforts, and the lack of a common focused direction. Since many contractors are working on similar computer applications in the transportation management area, ATMS will ensure that duplication of developmental efforts are minimized.

A major concern is that the DOE transportation management staff have suffered because many experienced traffic managers from both the DOE and contractor ranks have retired. As a result, many TMPs and contractor transportation management staff's are facing an increasingly complex transportation logistics environment with reduced levels of staffing and experience. In such instances, automation of some transportation activities will become a significant means for supplementing staff limitations.

The implementation of the ATMS program will provide the DOE with the following administrative and strategic benefits:

- Reliable quantitative information to the DOE management in a timely manner

- Available technological advances in order to reduce the current reliance on manual processes for the majority of its routine business functions

- Low-cost automated tools to perform expensive, labor-intensive functions

- Integrate separate semi-automated and manual functions into a seamless automated system

- A DOE-wide implementation of EDI to reduce error rates on hazmat documents, streamline clerical efforts, reduce paperwork, and speed information transmission

- Automated access to DOE-wide freight rates and routings, as well as routing guides for making instant routing/rating/carrier selection

- Automate the labor-intensive prepayment system for auditing freight bills and will reduce current payout to carriers.

Existing automated capabilities of the various contractors functions will be combined into an integrated architectural system. The Shipment Mobility Accountability Collection (SMAC) system database, which functions as the DOEs historical database, is an example of an existing system that will be enhanced by the ATMS program. Presently, the SMAC database serves as a logistics management tool for the DOE Operations Offices and their contractors for rate negotiations, monitoring carrier performance, and reporting to management. As presently envisioned, carriers will be able to transmit freight billing and shipment status information directly to the historical database via EDI.

It is contemplated that enhanced SMAC will function in a similar capacity to a commercial third party network or value added network. The SMAC database will be upgraded to function as an electronic mail box. It will be capable of receiving shipment status and freight bill information directly from carriers and performing needed software translation services. Additionally, the SMAC database will be able to convert data from a Transportation Data Coordinating Committee format to an American National Standard Code Information Interchange (ASCII) file, which can be imported to a TMP database file. Data in the standard ASCII format can also be readily imported from SMAC into contractor site level computer systems for use in a number of applications such as procurement, prepayment freight bill auditing, or inventory management. An immediate advantage of implementing EDI is the dramatic reduction in effort and cost expended by contractors in verifying and reporting their shipping activity to the current SMAC database. This process will greatly reduce data collection costs by allowing greater participation in the enhanced SMAC database by smaller sites. Presently, many DOE facilities do not participate in the current SMAC database, primarily because of the technical problems of uploading data to SMAC in its current configuration. This problem would be eliminated by direct EDI communication links between carriers that the DOE use and the current SMAC database.

Figure 1 presents a conceptual view of the integrated ATMS. The ATMS architecture will be comprised of several distinct application modules that are designed to perform specific functions for the DOE. Each application is integrated (or interfaced where necessary) with the other application modules to maintain a common database. This common database will be maintained according to rigorous systems architecture and specific data administration procedures. Figure 1 also distinguishes the four primary DOE transportation informational needs and categorized them as follows:

- Operational
- Hazardous materials (HAZMAT)
- Management reporting/analysis
- Historical data.

Each of the four transportation informational needs categories has specific computer applications that will assist the TMP and its contractors in their daily transportation operations.

The operational database modules include functions such as carrier rate and routing selection that is predicated on identification of the lowest cost carrier rates for a particular shipment. It should be noted that this is a legal requirement for federal agencies according to Public Law Number 99-627. Carrier freight bills will also undergo a prepayment audit to verify that the proper freight charges have been assessed by the carrier. The current status and locations of shipments, including hazardous materials and wastes, will be electronically ascertained using EDI technology and direct computer connections with selected carriers. The preparation of shipping documents, such as commercial and government bills of lading and export declaration forms, including the use of EDI and electronic funds transfer (EFT) technology will be incorporated into this component of the systems architecture design.

The HAZMAT database component of the ATMS will include computer-generated output such as emergency response data. The necessary emergency response module will allow the DOE TMP management and operations personnel, to access information needed in order to respond to an emergency involving a DOE hazardous materials shipment. Specific information relating to the shipping of hazardous materials including radioactive materials, and waste may prove to be invaluable in an accident scenario.

It is envisioned that the Department of Transportation's (DOT) Emergency Response Guide (ERG) will be input into a database, utilizing available technology such as optical character recognition (OCR). The computerized ERG database will then be accessed in order to provide TMP operations personnel with emergency response information pertaining to each class of hazardous materials. This information will be retrieved in printed format and will accompany specific shipments of hazardous materials as required by a recent DOT communications regulation number HM-126-C.

The HAZMAT database module of the ATMS will incorporate information from the radioactive material packaging (RAMPAC) and data from the packaging readiness database (PRD) to allow users to verify the technical descriptors of containers (cask cavity dimensions, approved radionuclide contents), container inventory, and present locations of usable nuclear containers.

Another functional capability of the HAZMAT module of the ATMS is TRANSCOM, an ATMS communication system that utilizes the technologies of navigation, satellite communication, and computerized database management to provide near-real-time position locations and two-way messaging capability for selected radioactive materials shipments anywhere in the United States.

An interface of the ATMS to hazardous waste tracking systems of individual facilities will be made available. This will allow the DOE to monitor and track hazardous materials/chemicals from the time they are procured, through the transportation process, and until they are received by the DOE shipping and receiving facility. These hazardous materials/chemicals shipments will be tracked even further from the warehouse inventory complex through the use of bar coding technology at DOE facilities through the plant usage cycle. When a chemical is no longer usable by the DOE facility, it will be tracked through the waste accumulation and disposal phase until it is shipped offsite to an Environmental Protection Agency Transportation Storage and Disposal (TSD) facility for ultimate disposal.

The management reporting and analysis module of the ATMS will provide a data retrieval capability for both ad hoc querying and routine management reporting. Specific transportation information will include carrier performance, shipment volumes by traffic lane and by shipping location, and DOE shipper performance data, such as, the percentage of inbound shipments procured free on board (FOB) origin versus FOB destination. An executive information system (EIS) will be developed to provide TMP and senior DOE management with access to information needed to better manage and control day-to-day transportation management activities of the DOE.

The historical component of the ATMS architecture consists primarily of an enhanced SMAC database. The current SMAC database serves as the central source of historical shipment information on the DOEs unclassified commercial shipments, including both hazardous and non-hazardous shipments. The new ATMS database will serve as a central source for data needed extensively for responding to requests for all types of shipping and receiving information. An automated interface to the ATMS database via an EDI link between the carriers and the field office site locations will enable the collection of historical data to be performed automatically by the carrier, dramatically reducing the present labor-intensive data entry process.

A strategic plan for the ATMS program was first developed in Fiscal Year (FY) 1989 along with a preliminary conceptual systems architecture. A planned product for FY 1991 is to develop an information strategy plan (ISP) using information engineering methodology and computer aided engineering tools (CASE). The ISP will provide "high level" architectures that will act as the "blueprint" from which the ATMS will be derived. A functional requirement of the ATMS as defined in the original "Department of Energy/Contractor Electronic Data Interchange Task Force Automated Transportation Management Strategic Plan," was that individual DOE sites will fund and develop their own ATMS computer applications to meet their own unique requirements. Because of the decentralized nature of the DOE field office organizations and the fact that most DOE facilities are operated by various contractors, it has been recognized that a certain amount of autonomy is necessary in the development of any ATMS. Conversely, it was acknowledged that there is a need for some data such as historical shipment information, HAZMAT, and emergency response data to be available at a centralized database location. In response to the varying degrees of need at different management levels for transportation data, as well as other factors, it has been decided that a computer system that can function at both the site and TMP level is needed.

Figure 2 shows a diagram of the distributed ATMS functional concept. The large circle on the left side of the diagram depicts the automated functions which would be performed at the site level using microcomputers (PCs), that are readily available throughout the DOE and contractor organizations. The option to download these applications to local work stations from a host computer may also be available. The input of inbound and/or outbound shipment data into the ATMS historical database that will reside at the central database location (depicted in the smaller circle on the right hand side of Figure 2) and will also be stored at the site level. As mentioned earlier, it is proposed that a direct EDI link between the carriers which the DOE and its contractors regularly use and the historical ATMS database be initiated. This will significantly reduce the data input required at the local level. However, even with a direct EDI interface between the carriers and the historical database, a certain amount of data entry at the local level cannot be avoided.

As previously stated, a primary goal of the ATMS is to provide an integrated computer system capability to assist the DOE and contractors transportation operation personnel in successfully processing the thousands of transactions needed to meet the day-to-day requirements. Certainly, a PC-based distributed ATMS concept will allow site transportation management functions to interface more effectively with other functions of the DOE or contractor organizations. An essential requirement for the DOE is that an adequate data interface be developed between the transportation management functions of an organization and site functions such as accounts payable, procurement, and warehousing. A DOE-wide centralized mainframe-based ATMS architecture will encounter many technical and political difficulties in attempting to integrate the multitude of current contractors' software and operating platforms into one centralized system. Therefore, a distributed PC-based systems architecture is thought to be the most effective short-term solution to TMPs automation needs. This PC-based solution will then be integrated with mainframe capabilities to provide a long-term solution in what will truly be a distributed national system.

Figure 2 also shows the central database in the smaller of the two circles. A feature of this long-term solution is a central TMP database that will incorporate elements of the SMAC historical database, now the central repository of DOE shipment information for hazardous and non-hazardous shipments. The conceptual design of the ATMS central database will include other functions, such as, a DOE-wide repository of data on carrier performance information to be used by TMP management to identify unresponsive carriers. This will aid site contractors in their carrier rate negotiations. Another ATMS module will be developed to serve as a repository for information collected by the DOE on carriers who are used to transport truckload quantities of radioactive materials as well as radioactive and hazardous wastes. At present, this information is available through onsite visits to carrier facilities and is gathered from annual questionnaires completed by carriers and from reports obtained from the Office of Motor Carriers, Federal Highway Administration. All this information is now maintained only in hard copy form. However, future plans for the ATMS motor carrier evaluation module, call for these data to be placed in an electronic data format, capable of being downloaded from the ATMS central computer to a DOE site traffic manager's PC.

At the same time, the ATMS central computer will host computer programs such as RAMPAC and PRD, two radioactive materials packaging and container inventory/location databases. The purpose of these packaging modules on the ATMS is to provide site operations personnel with access information on nuclear containers to ascertain that these packages are properly tested, maintained, and certified to transport radioactive materials and/or wastes.

An additional module on the ATMS host computer will be a carrier selection module. The DOE nationwide freight rates and carrier tenders will also be stored and maintained at the TMP level. With this information, all site locations will have immediate access to up-to-date carrier pricing (shipments) data of the DOE-owned materials for comparison with local rating and routing information. The ATMS screens will permit easy-to-use comparisons for all local traffic managers.

In order to integrate and coordinate all participating DOE contractors and carrier sites, the central ATMS system will collect and distribute non-secured information from the local ATMS site facilities. The information transferred to and from the host computer and the site facilities locations will be networked by any number of available communications methods yet to be determined (e.g., dedicated telephone line, modem, tape-to-tape exchange, and so forth).

As planned, the deployment of the ATMS will move forward in FY 1991 using a two-pronged high technology-low technology approach. Under the high technology approach, the systems architecture for the ATMS will be developed. An ISP utilizing CASE tools will be created in order to provide architectures for effectively integrating the cross-site computer applications into a distributed functional architecture. In addition, a functional requirements document for the ATMS program will be created utilizing CASE tools to define process decompositions and will be accomplished during FY 1991. A DOE-wide hardware analysis for evaluating a distributed system approach versus a central host computer design for the ATMS will also be conducted. A prototype EIS to make transportation information immediately available to TMP executives will be initiated under the high technology approach. Also scheduled for development in FY 1991 is an ATMS standards and procedures document as well as an implementation plan for the 1990s.

The primary thrust of the ATMS low technology approach is to provide day-to-day automated support to those transportation management activities which must be performed. The low technology approach to the implementation of the ATMS program will concentrate on delivering micro-based software tools to the DOE field office and contractor's organizations as soon as possible. Currently, available government or commercial transportation management software packages that have an identified potential use to the ATMS program will be distributed to selected DOE sites. A pilot project location will be specified to implement the prototype programs. The pilot project approach at one location where a field module is completed, is the standard method for implementing a national system. This field module will then be replicated site-by-site at each of the DOE facilities. Furthermore, the development of initial EDI capability between the central ATMS database, the carriers, and site locations will be established during the low technology approach.

A DOE-wide ATMS Task Force has recently been formed to provide guidance and to establish policy direction for the implementation of an integrated ATMS. The Task Force is comprised of individuals from several major DOE field office locations, and will report regularly to the DOE Manager of Transportation Operations and Traffic Headquarters. It is the goal of the ATMS Task Force to get as many contractor and DOE field office locations as possible moving forward together as a unified team towards the successful implementation of the ATMS program.

The need for an ATMS program at the DOE national level is not a perceived need, but one that is very real. As the DOE moves ahead during the decade of the 1990's, it is going to require more timely information to accomplish its mission of energy research and development, continued production of special nuclear materials for defense purposes, and effective environmental management and site restoration.

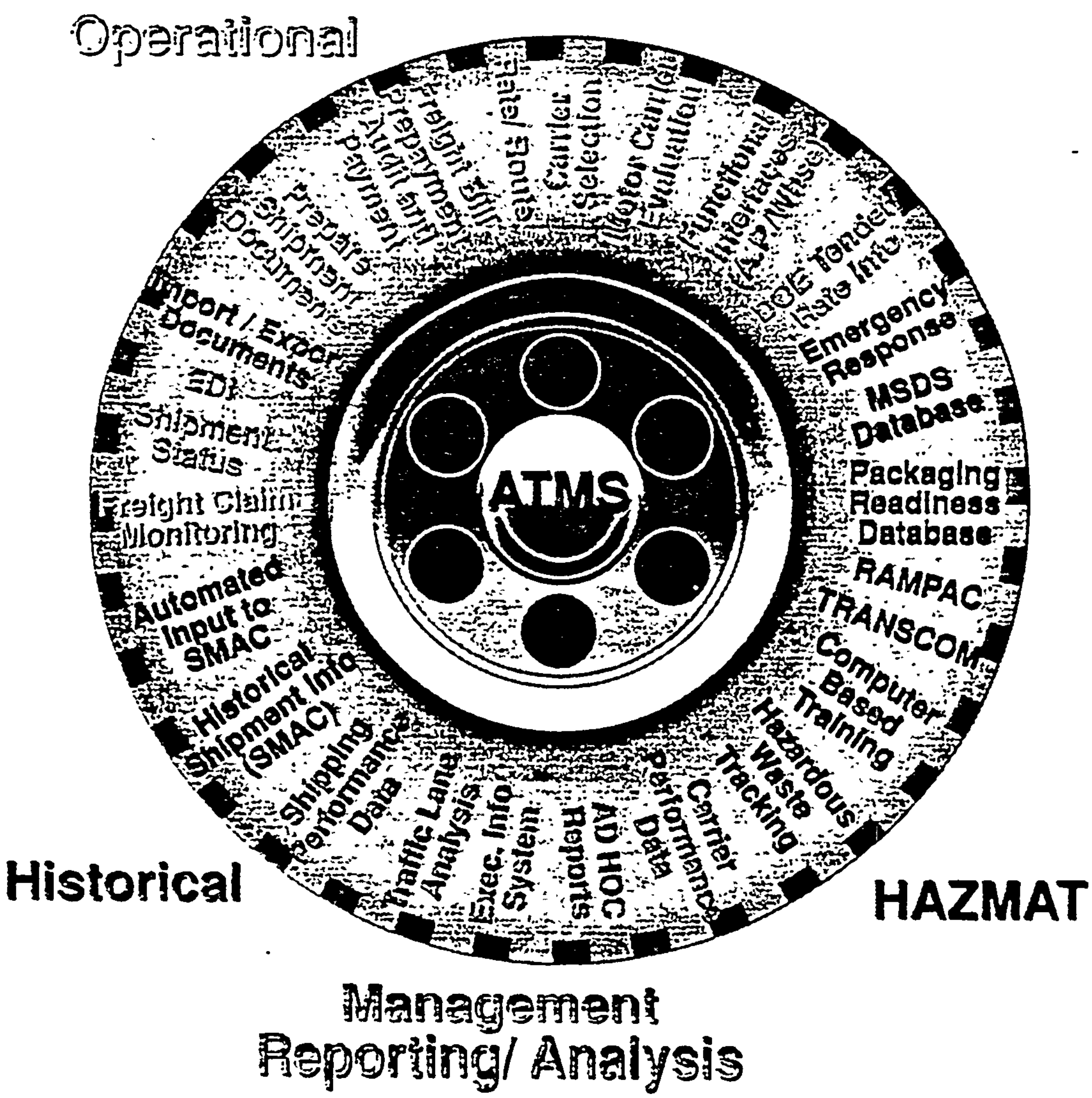
An integrated DOE transportation system is needed to provide the DOE transportation and environmental management executives the tools and information required to assist in the accomplishment of their mission. The task of the ATMS program is to develop and deploy this transportation information system at the site and national level. The ATMS will assist the TMP to move from the current "islands of automation" environment to one of an integrated system, capable of providing a seamless flow of information throughout the TMP infrastructure.

In conclusion, the ATMS program system architecture is being developed to support the vast majority of the TMP operational and informational requirements for transporting hazardous materials (including radioactive materials) and non-hazardous materials used in the day-to-day operations of the DOE facilities. The ATMS program will provide updated shipment status information of materials in route, including the locations of radioactive and hazardous waste shipments. The capability to perform required management reporting and administrative functions, such as the prepayment auditing and payment of freight bills, will be possible. Ultimately, it is envisioned that a DOE or contractor traffic manager will be able to perform virtually all basic and repetitive activities via automated tools provided by the ATMS program.

Figure 1. Automated Transportation Management System.
U.S. Department of Energy's Transportation Information System.

Automated Transportation Management System (ATMS)

DOE's Transportation Information System



R9101037.1

Figure 1

Figure 2. Distributed Automated Transportation Management System Functional Architecture.

Distributed ATMS Functional Architecture

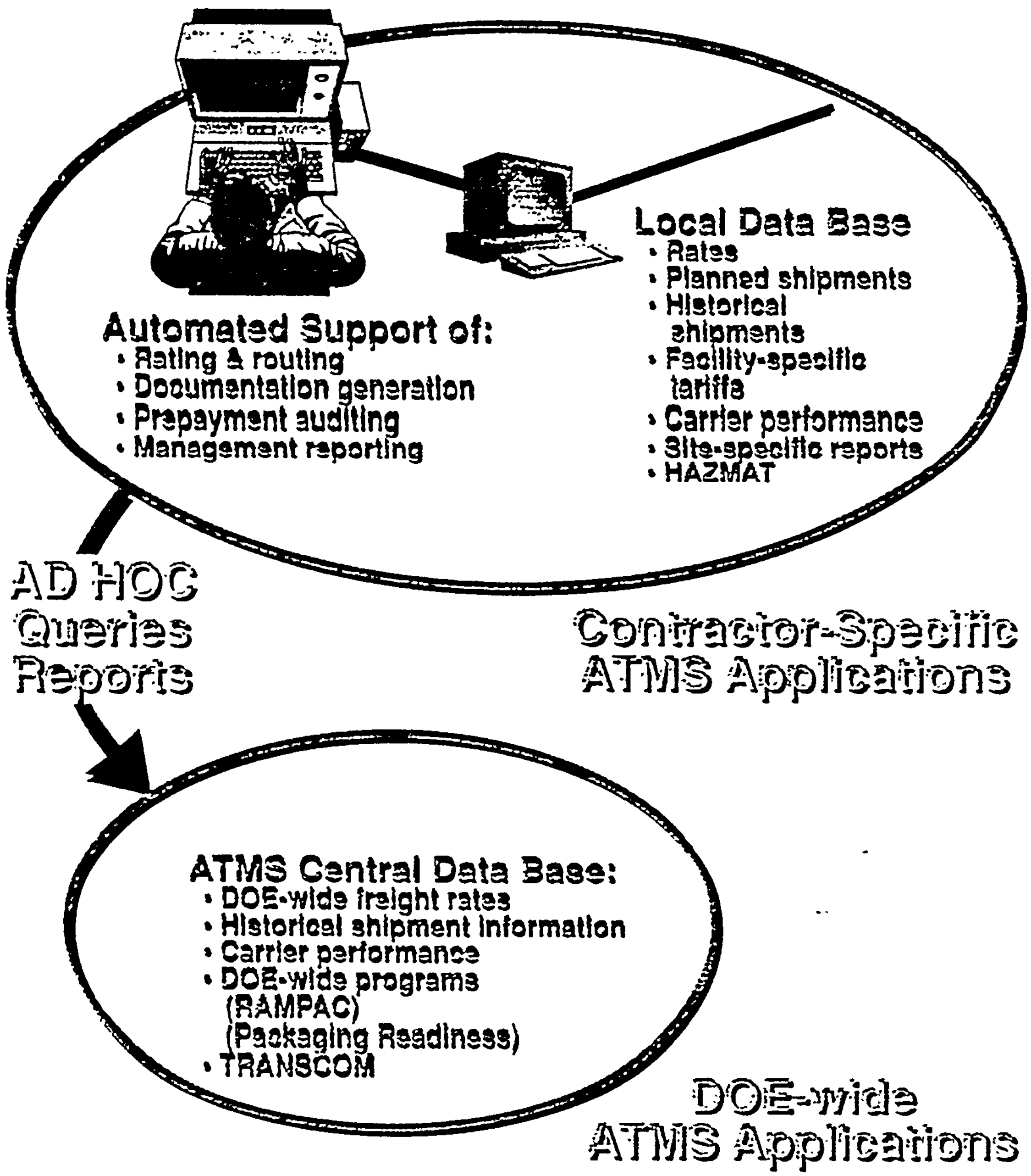


Figure 2

STORAGE

The Donald C. Cook Nuclear Plant Plan for On Site Storage of Radioactive Waste

Author: Walter T. MacRae

Affiliation: American Electric Power Service Corporation, Nuclear Operations Division, Radiological Support Section

I am going to talk today about the temporary on site storage of radioactive material at the Donald C. Cook Nuclear Plant in Bridgman, Michigan. We have a problem in Michigan. Actually, we have many problems in Michigan, but the one I am going to address is the need to store our radioactive waste. This problem will be shared by much of the country starting in 1993. I am going to explain our solution to the problem, and try to give you some insight on the decision process used to make some critical design decisions. Our solution wasn't intended to help us in our current situation. It was intended to store our wastes starting in 1993.

I am going to present to you our Radioactive Material Building. It is presently under construction.

Before I present the building, I want to explain why we decided to use a building instead of the option to use storage modules.

Our first step in the process was to determine if we wanted to use storage modules. When we started, Michigan was considered a bad boy, but they were still a member of the Midwest Compact, and there were written plans to build a disposal site. But, the site was not to operate until 1997. We had to consider a storage period of at least four years and most likely longer. Today the storage period is most likely longer. Very much longer.

An evaluation of the storage modules showed that this could be a useful option for some people. It could be a low cost option depending on waste generation. At our waste generation rates, storage modules are more expensive than a building. For us this cost benefit cross-over occurs between three and five years or at 30,000 cubic feet. Although important, cost was not the only consideration.

Shielding was an important consideration. The preferred dose rate for the external surfaces is 0.2 mrem/hr. Now this is below what is required by 10 CFR 20, but it is the limit we have adopted on site for an uncontrolled area. Optimally, we would want these containers to be in an uncontrolled area. The maximum thickness of most storage modules is 24 inches. This is not enough shielding. We recognized that with some creative placement of containers, the outer most dose rates could be kept low. But, this doesn't minimize the doses that would be received during inspections and it doesn't coincide with ALARA principles. Using storage containers would make it difficult to use remote controlled equipment and because of the size, an overhead crane or cherry picker would still be needed.

These containers would have to be protected from the environment, either individually with tarps or by some sort of building. If a building was built, cherry pickers probably couldn't be used. It would require some a dedicated crane system. If tarps were to be used they may not completely meet the requirements to protect from the weather. There would be no method to prevent the material from going through freeze-thaw cycles.

If a building is used the shielding would only be needed in the exterior walls. With storage modules the shielding is part of each package. The shielding will very quickly add up. For the waste being generated, the space needed for storage modules would be much greater than a building. There is also the appearance problem of having a little storage module farm.

Finally, the last criteria is future use. We expect to store waste on site for a long time. Assuming that we will one day be able to get rid of our waste, we will be left with whatever solution we propose now. The future use of storage modules is limited. The creative site could use them for anchors or even sea walls, but we wouldn't have much use for them. A building could be put to many future uses. It could be used for contaminated equipment storage, or during decommissioning.

Our final decision was to use a dedicated facility, Our facility is called the Radioactive Material Building.

The primary purpose of the Radioactive Material Building is to store the radioactive waste generated at the plant. It is not the only function of the building. It could also be used to store other material, either in staging for an outage or cleaning up from one. It could really be used in any way that was needed to support the plant. Its first purpose is to store waste. It was designed with that purpose.

The design criteria for this building are simple. The primary guidance was Generic Letter 81-38. We used this letter to generate the design. Much of this guidance was simple and lended to common sense. There were some criteria that were vague. The most important of these was the five year storage criteria.

A long, long time ago when the NRC wrote the generic letter, they probably didn't envision anybody storing radioactive waste for longer than five years. Also, it is written as an example of how long one could expect to store. Today, many people feel that if you intend to store more than 5 years you would need a license amendment to do it. The way our license is written, I feel that we would not need to amend our license. We do have some time. If my interpretation is wrong, I hope to have further guidance from the NRC before it becomes a problem.

In view of this, we designed our facility to hold a minimum of five years of waste. We determined the storage volume and types of waste by looking back over the last five years. The result was 80,000 cubic feet of storage would be needed. Well, in the last five years we along with much of the industry, have greatly reduced the waste generation. The building should be able to hold 7 to 10 years of waste as designed without being expanded.

The final criteria considered are the regulatory requirements. 10 CFR 20 was used to guide the design for the everyday operation. 10 CFR 100 was used to determine the number of curies that could be stored in this building. Ten percent of 10 CFR 100 was used as the maximum accident dose that would be allowed. This approach allows 25,000 curies to be put in our building using site specific meteorological data.

The facility consists of four areas: a service area, a truck bay, the cell storage area, and the DAW storage area.

The service area provides space for office equipment, a rest room, mechanical and electrical equipment rooms, and the remote crane console.

The truck bay can accommodate a tractor and trailer. In this area the trailer would be unloaded using a fork lift or the overhead crane.

The cell storage area has twelve cells. Each cell is sixteen feet square and twelve feet deep. Each cell has a drain to a common sump. Each cell has a two piece, two foot thick cell covers. Removal of the cell covers for access and handling of the waste containers will be done using the overhead crane.

The DAW storage area is located adjacent to the truck bay. Access to the DAW area is through a roll-up door or a man door. The floor elevation of the DAW area is the same as the loading dock.

The building is designed and built with provisions for expansion. Storage Capacity can be increased by 100 percent.

The building is above grade and has been designed to withstand combinations of various loads (dead, live, crane, wind, snow and earthquake) per applicable building codes. The facility has not been designed to withstand a tornado. The radiation shielding considerations have governed the thicknesses of the walls enclosing the cell area and the truck bay (up to the crane rail level) and the concrete cell covers.

For protection against weather, the exterior walls and the roof system will have insulation. The walls will have pre-insulated metal panels and the roof deck will carry a thick insulation and rubber membrane. The temperature range in the storage areas and the truck bay is designed to be maintained between 40°F to 104°F. A personnel environment will be maintained in the service area. The roof drains have been designed for 3" per hour rain per BOCA plumbing code. The water from the roofs will be discharged into a catch basin on the north side of the building. The catch basin will drain to a run-off ditch to the east of the building. The finished grade will be sloped away from the building. The nominal floor elevation of the building is 1'-0" above the finished grade.

The building is designed to prevent extremes of temperature. Therefore no adverse effects are expected because of extremes of temperature. The building has not been designed to control humidity. Some humidity control will be achieved because of the temperature control, and when extremes of humidity do occur they are expected to be for a short time. The possible effects of extreme humidity are expected to be accelerated container degradation. Only the metal boxes containing DAW are expected to be affected. HICs are made of polyethylene and are unaffected by high humidity. Packages will be inspected each quarter per the periodic surveillance program. The surveillance program will identify container degradation and mitigating actions will be taken to correct defective packages.

The waste will be kept secure by using locked and alarmed doors. Security will make routine patrols of the area. All exterior doors are equipped with locks and alarms. The roll-up door can only be opened from the inside. The security alarms are part of the fire detection system. These alarms will annunciate in the Central Alarm Station and the Secondary Alarm Station.

The heating and ventilation system has been designed to prevent the extremes of temperature from affecting the material and containers stored in the building. The system is designed to keep the temperature in the DAW area, the truck bay and the cell area within 40°F to 104°F. The service area has a heating, ventilation and air conditioning system designed to provide personnel comfort.

The heating and ventilating will be accomplished using two types of equipment. Electric unit heaters will be used to heat the building. The heaters will be horizontal, pull through air design. Each heater will have its own thermostat. Roof ventilators will be used to cool the building. Ventilators will be a hooded type direct drive, motor driven propeller fans.

The service area will be heated and cooled using a geothermal heat pump system.

The fire protection system will comply with or exceed all requirements of the latest edition of the National Fire Code and all state and local codes and ordinances as applicable. The system will include dry pipe sprinklers, detection and alarm systems, hose stations, portable fire extinguishers, and yard piping and hydrants.

The dry pipe sprinkler system will consist of automatic sprinklers. Ceiling mounted sprinklers will be used in the DAW area, the cell area and the truck bay. In addition, sidewall sprinklers will be provided in the truck bay. The sprinklers will have a temperature rating of 286°F. Ceiling mounted sprinklers will be used in the service area. These sprinklers will have a temperature rating of 165°F.

The fire alarm system will be used to signal a fire or a malfunction in the fire protection system. The truck bay and the cell area will be equipped with infrared flame detectors. Detection of a fire in the DAW area will be signaled upon the actuation of the sprinkler system. Manual pull stations will be provided in all areas of the building. Fire alarms will annunciate in the Central Alarm Station and the Secondary Alarm Station. Each of these facilities is manned 24 hours a day by security. Local annunciation will be provided in the building. Each device will be wired into an alarm control center. A detector activation will cause horn and red flashing light alarm devices to activate throughout the building. These alarm devices will be located so that they can be heard and seen from all areas of the building.

Hose stations and portable fire extinguishers will be provided in the building. Yard piping and three new fire hydrants will be added outside the building.

The drain system will be provided to collect all liquids in a closed sump. The sump will not have a release path from it to the environment. If the sump needs to be emptied, it must first be sampled. Based upon a radioactivity survey of the liquid, it will be disposed of in accordance with applicable regulations. If radioactivity above background is identified, the liquid should be taken to the plant and put into the plant drain system for processing.

Each cell will have its own drain. And a test port for each row of cells will be provided. The test port will assist locating the source of the radioactivity if any is ever found to exist. The piping and components in the drain system will be stainless steel. A drainage trench in the DAW area will be formed into the concrete floor. The shower in the rest room is for decontaminations and its drain will be directed to the sump.

The building will have an overhead bridge crane with a 45 ton hoist. A 10 ton auxiliary hoist will also be provided. The crane will primarily be used to move the HICs and other items from a truck to the cells. The crane can be operated in three modes.

The first mode will be remote radio control. The radio remote control will be able to control all functions of the crane.

The second mode will be by means of a console located in the control room of the service area. This console will control all functions of the bridge crane, including bridge, main and auxiliary trolley, lights, alarms, all hoist, grapple and power rotator functions. Visual reference to the crane will be provided by TV monitors built into the crane operator's console. The TV monitors will be tied into five CCTV cameras; three on the crane, two wall mounted. The CCTV cameras will have pan tilt and zoom features.

The third mode will be a backup in case the primary and secondary modes fail. It will consist of a control box on the crane bridge walkway. This control box will contain pushbuttons to control the crane.

Each hoist, trolley and bridge drive will have a backup motor installed. The backup motor will be available immediately upon the failure of the primary motor. The backup motors will allow the bridge and trolley to be moved to the truck bay for repairs, and they will allow hoist movement to unlatch a load.

The building is a poured, steel reinforced concrete building. In addition, structural steel was used for walkways, stairs, handrails, various embeds, etc. The roof uses steel joists and an 18 gage roof deck. The remaining structural details for the building are as follows:

1. Cell area

   The exterior wall thickness up to the crane rail level is 30 inches. The exterior wall above the crane rail is 18 inches. The thickness of the wall dividing the truck bay and the cell is 30 inches and the walls within the cells are 12 inches thick. Each cell is covered by a two piece cell cover. The cover is 24 inches thick.

2. Truck Bay

   The dock level slab and the dock walls are 12 inches thick. The thickness of the concrete slab above the sump is also 12 inches thick. The sump walls and floors are 18 inches thick. The sump is 28 feet long, 8 feet wide and 10 feet deep. The exterior walls to the truck bay are 30 inches thick.

3. DAW Area

   The thickness of the exterior walls are 12 inches. The thickness of the wall between the truck bay and the DAW Area is 24 inches. The floor slab is 12 inches thick.

4. Service Area

   The exterior walls of the service area are poured concrete 12 inches thick.

5. Foundations

   A mat foundation has been provided for the cell area and the truck bay. The frost line is 4 feet below the finished grade level and the concrete depth around the periphery has been provided for accordingly. The mat thickness is 3 feet thick in the truck bay and cell area. In the DAW area and service area, the exterior walls are supported on strip footings. The grade slab is 1 foot thick.

6. Roofing

   The roof deck is directly welded to the top chord of the joists spaced at 5 feet. The 4 foot deep roof joists span the entire width of the building and are pitched toward the north for roof drainage. The roof is drained by internally routed piping.

7. Expansion

The building has been designed to be easily expanded while being used. A number of features have been included to allow for expansion. The expansion of the cell area would be to the east. Another set of 12 cells can be added. The east wall will be poured up to 4 feet below the crane corbel level. In the middle of the wall there will be 15 foot wide cast in place removable concrete panels. A steel frame enclosure will be erected above this wall up to the roof level to support the siding. for additional shielding, a 4 foot high 16 inch wide high density block wall will be built with staggered courses along the top of the wall over its entire length. After the cell expansion has been built, the siding steel columns, block wall and concrete panels will be removed to allow free crane passage between the two cell areas.

The DAW area is to expand to the south side. Removable steel encases concrete panels have been left in place as provisions for future openings into the expanded area.

That is the physical description of the building. Now I will address the critical design decisions in the design of the building.

I call these critical design decisions because these areas that I felt we improved on what other people have done, we have done something contrary to what others have done, or was just an underlying philosophy we tried to maintain.

Flexibility was the most important philosophy we tried to maintain. Over the past years the waste industry has changed dramatically. And I expect it to change dramatically in the future, Therefore we did not want to lock ourselves into any specific technology or method of doing business. On our site, one of our most important philosophies has been that our main job at a power plant is to produce electricity. Therefore we have moved our processing off site to the various vendors. When we translate this back to the design of the building, a major criteria was to leave lots of open space.

The flexibility wasn't only maintained in the physical design of the building but with the operating criteria. We tried to keep the operating criteria simple. Flexibility was maintained by applying the operational criteria at the points of regulatory concern, the general public. For example, a maximum container dose rate is not part of our criteria. A dose rate on the external surface of the building is. This way we allow ourselves to use a variety of methods to keep the dose rates outside the building down.

The name was also a critical decision. We call our facility the Radioactive Material Building. Many sites are calling their facility after its primary purpose, a Low Level Radioactive Waste Storage Facility. When this gets into your licensing documents an inflexible licensing engineer or QA department will not allow the storage of anything but Low Level Radioactive Waste. We want the flexibility to put whatever we want into the building. This building will have an owner and he will control what will be put into the building. So, this will be controlled, but flexibility is maintained.

The next item is location. Many plants have put similar facilities in their radiation controlled areas. There are many good reasons for this including the control of radioactive material, and the possibility to tie into existing systems, especially the HVAC system. This becomes even more desirable if you want a waste processing building. If you were building a new plant this would be the way to go. But, we are not starting with a new plant, and if you have ever been at Cook Plant you understand the space restrictions at the plant. The plant is squeezed into the dunes on the eastern shore of Lake Michigan. We are not allowed to touch any of the existing natural dunes, and that further limits the available space.

Another very important reason to locate the building outside the RCA is cost. Workers in a radiation controlled areas or just protected areas have to meet all the requirements of fitness-for-duty and training. Not just radiation training, but for almost every type of skill that must be performed. Inside the radiation controlled area would add cost to your design by trying to avoid or tie into existing plant systems. Outside the protected area you might be able to start your design with a clean sheet of paper. This lowers your design cost, allows for cost-efficient construction techniques to be incorporated into the design, and most important it allows you to use standard laborers to do the work. This last item allowed us to avoid about 1/3 of the construction cost.

Processing is one area where we moved away from flexibility. The reason we moved away from flexibility is cost. Processing in a facility will require a negative ventilation system and a radiation monitoring system. Neither are provided in our design. This doesn't mean we will never be able to process in the building. The building has a closed sump, a sump that must be pumped to a truck or other container. Liquids would not be free released from this building. Power supplies and other supporting utilities could support processing under tents or other containments in the building. Processing is not forbidden in the building, but proper approvals and evaluations must be completed before it is allowed.

Finally, it is important to plan for expansion. The future of disposal options is in the hand of the politicians. I am not going to say that they will not move in a way that will require us to store for a long time, remember I work for a plant in Michigan, but I am not expecting them to act in my best interest either. If my interest aligns with their political goals, great, but meanwhile we must be prepared for the future. To me that means expansion. The design I presented here, with improving volume reduction technology, can be expanded to store the waste generated until the end of life. Each of you will have to take your best guess, and plan accordingly.

I don't know what the future holds for low level radioactive waste. Possibly, the track we are on now will generate a national solution, perhaps not. I expect that on site storage will be required by many waste generators. Our Radioactive Material Building will meet our needs for the next seven to ten years. Hopefully the decisions needed at the end of that period will be easy.

TECHNICAL CONSIDERATIONS AND PROBLEMS ASSOCIATED WITH LONG-TERM STORAGE OF LOW-LEVEL WASTE*

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ABSTRACT

If a state or regional compact does not have adequate disposal capacity for low-level radioactive waste (LLRW), then extended storage of certain LLRW may be necessary. The Nuclear Regulatory Commission (NRC) contracted with Brookhaven National Laboratory (BNL) several years ago (1984-86) to address the technical issues of extended storage. The dual objectives of this study were (1) to provide practical technical assessments for NRC to consider in evaluating specific proposals for extended storage and (2) to help ensure adequate consideration by NRC, Agreement States, and licensees of potential problems that may arise from existing or proposed extended storage practices. In this summary of that study, the circumstances under which extended storage of LLRW would most likely result in problems during or after the extended storage period are considered and possible mitigative measures to minimize these problems are discussed. These potential problem areas include: (1) the degradation of carbon steel and polyethylene containers during storage and the subsequent need for repackaging (resulting in increased occupational exposure), (2) the generation of hazardous gases during storage, and (3) biodegradative processes in LLRW.

INTRODUCTION

The Low-Level Waste Policy Act (PL 96-573, December 22, 1980) established state responsibility to provide disposal capacity for low-level radioactive waste (LLRW), and it was envisioned that all states would be self-sufficient in this respect. In addition, the Act encouraged the formation of interstate compacts which (subject to approval by Congress) may refuse LLRW from outside their respective compact areas. Congress approved amendments to the Act in December, 1985, which specified timetables for unsited states to demonstrate good-faith efforts to provide disposal capacity for LLRW and allowed the sited states to limit the quantities of LLRW accepted for disposal and to levy surcharges on the accepted LLRW. Therefore, a state or state compact may find itself without adequate affordable disposal capacity, and extended storage of waste may be required until disposal means are available. The waste may be stored for a period of several months to several years at the site of waste generation (e.g., on-site at a nuclear power plant), at the disposal facility, or at a state or regional facility dedicated to such extended storage.

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* This paper is based on work performed for the U.S. Nuclear Regulatory Commission.

There are several reasons for storing LLRW. Until recently the usual reason has been to allow for radioactive decay. Storage for decay is widely practiced by hospitals and universities. Storage is also practiced to consolidate waste for efficient processing and/or shipment by a waste broker. The possible long-term unavailability of adequate disposal capacity for LLRW provides a major reason for storage of these wastes. Another reason for extended storage is that existing disposal may become temporarily unavailable because of problems such as unavailability of transportation services, e.g., due to labor disputes or weather.

On-site LLRW storage needs arising from the unavailability of disposal capacity constitute a relatively new radwaste management problem in the United States. Most nuclear power plants were not designed with on-site LLRW storage capacity of extended duration since it was assumed that the LLRW would be shipped to a disposal site whenever a truckload had accumulated. Similarly, most non-fuel-cycle LLRW generators have operated under the assumption that the waste would be shipped for disposal rather than stored.

The U.S. Nuclear Regulatory Commission has provided guidance for LLRW storage practices at nuclear reactor sites in Generic Letter 81-38.[1] In this document the NRC has considered two phases or time scales for extended storage of LLRW at nuclear power plants:

1. interim contingency storage, for up to 5 years, and

2. long-term storage, for over 5 years.

Because of the uncertainties which still exist regarding the availability of LLRW disposal capacity, the NRC is aware that extended storage of LLRW may be pursued by nuclear power plant licensees and by other NRC licensees who generate LLRW.

To develop further guidance for the extended storage of LLRW by NRC licensees and to help ensure the continued protection of public health and safety, the NRC contracted with Brookhaven National Laboratory to address the issue of extended storage of LLRW, focusing on the waste form and container but also considering storage alternatives in order to establish the likely range of storage environments that the wastes would encounter. The dual objectives of this study were (1) to provide practical technical assessments for NRC to consider in evaluating specific proposals for extended storage and (2) to help ensure adequate consideration by NRC, Agreement States, and licensees of potential problems that may arise from existing or proposed extended storage practices. At NRC's request, BNL has previously presented summaries of the findings of the study.[2,3,4] In this paper, BNL, once again at NRC's request, summarizes the major points of the report on this topic to the NRC.[5]

CLASSIFICATION OF STORAGE FACILITIES

Various types of LLRW storage facilities, whether existing, under construction, or proposed, have been categorized in a survey of utility plans and actions which was conducted by the Electric Power Research Institute (EPRI)[6] and also in a New York State study of LLRW management practices.[7] The EPRI survey was published in July 1984, and contained information valid as of 1983. The EPRI survey classified on-site storage facilities into three categories, viz., reinforced concrete structures, pre-fab structures (concrete or metal panels) and bunkers. The New York State study grouped LLRW storage facilities into four categories, viz., shielded buildings, shielded storage modules, shielded casks, and unshielded facilities. Each storage facility is in some ways unique, and for the purposes of the present study, a spectrum of storage concepts based on both of the above-mentioned classification schemes will be considered.

The following spectrum of storage facility concepts ranges from shielded structures with temperature and humidity control through those with less environment control to ones with minimal shielding, as well as minimal environmental control:

- Large engineered structures. These are permanent buildings designed specifically for the extended storage of LLRW. They may be reinforced concrete structures or steel frame buildings with uninsulated metal siding and roofing. They are generally provided with separate shielded areas for the storage of dry active waste and solidified wastes. Typically, some control over the temperature and, sometimes, the humidity is provided, e.g., a heating system to prevent freezing during the winter. Overhead bridge cranes are used for remote handling of the waste packages.

- Shielded storage modules or bunkers. These are permanent concrete structures with removable covers. Waste containers are emplaced or retrieved from above with a crane.

- Shielded storage casks. These are all-weather concrete containers, usually cylindrical, that can be located outdoors and that are designed to hold waste drums or liners.

- Unshielded pre-fab structures. These are unshielded buildings which provide some degree of weather protection but have no temperature control system. Simple steel frame buildings with uninsulated metal siding and perhaps an overhead crane or hoist but no temperature control would fall into this category. These structures are generally intended for the storage of low-specific-activity wastes. The waste packages are handled by means of hand dollies, fork-lift trucks, or cranes. These facilities have generally been used for storage for decay rather than extended storage.

- Minimal unshielded facilities. These are simple fenced-in outdoor concrete pads or very simple storage sheds. Little or no environmental protection is provided by these facilities, which were generally intended as holding areas for waste packages awaiting pick-up by a waste broker and not as waste storage facilities.

STORAGE ENVIRONMENT CHARACTERISTICS

The behavior of radioactive wastes, of the binder materials in which they are immobilized, and of the container materials will be affected by the environment within the storage facilities.

The environmental variables considered are length of storage time, temperature, humidity, potential for wetting of the container, and radiation field. Unfortunately, explicit information about these variables is generally not presented in descriptions of LLRW storage facilities.

The potential storage time is a variable significantly impacted by factors other than technical considerations. The storage space available and the rate of waste production are, of course, important, but social, political, and economic factors that affect the availability of disposal sites for LLRW are likely to be the major considerations in determining the length of time for which storage of LLRW may be needed.

The temperature of the storage environment will vary only slightly in the more elaborate large engineered structures for containerized radwaste, which include HVAC systems in their design. A minimum temperature of 50°F (10°C) is explicitly mentioned by one utility for its LLRW storage facility.[8] Values for the relative humidity were not given, but the environment provided by this facility for the stored drums was considered non-corrosive. The critical value at which atmospheric corrosion becomes significant for steel ranges from about 50% to 70%. In the less elaborate large engineered structures, which have only heating and ventilation system, temperatures will be kept above freezing during the winter but may easily exceed 100°F during the summer. For example, temperatures for the indoor storage of resin waste in spent resin holding tanks at two nuclear power plants have been reported to range from 40°F to 90°F (4°C to 32°C) and 70°F to 100°F (21°C to 38°C).[9] At the other extreme, the wastes in a simple fenced-in concrete storage pad will be exposed to the outdoor temperature and the outdoor humidity, which over the course of a year in some locations may range from below -40°F (-40°C) to above 104°F (+40°C) and from 0% to 100%, respectively. For such outdoor storage there is, of course, a significant potential for wetting of the container by rain or, in locations near bodies of salt water, by salt spray, which is very corrosive towards carbon steel.

For α and β radiation it may be assumed to a very good approximation that radiation emitted within the waste package is absorbed within the package. The γ-radiation field within a particular waste package will depend on the radiation emitted within the package itself and also on the γ radiation emitted by nearby packages. The γ radiation emitted within a particular package is generally not completely absorbed within the package itself. For example, at points of contact between two containers loaded with γ emitters, the dose to the container material to a very good approximation will be the sum of the doses to those points for each of the two containers in isolation, i.e., when considering the dose to waste packages stored in proximity to one another, the γ-radiation field intensities of the individual packages should be superimposed. The dose to the contents of a waste package from the adjacent waste packages in a closely packed stacked array of such packages may be conservatively estimated by replacing the individual waste packages by an infinite medium. For example, the γ-ray dose to the contents of a stacked 55-gallon drum may be conservatively estimated by tripling the γ-ray dose to a 55-gallon drum in isolation. (It is assumed in making this estimate that all the drums in the stacked array contain the same concentrations of γ emitters.)[5]

It should be noted that in certain respects, the storage environment can be more severe than the disposal environment. According to guidance provided by the NRC to waste generators, under the expected disposal conditions, Class B and C waste forms should maintain gross physical properties and identity over a 300-year period and high integrity containers should be designed to maintain their structural integrity over such a period. Yet, because of the greater severity of certain storage environment, waste packages which would be expected to meet the 300-year disposal lifetime criteria may suffer severe performance degradation over a much shorter extended storage period. Among the ways in which a storage environment can be more severe than a disposal environment are temperature fluctuations (in unheated facilities in areas with cold winters) and corrosive atmospheres (e.g., industrial and marine atmospheres, as well as acid deposition). Also, no subsequent handling of the waste package after disposal is anticipated. Stored waste packages, on the other hand, need to maintain sufficient integrity to prevent dispersal of the waste during storage, transport, and handling up to and including emplacement for disposal. Loss of waste package integrity prior to disposal will require repackaging of the waste.

PERFORMANCE OF THE LOW-LEVEL RADWASTE PACKAGE DURING STORAGE

In previous presentations, as well as in the final report, an overview was given of the properties and behavior of LLRW streams, solidification agents, and container materials. The emphasis was on those characteristics of these materials that may be important for predicting the behavior of the waste forms and containers during extended storage and for assessing the effect of extended storage on waste form stability and container integrity during transport and after disposal. In addition to ordinary chemical processes which may degrade the performance of the binder or container materials (e.g., atmospheric corrosion of carbon steel containers), the effects of the radiation field on the properties and behavior of the waste package materials were also considered.

It must be emphasized that non-radiolytic effects are likely to be the primary concern for the majority of LLRW packages. Based on the concentrations of radionuclides, most LLRW packages are found to contain Class A waste. For example, according to a recent study by New York State,[10] the LLRW volumes generated by the commercial sector (i.e., commercial nuclear power plants, academic and medical institutions, and industries) may be categorized as follows: 60% Class A, 30% Class B, and 10% Class C. Even higher percentages of Class A waste have been estimated as a result of a survey carried out by BNL for the NRC.[11] The 16 nuclear power plants responding to the survey all reported that over 80% of their LLRW volume shipped off-site in 1984 was Class A. In this regard, it should be emphasized that the information on waste and waste package characteristics presented previously in summary form[2] and in the final report to the NRC[5] is based on the results of tests and experiments that in many cases, particularly for phenomena involving radiation, were carried out under worst-case (or even beyond realistic worst-case) conditions in order to accelerate testing or for the sake of conservatism.

Potential Problem Areas

Potential problem areas for the extended storage of LLRW are considered in this section. It is assumed in the following that the waste is not to be repackaged for shipment, but is to be shipped from the extended storage facility and disposed of in the same containers used for storage. These two assumptions are in accord with the design guidance given by the NRC for temporary on-site storage of LLRW.[12] Under these circumstances, the waste would have to meet the requirements for repackaging and transportation of radioactive materials as set forth in 49 CFR Part 173 Subpart I and 10 CFR Part 71. In addition, the waste and/or container would have to meet the requirements for disposal set forth in 10 CFR Part 61, in particular, Sections 61.55 and 61.56. A further corollary of these assumptions is that liquid waste will not be stored for extended periods unless it can be processed in the storage container to a form suitable for disposal without repackaging.

The areas of concern about extended storage of LLRW may be grouped into two categories:

1) performance of the waste, waste form, and/or container material during storage, and

2) effects of extended storage that are important after the storage period.

Only a few of the data available are directly relevant to the performance of low-level waste packages during storage and subsequent handling (e.g., radiolytic gas generation data from the Epicor-II pre-filter resins at TMI-2, atmospheric corrosion of steel containers of transuranic wastes) and thus their performance for the most part must be inferred from data on the characteristics of the storage environments and the properties of the waste package components. From the various data, the following problems, and the specific circumstances under which they may be expected to arise, are identified:

- external corrosion of steel containers stored outdoors,
- internal corrosion of steel containers,
- radiation-induced embrittlement of stored polyethylene containers,
- radiolytic gas generation from stored ion-exchange resins and bituminized wastes,
- occupational exposure, and
- biodegradation of institutional wastes.

In the following sections those problems are discussed, mitigative measures are considered, and where applicable, NRC guidance in these matters is noted. For references, the reader is referred to BNL's final report on this task to the NRC.[5]

External Corrosion of Steel Containers Stored Outdoors

If steel containers of radwaste, especially carbon steel drums or liners commonly used for Class A and stabilized wastes, are stored outdoors, then the exposed surfaces of these containers will be subject to atmospheric corrosion. In principle, facilities such as simple fenced-in concrete pads are to be used only as holding areas prior to shipment for disposal, but in the event that disposal capacity should become temporarily and unexpectedly unavailable, such facilities may become de facto storage areas. From actual field data for the atmospheric corrosion of carbon steel containers, it has been concluded that uniform atmospheric corrosion should not be a problem for the structural integrity of carbon steel drums since the estimated quantity of uniform corrosion over period of one to two decades represents only a fraction of the nominal 50- to 60-mil wall thickness of a typical 55-gallon carbon steel drum. However, non-uniform modes of corrosion, e.g., pitting corrosion and enhanced corrosion at welds, seams, and areas of moisture accumulation, may result in localized deterioration of the container and release of the contents of the drum or liner. For example, at the Idaho National Engineering Laboratory (INEL) and at Hanford, both low-humidity sites, carbon steel drums corroded mainly on the lids and at points of contact with the ground. Also, rusty 55-gallon drums received at the Richland disposal site had generally been in storage for at least six months. Such corroded containers may not have sufficient structural integrity to withstand handling after storage and may not meet the disposal site acceptance criteria. Repackaging of the wastes, which will likely result in additional occupational exposure, may become necessary.

In Generic Letter 81-38,[1] Section III(b), the NRC has provided guidance with regard to atmospheric corrosion of radwaste containers during storage. The effects of atmospheric corrosion upon steel containers may be mitigated by the selection of a more corrosion-resistant alloy as the container material or by use of protective coatings. For example, at Oak Ridge, a humid site, mild steel drums were replaced by stainless steel drums. It is further stated in Generic Letter 81-38 [in paragraph III(d)4] that steps should be taken to prevent corrosion of the containers by the weather and by accumulation of water. An air support weather shield was used effectively at INEL, a dry site, to reduce corrosion of carbon steel drums. At more humid sites, condensation of moisture under such a simple structure may enhance corrosion and thus a simple storage shed may be more effective in limiting external corrosion of the containers. A large engineered storage facility with controlled temperature and humidity conditions can provide a relatively non-corrosive external environment for the waste containers, but such a facility is expensive. The degree of protection which a storage facility should provide will depend on the severity of the climate; while a simple air support weather shield may provide adequate protection against corrosion of carbon steel drums in a mild, dry climate, more elaborate facilities with some degree of temperature and humidity control may be necessary in humid climates with extreme temperatures and corrosive atmospheres (e.g., industrial or coastal areas). Monitoring of the stored containers in any of these facilities may be accomplished by visual inspection either directly or remotely, with due regard for minimization of occupational exposure. A program of at least quarterly visual inspection is specified in Generic Letter 81-38.

Internal Corrosion of Steel Containers

Internal corrosion of the container material by the contents of the container is another possible mode of degradation of container performance during extended storage. There is relatively little quantitative information on the corrosion of carbon steel in contact with LLRW. Using available data and assuming uniform corrosion, the time for complete corrosion of an 18-gauge 55-gallon carbon steel drum was estimated to be one or two decades for unsolidified boric acid wastes and for a decontamination agent solidified in vinyl ester-styrene. Pitting corrosion may result in even earlier penetration of the drum wall. However, even if the container wall is not penetrated by pitting, a gradual loss of structural strength will occur before complete corrosion of the container wall. Localized corrosion of carbon steel at the interface between the cement-solidified radwaste and the air has also been observed. Containers which have been corroded by interaction with their radwaste contents may not have sufficient structural integrity to withstand handling after storage and may not meet the disposal site acceptance criteria. In addition, there is the potential for release of the contents. Repackaging of the wastes will likely result in additional occupation exposure.

In Generic Letter 81-38, Section III(b), the NRC has provided guidance with regard to radwaste container corrosion caused by incompatibility between the container materials and the wastes or waste forms. In accord with this guidance, the effects of corrosion of the steel container materials by the waste may be mitigated by the selection of a more corrosion-resistant alloy. Special steel alloys have been proposed as container materials for high integrity container designs recently submitted for approval. Further, protective coatings may be used to mitigate corrosion of the container by the waste (in accord with guidance given in Section V(d)2 of the Generic Letter).

Corrosion-resistant materials such as stainless steels may be used to store most LLRW with a relatively high degree of assurance against corrosion of the waste container during storage. Selection of a container material will depend upon the corrosivity of the contents and on the anticipated length of the storage period. For example, carbon steel drums probably have sufficient resistance to corrosion by dry contaminated material such as paper or trash so that they may be used to store these materials for several years, neglecting external corrosion, but may not have adequate corrosion resistance for use in extended storage of dewatered (Class A) ion-exchange resin wastes of some solidified radwastes.

Monitoring of the stored containers for internal corrosion is more difficult than monitoring for external corrosion. Internal corrosion will not be detectable by visual inspection until the container has failed, either by penetration or by loss of structural integrity. Nondestructive examination techniques, (e.g., ultrasonic probes) are available for detecting corrosion on internal surfaces, but implementation of such techniques may result in an increase in occupational exposure.

Radiation-Induced Embrittlement of Stored Polyethylene Containers

High-integrity containers (HICs) fabricated from high density polyethylene (HDPE) and containing high activity wastes may be subject to radiation-induced changes in properties during extended storage. Dose rate as well as the dose delivered to the HIC material can be important in determining the nature, magnitude, and rate of occurrence of such changes. Radiation-induced gas generation, oxidative degradation, and cross-linking have been observed in polyethylene materials; embrittlement resulting from the radiation-induced cross-linking is of concern for extended storage. Unfortunately, estimates of the time to reach the ductile-to-brittle transition at realistic dose rates, expected to be between 250 to 1500 rad/h, were obtained by extrapolation of data at higher dose rates, primarily between 2 and 100 krad/h. It was concluded that embrittlement of the HDPE material could occur within a year. The container may then not withstand handling after storage and may no longer meet the acceptance criteria for HICs at a disposal site. Repackaging of the wastes may become necessary and will likely result in additional occupational exposure. Radiation-induced embrittlement may also occur in other polymeric materials considered for waste containers.

Although no explicit guidance is given by NRC in Generic Letter 81-38 with regard to changes in the properties of polymeric materials, the effects of radiation and aging should be considered in the design of and selection of materials for HICs. Alternatively, the waste could be stored in an on-site holding tank, if practicable, and not transferred to a HDPE HIC until immediately before shipment for burial. Note that the NRC has not approved any HIC fabricated solely of HDPE, although the NRC has approved HICs with major components fabricated from HDPE.

Radiolytic Gas Generation From Stored Ion-Exchange Resins and Bituminized Wastes

Radiolytic generation of gases from ion-exchange resins has been observed both during irradiations in the laboratory and from heavily loaded spent resins in the field. On the basis of laboratory data, similar gas generation may be expected from heavily loaded bituminized wastes. Radiolytic hydrogen gas production is expected from both bitumens and ion-exchange resins. For example, a 55-gallon container of bituminized waste could, in principle, generate more than its own volume of gas in five years and result in pressurization of a gas-tight container. If the generated gas is released from the container into a confined unventilated storage area, the accumulated hydrogen gas could eventually exceed its lower flammability limit in air (9.5 volume percent at 25°C and 1 atm). Radiolytic gas generation in ion-exchange resins may be accompanied by free liquid production. Breach of a container from pressurization or corrosive free liquids could necessitate further processing and repackaging of the wastes with the concomitant additional occupational exposure.

In Generic Letter 81-38, Section III(b), the NRC has provided guidance with regard to radiolytic and other kinds of gas generation from stored waste containers. In addition to this guidance, i.e., special vent designs to relieve container pressurization and one-year maximum storage times, adequate ventilation of the storage areas may be necessary to prevent flammable or explosive gas accumulations. Significant gas accumulations could, in principle, occur within one year. It is therefore recommended that if only limited disposal capacity is available, the highest activity waste be shipped for disposal first. (The NRC has recently included requirements regarding the generation of combustible gas mixtures in NRC Certificates of Compliance for transport packages. These conditions typically limit hydrogen generation to 5% by volume of the secondary container gas void during twice the expected shipment time.[(13)])

Occupational Exposure

Estimates of occupational exposure from the operation of extended storage facilities indicate that such exposure constitutes only a small portion of the total occupational exposure at nuclear power plants. For example, estimates of the annual radiation exposure during storage operations have ranged from a high of 35.2 man-rem in a generic evaluation (for a 1000 MWe BWR) by the Atomic Industrial Forum[(14)] to a low of 4.1 man-rem for a site-specific evaluation (of two 1000 MWe BWR units).[(15)] These figures should be compared to occupational doses reported at

U.S. commercial LWRs in 1981: 1400 and 2300 man-rem per 1000 MWe for BWRs and PWRs, respectively.[16]

Biodegradation of Institutional Wastes

Since storage of non-fuel-cycle wastes at nuclear power reactor sites has been proposed, a few brief comments on the biodegradation of institutional wastes will be given here. (The NRC has issued Generic Letter 85-14 on use of nuclear reactor sites for the storage of wastes not generated by the utility licensee.) The institutional wastes subject to biodegradation during storage are biological wastes such as animal carcasses, animal bedding and excreta, and labeled culture media. Since such wastes may contain pathogenic organisms, biodegradative generation of gases and liquids can lead to pressurization and corrosion of containers and to dispersal of pathogens. The gases and liquids produced from biological radwastes during storage as well as their rates and quantities or generation will depend on the microbes present, the nature of biological wastes, and the environmental conditions such as pH, temperature, moisture, and partial pressure of oxygen, i.e., aerobic vs. anaerobic conditions.

Because of the uncertainties regarding biodegradation, attention should be given to packaging specifications for storage of biological pathogenic or infectious radwastes. Packaging for the disposal of such wastes has been considered, e.g., the NRC requires (in 10 CFR Section 61.56) that waste containing hazardous, biological, pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the nonradiological materials. Further, the site licensees for the LLRW disposal facilities have packaging criteria for the disposal of radioactive biological wastes. If practicable, such wastes should either be stored for radioactive decay in refrigerated facilities to retard biodegradative processes or should be incinerated.

Regulatory Concern

Another problem which may apply to some institutional LLRW as well as to a small subset of fuel-cycle wastes is more of a regulatory issue than a technical issue. Some of these LLRW may be potentially hazardous wastes which, in principle, could be subject to regulation by the Environmental Protection Agency (EPA) as well as by the NRC. Storage of hazardous wastes is addressed in the EPA regulations in terms of the accumulation time for such wastes at the site of waste generation, e.g., in 40 CFR Section 262.34, where limits on the accumulation time are specified. At the time of this writing, unresolved issues remain regarding the regulation of such mixed wastes.

Recommendation

This paper will conclude with a recommendation regarding further work dealing with potential problems of long-term storage of LLRW. Evaluations of such storage facilities, whether generic or facility-specific in nature, should incorporate a failure modes and effects analysis and a quantitative uncertainty analysis. The purpose of a failure modes and effects analysis is to identify, evaluate, and document failure modes contributing to system unreliability. Such an analysis will also facilitate application of preventive and mitigative measures. Note that such an analysis is not a "high tech" undertaking! A follow-on quantitative uncertainty analysis will put numerical values on the potential failure scenarios. The methodology is already well developed, having been used extensively in nuclear power plant and non-nuclear industrial safety applications. A quick literature search revealed only one such analysis related to radwaste storage, namely, a Japanese study[17] published over a decade ago.

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THE CRISIS IN LLRW DISPOSAL
SHORT- AND LONG-TERM EFFECTS ON THE BIOMEDICAL COMMUNITY

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Most simply put, the inability to dispose of LLRW after 1993, and the consequent need to store waste at the site of generation, as proposed in most interim management plans, could virtually cripple the biomedical research community in the United States. The inability to dispose of wastes would limit or prevent the use of radioisotopes in Cell Biology, Molecular Biology, Neurobiology, Experimental Pathology, Genetics research, Cancer research, AIDS research, and many other areas. In those studies in which radioisotope use is absolutely critical, and cannot be reduced or eliminated without jeopardizing the research, the investment of time, expertise, and money that laboratories and institutions will have to make to deal with the problems of storage will directly reduce the resources available for the research.

As many of you realize, the biologic and biomedical research communities are the largest generator constituency, in volume, after the electric utilities. In terms of their sheer numbers, geographic distribution, and economic impact on their communities, they may be a much more significant constituency in many parts of the country. We must include in the bioscience constituency the manufacturers of radiopharmaceuticals and radiochemicals, such as DuPont-Merck, Cintichem, ICN, Becton-Dickenson, and many others that supply the radioactive materials we use in biomedical and biologic research, in diagnostics, and in therapeutics.

To provide another perspective on the magnitude of this problem, it might be instructive to examine the large and broadly based constituency from a geographic point of view and to try to correlate the concentration of research institutions with the degree of progress, or lack thereof, in various states and compacts.

It should come as no surprise that the most populous states, especially those of the east and west coast, and the Midwest, have the largest numbers of research institutions; that includes universities, medical and dental schools, osteopathic schools, veterinary schools, and independent research institutes. Just listing the medical, dental, osteopathic, and veterinary colleges, and the research institutes, both public and private, we get the following approximate figures:

New York State leads the pack with 22; California, with 12, Pennsylvania and Illinois, with 11 each, Texas with 9, Massachusetts and Ohio with 8 each, and Missouri, with 7, are not far behind. We must not forget the D.C. metropolitan area with George Washington and Georgetown universities, the University of Maryland and Johns Hopkins, and, most prominently, the National Institutes of Health (NIH). One of the other big players, with some interesting sidelights we will discuss later, is North Carolina, with 3 major medical schools and the Research Triangle corporations and institutes,

Although there are many excellent research laboratories and institutions in most of the other 40 states, these ten loci account for 60% to 70% of the peer reviewed, externally funded biomedical research. It is reliably estimated from data provided by the NIH that more than 80% of all extramurally funded biomedical research is dependent on the use of radioactive materials for its successful conduct.

And where are the manufacturers of the research chemicals and pharmaceuticals? The biggest players, as named above are probably DuPont-Merck (formerly New England Nuclear) in Massachusetts, Cintichem and, on a smaller scale, Schwarz-Mann division of Becton-Dickenson in New York, and ICN in California.

Now, what is happening in those ten loci relative to LLRW disposal? With the exception of California, not one of the states or compacts in which this research is carried out will even have a chance of meeting the Jan. 1, 1993 milestone of the LLRW Policy Amendments Act.

The situation in New York is probably the grimmest. The Governor met the 1990 milestone by certifying that NYS would manage its LLRW between 1993 and 1996 by storage on-site, and at the brokers, Radiac and NDL Industries, while NY proceeded with its "siting" process. Since then, the Siting Commission has been told to back away from siting and to concentrate on method and the Energy Authority has been directed to study the economics of *indefinite long-term storage on-site* and the economic feasibility of a central storage facility for class A academic research waste, only. Apparently, no thought has been given to the waste produced by the manufacturers of the radioactive materials used in that research.

There has recently developed a flickering flame of hope in NY as residents of West Valley and the Town Board of Ashford have indicated that they would welcome an LLRW storage and disposal facility there if a viable benefits package can be developed and legislated. We are very busy trying to fan that flame into a blaze.

Pennsylvania and Maryland (with the NIH in Bethesda), are part of the Appalachian Compact, a compact that is just beginning its siting process and one whose members also based their 1990 certifications on a plan for on-site and broker storage. Interestingly, they were counting on the same storage space at the same brokers that was counted in the NYS certification. To expect the brokers to be able to expand to meet these needs is ludicrous. Radiac is currently in serious disagreement with the Brooklyn community in which it is located and NDL cannot even get permission from the Peekskill zoning and planning board to expand its office space. Massachusetts continues to flirt with denial of access to the current sites because it has done everything possible to drag its feet.

Illinois and Texas, which, at an earlier time, seemed to be well ahead of other states in identifying sites, have met with local resistance and have retreated for reevaluation. Texas, however, appears to be moving forward, again. Even North Carolina, a member of one of the three compacts with a current site, has not been able to identify the new site for the compact, in North Carolina, and is in danger of having nowhere to go if the site at Barnwell actually closes in 1993 or remains open only for wastes generated in South

Carolina. Most recently, the Governer of S. Carolina announced that he would collect a $160.00 surcharge rather than the $120.00 mandated in the amendments act.

What do we actually produce as waste in biomedical research? Let's begin by stipulating agreement with one of the more strident arguments of the opposition to siting disposal facilities. It is quite accurate to say that *the purely medical uses of radioisotopes, in diagnostic and therapeutic procedures,* produce very little waste because most of those isotopes are very short lived and are held for decay, or the equipment that produces them is recycled to the manufacturers. That statement ignores, however, the waste produced in the manufacture of those very isotopically labeled chemicals and pharmaceuticals.

On the other hand, we are not talking about trivial amounts of waste or about a cottage industry when we talk about LLRW generated in biologic and biomedical research. In NY State, biomedical waste accounts for 30-40% of the total *volume* generated in that state each year and is likely to increase as more research, diagnostic, and treatment uses for radioactive materials are developed. The anti-nuclear activists repeatedly claim that biomedical waste is a trivial component of the waste stream because the percent of the total *radioactivity* is only about 1-2% of that generated by the utilities. On the contrary, in NYS in 1990, non-utility waste, primarily biomedical research waste and waste from the principle manufacturer of radiochemicals and radiopharmaceuticals in NY accounted for **59%** of the radioactivity. An examination of the ten year history of waste generation in NYS shows that in nearly half of those years non-utility waste, as described above, has accounted for nearly half of the radioactivity. In Michigan, also, it now accounts for majority of the waste. We must emphasize that, whether the percentage of the radioactivity in the biomedical waste stream is small or large, it is contained in nearly 40% of the waste volume. More importantly, as much as 75% of that volume can consist of animal carcasses containing amounts of ^{14}C and ^{3}H that might otherwise be classified as *de minimus* and would not have to be treated as LLRW if they were in aqueous solutions. For those institutions located in jurisdictions in which incineration of animal carcasses containing ^{3}H and ^{14}C is not allowed, the cost of disposing of radioactive animal carcasses by currently approved methods exceeded *$21.00/lb* this year, and has risen to over *$36.00/lb* as the brokers begin collecting the surcharges mandated for January 1, 1992.

I will interrupt the flow of argument here, briefly, to describe a typical experiment in which an isotopically labeled compound is used to study cell renewal. I've chosen an actual study done in my lab when I was still at Columbia University, in about 1970, for reasons that will become apparent.

In 1970, it was well understood that carcinomas, epithelial cancers, occurred in those epithelia whose cells divided, i.e., renewed themselves most rapidly, such as skin, colon, cervical and vaginal epithelium, mammary ducts, and bronchi. It was more difficult to understand the origins of so-called soft-tissue tumors, i.e., connective tissue tumors and most smooth muscle tumors, because there was not much evidence to indicate that the cells of these tissues divided regularly. The study was undertaken, therefore, to determine if there were populations of fibroblasts and smooth muscle cells that did replicate regularly and whether, if there were, these could be related to the more common types and sites of soft-tissue tumors.

Imagine, then, a laboratory bench about 20 feet long on which 22 rabbits sit swaddled in disposable diapers, covered with surgical towels, with only their heads and ears exposed. A 26 gauge needle is taped into an ear vein of each rabbit and each animal will receive five sequential injections, 30 minutes apart, of 1 mCi of ^{3}H-thymidine, thymidine being one of the precursors of the DNA that must be duplicated before a cell can divide. By keeping the level of the labeled compound elevated for 2 hours, maximum labeling of cells entering cell division can be achieved (Table I).

Following the injection, pairs of animals were killed with an overdose of pentobarbital at various lengths of time ranging from 2 hours to 21 days and multiple tissues harvested and processed for autoradiography. After fixing and embedding the tissues, sections were cut and mounted on slides and the slides were dipped in a liquid photographic emulsion, in effect making each slide a miniature photographic plate. The dipped slides were sealed in light-tight boxes and exposed for 7-10 days to the radiation from the tritium in the sections of tissue. Because of the 0.5μm path of the ß radiation from ^{3}H, the location of cells that have taken up the thymidine can be very precisely determined by developing the emulsion and, subsequently, staining the sections for light microscopic examination. For this example, we will look at fibroblast renewal in the dermal layer of the skin (Figure 1). The developed, stained slides were photographed at low power and 11 x 14 inch prints made that included the whole of each section. Two investigators, using a two headed microscope, then examined each section and marked on the accompanying photograph the precise location of each labeled cell. Tracings of these marked photographs were then made, labeled cells counted, and labeled cell per cm^2 of map calculated. The results are shown as figures 2-5. These clearly demonstrate an increase in the number of labeled cells with time after a multiple-dose pulse of ^{3}H-thymidine, indicating cell renewal and, also, show the migration of the cells from the zone of replication adjacent to the base of the epithelium through all parts of the dermis. The results are summarized in Table II.

Experiments such as this one eventually demonstrated that there are, indeed, regularly replicating populations of fibroblasts and smooth muscle cells and that the same theoretical considerations that explain the origin of carcinomas in rapidly renewing epithelia can explain the origin of many sarcomas and other soft-tissue tumors.

So much for a simple presentation of some of how a Cell Biologist might use an isotopically labeled compound. What about the waste produced? This is listed in Table III. And how did we handle the waste in 1970? Each animal and its diaper, syringes, and needles was placed in a heavy duty polyethylene bag to which was added 500 ml of formalin. Five such bags were packed into a 5 gallon radioactive waste pail for collection and disposal. Life was a lot simpler then. The main reason for presenting some of these details, however, is shown in Table IV. This compares the cost of doing the experiment in 1970 with the cost of doing the experiment in 1990 and compares both of these to, probably, a low estimate of the cost of doing the experiment in 1992. The costs of animals has gone up very rapidly, largely due to new acquisition, quarantine, housing, and care regulation promulgated to protect animal research from the animal rights nuts. The cost of the isotopically-labeled compound has risen surprisingly little but we cannot predict what will happen by next year as the supply of tritium dries up and Dupont has to recover the tritium it uses in manufacture of radiochemicals to recycle it. I have estimated $600/5mCi but that is probably low. The cost of disposal, however, has skyrocketed twice. In 1970, the cost of disposal for the first five rabbits was $5/kilo, that for the 17 others was $2/kilo, giving an average of $2.70/kilo. Compare that to $33/kilo until this month and the $60/kilo at our institution now that the brokers have begun to collect the $120/ft^3 surcharge.

To put these costs in some context, however, we must look at the history of grant funding from 1970 to now. At that time the average investigator initiated grant, what NIH calls an R-01, had direct costs of about $50,000; this has nearly doubled in 20 years. However, the proportion of the direct costs accounted for by salaries has gone from about 60% in 1971 to nearly 80% in 1990, thus producing only a very slight increase in funds actually available for experiments while the costs of the experiments, as shown here, have gone up nearly 650%. I couldn't afford to repeat this experiment today!

The cost of disposing of radioactive animal carcasses now exceeds the cost of the animals, themselves. In NYS, and other states as the provisions of the Clean Air Act are interpreted by state and local governments, even many institutions that can currently incinerate animals containing *de minimus* amounts of ^{14}C, ^{3}H, and ^{125}I, usually institutions located outside major urban areas, will no longer be able to do so because their incinerators will not meet the new regulations. These institutions will either have to ship, as long as they are able, at costs currently pegged at $60/Kilo or, after 1 January 1993, have to provide freezer space to store these carcasses *indefinitely*. Costs that were traditionally borne by the institutions as part of the overhead costs of doing research will now begin to be charged back to individual investigators as direct charges against the already limited research budgets. Shipping costs are already beginning to be charged back. It will not be long before the capital costs of building new storage facilities, including mammoth freezers, and the operating costs of those storage facilities will become chargebacks against research budgets. If the research enterprise is seriously impeded or diverted, discoveries concerning the basic functions of cells and tissues and the basic nature of disease that may immediately or, even, eventually be applied to reduce human suffering simply will not be made. If it becomes difficult or impossible to carry on the types of studies that are now at the cutting edge of biomedical research, studies that almost uniformly use radioactive materials, not only will we lose the information that might come from those studies but we are very likely to lose the people who carry on those studies, in the best case to other states and other institutions, even to other countries, in which the atmosphere is more conducive to research, in the worst case to the whole biomedical research enterprise. We are now facing the fact that young people are not going into basic science as a career; there are fewer graduate students in the biomedical sciences just at a time when that field is exploding with new ideas and new information. Just as physicians have become discouraged with regulations that limit their ability to practice what they believe is the best medicine and are advising their own children and other young people not to go into medicine, so, too, are scientists becoming discouraged with restrictive regulation and with the contraction of research funding, particularly for new investigators; many of our best and brightest students are either not going into basic biomedical research or are leaving it after a few years to seek more rewarding careers in other fields.

These are some of the agonizing personal and societal outcomes that simple loss of the ability to dispose of low-level radioactive waste can produce. It is, admittedly, a worst-case scenario. But how much better, really, is the best case scenario now envisioned by most states and compacts in the interim storage plans submitted as part of the 1990 certifications? Those plans call for each generator to store on site and for the major brokers in several states to expand their facilities to accommodate those generators who cannot store on site.

What does storage on site really mean to the biomedical users? Granted that all of us now hold material for decay, generally up to a maximum of one year. Some isotopes could, with expanded facilities, be held, practically, for up to three years for decay. That would cover ^{35}S but that would not substantially reduce our volume of waste. Remember that the biggest players in the biomedical research field are still ^{14}C and ^{3}H, clearly not isotopes that conveniently can be held in the RSO's laboratory for decay. In addition, most of those two isotopes are contained in animal carcasses, a high volume, low radioactivity waste that, even now, is extremely difficult to package for disposal and that might prove virtually impossible to store safely for extended periods. Space, waste form, safety, lack of knowledge of how the normal waste containers will hold up in extended storage, cost of personnel to monitor storage facilities, training of such personnel and their supervision, even such a simple problem as long-term record keeping are problems that must be addressed in planning for any interim storage program. At the Albany Medical College, we undertook preliminary planning for what would have been needed in 1993 to implement the interim management plan in the Governor's certification and came up with frightening results. At minimum, 10,000 cubic feet of space, including 5,000 cubic feet of freezer space would have been required to store low-level radioactive wastes generated between January 1, 1993 and 1996. If space could have been found at our institution, and one plan was to take what is currently patient care space for this use, the renovation costs, alone, of existing space in 1991 dollars were estimated at well over $100,000. As yet, there are no estimates of the long range costs of managing such a storage facility. And Albany Med, generating about 600 ft^3/year and, until last July, incinerating animal carcasses, is one the smaller biomedical generators in New York. These preliminary calculations have become useless because our volume will now be more than 2500 ft^3/year. Consider what kinds of problems are posed for Columbia University or Memorial Sloan-Kettering Cancer Center, sitting on some of the most expensive real estate in the world with some of the highest construction costs in the country, even assuming that space can be found on their campuses or in their buildings and that the necessary permits for construction or renovation can be obtained.

If, as anticipated, we must resort to interim (read indefinite), on-site storage, we won't have one properly-designed, monitored, state-of the art *disposal facility,* as both the Federal and state laws require, for which a well-regulated state agency is responsible. Rather, in NY State alone, we can have as many as 200 storage sites, many in heavily populated urban settings, many of them run by people who are not health physicists or radiation safety officers. And what if the institutions and industries involved follow the pattern of the governments? The Federal government has said to the states, "You deal with it". In New York and other locations, the state is now saying to the generators, "You deal with it". What if the institutions say to the investigators, "You deal with it"? At the Columbia University College of Physicians and Surgeons, alone, we could end up with 200 laboratories acting as independent storage sites. If we project this to all of the academic, medical, and industrial users in NYS, alone, we could be faced with as many as 5000 to 10,000 individual sites. I hesitate even to contemplate the number of potential sites if this were to occur in most of the presently unsited states and compacts.

We will have chaos in the management of the low-level radioactive waste stream.

The case just outlined is still better than what is likely to happen. As the cost in dollars, space, personnel, and time needed to manage LLRW at nearly 200 sites in NYS, and, probably, thousands of sites across the United States, become first evident and then overwhelming, many doctors, hospitals, diagnostic laboratories, and even research facilities will question their ability to continue to use the isotopic procedures they normally use. Many will be forced to suspend that use because of costs, others for lack of space to store, others simply because it becomes too much of a hassle. If the U.S. manufacturers of radiopharmaceuticals, can't handle LLRW, the supply of radiopharmaceuticals will begin to dry up. We could, in a relatively short time, be faced with shutdown of many essential diagnostic and and treatment modalities that use radioisotopes.The health and welfare of our citizens would be directly threatened by our inability to continue to use the best procedures for diagnosis and treatment. Imagine what would happen if we couldn't use radioiodine for the treatment of thyroid disease; we would be back to slitting people's throats to treat simple goiters. Not only will the inability to perform nuclear medicine procedures pose an economic burden on the hospital and medical industry, the loss of income from services now performed, it will, most simply put, **cost lives**, the lives of those who cannot get diagnosis and treatment in a timely manner close enough to home.

While most of the above describes the effects of the current crisis on the biomedical research community, itself, our real concern as biomedical scientists, the concern of health physicists, and the primary concern of regulators, health officers, and environmental officers in states and compacts, must be protection of the health and safety of our citizens. The plea I make, from the admittedly vested perspective of a biomedical scientist for whom radioisotope use is essential for the continuation of his research, is to make the best use we can of all of our considerable experience, skills, intelligence, and dedication finally to devise and promote an LLRW disposal policy and system for the United States that will allow us to continue to promote the health and safety of our citizens by promoting research and enabling us to transfer the results of that research to medical diagnostic and therapeutic procedures.

I have presented some perspectives on the effects of long-term storage on biomedical research and, through the effects on the manufacturers of radiochemicals and radiopharmaceuticals, on the diagnostic and therapeutic practice of nuclear medicine. We must not neglect, however, the effects on the development of new drugs. The FDA requires animal studies using isotopically labeled versions of new drugs in order to determine where the drug localizes in the body and the steps in the metabolism of the drug. The inability to dispose of LLRW, or the increased costs of developing long-term storage facilities at each research unit of each pharmaceutical manufacturer not only would slow down the development and approval of new drugs, a process that is already too slow for many who suffer from both chronic and acute diseases, but would significantly add to the cost of new drug development and, therefore, the cost of the drug to patients.

In considering long-term solutions and interim solutions to the LLRW problem, we frequently find ourselves operating in political arenas in which scientists are not entirely comfortable. We are asked to consider good waste-bad waste scenarios, to examine the question of whether biomedical waste is more politically acceptable than industrial radioactive waste or than that worst of bugaboos, LLRW from utilities. To fall into that kind of semantic trap is perhaps even more dangerous for the future of the biomedical research enterprise than what I have already described. If centralized waste management facilities are developed for academic or biomedical LLRW separate from any management plan for industrial and utility waste, the costs will be even more astronomical than those anticipated for on-site storage. Academic and research institutions will not be able to afford to dispose of waste and, therefore, will have to stop using isotopes, producing, even more quickly, the very catastrophic results that trying to make them more "politically acceptable" was intended to avoid. For the biomedical research community and the manufacturers of isotopically labeled chemicals and pharmaceuticals on which it depends, indefinite, or even *long-term on-site storage is simply not a workable solution to the LLRW problem.* Continued access to existing sites or, if needed for political reasons, development of a few new disposal facilities, are the only feasible alternatives that will allow biomedical research enterprise and nuclear medicine to continue to provide the discoveries and services that improve the health and welfare of our citizens.

Table I

CELL RENEWAL EXPERIMENT R-10
May 1970

22 RABBITS

15 TISSUES FROM EACH ANIMAL

EACH ANIMAL RECEIVED 5 mCi 3-H THYMIDINE

Table II

Labeled mesenchymal cells at various depths in the dermis (%)

Time	1st quarter	2nd quarter	3rd. quarter	4th quarter	Labeled cells per cm2 of map
2 hours	71	10	8	11	0.9
2 days	49	27	16	8	5.6
5 days	22	19	28	31	16
21 days	16	17	28	29	15

Table III

WASTE PRODUCED
May 1970

22 CARCASSES

22 DISPOSABLE DIAPERS

27 NEEDLES

110 SYRINGES

24 FEET OF BENCHKOTE

Table IV

COMPARATIVE COSTS

	1970	1990	1992
RABBIT	$6	$35	>$40
3-H Tdr	$125/5mCi	$480/5mCi	???
DISPOSAL	$25 per 5 Gal. pail; $10 each add'l pail.	$33/Kilo	$60/Kilo
TOTAL COST	$822	$3,896	>$5,200

FIGURE LEGENDS

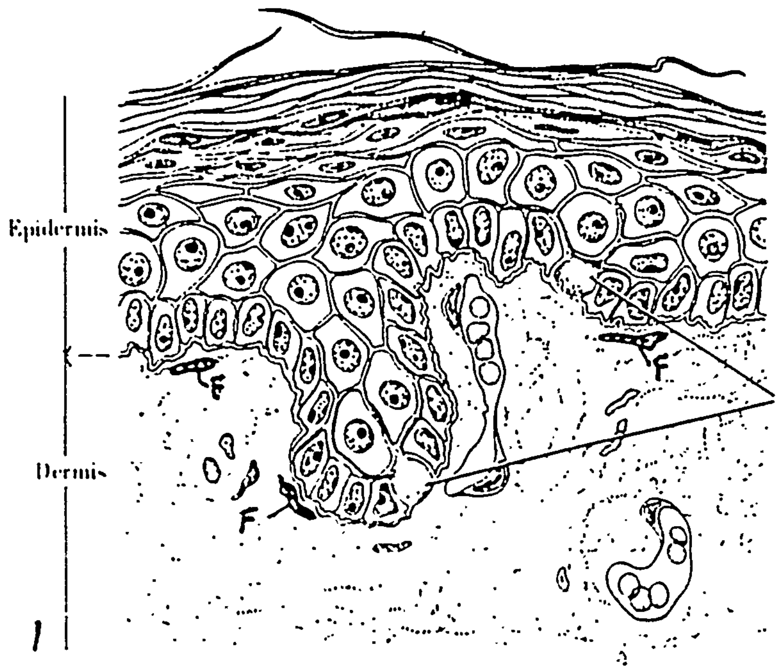
Fig. 1. A diagram of skin showing dermis and epidermis. The replicative population of the epidermis is the deepest layer; the dermal fibroblasts (F), as shown in this study, have their replicative zone immediately beneath that of the epithelial layer.

Fig. 2. A reduced tracing of the dermis from the map marked in the process of counting a section of skin from a rabbit killed two hours after a pulse of 3H-thymidine (2 hour animal). Each dot indicates the location of a labeled mesenchymal cell (fibroblast). Many of the dots that appear to be at some distance from the dermal-epidermal junction are, in fact, labeled fibroblasts immediately subjacent to the basement membrane of hair follicles.

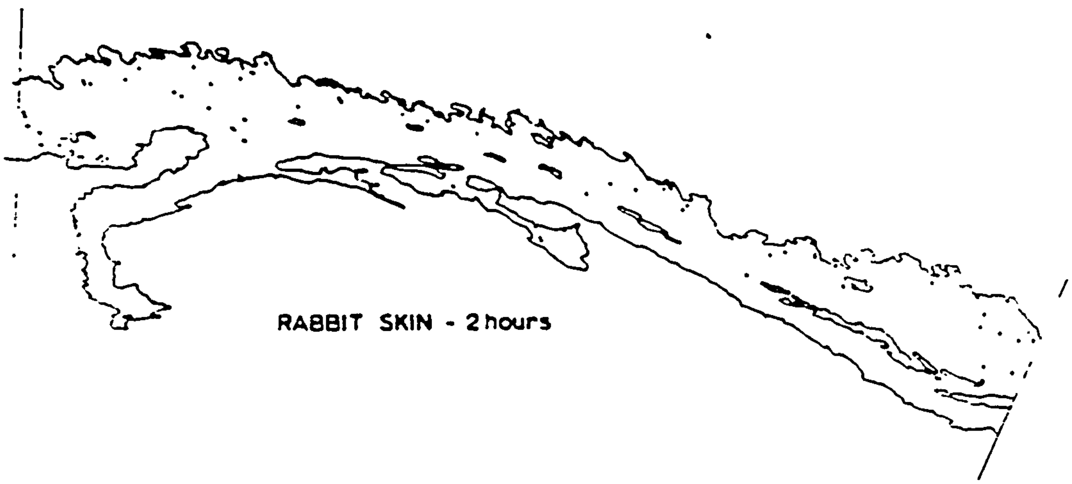
Fig. 3. A reduced tracing from the counting map of a two day animal. Both the increase in the total number of labeled cells and the migration of labeled cells away from the dermal-epidermal junction are obvious. In this map, as well as in Fig. 2, there is a suggestion of localized areas of higher replicative activity.

Fig. 4. A reduced tracing from the counting map of a five day animal. Again, an increase in the number of labeled cells is obvious. Note, also, that the distribution of labeled cells is almost uniform throughout the dermis and that a smaller area of dermis had to be counted to register a statistically significant number of labeled cells.

Fig. 5. A reduced tracing from the counting map of a 21 day animal. Although the number of labeled dermal cells is similar to that seen in the 5 day animal (see Table II), there is a further shift in the zone of heaviest labeling toward the deeper dermis.

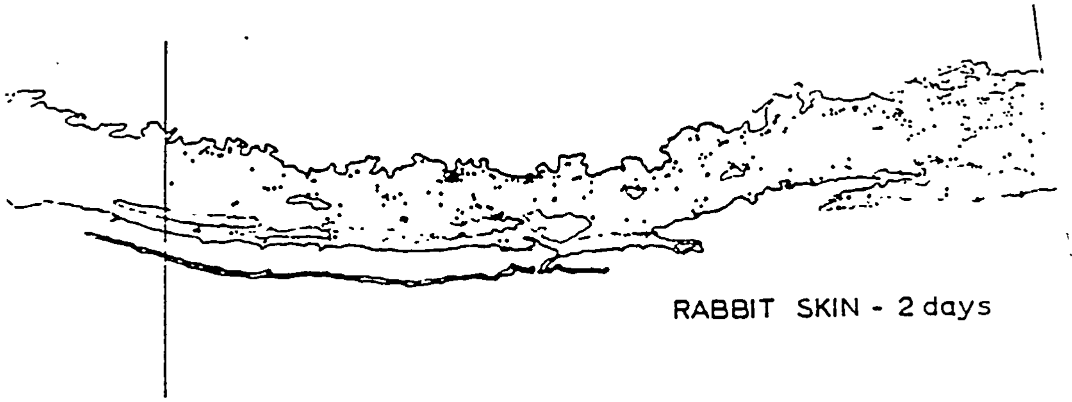


1



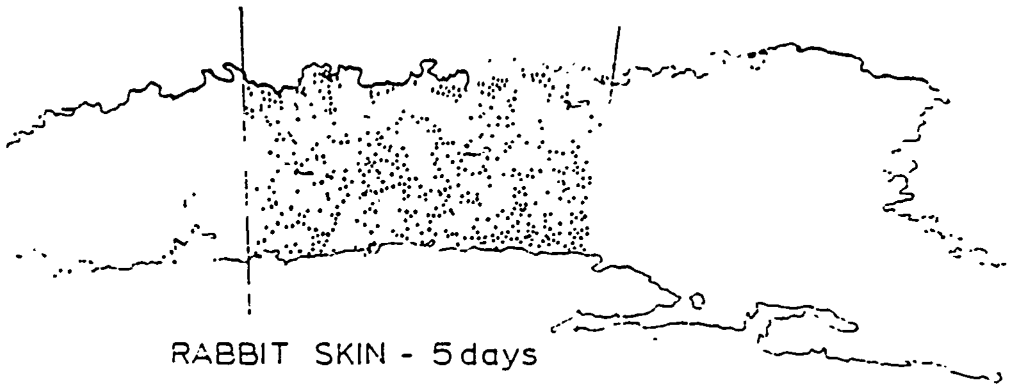
RABBIT SKIN - 2 hours

2

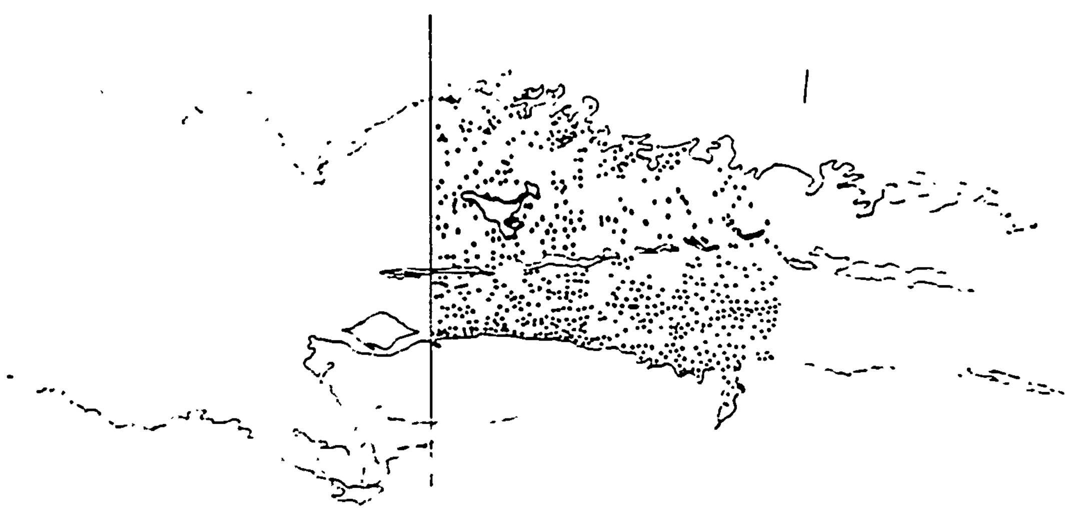


RABBIT SKIN - 2 days

3



4



5

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CANADIAN EXPERIENCE WITH STORAGE OF LOW-LEVEL RADIOACTIVE WASTE

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ABSTRACT

This paper provides an overview of LLRW generators in Canada and the types of wastes produced. Current practices and facilities for interim storage of LLRW are described, together with some discussion of their evolution. Facilities employed at the Chalk River Laboratories site of AECL Research and at the Bruce Nuclear Power Development of Ontario Hydro are featured. A summary of progress towards new facilities for the long term management of LLRW in Canada is given.

1. INTRODUCTION

This paper begins with an overview of Canadian low-level radioactive waste (LLRW) generators and waste streams. Next, current storage practices and the evolution of present day storage facilities are presented. In conclusion, an outline of progress toward permanent disposal of LLRW in Canada is given.

Two themes emerge. First, it can be seen that good interim storage facilities have evolved and are in place in Canada for LLRW arising from the nuclear fuel cycle and the use of radioisotopes. Secondly, current initiatives are making encouraging progress towards establishing new permanent facilities for both LLRW produced on an ongoing basis, and an historical inventory resulting from the early years of radium and uranium production in Canada.

Definition and Classification of LLRW

Low-level waste has a different definition in Canada than in the United States. In Canada it is defined by exclusion. If a waste is radioactive, but it is not high-level waste, nor uranium mill tailings, then it is classed as low-level waste, and comes within the mandate of the Low-Level Radioactive Waste Management Office (LLRWMO). In terms of equivalent U.S. classifications, all wastes from the very lowest of the Class A waste right up to greater than Class C are included.

Some of the major Canadian generators who operate interim storage facilities have their own internal classification systems. These are focused on short term handling and storage requirements for these materials, not on long term disposal requirements. Such classification systems assist in routing wastes to suitable storage facilities.

Although formal nation-wide classification systems do not exist, waste characteristics are considered in planning for permanent disposal. The hazardous lifetime of the waste is the most important parameter. The same type of disposal facility is not required for all types of waste. That is, the solution to the problem can be tailored to the characteristics of the waste.

2. OVERVIEW OF CURRENT LLRW PRODUCTION AND STORAGE RESPONSIBILITY

Volume

The total volume of LLRW produced in Canada is currently around 175,000 cubic feet per year. This is about 1/10 of the current American rate, excluding defense related activities. This is not unexpected given that the population of Canada is about 1/10 of that of the United States, the contribution of nuclear energy to total energy supply is about the same in both countries, and the level of technology in research, medicine and industry is about the same.

Canada does not have LLRW streams comparable to those arising from the US DOE defense related programs, or to those from reprocessing of power reactor fuel as in France and the United Kingdom. Some research has been done in the past on fuel reprocessing technology for CANDU reactors, (the term CANDU reactor refers to a nuclear power reactor which is fuelled with natural uranium and uses heavy water as the moderator. Heavy water contains the deuterium isotope, and the name CANDU comes from CANada Deuterium Uranium) but only at the laboratory or pilot scale, so this type of waste stream is also not a significant historical contributor.

The recent volume trend is down. Five years ago, the figure quoted was 200,000 to 250,000 cubic feet per year, now it is under 200,000 cubic feet. This trend is being driven both by direct cost considerations and by the much increased recognition by society as a whole of the need to conserve and protect our environment. Both improved, and broader application of, volume reduction methods, and reduction in raw waste volume have been factors. For example, if one always unpacks supplies and equipment outside the active area of the plant, packaging materials are not part of the LLRW stream.

Organizational Framework

There are essentially four types of organizations or groups of stakeholders associated with the management of LLRW arising from the use of nuclear energy in Canada. These are: 1) the federal government, its departments and agencies; 2) the nuclear fuel cycle producers; 3) the radioisotope producers and users; and 4) the public. Each of these groups is discussed briefly below.

FEDERAL AGENCIES AND DEPARTMENTS. The federal agencies and departments do not generate LLRW but are involved with its management and regulation.

The federal department responsible for policy for energy in Canada, including nuclear energy and consequently radioactive wastes, is the **Department of Energy, Mines and Resources (EMR).**

The regulatory agency is the **Atomic Energy Control Board** (AECB), which has similar responsibilities to those of the Nuclear Regulatory Commission in the United States. In general, Canadian regulations tend to be focused on broadly based performance criteria. There is very little in the way of detailed prescriptive regulations. That is, the onus is on the licensee who is responsible for the radioactive waste, or for the reactor, or other regulated facility to come to the regulator, to tell them what action is planned, and to explain how it meets the performance criteria and how ongoing safety will be ensured. The review process then goes on from there.

In addition to AECB regulatory environmental requirements, independent and public reviews are required by the federal government. Although nuclear energy is an area of federal jurisdiction, the regulatory and environmental processes take provincial concerns into consideration as well, in order to avoid duplication.

The Low-Level Radioactive Waste Management Office (LLRWMO) was established by the federal government in 1982 to resolve historic waste problems (those for which the original producer can no longer reasonably be held responsible) that are a federal responsibility, to ensure that a user-pay service is established for the disposal of LLRW produced on an ongoing basis, and to address public information needs about LLRW. The LLRWMO is operated by AECL Research through an agreement with EMR, the federal department which provides the funding and establishes national policy.

Other major federal groups are the independent siting task forces which have been established to locate new permanent sites for specific waste inventories. They use a voluntary siting process, which is discussed in Section 4 of this paper. Two Siting Task Forces are presently active: one in Ontario dealing with a large historic inventory of LLRW currently located in the Port Hope area, and a second in British Columbia dealing with a much smaller historic amount which has nonetheless been a substantial social and political issue in the past.

NUCLEAR FUEL CYCLE LLRW PRODUCERS. The major producers of LLRW in Canada, as in the U.S., are associated with the nuclear fuel cycle. This includes those involved in electric power generation, research reactor operations, and uranium processing or fuel production. All of these major producers, except the fuel fabricators, are either federal or provincial crown corporations. That is, they operate in the form of a normal corporation with a board of directors, but the only shareholders are the governments.

Producers are responsible for the management of wastes from their operations, and all of these producers, with the exception of the fabricators of nuclear fuel who produce relatively small volumes, have historically operated their own storage facilities.

Among the provincial electric power utilities in Canada, Ontario Hydro is the largest generator of electricity from nuclear power reactors. Ontario Hydro operates seventeen large CANDU reactors, with three more in the final stages of construction or commissioning. It is the largest producer of LLRW in Canada, with an initial volume of about 250,000 cubic feet per year. Extensive use is made of volume reduction resulting in a volume of about 100,000 cubic feet per year for ongoing management. Hydro Quebec and New Brunswick Hydro have one reactor each with much smaller volumes of LLRW produced.

The physical characteristics of LLRW from CANDU reactors are generally similar to those of the light water reactors used in the United States. Most of the volume is low specific activity dry solid waste. Most of the radioactivity is found in filters and ion exchange resins used for purification of the reactor coolant and moderator, and in irradiated hardware from in-core systems.

Waste characteristics in terms of radionuclides represented are also similar, with a couple of exceptions. First, tritium is present to a greater extent, because the CANDU reactor uses heavy water, that is, deuterium oxide, as coolant and moderator. Although the neutron capture rate in deuterium is low, which is why natural uranium can be used as the fuel, there is some activation of the deuterium to produce tritium. Secondly, carbon-14 is also present to a greater extent, due to the large volume of, and higher neutron flux in, the moderator, relative to that found in a light water reactor. Resins used for moderator purification represent a low fraction of the waste volume, but have substantial carbon-14 concentrations. This waste stream would correspond to Class C and greater levels according to the U.S. classification system.

Atomic Energy of Canada Limited (AECL) is the national R&D organization in Canada for the development of nuclear energy, including radioactive waste management systems. One major division, AECL CANDU located in Toronto, is responsible for power reactor design and development. The other major division is AECL Research, which operates major R&D facilities at the Chalk River Laboratories (CRL) in Ontario and Whiteshell Laboratories (WL) in Manitoba. AECL Research is the second largest producer of LLRW in Canada generating 35,000 to 40,000 cubic feet per year typically at the CRL site, after volume reduction, and much less at the WL site. This is partially because the WL site is smaller, and partially because of the differences in the types of research done.

Cameco, which includes the former Eldorado Nuclear Limited (Eldorado), is active in uranium mining and processing. It operates a uranium refinery at Blind River, Ontario and uranium conversion plants at Port Hope, Ontario. Historically, Eldorado was a major producer of LLRW, however extensive recycling of process residues now takes place. This, combined with volume reduction of the remaining waste, results in about 10,000 cubic feet per year of current production. This is now being warehoused at the processing facility sites.

Two companies manufacture CANDU reactor fuel. The volumes of LLRW are small, typically a few thousand cubic feet per year in the past, with less now due to recently introduced volume reduction and waste decontamination practices.

RADIOISOTOPE PRODUCERS AND USERS. Other major generators of LLRW are the radioisotope producers and users across Canada. AECL Research is the major producer of radioisotopes at the CRL site. Processing of radioisotopes and production of products for their use in medicine, research and industry is done by Nordion in Ottawa, Ontario. There are five thousand licensed users in Canada. Radioisotope production and use accounts for about 20% of the total volume of LLRW.

Historically, all of the small volume producers (including also the nuclear fuel fabricators) have shipped their wastes to the Chalk River Laboratories (CRL) site of AECL Research on a fee-for-service basis. These currently total about 30,000 to 35,000 cubic feet per year.

Some U.S. compacts and single states have LLRW production rates in the 35,000 to 70,000 cubic feet per year range (Radioactive Exchange 1991). This roughly compares with the scale of operation needed to address the combined needs of small generators in Canada. There are plans to develop new disposal facilities in the U.S. for these volumes. However, it seems that such plans are driven by social and political considerations, not by technical and economic considerations.

As an alternative for Canada, having a major producer provide long-term waste management services for the small producers, as an addition to the major producers' own operation, is a viable solution. In fact, on the basis of economic considerations, a new facility at what might be called a "green field" site should only be considered if at least one major producer were also prepared to send wastes there on a fee-for-service basis.

PUBLIC GROUPS. Other major stakeholders are clearly environmental and special interest groups, and the public at large. Politicians at all levels, including the federal, provincial and municipal level, are key players. As has occurred in other countries, past events in Canada have shown that LLRW management issues cannot be resolved on the basis of only technical and economic considerations (Franklin 1991).

Responsibility

In essence, the general approach to radioactive waste management in Canada puts the onus on the producer/owner to be responsible, and to ensure compliance with regulatory criteria (Morrison et al 1991). However, in Canada a significant proportion of the existing inventory of low-level wastes is considered to be historic wastes.

Historic wastes are low-level radioactive wastes which are managed in a manner no longer considered acceptable, but for which the original producer can no longer reasonably be held responsible. Responsibility thus has to be exercised by government. The LLRWMO acts as the agent of the federal government in matters related to historic LLRW management.

3. LLRW STORAGE - EXPERIENCE AND CURRENT PRACTICE

The following section describes current storage practice. Substantial centralization of storage has occurred at Ontario Hydro's LLRW facilities at the Bruce Nuclear Power Development site, and at the Chalk River Laboratory site of AECL Research for LLRW from small volume producers and the company's own operations. Therefore, although individual generators are responsible for the LLRW they produce, storage sites are not small, widely scattered ones at many generators' sites. Rather, a few sites serve the entire country. In addition, facilities for storage of certain historic LLRW, mainly inventories of contaminated soils, have been constructed in the Town of Port Hope, Ontario.

All of the sites and facilities discussed below are for interim storage, not permanent disposal of LLRW. No facilities exist in Canada today that are licensed by the AECB as permanent disposal facilities or sites. As discussed in Section 4 of this paper, a transition from storage to disposal is now in progress.

Bruce Nuclear Power Development (Power Reactor LLRW Storage)

Ontario Hydro, North America's largest nuclear utility with a total of 20 CANDU reactors currently in operation or advanced stages of construction, has been practicing centralized storage of its low and intermediate level radioactive wastes safely for

20 years at its Bruce Nuclear Power Development site (Ontario Hydro 1991). The 17 operating reactors produce about 250,000 cubic feet of radioactive waste per year. The wastes are transported from three nuclear generating sites in Ontario to the processing and storage site at the Bruce Nuclear Power Development (BNPD) 150 miles northwest of Toronto. At BNPD the wastes are volume reduced by incineration where possible, and by compaction where this is possible for non-incinerable wastes. Currently 100,000 cubic feet per year are added to storage. In the 20 years the site has been used, about 900,000 cubic feet of wastes have been stored. Another 1,400,000 cubic feet of wastes could be in storage by the time decommissioning is expected after 2010. Ontario Hydro is currently developing a long-term LLRW management plan.

All radioactive wastes are stored in engineered structures. Both above ground and in-ground structures are employed, depending on the waste characteristics. Concrete prefabricated buildings and quadricell facilities are used above ground. In-ground structures include: concrete trenches, tile holes and in-ground containers. Each structure has undergone several phases in its evolution beginning with relatively simple concrete trenches and tile holes.

From the beginning, development of storage facilities at Ontario Hydro's site have been based on the following principles: 1) all materials are stored in a retrievable manner in facilities with a design lifetime of 50 years; 2) no radioactive materials are placed directly in soil; engineered structures are used; 3) only solids are placed in storage; liquids which are potentially much more mobile and hence more difficult to isolate from the environment are first immobilized; and 4) all waste placement is treated as interim storage. Components of the waste may outlive the expected lifetime of the storage structures and and hence may need to be retrieved and sent to ultimate disposal.

Low Level Waste Storage Buildings are currently used to store volume-reduced, low specific activity waste, which accounts for approximately 97% of Ontario Hydro LLR wastes. These are above-ground modular warehouse type structures, each with a storage capacity of approximately 280,000 cubic feet. Radiological shielding is provided by the concrete walls, roof and floor of the building. The waste is stored in rectangular metal containers and racks of various types to optimize storage capacity. The above-ground warehouse is much less costly to construct and operate than in-ground trenches or other structures. The first unit was placed in service in 1982.

Other major advantages offered by the buildings relative to in-ground trenches are more efficient use of land and shorter construction lead time. The buildings also allow stored wasted to be "cascaded". That is, that fraction of the waste which has the lowest activity level stored in trenches can be retrieved and stored in the buildings, thereby providing reusable space in the trenches. Also, selective removal of adequately decayed waste from the tile holes to the trenches increases the storage space available in existing tile holes for new higher activity level wastes. "Cascading" thus eliminates, or at least decreases, the need to build new facilities with high costs per unit volume of storage space.

Quadricells are above ground, reinforced concrete modules consisting of two independent envelopes with a monitored interspace. There are 15 quadricell modules in the 20 ft. wide by 270 ft. long by 18 ft. high quadricell facility. Each module, consists of a 18 ft. high cubic structure internally separated into four cells, and with a cylindrical concrete vessel placed within each cell. Each module is covered with a removable concrete slab and is equipped with a sump which can be sampled. Quadricells are primarily designed to contain bulk spent ion exchange resins from the in-station storage tanks. Bulk resin is transported inside Type B shipping flasks and bottom unloaded in a shielded manner into the quadricell. Each quadricell module has a storage capacity of about 850 cubic feet.

Concrete Trenches are one of the initial types of facility, placed in service between 1974 and 1979. They are approximately 130 ft. long by 23 ft. wide by 10 ft. deep, with 15 inch thick walls, and are divided into either three or six sections. The bottom of each section slopes to a sump and standpipe to permit water detection and removal. The hydrogeological characteristics of the till deposit at this site have been determined to provide low permeability (3.9×10^{-8} inches/sec) and geochemical retardation for any nuclides that may escape. Processed and nonprocessible wastes, unpackaged or packaged in barrels and boxes, are loaded either manually or by crane into trenches. When loaded, trenches are covered with 1 ft. thick precast concrete lids with neoprene gaskets.

One of the initial trench sections rose 6 inches after a period of heavy rain soon after construction. Underdrainage was installed to correct the problem in subsequent trenches. Minor water leakage problems persist in some trenches.

Concrete Tile Holes are another of the initial types of facility, and were constructed by making a large excavation and installing standard 2.3 ft. inside diameter by 11.5 ft. deep precast pipe sections on cast in place reinforced concrete base slabs. Each structure has a storage capacity of 35 cubic feet. The precast pipes were grouted to the slab and hot coal tar sealant was applied to the pipe bottom. Emulsified asphalt was used to waterproof the pipe outer surface, and a subsurface drainage system was installed. The excavation was then backfilled with earth and paved with asphalt. Water inleakage was observed in thirty-seven of the original eighty tile holes soon after construction and steel liners were installed to correct this problem.

In Ground Containers (IC) are now being built for the highest activity component of the LLRW stored at the site. The design consists of an outer liner constructed from seamless, single longitudinally welded or spiral welded carbon steel pipe, with a welded bottom base plate. These structures have a capacity of either 70 cubic feet or 425 cubic feet depending on pipe diameter selected. The outer liner is installed in an augered borehole, and then grouted to the soil. The inner liner, also constructed of seamless, spiral welded carbon steel pipe, has a seal-welded bottom base plate. The thickness of both the inner and outer pipe, was chosen to provide adequate corrosion resistance for the 50-year design life and to withstand construction handling. A sampling line, which can also be used for dewatering if necessary, is attached to the exterior wall of the inner liner. The cover plate, which bolts to a flange welded to the outer liner, is provided with a pipe plug assembly to permit access to the liner interspace for activity measurements and to check for water infiltration. A gasket between the cover and flange prevents water ingress. Asphalt paving covers the ground level working surface. The IC was designed to rely on skin friction and weight to counteract hydrostatic uplift forces and does not incorporate a subsurface drain system. The elimination of the subsurface drain eliminated a potential effluent release pathway to surface waters.

The other provincial utilities with a single unit generating station each, Hydro Quebec and New Brunswick Hydro, operate LLRW storage facilities at the reactor sites. These storage facilities are similar in concept to the Ontario Hydro concrete trenches and tile holes.

Chalk River Laboratories (Nuclear R&D and Radioisotope LLRW Storage)

AECL Research has been storing wastes from nuclear research and development at its CRL site since 1946 and has, for several decades, also managed the wastes from radioisotope production and use in Canada.

Initially, all LLRW at CRL was placed in trenches excavated above the water table in the sandy soils of the site. Later, trenches lined with asphalt were used. As waste management practices became more sophisticated, better designs of engineered facilities, which will readily allow retrieval of the wastes for future disposal, were put into service. Today, only wastes with low concentrations of short half-life activity are put into trenches, with the rest being stored in engineered facilities. Current designs are described below.

Cylindrical Concrete Bunkers about 20 feet in diameter and 13 feet deep with a nominal capacity of 3,500 ft^3 each are used to store wastes that can be handled safely without protective shielding. The cylindrical modular form has been found to be more convenient and durable than the earlier rectangular versions. The bunkers are located near surface in free-draining sandy soils at least one meter above the highest level of water table. Each bunker has a sump from which water that might collect during waste emplacement can be removed. Removable roofs are installed to exclude rain or snow ingress during storage periods.

Concrete Tile Holes similar to those used by Ontario Hydro provide storage for wastes transported in shielding casks because of their external radiation fields. Tile holes enable wastes to be emplaced directly from the casks while maintaining shielding for the operating crew. The concrete tile holes have diameters ranging from

1 foot to 3 feet and depth of about 16 feet. Some holes have an internal steel liner as an added containment barrier. Each hole is closed with a removable shielding plug.

The current focus of AECL's LLRW program is to make the transition from interim storage to permanent disposal at the CRL site (Charlesworth 1989). The initial objective is demonstration of the Intrusion Resistant Underground Structure (IRUS) facility, described briefly in the last section of this paper.

A complementary program is directed at assessing the need for remedial action at old CRL storage sites, and implementing the required activities. Groundwater contaminant plumes have been extensively studied and surface wastes are routinely monitored. The radioisotope and fission product wastes at these old sites are of relatively short half-life. That is, long lived alpha emitters such as plutonium, and other substances such as organic solvents which would be of long term concern, are generally not present because chemical processing of irradiated fuel was never carried out on a significant scale. Thus, although the volume of soil is substantial, many of the old sites can be managed simply by ongoing monitoring and institutional control, or by in-situ methods. The latter will be facilitated by the development of new technologies such as a recent demonstration of selective removal of strontium-90, the major radionuclide in the particular contaminant plume being treated.

At the WL site of AECL Research, the LLRW storage facilities initially placed in service in the 1960's were unlined trenches and in-ground concrete bunkers and tile holes. The water table at this site is higher than at CRL however, and caused operational problems with water ingress to facilities, even though the site geology provided a low permeability soil. These designs were gradually replaced and all LLRW at this site is now placed in above grade engineered storage facilities.

Port Hope Area Wastes (Historic Inventory)

Production of LLRW in Canada started in 1933 when Eldorado Gold Mines Limited began refining radium at a plant in Port Hope, Ontario. The production of uranium was added in 1942 and, because of its strategic significance, the company was made a federal Crown Corporation (Eldorado) in 1944. Initially, the wastes from this industry were treated no differently from other types of industrial waste. Processing residues and other contaminated wastes from the refinery were used as fill materials during construction activities and sent to landfill sites. Contamination was spread to other locations by wind and water transport from storage sites, salvage of contaminated building materials and spillage from haul vehicles. The problem of residual wastes in Port Hope was recognized in the mid-1970's and a large scale cleanup program carried out. This work was concentrated on developed properties. As a result, quantities of contaminated materials remain in a number of large undeveloped areas and in smaller pockets. The LLRWMO is responsible for cleanup of these historic wastes remaining in Port Hope. Although other historic waste locations exist in Canada the inventory at Port Hope is by far the largest.

As the Canadian nuclear program developed after the second world war, production of uranium quickly became the most important component, and radium production ceased in 1953. As understanding of the effects of radiation improved, the indiscriminate management of wastes was replaced by the use of dumping under controlled access, and then shallow land burial of wastes in dedicated and controlled facilities. Unfortunately, when the choice of sites was made in the 1940's and 1950's, leaching and contaminant transport were poorly understood, and substantial contamination of the host soils has occurred. Two major sites are involved, referred to as the Welcome and Port Granby sites. The sites are maintained by Cameco, the new company formed by the merger of Eldorado and a uranium mining company, however, the federal government is mainly responsible for funding the remediation program for the old sites through its prior ownership of Eldorado. The development of this remediation program has led to Canada's only radioactive waste management facility siting process to date, as described in the next section of this paper.

In all, there is about 31 million cubic feet of processing residues and contaminated soils in the Port Hope area, from the waste management practices of the radium and uranium industry in the 1930's, 1940's and 1950's. There are substantive differences in radiological, chemical and physical characteristics between these wastes and LLRW produced today from nuclear power production and radioisotope use. At many of the old sites, for every cubic foot of waste that was originally produced, there is now about 10 cubic feet of contaminated soil, which has become part of the overall problem. The contaminants are natural uranium with radionuclides and heavy metals present in the original ores that were processed. Arsenic is the most significant in terms of amount, mobility and toxicity.

As described in the next section, encouraging progress is being made towards establishing a new permanent site for the Port Hope area wastes; however, it will be some years before it will be available.

In the interim, a program of contamination delineation and waste consolidation has been underway in Port Hope since 1988 (Zelmer 1991) (Case et al 1991). This has had very positive results in terms of immediate environmental improvement (McCallum et al 1991). It has resulted in construction of in-situ consolidation sites and designated temporary storage sites (TSS's) in the Town.

In-situ Consolidation sites constructed at two locations in Port Hope now store about 1.2 million cubic feet of contaminated soil. Typically these are custom designed to accommodate the waste found at the subject remedial property; therefore, sizes and capacities vary. Multilayer engineered caps consisting of clean soil and a welded plastic (HDPE) layer provide radiation shielding, rainfall deflection and intrusion protection. Regular physical inspection and routine environmental monitoring is practiced at each site. The two facilities now constructed accommodate approximately 70,000 and 1.1 million cubic feet respectively.

Temporary Storage Sites (TSS) consisting of simple fenced paved areas have been constructed and licensed for receiving LLRW. Here, stockpiled materials can be secured and covered with weighted tarpaulins. One such operating storage site receives waste from minor excavations arising from residential and commercial construction and redevelopment activities in the urban area. This site has a nominal waste capacity of approximately 100,000 cubic feet and a 5-year life span.

4. CURRENT INITIATIVES

Existing and Future LLRW Inventory

Table 1 portrays the current and estimated future inventory of LLRW in Canada over the next 35 years or so. It can readily be seen that low level waste management in Canada has two aspects (Pollock 1991). One is the need for remedial actions for existing inventories, primarily those in the Port Hope area. The other is the development of permanent disposal facilities for present day production.

Table 1
Estimated Volume of LLRW
to the year 2025
(millions of cubic feet)

Existing Inventory	
• Nuclear Fuel Cycle and Radioisotope Use	
- AECL Research (CRL)	10.5 (soils)
	1.5 (LLRW)
- AECL Research (WL)	0.6
- Ontario Hydro (BPND)	0.9
- Other	<0.1
• Port Hope Area	
- LLRWMO Historic Sites	9.5
- Port Granby and Welcome	21.5
• Other LLRWMO Historic Sites	<0.5
Projected Arisings	
• Ongoing	6-12
• Decommissioning	3.5
	54-60 M ft^3 (1.5-1.7 M m^3)

New Sites for Management of Historic Wastes

The initial effort to develop a new site for the Port Hope area wastes was undertaken by Eldorado. The process used can be called a technically driven process. The sequence of activities was: to carry out the technical studies needed to identify the new site, to announce what was planned, and then to attempt to convince neighbours and others who perceived themselves affected, that this was a good idea. This has been referred to as the DAD approach - decide, announce and defend. It did not work.

By late 1986 the objections were such that the government called a halt and appointed a Siting Process Task Force to find a better approach. Here are some of the familiar messages the Task Force heard from groups they consulted. "Consultation is too little, too late." "Citizens want some control over what happens in their own community." "There is lack of trust in government, and experts." "An inequity exists between those who benefit and those who live near the facility."

The basic recommendation was that the federal government should turn the process around and deal with the social issues first. To do this, the Siting Process Task Force recommended a series of principles, with the cornerstone of the process being voluntary participation (SPTF 1987). This is combined with a joint cooperative problem solving process where the people accepting a new facility will have true input at the front end as to what gets done. As well, without being specific, there is an assurance that the community will be better off at the end of the day than it was at the start. The actual package for impact mitigation and community offsets is not specified in any detail. Its development is also a part of the overall process.

This was an independent task force appointed initially by the Minister of EMR, reporting back to the Minister at the end of 1987. A new Siting Task Force was appointed in late 1988 to implement the process. It is a multi-stage process. The first major checkpoint was at the end of the third stage, when the Siting Task Force came back to the Minister and advised on their progress.

Step one was to establish the ground rules. Step two began when all municipalities in Ontario were invited to send representatives to information meetings. Out of the 800 invitations arose some 28 expressions of interest, which resulted in 14 communities moving to the third stage, a very key stage, called Community Information and Consultation. A representative group called the Community Liaison Group, and made up of 10-12 representatives of the community was selected by the task force, with input from municipal council and community organizations. Its purpose was to represent broad perspectives from the community.

The completed phase III report was delivered in 1990 (STF 1990). Three communities, the Deep River area, which is the historic site of AECL's operations and two northern Ontario communities have said that they would like to move on to the detailed technical assessments in phase IV. Technical studies have not yet been done, because social aspects are being dealt with first. Only after they are dealt with, do the technical details of site selection and facility design proceed. Also there are three communities in the Port Hope area that are current locations of these wastes. Two of the three have said that, although their preference is for removal of the wastes to a new site, if at the end of the process the wastes have to stay, then they want to be involved in putting in place once and for all, a good solution. The third community is quite adamant about removal of the wastes to a new site.

In 1991, continuation of the Siting Task Force process was announced. Three years are scheduled for the phase IV process to carry out the detailed assessments, and this is to be followed by a final phase V year to wrap up all the details in the form of agreements. A further period will be required to perform the detailed design, and locate and construct the new facility.

In parallel with, and complementary to, the Siting Task Force process, the Low-Level Radioactive Waste Management Office has completed cleanup work at a number of historic waste sites on an interim storage basis. Although final disposal is still required for these contaminated materials, these interim remedial actions have eliminated health risks and remedied environmental problems. Experience has shown that a comprehensive public consultation process can be successful in establishing interim storage facilities at the sites where the contaminated soil and other materials are located (Franklin 1991). This is in contrast to the unsuccessful outcomes of earlier effort to establish interim storage sites involving relocation of the wastes. Various designs of engineered storage facilities are used, with the basic criteria being that there will be no measurable impact above normal background radiation levels at, and near, the facility.

Development of Permanent Disposal Facilities for Ongoing LLRW Production

The federal policy is that the producers of LLRW have the responsibility for its management. Major waste producers such as Ontario Hydro and AECL can thus determine their own long-term waste management strategy. This could include the development of their own disposal facilities, and AECL Research is proceeding with an application to the Atomic Energy Control Board, for approval to construct and operate a demonstration unit of a modular near surface disposal system at the Chalk River Laboratories site, for wastes produced by AECL and those now received from small volume producers.

The system, designated as IRUS (Intrusion Resistant Underground Structure) is designed as an underground concrete vault that will safely contain about 70,000 cubic feet of LLRW, with hazardous lifetimes of up to 500 years, in each disposal unit. A new Waste Reception Center will also be constructed. Construction of both the Waste Reception Centre and an IRUS disposal unit is expected to start in 1992, and both should be in operation by the end of 1993.

5. SUMMARY

LLRW has been stored in Canada for almost 60 years. Early facilities reflected the lack of knowledge and poor understanding of what was needed to provide adequate containment and isolation of the wastes. The inventory of wastes resulting from the early years of radium and uranium production in Canada thus include substantial quantities of contaminated soils.

Storage facilities have evolved into well engineered facilities which now provide excellent containment and isolation of the LLRW resulting from radioisotope use and from electricity production by nuclear reactors. This has involved a combination of better designs and operating practices to prevent water ingress and, in many cases, the use of above ground structures. The concept of centralized sites is important, so that a limited number of sites serve the entire country. This allows the use of staff and facilities dedicated to the safe management of LLRW, rather than making LLRW management just an addition to the main activity carried out by small volume waste generators.

Current initiatives for historic wastes are directed at resolving the siting issue for new permanent facilities and performing interim remedial work where needed in the meantime to protect public health and the environment. With respect to LLRW produced on an ongoing basis, the focus is on demonstrating near surface disposal technology to facilitate the change from interim storage to permanent disposal.

It will be clear within, at most, several years what the outcome and impact will be of these current initiatives. The LLRWMO is currently assessing several other questions or issues related to the long-term management of LLRW in Canada. These assessments, and the outcomes of the current initiatives, will determine the need for future government initiatives.

6. ACKNOWLEDGEMENTS

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Low-Level Radioactive Waste Storage Issues: Cortland County's Perspective

by Cindy M. Monaco
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Abstract

Cortland County, New York contains two of five potential sites for the State's low-level radioactive waste (LLRW) disposal facility. From the outset, local governments and citizens have strongly opposed the state siting commission's confrontational approach, thereby essentially creating a stalemate. This necessitated the State's considering long-term onsite storage of LLRW as a temporary management option.

In addition to meeting a pragmatic concern, onsite storage of LLRW is a waste management alternative that addresses the qualitative issue of equity. Current national policy allows LLRW generators to readily abdicate responsibility for the wastes they produce; a sited area finds this unacceptable. Moreover, when the State attempts to fulfill this misplaced responsibility by forcefully siting a waste disposal facility, the host community is stripped of its right of self-determination. Basic issues of fairness are ignored, and an untenable situation results.

Cortland County has worked diligently with the state legislature, individual generators, and regulatory agencies to assist in developing a management plan which is sound from both a technical and non-technical perspective. Due to the county's initiative, the State Legislature has funded a comprehensive study of onsite storage; this study is currently in progress. The county has specified particular concerns of the institutional generators and has suggested several management options where storage for decay is not feasible. The State's LLRW storage study will evaluate these alternatives in detail.

Long-term storage of LLRW is a management option which, with proper planning, can be accomplished safely. The Nuclear Regulatory Commission, while it does "not look favorably" on long-term onsite storage of LLRW, has stated that no technical limitations exist to implementing such a program. Additionally, the successful Canadian storage programs demonstrate that, from a health and safety standpoint, long-term onsite storage of LLRW is a viable option. The long-term storage option would reduce the pressure to hastily or haphazardly establish new disposal sites; it would thus allow waste generators to pursue more technically and socially sound approaches to waste management.

In summary, carefully planned long-term onsite storage is a reasonable alternative to the forceful disposal facility siting processes being pursued in this nation. Onsite storage is but one of many management options which force generators to assume primary responsibility for managing their waste products. From the perspective of an unwilling community, maintaining generator responsibility is the only fair and equitable approach to waste management.

Low-Level Radioactive Waste Issues: Cortland County's Perspective

Cindy M. Monaco
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In New York State, the need for temporary long-term onsite storage for low-level radioactive waste (LLRW) is apparent. It has resulted due to the State siting commission's inept execution of a process designed to forcefully site a disposal facility. Cortland County, which is one of the two potential host counties, views onsite storage as a waste management alternative which can be accomplished safely and which would afford the state and waste generators a more equitable means of managing the waste.

From the outset, New York State's siting effort has been contentious. The confrontational nature of the process reached epic proportions through 1989 and into the early part of 1990. In Cortland County there has been widespread and well-organized local government and citizen opposition to the State's plan. This has taken the form of challenges in the technical, legal, and political arenas; massive protests; and civil disobedience. As long as several years ago, it was clear that the "siting by force" approach would experience lengthy delays; lead to even more widespread civil disturbances; and, in all likelihood, would not be successful.

Given the protracted situation which evolved due to the pervasive administrative and technical deficiencies in the State siting commission's process, Cortland County recognized the need for a longer-term interim management program than the two-year plan originally anticipated by the State.[1] The county was quite concerned that provisions be made for effective waste management. To allow for the potential of waste storage at generator sites, the county thus urged that comprehensive data regarding the onsite storage capabilities of generators be compiled.

In addition to pragmatic considerations, the county was equally as concerned with the federal and state governments' blatant disregard for issues of equity in matters concerning radioactive waste management. In short, the conventional siting processes of this nation have generally ignored qualitative concerns or issues of fairness. Governments and industry alike often view these qualitative factors with disfavor. Yet, ignoring these types of concerns has doomed many siting processes to failure.

From a sited community's perspective, it is absolutely unacceptable that generators be allowed to so easily abdicate responsibility for the wastes that they produce.

This is a fundamental concern of all communities, particularly rural ones, that, because of their low population densities, stand to be targeted as hosts of noxious facilities. Such communities are well aware of the inequity in being forced to carry the full burden of risk while the industry's benefits are enjoyed by affluent, more populous communities -- communities which because of political reasons would never be deemed potential hosts. Moreover, sited communities do not consider a generator's payment of disposal fees as synonymous with the generator's maintaining responsibility for the waste.

Forcing a community to accept a commercial waste disposal facility places the private interests of the waste generators above the interests of the targeted community. The unwilling community is stripped of its right of self-determination. Forceful siting attempts wreak havoc on the social fabric of the target community for prolonged periods of time; sometimes the damage that is done is irreparable. Ironically, these projects usually do not come to fruition. More often that not, such projects amount to nothing more than a colossal waste of time, effort, fiscal resources, and emotional energy.

To address both the pragmatic considerations and the concerns of equity, Cortland County believed it prudent for the state to critically examine the ability of individual generators to store waste onsite on a long-term basis. The county has invested significant energy in working with the State legislature, individual generators, and regulatory agencies to develop an effective temporary waste management scheme.

In early 1990, Cortland County approached New York State Senator James Seward, Chairman of the Energy Committee, and requested that funding be appropriated for a study of the technical, regulatory, economic, and administrative aspects of long-term onsite storage. The county requested:

1. that the ability of all generators to store onsite for a minimum of ten years be investigated, with the ten year figure being a pragmatic consideration; and
2. that the economic feasibility of developing regional storage sites for Class A institutional waste be examined. (Here the county recognized the potential for problems with storage at every medical and academic generator location. If, after careful study, onsite storage at certain locations proved not to be feasible, the regional storage provision could provide an alternative management option. Of course, Cortland County would expect the burden of proof to be on the institutional generators to prove that state intervention on their behalf was warranted and in the public interest.)

The language adopted in the bill is similar to the county's original request, and the study is currently underway.

Cortland County does recognize the special concerns of institutional generators.

Although medical and academic waste is almost exclusively Class A material and is expected to account for only twenty percent of the volume and less than two-tenths of one percent of the activity to be disposed in the proposed state facility,[2] no one disputes the need to properly manage this waste. The county believes that the onsite storage study is the first step in this direction. One facet of the study will be to identify the capacity of institutions to store onsite for decay and to expand storage capacity.

Where storage for decay is not feasible, the county has suggested the following possibilities:

1. Medical or academic institutions which do have storage capacity could be encouraged and/or funded to accommodate other institutions' waste streams. This "regional storage system" approach could meet the needs of the medical and academic communities without proliferating many individual storage sites throughout the state. Moreover, this regional storage approach could accommodate those industrial wastes resulting from the production of radiopharmaceuticals. Indeed, the county does not advocate storage at every generator site; rather, it believes that a regional approach would be far preferable from a technical and regulatory perspective than would be storage at every institutional generator site.
2. The use of in-state and out-of-state brokers should be maximized to assist in interim management of the waste.
3. The potential for storage of institutional waste at the utilities should be fully examined. While "as a matter of policy, the NRC is opposed to any activity at a nuclear reactor site which is not generally supportive of [reactor] activities,"[3] [4] storage of institutional waste and waste resulting from the production of radiopharmaceuticals should present no undue health and safety problems. Thus, acquiring the necessary license amendments from the NRC need not present insurmountable difficulties. Given its low activity, storage of institutional waste at utilities is not problematic from a technical perspective. With proper support from the state and the NRC, a management program could almost certainly be developed.

Cortland County has done additional work in trying to assess the needs of institutional generators. County representatives have met with different institutional waste generators to discuss plans for future waste management, and, where possible, to offer assistance in preparing for the 1993 deadline. Unfortunately, certain state regulatory agencies which license medical and academic users have voiced their reluctance to explicitly specify requirements for long-term storage at individual institutions. (Existing regulations are written for short-term storage only.) Indeed, this lack of action appears to be directed toward discouraging institutional generators from taking the initiative to develop their own management capabilities. In Cortland County's opinion, this attitude is neither prudent nor responsible. (Attempts have been made to justify this attitude based on two factors: the NRC's less than enthusiastic feelings about storage; and the role that generators' independent actions might play in "unmotivating" the State's current waste disposal program.)

This raises interesting concerns regarding the waste management options available to generators as a result of limitations imposed by state and federal regulatory agencies, and it brings to mind an obvious question: Do there exist technical limitations to safe long-term on-site storage of LLRW? To address this question, we examine the utility waste issue since, in New York State (as in most other states), the utilities produce the vast majority of both the volume and activity of the low-level waste stream.

Cortland County has discussed long-term storage at great length with the NRC. These discussions were prompted by the NRC's May 3, 1990 memorandum (SP-90-80), which states that the NRC will "not look favorably" upon long-term storage of LLRW at reactor sites after January 1, 1996. In meeting with the NRC, the county was informed that the abovenamed memo did not espouse actual NRC policy; rather, it indicated an NRC "posture," inspired by the agency's desire to promote its interpretation of the LLRW Policy Amendments Act's (LLRWPAA's) directives.

With regard to the LLRWPAA, the NRC did acknowledge (and concur with the county's sentiments) that it has no enforcement role under the provisions of this law. NRC representatives also noted that, while the NRC did not wish to hinder states' progress, it also did not have the responsibility to strong-arm the states into meeting the terms of the Act. Yet, the NRC had formerly attempted to justify its anti-storage position by pointing to constraints imposed by the LLRWPAA. In the county's opinion, the NRC's interpretation of the law goes far beyond the legislation's actual language or intent. The NRC's primary responsibility as a regulatory agency is to protect public health and safety. Thus, its actions should be based on technical, not political, considerations. The county views NRC's LLRW anti-storage "posture" as a political decision with no technical or legal basis.

With respect to safety concerns, the NRC admitted that long-term storage at reactor sites does not pose threats to public health, and that there are no technical limitations to implementing a long-term onsite storage program for LLRW. Given the NRC's position that "spent fuel can be stored safely and without significant environmental impact ... for at least 100 years,"[5] it would have been difficult to make any claims to the contrary. In light of the Commission's high-level radioactive waste storage policy, suggesting that onsite storage of the much lower activity material could pose a threat to public health would surely fly in the face of logic.

Given that the NRC has recognized that there do not exist technical barriers to safely storing LLRW at reactor sites, this option should not be precluded as a management possibility. The full array of technically sound management options should be available to the states. Indeed, the on-site storage programs at the Bruce Nuclear Power Development and at Chalk River Laboratories in Ontario, Canada clearly demonstrate that effective long-term on-site management of LLRW is feasible.

This brings to light the striking attitude difference between Canadian and U.S. regulatory agencies and between Canadian and U.S. waste generators. In Canada, the primary burden of LLRW management is placed where, in the county's opinion, it rightfully belongs -- on the generators. Moreover, Canadian regulatory agencies do not so strongly discourage (as to almost effectively bar) implementation of technically feasible management options. In addition, the Canadians learned ten years ago that the "siting by force" approach to nuclear waste management was doomed to failure. They, thus, have recognized the importance of considerations such as fairness and equity in developing management programs. Finally, unlike in the U.S., Canadian generators do not behave as if it is their inalienable right to have some other entity responsible for their waste. For Canadian generators, low-level and intermediate level waste management is part of the financial, social, and political cost of doing business. In Cortland County's opinion, much can be learned by studying the Canadian approach to waste management.

In New York State, there exist many different attitudes about onsite waste management. Several citizens' groups advocate immediate dissolution of the State's siting commission and onsite storage at each generator now. From the county's perspective, this recommendation is premature. The county is uncertain as to the actual space limitations of various medical and academic generators; it also believes that a program which did not adopt a regional onsite storage approach could create regulatory difficulties and questionable economic situations. The state's onsite storage study will examine these issues, and the county will make its determination after a thorough investigation of all relevant data has been made. Cortland County does affirm, though, that the state should have the benefit of this data prior to committing itself to any program -- be it a long-term onsite storage program or the federally mandated disposal program. The county also firmly maintains its position that those who generate the waste should be responsible for its management, and that, in no event, should the state be forcing radioactive waste upon an unwilling community.

In conclusion, Cortland County submits that there is a dire need for generators and regulators to critically examine the LLRW management situation that exists in this nation and to act accordingly. If the LLRWPAA is declared unconstitutional in total or in part, states will no longer be compelled to enter the waste disposal business. Contrary to what many of you have been led to believe, the county contends that there is a reasonable chance that the "take title" provision will fall. Regardless of the outcome of the lawsuit, however, it is clear that another approach to waste management is needed; the LLRWPAA is simply not working. With the possible exception of the Southwest Compact, the operation of any new disposal facilities will, in all likelihood, not occur until after the 1993 deadline (and, for some regions, well beyond the 1996 deadline). Thus, purely from a pragmatic standpoint, there is a need to develop long-term onsite management programs. In addition, the long-term storage option would reduce the pressure to hastily or haphazardly establish disposal sites, and thereby allow for the pursuit of more technically and socially sound approaches to LLRW management.

Long-term onsite storage of LLRW is technically feasible. The evidence is overwhelming that onsite storage programs can be developed to adequately protect public health and safety. Just as significant, this management option addresses the all important issue of equity -- an issue which does not even seem to be given consideration in the conventional siting processes of this nation. Cortland County asserts that U.S. waste generators and regulatory agencies urgently need a major attitude readjustment with regard to approaches to waste management. In particular, the county strongly suggests that the NRC direct its attention away from the sheer convenience of the waste generators and, instead, direct it toward an unbiased examination of the full range of management options.

At national conferences, how often is it the case that the public's perception of the nuclear industry is a major topic of discussion? Without fail, a significant portion of every conference is devoted to this concern, about which speakers voice innovative problem-solving suggestions ranging from funding massive educational programs to developing new "positive imagery." Indeed, the problem is neither lack of information nor poor public relations' efforts. The difficulty is not what the industry perceives as ill-founded conceptions on the part of the public. The industry fails to recognize or acknowledge that the true problem is its unwillingness to accept responsibility for its waste products. The experiences of our Canadian neighbors and the reality in this country speak to a much more cost-effective approach, and one that would meet with much more success than would intensified public relations efforts:

Generators must take responsibility for their wastes and not force waste management sites on unwilling communities.

The public is willing to accept nothing less.

[1] NYSERDA, Developing a New York State Plan for Interim Management of Low-Level Radioactive Waste, Jan. 30, 1989

[2] NYS LLRW Siting Commission, Source Term Report, Jan. 1990

[3] US NRC, SP-90-80, Storage of Low-Level Radioactive Waste, May 3, 1990

[4] US NRC, SECY-90-318, Low-Level Radioactive Waste Policy Amendments Act Title Transfer and Possession Provisions, Sept. 12, 1990

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REGULATORY CHANGES

GROUND-WATER PROTECTION, LOW-LEVEL WASTE, AND BELOW REGULATORY CONCERN: WHAT'S THE CONNECTION?

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ABSTRACT

The Environmental Protection Agency (EPA) has a responsibility to protect ground water and drinking water under a wide variety of statutes. Each statute establishes different but specific requirements for EPA and applies to diverse environmental contaminants. Radionuclides are but one of the many contaminants subject to this regulatory matirix. Low-level radioactive waste (LLW) and below regulatory concern (BRC) are but two of many activities falling into this regulatory structure.

The nation's ground water serves as a major source of drinking water, supports sensitive ecosystems, and supplies the needs of agriculture and industry. Ground water can prove enormously expensive to clean up. EPA policy for protecting ground water has evolved considerably over the last ten years. The overall goal is to prevent adverse effects to human health, both now and in the future, and to protect the integrity of the nations's ground-water resources. The Agency uses the Maximum Contaminant Levels (MCLs) under the Safe Drinking Water Act as reference points for protection in both prevention and remediation activities.

What's the connection? Both low-level waste management and disposal activities and the implementation of below regulatory concern related to low-level waste disposal have the potential for contaminating ground water. EPA is proposing to use the MCLs as reference points for low-level waste disposal and BRC disposal in order to define limits to the environmental contamination of ground water that is, or may be, used for drinking water.

1.0 INTRODUCTION

The Environmental Protection Agency (EPA) has a responsibility to protect ground water and drinking water under a wide variety of statutes: Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Atomic Energy Act (AEA), among others. Each of these statutes lays different requirements on EPA, sometimes very prescriptive and sometimes more general in nature. These authorities relate to a wide variety of environmental contaminants. Radionuclides are but one of the numerous environmental contaminants subject to the regulatory matrix.

Low-level radioactive waste (LLW) management and disposal as well as the disposal of LLW determined to be "below regulatory concern"(BRC) are activities with the potential to contaminate ground water. EPA policy for protecting ground water has evolved concurrently with the development of EPA's draft proposed rule for the management and disposal of LLW (40 CFR 193). It is the purpose of this paper to describe the evolution of EPA's activities and policies in ground-water protection and how these influence the form and content of EPA's draft proposed rules for the management and disposal of LLW.

2.0 GROUND-WATER PROTECTION - THE EARLY YEARS

In the late 1960s, environmental monitoring discovered synthetic organic chemicals in ground water used for drinking water in several states. Further discoveries of contaminated wells and environmental incidents, such as Love Canal, continued in the 1970s and emphasized the vulnerability of ground water to contamination. Ground-water quality became a primary concern. Congress enacted the SDWA, RCRA, and CERCLA (Superfund), which recognized the need to protect ground water and surface water.

EPA acted to coordinate protection of ground-water quality in the early 1980s. State, local, and federal governments were responding to the increasing number of ground-water threats without a coordinated approach. Federal statutes were enacted at various times for different purposes and inconsistency developed in EPA's regulations. While some inconsistency might be expected, there were inconsistencies that hindered a cohesive approach to ground-water protection. In 1983, EPA formed an intra-agency task force to evaluate program inconsistencies at various levels of government and how best to proceed with the business of ground-water protection. A draft strategy for ground-water protection evolved from this Agency decision-making process and was distributed to State officials, business, industry, and environmental organizations for comment. Approximately 150 organizations submitted comments. As a result, EPA revised the draft strategy for final consideration by senior Agency decision-makers. The final result, the 1984 Ground-Water Protection Strategy, presented a consolidated statement of EPA ground-water policy. The strategy has four goals:

(1) Foster stronger State programs for ground-water protection;

(2) Cope with inadequately addressed sources of ground-water contamination;

(3) Establish a framework for decsion-making by EPA programs; and

(4) Strengthen EPA's internal ground-water organization.

The core of EPA's 1984 Ground-Water Protection Strategy originated from the third goal. As a framework for decision-making, the Agency adopted a differential protection policy for ground water. In other words, ground water should be protected according to its value and use. The higher the value and use of ground water, the greater the level of protection afforded. The highest beneficial use of ground water is that used for drinking water. To implement differential protection, the strategy divided all ground water into three classes based on their respective value:

Class I: Sources of drinking water that are highly vulnerable to contamination and are either (a) irreplaceable to a substantial population or (b) ecologically vital.

Class II: All non-Class I ground water that is a current or potential source of drinking water.

Class III: Ground waters not considered potential sources of drinking water but which may have other beneficial uses.

The 1984 strategy further recommended levels of protection appropriate for the different classes. To prevent contamination of Class I ground waters, this strategy recommended a ban, by guidance or regulation, on siting of facilities over such ground water. Cleanup is recommended to background or levels equivalent to limits in the Safe Drinking Water Act (i.e., MCLs). Class II ground waters should receive protection consistent with baseline protection levels afforded by existing regulations. In terms of cleanup, the strategy recommended different levels depending on whether the ground water is a current, versus a potential, source of drinking water. Finally, Class III ground waters could receive a lesser level of protection than Class I and Class II.

In late 1986, EPA issued draft guidelines for ground-water classification under the 1984 Ground-Water Protection Strategy. These guidelines further defined the classes, concepts, and key terms related to ground-water classification. They also described the procedures and information needs for classifying ground water. EPA recognized that various programs within EPA and many State programs were already incorporating some kind of classification system for ground water. For example, by October of 1988, 48 States and 7 Territories had developed either a draft or final ground-water protection strategy. Many of these were tailored to specific needs, land use, or hydrogeological conditions. These draft guidelines generated comments from 75 groups and individuals representing Federal, State and local governmental agencies, individual companies, trade associations, environmental groups, and private individuals. While endorsing differential protection of ground water by a wide margin, the overwhelming majority of commenters expressed a need for more information and details on mechanisms for implementing the guidelines in order to fully evaluate programmatic implications. Given the multitude of State ground-water strategies and classification systems already in existence, EPA did not finalize its suggested ground-water classification system as a regulation. Instead, EPA left the draft ground-water classification guidance issued in 1986 as an example to assist States developing their own ground-water classification systems.

3.0 RECENT POLICY DEVELOPMENT

In 1988, the Administrator requested EPA Regional Offices to develop a "white paper" on how to deliver the Agency's ground-water program in the most integrated and effective fashion. The principal findings of this analysis were that EPA needed to clearly establish policy on ground-water protection and that EPA should direct more resources towards prevention of contamination.

The EPA Administrator established a Ground-Water Task Force, chaired by the Deputy Administrator, in July 1989 to review the Agency's ground-water protection program and to develop concrete priniciples and objectives to guide Agency decisions. This task force consisted of senior Agency managers from selected regional offices and all EPA programs with ground-water related responsibilities. State and local governments, other Federal agencies, environmentalists, industry, and public interest groups contributed significant input as well. This task force produced a document representing EPA's strategy for protecting ground water in this decade, titled "Protecting the Nation's Ground Water: EPA's Strategy for the 1990s" (Report number 21Z-1020, July 1991). This report states Agency policy accompanied by implementation principles that provide for an aggressive approach to ground-water protection. The primary components of EPA's strategy are:

(1) Ground-Water Protection Principles

(2) Agency Policy on the Use of Water Quality Standards

(3) Roles of EPA Program Offices (including Regions) Towards Implementing the Ground-Water Protection Principles

(4) Roles of EPA, other Federal Agencies, and the States in Promoting Comprehensive Ground-Water Protection

(5) EPA Management of Ground-Water Data and EPA's Research and Development Plans

The first component, the Ground-Water Protection Principles, establishes the overall goals of the strategy, namely, to prevent adverse effects to human health and to protect the environmental integrity of the nation's ground water resources. In determining the appropriate protection strategies, EPA will consider the use, value, and vulnerability of the ground-water resource, as well as social and economic factors. With respect to prevention, ground water should be protected so currently used and reasonably expected drinking water supplies, both public and private, do not present adverse health risks and are preserved for present and future generations. With respect to remediation of ground water, activities must be prioritized to first limit risks to human health and then to restore currently used and reasonably expected sources of drinking water, whenever such restorations are practicable and attainable.

The second component of the EPA strategy, Agency Policy on the Use of Quality Standards, provides that the Maximum Contaminant Levels (MCLs) promulgated under the SDWA will be the principal "reference point" in making decisions related to the prevention and remediation of ground water. Successful prevention of ground-water contamination is measured against limiting contamination to the extent practicable, using best technologies, to levels below the MCLs. Remediation will generally attempt to achieve a total lifetime cancer risk level in the range of one in ten thousand to one in a million. However, factors such as the cumulative effect of multiple contaminants, unusual population sensitivities, technological practicablility, and cost may influence the ultimate selection of a more or less stringent level of protection in the case of remediation.

The remaining principles relate to EPA, other Federal agencies, and State efforts at ground-water protection in areas unrelated to the authority used to develop EPA's draft proposed low-level radioactive waste standards, the Atomic Energy Act authority. In this case, EPA develops generally applicable environmental standards applicable to facilities licensed by NRC or regulated by DOE. Such standards are then implemented by NRC and DOE, respectively. In this regard, EPA will work with other Federal agencies having ground-water protection responsibilities to strive for consistency with the goals of EPA's Ground-Water Strategy for the 1990s.

4.0 GROUND-WATER PROTECTION IS THE CONNECTION

The first two components of EPA's Ground-Water Strategy for the 1990s listed above have existed in one form or the other within EPA for many years and are now formally announced Agency policy. Since EPA's regulatory development process routinely involves coordination between numerous EPA program offices, it is not surprising that EPA's draft proposed standards for the management and disposal of low-level radioactive waste (40 CFR Part 193) reflect the key elements of EPA's Ground-Water Strategy for the 1990s.

So, what's the connection? It's ground-water protection. The disposal of low-level radioactive waste, whether as a regulated waste or in the context of a below regulatory concern criterion, has the potential to contaminate ground water. The present version of EPA's draft proposed standards for low-level waste incorporate a separate section for ground-water protection and are couched in terms of the ground-water classification system developed along with the original 1984 strategy (Table 1). Different classes reflect ground waters of different value and use; levels of protection vary depending upon the value and use of the ground water in question. Ground water that is, or may be a source of drinking water, would be protected to a level of 4 millirem per year (or zero in the case of especially valuable Class I ground water). Note that the level of 4 millirem per year is the MCL for radionuclides in drinking water, 40 CFR Part 141. Such MCLs are the yardstick for prevention under EPA's Ground-Water Strategy for the 1990s. It should also be noted that the ground-water protection requirements of EPA's draft low-level waste standards would be applicable to both pre-disposal management and disposal.

EPA's ground-water protection policy has also influenced consideration of the level of protection associated with the disposal of low-level radioactive waste characterized as below regulatory concern. After extensive analysis of the potential health risks of disposing of certain low-level waste types (having very low concentrations of radioactivity) as ordinary municpal trash, it became clear that a BRC criterion somewhere in the range of a few (i.e., one to five) millirem per year to a member of the critical population group would result in approximately the same population risks and similar cost savings to waste generators. A BRC criterion on the order of a few millirem per year is also significantly below the proposed level of regulation and is not much different than similar BRC recommendations offered by national and international advisory committees and levels considered or used in other nations. At this stage in the decision-making process, the concern for Agency-wide consistency arose. In this context, it was pointed out that the Agency uses a 4 millirem per year level to define "safe" drinking water. One must consider that the disposal of low-level waste, even that characterized as "below regulatory concern," has the potential to contaminate underground sources of drinking water. A BRC criterion of 4 millirem per year would be consistent with Agency policy for protecting ground water as well as the numerous other considerations affecting the choice of a BRC level applied to low-level waste disposal.

5.0 SUMMARY

Ground-water protection is an issue that pervades numerous EPA regulatory programs. Contamination of ground water, whether from previously undetected contaminants at low levels in numerous underground sources of drinking water or from dramatic incidents, prompted Congress to enact numerous laws aimed at limiting or remediating such contamination. As EPA began to implement many of these statutes, the need for consistency in ground-water protection became evident. By 1984, EPA formalized its first ground-water protection strategy, which espoused the protection of ground water according to its value and use and proposed a three-tiered classification system for ground water. This 1984 strategy provided a basic foundation for incorporating some level of consistency in ground-water protection by EPA program offices. At the same time, the Agency realized that input from the Regions would be desirable as well as more definitive policy on the principles for protecting ground water and the levels of protection that would be judged acceptable. In July 1989, EPA Administrator Reilly established the Ground Water Task Force, which re-shaped the 1984 strategy with more clearly stated principles, policy, and acceptable risk levels. The result of this effort is EPA's Ground-Water Strategy for the 1990s, which will influence EPA's internal ground-water protection programs and external relationships with States and other Federal agencies.

As EPA ground-water protection policy evolved, EPA has developed draft proposed standards for the management and disposal of low-level radioactive waste. As indicated above, Agency policy on ground water protection has had a profound influence on the content of these standards. A separate section related to ground-water protection has been incorporated that protects ground water according to its value and use. Ground-water protection has even influenced consideration of the level of protection that would be afforded for the disposal of BRC waste, under these draft proposed standards. As these standards continue under interagency review, EPA's policy on ground-water protection is clear and will influence the form and content of formally proposed standards for the management and disposal of low-level radioactive waste.

TABLE 1

EPA DRAFT PROPOSED STANDARDS LOW-LEVEL AND NARM WASTE

PROPOSED REQUIREMENT	PROPOSED LEVEL (MREM/YR) *
ATOMIC ENERGY ACT LOW-LEVEL WASTE (LLW)	
PRE-DISPOSAL MANAGEMENT	25
BELOW REGULATORY CONCERN (BRC)	4
DISPOSAL SITE PERFORMANCE	25
GROUND WATER PROTECTION	CLASS I: ZERO CLASS II: 4/25 OR 4 CLASS III: 25
NATURALLY OCCURRING AND ACCELERATOR-PRODUCED RADIOACTIVE MATERIALS (NARM)	
REGULATED NARM (>2 nCi/g) DISPOSAL	DISPOSE AT ATOMIC ENERGY ACT LLW SITE

* Annual Committed Effective Dose Equivalent

REGULATORY GUIDANCE ON SOIL COVER SYSTEMS

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INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) in September 1991, completed revisions to 14 sections of the "Standard Review Plan (SRP) for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility." The 14 sections included in the revisions to the SRPs are listed in Table 1. The overall SRP is published as NUREG-1200 and provides guidance, to NRC staff reviewers, for performing safety reviews of license applications to construct and operate a low-level waste (LLW) disposal facility. The major purposes of the SRP are to ensure the quality and uniformity of the NRC staff's safety reviews, and to present a well-defined base from which to evaluate the acceptability of information and data provided in the Safety Analysis Report (SAR) portion of the license application.

SRP 3.2, entitled, "Design Considerations for Normal and Abnormal/Accident Conditions," was one of the sections that was revised by the NRC staff. This revision was completed to provide additional regulatory guidance on the important considerations that need to be addressed for the proper design and construction of soil cover systems that are to be placed over the LLW. The cover system over the waste is acknowledged to be one of the most important engineered barriers for the long-term stable performance of the disposal facility (NUREG/CR-4701, 1986).

The guidance in revised SRP 3.2 summarizes the previous efforts and recommendations of the U.S. Army Corps of Engineers (COE), and a peer review panel on the placement of soil cover systems. NRC published these efforts in NUREG/CR-5432. The discussions in this paper highlight selected recommendations on soil cover issues that the NRC staff considers important for ensuring the safe, long-term performance of the soil cover systems . The development phases to be discussed include: (1) cover design; (2) cover material selection; (3) laboratory and field testing; (4) field placement control and acceptance; and (5) penetrations through the constructed covers.

Table 1

Standard Review Plan Revisions - September 1991

SRP NO.	TOPIC
1.0	Licensing Process
2.4.1	Surface Water Hydrology
3.2, App. A	Design Considerations - Guidance on Soil Cover Systems Placed Over Low-Level Radioactive Waste
3.4.4	Erosion and Flood Control System
4.1	Receipt and Inspection of Waste
4.2	Waste Handling and Interim Storage
4.3	Waste Disposal Operations
5.1.1	Surface Drainage and Erosion Protection
6.1	Release of Radioactivity - Introduction
6.3.1	Surface Drainage and Erosion Protection
7.1	Occupational Radiation Exposures
7.2	Radionuclide Inventories
7.3	Radiation Protection Design Features and Operating Procedures
7.4	Radiation Protection Program

COVER DESIGN

The 10 CFR Part 61 regulations require the following functions to be fulfilled by the waste cover system :

1. Minimizing infiltration through the cover from precipitation and surface runoff or runon.

2. Minimizing the contact of water with wastes, through removal of water as runoff before it infiltrates, through drainage layers after it infiltrates (percolation), and through the use of low-permeability barriers around the wastes.

3. Minimizing surface erosion.

4. Minimizing differential settlement and subsidence of the cover, and more importantly, damage to the cover as a result of differential settlement and subsidence of the wastes, or of highly compressible foundation soils.

5. Limiting the radioactivity dose rate at the ground surface of the cover to acceptable levels.

6. Providing resistance to damage to the cover as a result of burrowing animals or root penetration (biointrusion).

7. Providing resistance to damage to the cover as a result of freezing and thawing.

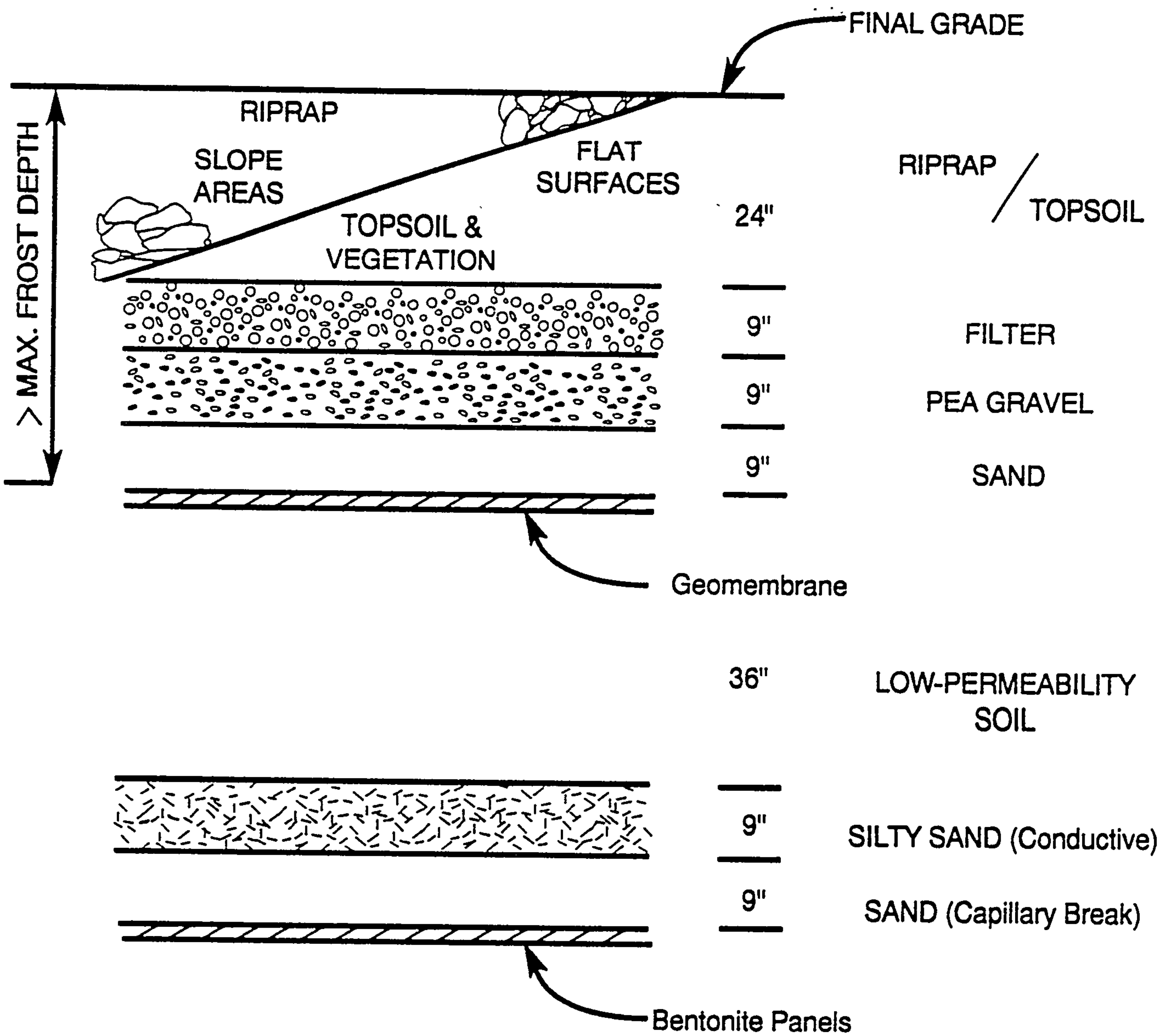
8. Providing long-term stability over the covered wastes, without the need for active maintenance.

The initial preference in design to fulfill the required cover functions would be to use a low-permeability soil layer for the cover, such as an inorganic clay, that could be compacted to achieve the desired low-hydraulic conductivity condition. Although most of the previously listed cover functions would be satisfied with this single material selection, the fulfillment of certain functions, such as resistance to erosion, biointrusion, and freezing and thawing would be questionable. The need for the cover to resist damage is crucial, because of the very long period of time over which the cover system is expected to perform. In recognition of the various required functions of a cover system, which are actually, to some extent, competing and conflicting, a multi-layered cover is recommended in revised SRP 3.2. The intent of the multi-layer approach is to use the best materials, in separate layers, that complement and improve the performance of the adjacent layers within the cover, as well as contributing to the overall performance of the entire cover system, itself. An important condition to be met when selecting and installing a multi-layer cover is that differential settlements would need to be minimized. Conversely, a multi-layer cover should not be installed at a disposal facility where differential settlements would not be minimal. For example, placing a multi-layer cover over unstable Class A waste should be avoided until such time that actual settlements and subsidence would have taken place. In actuality, this could be a very long time frame that could potentially jeopardize meeting other regulatory requirements related to the avoidance of active maintenance. This problem results from the slow deterioration and decomposition processes that would be expected for the unstable wastes. Adverse differential settlements can be minimized by requiring : (1) a firm and stable foundation beneath the wastes to be placed, (2) stable waste forms, and (3) minimization of void spaces in and around waste containers.

Figure 1 is a sectional view of the layers that would typically be conceptualized for a multi-layered cover. The thicknesses of the individual layers shown on Figure 1 are recommended minimum values and are guided by practical experience that recognizes the limitations of both operations and equipment, regarding placing soil fill in the field.

MATERIAL SELECTION

Designers have a natural tendency when constructing soil cover systems over waste, to select readily available local materials, because of economic considerations. Sometimes these economic considerations result in a proposal to use types of soils in covers, that make fulfillment of the required functions highly questionable. To address this problem, guidance is provided in revised SRP 3.2 by adding two tables that rate soils for their acceptance in having the desirable characteristics to fulfill the required cover functions. Tables 2 and 3 present the information listed in revised SRP 3.2, for rating the soils



CONCEPT OF MULTI-LAYERED SOIL COVER

FIGURE 1

according to their desirable characteristics as low-permeability soils, and as drainage soils, respectively. The symbols for the soil types shown in Tables 2 and 3 are based on the Unified Soil Classification System (USCS), which is explained in detail in NUREG/CR-5432, Volume 1.

LABORATORY AND FIELD TESTING

Guidance is provided in Volume 3 of NUREG/CR-5432, to help an NRC staff reviewer evaluate the scope and adequacy of a laboratory and field testing program, for the low-permeability and drainage soils that are proposed to be placed in a multi-layer cover design. The guidance addresses the technical differences that exist, in actual practice, regarding the use of laboratory testing versus field testing, to establish hydraulic conductivity of the low-permeability soils. Laboratory testing conducted on representative samples, and whose limitations are recognized, based on the selected testing equipment and test procedures, is acknowledged to be acceptable practice. However, to best duplicate the condition and structure of field compacted soils, and to have the capability of testing much larger areas and volumes of soil than can be tested in the laboratory, the NRC staff recommends that field tests for hydraulic conductivity (e.g., pan lysimeter or sealed, double-ring infiltrometer) be performed on test fills that are constructed using the same low-permeability materials and methods as would be required in actual cover construction.

FIELD PLACEMENT CONTROL AND ACCEPTANCE

The staff would use the guidance in revised SRP 3.2 which covers the adequacy and acceptability of field placement control, to assess an applicant's proposed program. The guidance covers the acceptability considerations of an applicant's quality control testing program, testing frequency, and the qualifications of proposed construction personnel who would actually implement and execute the field control program. Adequate information that would need to be provided on borrow excavation plans in a license application, is also discussed to ensure that needed materials with the required important engineering properties are sufficiently available.

Table 2 -

Desirable Characteristics of Low-Permeability Soils for Waste Covers

Characteristic	Ratings			Comments
	Preferred	Acceptable	Undesirable	
USCS Soil Classification	CL	CH, SC, CL-ML	MH, ML, SM	a.
Plasticity Index (PI)	15 to 25	7 to 40	< 7 > 40	b.
Liquid Limit (LL)	30 to 50	20 to 70	< 20 > 70	
Coarse Fraction				
+1-in. size	None	≤3% by wt.	>3% by wt.	c.
+1/4-in. size	≤5% by wt.	5 to 10%	>10% by wt.	
Fine Fraction (% finer than No. 200 sieve size)	30 to 65%	15 to 100%	< 15%	d.
Hydraulic Conductivity (under expected long-term field conditions)	Dependent on project-specific conditions		$>1x10^{-7}$ cm/sec	e.
Organic Material	None	< 1% by wt.	> 1% by wt.	f.
Shear Strengths	Dependent on project-specific conditions			g.

a. Local availability impacts choices. The symbols CL, CH, etc., are based on the Unified Soil Classification System (USCS) which is explained in NUREG/CR-5432, Volume 1.

b. PI <7 or LL <20 may result in difficulty in meeting hydraulic conductivity requirements. PI >40 or LL >70 may result in workability problems, (i.e., hard when dry, sticky when wet, and difficult to adjust moisture content).

c. Larger percentages of coarse fraction may result in difficulty in meeting hydraulic conductivity criteria and may lead to damage of geomembranes, if used. Maximum particle size must be much less than lift thickness.

d. Fine fraction <15% may result in difficulty in meeting criteria for hydraulic conductivity. Fine fraction >85% may result in workability problems.

e. Higher values of hydraulic conductivity could result in difficulty in satisfying long-term performance requirements.

f. Organic material increases hydraulic conductivity, and compressibility, and decreases long-term stability and shear strengths.

g. Minimum strength criteria must be based on site-specific considerations for stable slopes, adequate bearing capacity, limiting settlements and cracking.

Table 3 -

Desirable Characteristics of Filter and Drainage Soils for Waste Covers

Characteristic	Ratings			Comments
	Preferred	Acceptable	Undesirable	
USCS Soil Classification	For Drainage: Cobbles, GW, GP	SP, SW	GM, GC, SM SC	a.
	For Filters:	Apply accepted criteria for selection, based on characteristics of soils to be protected and drained.		
Hydraulic Conductivity	$\geq$ 1 cm/sec	> $1x10^{-2}$ cm/sec	< $1x10^{-3}$ cm/sec	b.
Coarse Fraction				c.
Fine Fraction (% finer than No. 200 sieve size)	< 5%	< 8%	> 12%	d.

a. Local climate, availability, and location of layer within cover cross-section impact choices. For example, cobbles provide excellent drainage, but are not satisfactory as filters.

b. Hydraulic conductivity is the most important factor. Hydraulic conductivity value of drain should be at least 10,000 times higher than hydraulic conductivity value of soil to be drained, and high enough to quickly drain estimated infiltrating water w/large safety factor. Thickness is an important consideration for selecting minimum hydraulic conductivity of drain.

c. Physical and chemical stability are more important than actual percentages of coarse fraction.

d. Permeability is greatly reduced by clay, silt, and even fine sand sizes.

PENETRATIONS THROUGH CONSTRUCTED COVERS

Guidance is provided in revised SRP 3.2 to address the occasions when man-made penetrations, through a properly constructed soil cover, are proposed. The guidance recommends that all penetrations be avoided, whenever possible. Innovative ways to avoid penetrations (e.g., lateral extension of monitoring instruments away from the waste disposal location) are encouraged. Where penetrations of the cover are unavoidable (e.g., to accommodate an important monitoring need), guidance is provided for carefully locating, constructing, and sealing the penetration, to maintain the cover's integrity. Where penetrations of the cover are to be made, guidance is provided on the essential considerations that need to be addressed (e.g., assessment of the potential differential settlement between the installation materials and the soil cover system), to ensure against disruption of the cover's performance.

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NORM - THE NEW KID ON THE BLOCK

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INTRODUCTION

The existence of radioactive materials in accumulations of scale and sludge in oil and gas production equipment is a relatively new issue. This developing issue first gained international attention in 1981 when significant radiation levels were detected on oil and gas production platforms in the North Sea; it didn't become a domestic issue until 1986 when a similar situation was detected in a Mississippi pipe yard. Most published papers on the occurrence of Naturally Occurring Radioactive Materials (NORM) in oil and gas production equipment have been based on studies of NORM-related activities in the United Kingdom (North Sea NORM). This paper addresses the occurrences and regulation of NORM in the U.S. oil and gas production industry as experienced, witnessed and/or observed by the author over the past four years.

But first, a brief review of the accumulations and regulatory situation of NORM generated by other U.S. industries in order to be able to put things in perspective.

Naturally occurring radioactive materials are contained, to various degrees, in everything on earth -- even our bodies; and every plant, animal and human being that has ever lived on this planet has been bathed in radiation (terrestrial and cosmic) every second of its life. NORM is an integral part of our environment. However, the concentration of NORM (except the creation of concentrated mineral deposits during the formation of the earth) is not natural.

Uranium and thorium are NORM. Uranium has been extensively mined, milled and otherwise enhanced in support of the nuclear weapons program and the nuclear power industry. Thorium has also been produced to a lesser extent, in support of the nuclear power industry. Natural uranium and thorium are termed Source Materials in the nuclear industry. Source Materials have been regulated (licensing and radiation protection requirements) in the U.S. since 1954. Natural uranium and thorium ("Old-NORM") are the radioactive parents of all of the NORM subsequently discussed in this paper, including oil and gas production NORM ("The New Kid On The Block"). The radioactive daughters of natural uranium and thorium (i.e., radium-226, radium-228, thorium-228, radon-222, radon-220, lead-210 and polonium-210) are the primary isotopes of concern constituting "NEW-NORM". As various industries have developed, additional occurrences of New-NORM have been introduced into our immediate environs. The occurrences and/or the magnitudes of these New-NORM were not envisioned when early federal and state radiation control regulations were formulated, and, as such, most existing radiation control regulations are not considered applicable to New-NORM.

Old-NORM and New-NORM are different only in how they are perceived; they are in fact the same, or at least derived from the same sources. All of them have been around since time began.

Examples of New-NORM are phosphogypsum from the manufacture of phosphate fertilizer, phosphate fertilizer, uranium mine overburden, coal ash from coal-fired power plants, minerals processing wastes, sludges and resins from domestic water treatment plants, and scales and sludges from the oil and gas production industry. The radionuclides of primary concern in all of these wastes are radium and its daughter products. In a 1988 Draft Report on Diffuse NORM Wastes, the U.S. Environmental Protection Agency (EPA), Office of Radiation Programs, the EPA characterized the various diffuse NORM wastes and provided 20-year generation volumes as shown in Table 1. In the same Report, it was pointed out that most radionuclides are regulated under the authority of the Atomic Energy Act (AEA), but that the AEA excludes all NORM except high grade uranium and thorium ore, any materials containing uranium and/or thorium, and uranium mill tailings. That Report also stated that EPA was in the process of developing regulations pertaining to the disposal of NARM (Naturally Occurring and Accelerator-produced Radioactive Materials) wastes with specific activities greater that 2,000 picocuries per gram, and that no Federal regulations existed or were being developed for diffuse NORM wastes with lower specific activities. The "developing regulations" for NARM have not emerged, and, except for some regulatory activity pertaining to oil and gas production NORM (the industry producing the smallest amount -- in both volume and activity --see Table 1), which will be addressed later in this paper, as well as guidelines issued in the early 1980's in the States of Illinois and Michigan for disposal of drinking water treatment plant wastes containing radium (the industry producing the second smallest amount of NORM), there does not appear to be any real effort (either on the federal or states level) to address regulation of diffuse NORM wastes. This implies that, in general, diffuse NORM wastes should not be considered to be an immediate environmental concern.

However, let's proceed with discussion of U.S. oil and gas production NORM; the remainder of this paper will address various aspects of this limited topic. Estimates, statements, views and opinions contained here-in are solely those of the author -- although, the author has consulted with various knowledgeable people (i.e., the staff of Rogers and Associates Engineering Corporation of Salt Lake City, UT, among others).

SOURCES OF OIL & GAS PRODUCTION NORM

The sources of NORM found in oil and gas production equipment and facilities are deposits of natural uranium and thorium in the subsurface geological formations from which oil and gas are produced. The natural uranium and thorium, as well as some of their decay products, are mostly immobile and remain in the subsurface formations; whereas other radioactive decay products are partially mobilized and carried up the well tubulars to the surface in produced salt waters; radon is completely mobil and is produced with natural gas. (See Figure 1).

OCCURRENCES OF NORM

Not all wells will produce significant concentrations of NORM. Estimates have ranged from 15 to 50 percent; the author's experience has been that approximately 28 percent of oil and gas field equipment is currently NORM-contaminated. Downstream oil processing equipment is normally not of concern (that is, beyond pipeline upstream accumulator tanks where low-level NORM-contaminated solids and sand tend to drop out). However, downstream gas processing equipment may well become NORM-contaminated, the degree(s) to which depending upon how and when the gas is processed.

Further, new oil wells normally do not produce NORM, even if wells are completed in formations containing localized deposits of natural uranium and/or thorium. The phenomenon of NORM production in oil wells is associated with salt water production; e.g., as the oil reservoir is depleted to the point that significant salt water intrusion and co-production with oil occurs, radium is carried (soluble and insoluble forms) to the surface in the produced fluids.

At the present time there is no accurate method of predicting which oil wells will eventually produce significant NORM concentrations - the only way to know whether or not equipment contains NORM is to survey for it on a routine basis (an oil well not producing NORM at the present may do so sometime in the future). Conversely, if a gas well is going to produce significant concentrations of radon along with natural gas, such radon concentrations will be present at the outset (and the presence of significant concentrations of radon in natural gas streams can be detected by equipment external radiation surveys).

An American Petroleum Institute (API) study published in 1989 summarized NORM survey data collected by several major oil and gas production and processing companies. Nearly 37,000 data points were included in the API study. In an attempt to characterize the NORM occurrence pattern(s), the API study summarized the survey results both on a national basis and on individual states bases. Basic NORM survey data were not collected in many states, and, as pointed out above, only a few companies (approximately 10) participated in the study, and those companies did not survey all of their facilities. As such, many states and far more oil and gas production/processing fields and facilities are not represented in the API study. Be that as it may, the API study was both a good and much needed first effort.

Subsequent to the surveys conducted for the basis of the API study, an abundance of NORM surveys have been conducted throughout the industry - by those same companies, and by/for many other oil and gas industry companies. The generalized assessment of these more recent survey data by the author is that: 1) some facilities that were classified as non-NORM previously are now classified as being NORM-contaminated; 2) NORM-associated radiation levels are generally higher than previously reported; and 3) the occurrence of oil and gas industry NORM is more prevalent than previously indicated.

ACCUMULATIONS OF NORM

This discussion on where NORM accumulates in oil and gas production equipment and facilities is based not only on literature research, but also in light of an abundance of hands-on experience by the author.
In oil production, as previously noted, if NORM is going to be produced it is normally produced concurrently with salt water; and wherever the salt water goes, so goes the NORM, and NORM accumulation (or deposits) may be found in:

- Tubulars - usually internal, but occasionally external;
- Downhole casing - occasionally, usually internal, but sometimes external;
- Well-heads, and header systems;
- Free water knock out vessels;
- Separators;
- Flowline heaters (usually only inside the coils);
- Heater treaters;
- Flowlines;
- Various field accumulator tanks and vessels;
- Valves and pumps;
- Produced water disposal pits (being phased out);
- Produced water injection systems components (tanks, piping, valves, pumps, etc.);
- Pipeline upstream accumulator tanks.

Other locations where oil production NORM may be found due to past practices, as well as due to transfer from the original locations, include:

- Spill sites;
- Soil and shells at well sites and tank batteries;
- Land fills;
- Land-farmed areas;
- NOW disposal facilities;
- Pipe and equipment yards;
- Contractor yards;
- Vendor facilities;
- Scrap yards;
- Smelters;
- Fences, cattle guards, pipe and chemical drum storage racks, equipment bins, structural steel in buildings and bleachers, etc.;
- Barges (floating and sunken) containing scrapped equipment and/or waste materials;
- NORM cleaning and/or storage facilities.

In natural gas production, as previously noted, if radon is going to be produced in significant concentrations, it will be present in gas streams from day one; the radon will be an integral component of the gas stream, and wherever the gas goes, so goes the radon, and NORM deposits may be found in the following field equipment:

- Tubulars;
- Well-heads, and header systems;
- Separators;
- Flowlines;
- Valves.

Radium may also be present in water produced with natural gas. However, essentially all of the radium is removed in the field equipment.

If the natural gas stream is not fractionated (e.g., processed to separate it into propane, ethane, butane, etc.) the radon will continue to flow along with the natural gas through the distribution system, and deposits of radon decay products (i.e., lead-210 and polonium-210) will occur at pumps, valves, pipe bends and other flow restrictions. The amounts of such deposits will decrease with distance (time related) in the production/distribution system from the gas reservoir. However, if the gas stream is fractionated, the majority of the radon (and subsequent decay products) goes to the propane and ethane lines because the vapor pressure of radon is similar to those of propane and ethane. As such, NORM deposits may be found in the following components of propane and ethane lines in gas processing plants:

- Couplings and pipe joints;
- Pipe elbows;
- Pumps and valves;
- Storage tanks;
- Transfer lines.

It is to be noted that there have been reports of NORM accumulations found in chemical plants. However, they appear to be isolated to a few discrete locations (i.e., control valves, pump impellers, etc.). Also, from the available literature on the subject, it doesn't appear that significant concentrations of oil and gas production NORM are contained in respective consumer products.

Of course, if natural gas is routed to a geological storage structure without fractionation, the surfaces within the structure become NORM-contaminated with lead-210 and polonium-210. But this is okay, in that this technology provides for removal of NORM from the gas stream before domestic or commercial use, as well as inherent disposal of some of the industry's NORM.

CHARACTERISTICS OF NORM ACCUMULATIONS

In general, natural uranium and thorium occur in the earth's crust at an approximate ratio of 10-to-1. Therefore, it would be reasonable to expect to find, on the average, much more uranium decay products (i.e., radium-226, and radon-222) than thorium decay products (i.e., radium-228, thorium-228, and radon-220) in oil and gas production NORM wastes. However, this does not appear to be the case; in fact, sometimes there is more radium-228 than radium-226 in the scales and sludges.

In a recent study, 195 samples of scale and sludges were collected from oil and gas production equipment that had been out of service from a few years to many years; the equipment represented many different production areas along the Gulf Coast, and had previously been classified as being NORM-contaminated. In 184 of the samples, the radium-226 concentration exceeded the radium-228 concentration:

	pCi/g				
	Highest Value	Lowest Value	Average Value	Median Value	90% Less Than (pCi/g)
Ra-226:	10,100	0.1	1,050	450	3,000
Ra-228:	4,060	0.1	610	150	1,500
			Ra-228/Ra-226 Ratios		
	0.98	0.04	0.47	0.52	--

[The highest radium content of oil and gas production NORM waste that the author has been involved with to-date has been 42,800 pCi/g (40,000 pCi/g of radium-226 and 2,800 pCi/g of radium-228; Ra-228/Ra-226 ratio = 0.07)].

Of the 195 samples mentioned above, 11 exhibited radium-228 concentration greater than respective radium-226 concentrations:

	pCi/g				
	Highest Value	Lowest Value	Average Value	Median Value	90% Less Than (pCi/g)
Ra-226:	3,600	1.5	2,190	2,780	3,570
Ra-228:	4,060	2.7	2,560	3,230	3,960
			Ra-228/Ra-226 Ratios		
	2.01	1.04	1.35	1.15	--

In 182 of the 195 samples, the thorium-228 was in equilibrium with the radium-228 (e.g., Th-228 activity = Ra-228 activity). In the other 13 samples, the thorium-228 concentrations exceeded respective radium-228 concentrations:

	pCi/g				
	Highest Value	Lowest Value	Average Value	Median Value	90% Less Than (pCi/g)
Ra-228:	1,590	9.4	790	1,030	1,160
Th-228:	2,560	24.6	1,270	1,560	2,090
			Th-228/Ra-228 Ratios		
	2.85	1.14	1.82	1.64	--

The percentages of the 195 samples whose activity exceeded 2,000 pCi/g were:

18% (if only Ra-226 considered);
29% (if Ra-226 & Ra-228 considered);
35% (if Ra-226, Ra-228 & Th-228 considered).

In a related study, 29 samples of scale and sludge were collected from equipment on oil production platforms off the Gulf Coast. All of the associated wells were producing from the same reservoir, and the equipment were operational. In 23 of the 29 samples, the radium-228 concentration exceeded the radium-226 concentration:

	pCi/g				
	Highest Value	Lowest Value	Average Value	Median Value	90% Less Than (pCi/g)
Ra-226:	1,770	0.5	360	100	1,320
Ra-228:	2,640	2.4	490	85	1,830
			Ra-228/Ra-228 Ratios		
	4.80	0.34	1.55	1.31	--

In an unrelated program, 66 samples of sludge were collected from produced water disposal pits in Louisiana; the pits are scheduled for closure since the State now requires re-injection of produced waters. In 56 of the samples, the radium-226 concentration exceeded the radium-228 concentration:

	pCi/g				
	Highest Value	Lowest Value	Average Value	Median Value	90% Less Than (pCi/g)
Ra-226:	38.0	0.8	6.9	4.2	20.2
Ra-228:	12.0	0.7	2.8	1.6	7.9
			Ra-228/Ra-226 Ratios		
	0.94	0.17	0.55	0.45	--

Of the 66 samples, 9 exhibited radium-228 concentrations greater than respective radium-226 concentrations. However, none of the concentrations (both radium-226 and radium-228) exceeded 1.7 pCi/g, with 2σ errors ranging from ±0.1 to ±0.3 pCi/g, thus making a statistical analysis meaningless.

The concentration of radon in natural gas at the wellhead varies from several pCi/l to hundreds of pCi/l. Although the presence of radon in gas production and processing equipment is of limited radiological consequence (except for personnel entry into respective equipment), the presence of significant concentrations does provide a simple means of determining whether or not, and if so, where, there will be radiological concerns during maintenance activities, for discarded equipment, or during facility abandonments, in that the gamma emissions from several of the short-lived decay products of radon are readily detected by external (equipment, pipes, etc.) surveys during routine facility/plant operations. However, because of the short halflives of radon and its gamma-emitting daughters, potential problem areas can not be detected by external surveys for more than a few hours after the gas flow through respective equipment or piping has ceased. From that time on, if appropriate determinations had not been made prior to shut-down, it is necessary to make alpha/beta surveys of internal surfaces of equipment and piping upon entry in order to evaluate potential radiological concerns due to radioactive metal decay products (Pb-210, Po-210, etc.) of radon that may have plated out on internal equipment surfaces.

As noted previously, if natural gas is not fractionated, radon and its decay products are not concentrated. However, fractionation of the gas increases the concentrations of radon and its decay products in respective propane and ethane lines by a factor of approximately 200 over those in the plant feed gas.

In general, scales found in tubulars, pipe and field vessels contain the highest concentrations of NORM, and exhibit the highest radiation levels. Relatively speaking, tank/vessel and pit sludges (as well as contaminated soil and shells) are low-level NORM - but the respective volumes are much greater than pipe/vessel scale volumes. Also, gas production scales and sludges constitute much smaller volumes than do oil production scales and sludges, although they sometimes exhibit significant radiation levels.

Scale and sludges in oil production equipment are relatively easy to remove (with the right cleaning equipment), whereas scale in gas production equipment is frequently much more difficult to remove with the same cleaning equipment; however, removal of scale from gas plant processing equipment can be accomplished relatively easily. From the economic viewpoint, it is cheaper to forego any attempts at cleaning some equipment, and designate it for burial at a licensed NORM disposal facility; examples of such equipment are:

- Tubing strings from some gas production wells, as well as associated wellheads and some surface equipment/vessels;
- Certain equipment due to complexity of design; i.e., gas lift mandrels, wellheads, flowline heater coils, etc.).

NORM WASTE VOLUMES & DISPOSAL COST ESTIMATE

An EPA 1988 estimate of approximately 45,000 cubic yards of petroleum pipe scale, representing a 20-year inventory, was presented earlier in this paper (see Table 1). That estimate may be good if, in fact, it represents the volume of scale removed from tubing strings and flowlines, only. However, there are many other sources of NORM-contaminated materials associated with the production of oil and gas, as noted in the previous two sections of this paper. Based on NORM cleaning experience to-date, identification of the various types NORM-contaminated equipment and materials (and associated NORM waste volumes), projected facility abandonments, etc., the author estimates that approximately 2,000,000 cubic yards (more or less, depending upon the economics of cleaning versus disposal as-is) of NORM waste will be generated in the U.S. oil and gas production industry by the year 2020.

The cost to ship this volume of NORM waste to Utah and bury it in Envirocare's Facility at today's rates would be approximately 1.7 billion dollars (more or less). It is to be noted that this does not include costs for...

- Equipment cleaning;
- Pit closures;
- Site (production, pipe yards, scrap yards, etc.) cleanups;
- Surveying;
- Sampling & sample analyses;
- Containers & packaging;
- Administrative activities.

... which can easily kick up the industry's cost to 10 billion dollar's for NORM equipment cleaning, NORM-contaminated sites cleanup, and NORM waste disposal.

RELATIVE HAZARDS & RADIATION EXPOSURES

Although it appears that the occurrence of oil and gas production NORM is more prevalent, and that associated radiation levels appear to greater than indicated several years ago, respective personnel radiation exposures remain small. For industry workers, as well as the general public, this is because the NORM is contained within steel piping and vessels throughout the production and processing operations; such conditions minimize both external and internal radiation exposure potentials.

The typical oil field worker along the Gulf Coast does not receive as much radiation exposure as the typical office worker in Denver, Colorado; and the typical oil production platform worker off the Gulf Coast will receive even less (due to water shielding the terrestrial component of the background radiation).

The most potentially exposed (to oil and gas production NORM) people are those performing NORM decontamination work on a routine basis. Tiger Cleaning Systems has monitored approximately 50 of its employees who routinely work with NORM for over two years; the individual dosimeters are exchanged quarterly; the range of measured external radiation exposure is zero to 30 mRem per quarter, with more than 90 percent being less than 10 mRem; the routinely allowable exposure is 1,250 mRem per calendar quarter.

The potential for significant external radiation exposure due to oil and gas production NORM is negligible. Further, the potential for significant internal radiation exposure is small due to the controls, preventive measures, precautions and protective procedures imposed by the industry (mostly on itself).

A real internal radiation exposure potential situation exists when NORM is (radon), or is made airborne by handling or working NORM-contaminated materials in a dry state, and although the potential for exposure is minimized by industry-imposed controls, respiratory protective equipment should be worn by personnel making tank entries, working with loose and dry NORM-contaminated materials, and when cutting, welding, scrapping or grinding on equipment containing or coated with NORM.

Tiger Cleaning Systems conducts monitoring for airborne NORM at its NORM cleaning facility in Morgan City, LA, and at each temporary jobsite during cleaning operations for each customer's job; airborne concentrations of NORM are routinely less than 3×10^{-14} μCi/ml, which is a factor of 10^3 below the maximum permissible concentration (MPC) for industry workers, and a factor of 10^2 below the MPC for the general public.

REGULATORY STATUS

To the author's knowledge, no federal regulations specifically pertaining to diffuse NORM have been enacted. However, the oil and gas production industry, as a general rule, is applying the OSHA standards for ionizing radiation (29 CFR 1910.96) to the worker environment, as well as individual state's standards for protection against radiation. Further, transportation of NORM and NORM-contaminated equipment is usually conducted in accordance with pertinent DOT regulations (49 CFR 173, subpart I),

The need to comply with these standards and regulations has been disseminated throughout the oil and gas production industry by the various Industry agencies, associations and councils; such efforts were initiated in 1986, shortly after the Mississippi pipe yard incident that made oil and gas production NORM a domestic issue. For the most part, the oil and gas industry is apparently controlling its NORM, and protecting its people and the environment without the support of specific comprehensive regulations -- not only in the one state that has enacted specific oil and gas production NORM regulations, but as a community across the country; and this has been accomplished principally through the efforts of the industry agencies, associations and councils with the support of their membership. However, the degrees success in achieving control has been dependent on several factors, including:

- Methods/techniques of disseminating guidelines;
- Individual time-tables, schedules and priorities;
- Companies' sizes, resources, and safety and environmental commitments.

As such, and on the down-side, a few companies (both producing and cleaning types) continue to ignore industry-set guidelines, and in some cases regulations and standards as well, for economic purposes -- most likely due to the absence of comprehensive and/or unenforced regulations.

In an early attempt (on-going for many years now) the Conference of Radiation Control Program Directors, Inc. (CRCPD), whose membership includes representatives from every state, has been drafting Suggested State Regulations for Control of Radiation (SSRCR); Part N of the SSRCR pertains to regulation and licensing of NORM. As things stand at the time, draft no. 7 of Part N will probably be slightly revised, based on solicited comments, and issued in final form as a guide.

In the absence of a CRCPD consensus, and seeing an immediate need, the State of Louisiana promulgated emergency NORM regulations in February 1989 -- followed by permanent NORM regulations in September 1989. To-date, Louisiana is the only state to promulgate NORM regulations. These regulations are scheduled to be revised in the near-term; the revised regulations will reduce the primary action level from 50 μR/hr to 25 μR/hr, and will significantly increase the impetus on the industry to decontaminate equipment and facilities, and to properly dispose of the resultant NORM waste.

Texas has recently received comments on the third draft of its proposed NORM regulations, and will probably promulgate them in the near-term without any major changes from draft no. 3. The primary action level will be 25 μR/hr above background.

Although the primary action levels in the proposed LA regulations revision and the proposed TX regulations are similar, there are some significant differences; for example:

- The TX regulations contain fixed - and removable - contamination release criteria; the LA regulations do not;
- In the LA regulations soil contamination is limited to 5 pCi/g in the top 15 cm (for unrestricted release); in the TX regulations the top 15 cm is limited to 30 pCi/g as long as the radon emanation rate does not exceed 20 pCi/m^2/sec;
- The LA regulations require general licensees to survey, document and notify the State of occurrences of NORM; the TX regulations do not;
- The TX regulations require survey instruments to be calibrated annually; the LA regulations require instruments to be calibrated every six months;
- The TX regulations allow NORM-contaminated materials to be recycled through smelters; the LA regulations do not address this issue;
- The TX regulations allow down-hole disposal of NORM-contaminated fluids; the LA regulations do not address this issue;
- The LA regulations place time limits on storage of NORM waste in general and specific licensee's facilities, as well as in commercial storage facilities; the TX regulations do no address this issue;
- The LA regulations impose routine inspection requirements on general licensees; the TX regulations do not address this issue;
- The LA regulations impose certification criteria on personnel performing NORM surveys; the TX regulations do not address this issue;
- The TX NORM regulations provide specific criteria for both general and specific licensees; the LA NORM regulations address only general licensee requirements (except for storage time limitations).

No other state has issued proposed NORM regulations for comment; however, increased interest is being expressed in several states.

The State of Michigan issued NORM Guidelines earlier this year, which are similar in content to Lousiana's existing NORM Regulations.

The State of Mississippi regulates the transportation of NORM within and through the State in accordance with its standing regulations for radioactive materials. Further, Mississippi currently does not allow cleaning of NORM-contaminated equipment within the state, but does allow such equipment to be removed from the State for cleaning.

The States of Florida and Illinois are not concerned (in 1989) with regulating oil and gas production NORM as long as the industry managed it in a responsible manner - as was indicated at that time. Florida is much more concerned about its phosphate/ phosphogypsum industry NORM; and in Illinois, oil and gas production NORM is not significant when compared to the State's nuclear power industry.

Under the existing regulatory status (e.g., the absence of specific comprehensive regulations on which to establish finite and supportable programs), and having only one available disposal option for solid NORM wastes, the oil and gas production industry is reluctant to do more than NORM-storage in-place unless it is necessary to clean equipment in order to continue production. In fact, marginal production may be shut-in in some cases rather than having to deal with NORM at this time.

NORM DISPOSAL

Reinjection of produced waters, which contain a wide range of NORM concentrations, is routinely practiced. In fact, this is the preferred NORM disposal option; and if all of the NORM could be made to stay in the produced waters there would not be a NORM disposal dilemma. However, that has not been the case, and the need exists to dispose of relatively large volumes of NORM solids and sludges, as well as NORM-contaminated equipment.

There are three operational low-level radioactive waste disposal sites in existence today; however, in general, oil and gas production NORM wastes are not acceptable at these disposal sites. Envirocare of Utah is the only licensed NORM disposal facility in existence today. Two other NORM disposal sites are known to be in the planning stage.

One site is near Brackettville, TX; however, the initial license application for this site does not include NORM disposal - only uranium mining/milling by-product materials. The TX Legislature has not authorized licensing of commercial NORM disposal facilities. The TX Bureau of Radiation Control has reviewed the license application and supporting documentation for the Brackettville, TX disposal facility, and has recommended that it be licensed (for uranium mining/milling by-product materials), and the subsequent public hearing is now scheduled to start on January 6, 1992. Even if the facility is licensed, a future license amendment may have to be issued before the facility can receive NORM - and this will require additional legislative action. As such, the Brackettville, TX facility is not likely to be available for NORM disposal in the near-term.

The second possible future NORM disposal facility is located near Spokane, WA, at the Dawn Mining Company Millsite. Dawn Mining mined uranium ore nearby, and processed the ore at the Millsite. Dawn Mining has proposed to the Washington State Department of Health that it be allowed to receive and dispose of NORM waste as a means of generating revenue needed to reclaim the Millsite. The State's initial evaluation of the proposal will not be known until November 19, 1991, and even if the State's evaluation is favorable (to Dawn Mining), a second public hearing is required; and considerable work would be necessary at the site before NORM waste could be received. As such, the Dawn Mining Facility will not be available for NORM disposal in the near-term.

Several down-hole disposal of NORM-waste tests (during plug & abandonment (P&A) programs) have been conducted in Louisiana; each test was authorized by the State. All such test cases conducted to-date have proven to be uneconomical.

A larger scale offshore down-hole disposal test case is currently planned for mid-1992, and undoubtedly more on-land down-hole tests will be forthcoming. However, even if the economics can be brought into line, the commercial technology for down-hole disposal will most likely not be available in the near-term.

The proposed TX NORM regulations authorize general licensees to inject fluids containing NORM into wells approved by the Railroad Commission of TX as Class II Injection & Disposal Wells, provided the slurry can be pumped and the entrained solids are so fine-grained that they will not plug off the injection formation. The accompanying definition of fluids is, "any material or substance which flows or moves, whether in a semi-solid, liquid, sludge, gas, or any other form or state". While at first glance this may appear to provide relief to the NORM disposal situation (at least in TX), it may well prove that economics will dictate that injection will be feasible for nothing more than produced waters.

In any case, it would appear that Envirocare of Utah is going to be the only real game in town, as far as disposal of solid NORM wastes is concerned, for several years to come.

<u>SUMMARY</u>

The occurrence of NORM in domestic oil and gas production equipment and facilities first became an issue in 1986. Shortly thereafter, the industry self-imposed guidelines to control the spread of NORM and to protect the industry work-force. No federal regulations exist for NORM, and the only state to promulgate oil and gas production NORM regulations to-date has been Louisiana - in 1989. Texas is the only other state which has indicated that it intends to promulgate oil and gas production NORM regulations.

There is only one NORM waste disposal option currently available to the industry - Envirocare of Utah.

Although the industry has been largely successful in controlling the spread of NORM contamination and protecting its people, the measures implemented to achieve these objectives are only stop-gap measures until state or federal regulations are put in place, and viable disposal options are made available. Without consistent and enforced NORM regulations, the industry's stop-gap measures will erode with time as economic pressures come to bear.

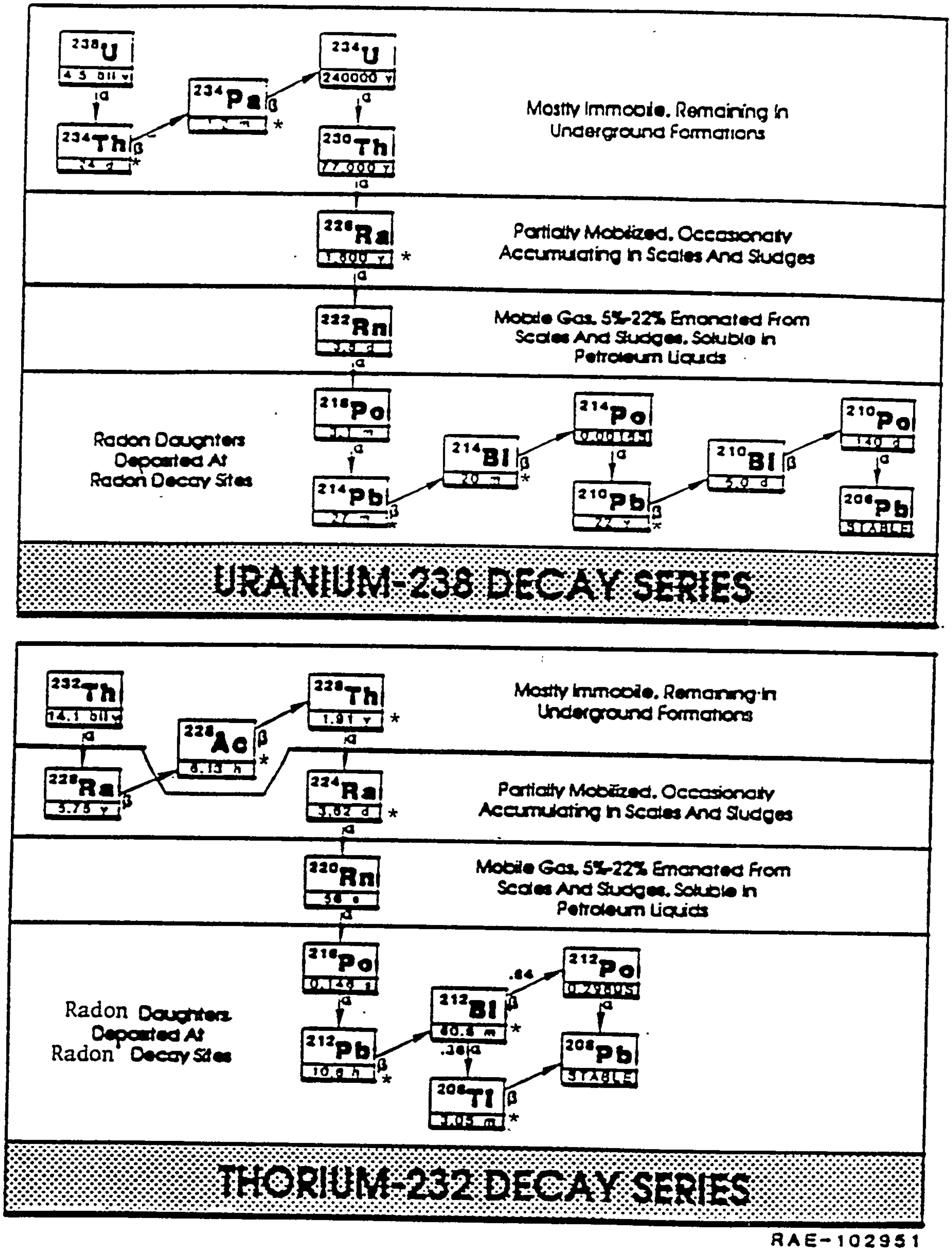
The single most cleanup-retarding factor is the lack of disposal alternatives; the second is the lack of uniform and comprehensive regulations. The domestic production of oil and gas is a nation-wide industry, and many oil and gas production companies operate in several states -- they should be regulated consistently from state to state.

able 1: 20-Year NORM Waste Generation[1] - Volumes and Activities

ORM Waste Stream	20-Year[2] Volumes (Yd^3)	Average Ra-226 Activity (pCi/g)	20-Year Generation Activity (Ci)
'ranium Mine Overburden	1×10^9	20	2×10^4
hosphate Wastes			
Phosphogypsum	8×10^9	30	2.4×10^5
Slag	4×10^5	40	15
Scale	150	1×10^3	0.2
hosphate Fertilizer	1×10^8	10	1×10^3
oal Ash			
Fly Ash	2×10^9	5	5×10^3
Bottom Ash	5×10^8	5	2×10^3
linerals Processing Wastes	2×10^8	100	2×10^4
'rinking Water Treatment /astes			
Sludges	4×10^5	10	4
Ra Selective Resins	8×10^3	3.5×10^4	3×10^2
etroleum Pipe Scale	4.5×10^4	100	6

.) Excerpts from "Diffuse NORM Wastes: Waste Characterization, Preliminary Risk Assessment, and Regulatory Control Options", U.S. EPA Office of Radiation Programs, September, 1988 (Draft).

!) Metric Tonnes listed in the document referenced in footnote no.1 were converted to cubic yards using 109 lb/ft^3 for scale and slag, and 82 lb/ft^3 for all other waste forms.



(* Also Gamma Emmiters; the Gamma Emmissions from the other Isotopes are insignificant.)

FIGURE 1. PRINCIPAL NUCLIDES, DECAY MODES, AND MOBILITIES OF THE URANIUM - 238 AND THORIUM - 232 DECAY SERIES.

THE TORTOISE AND CLEAN AIR -- A CALIFORNIA STORY

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Abstract

The authors evaluate the process by which the twenty-two distinct licenses, permits, approvals and agreements necessary to construct and operate a low-level radioactive waste disposal facility in the State of California were (or are) being obtained. The stability of the NRC/Agreement State low-level waste regulations over the past several years has facilitated the preparation and review of an application to construct and operate a "Part 61" disposal facility. However, the myriad of other licenses, permits, approvals and agreements required from local, state, and federal agencies have involved significant additional effort. These approvals involve matters ranging from the relocation of desert tortoises to operating a citizens band radio. Potential applicants are advised to keep their eyes open not only for existing permit requirements but also for future requirements that may be pending during the course of a protracted licensing process. For instance, U.S. EPA Clean Air (NESHAP) standards are officially in abeyance. However, a prudent applicant is well advised to prepare for implementation of the NESHAP standards as initially proposed to avoid potential project delays. Also, it is advisable to anticipate U.S. EPA -- or state -- groundwater standards which may be more stringent than those currently in NRC's LLW regulations. In California, state requirement have dictated application of a 4 millirem/year dose standard.

Potential applicants to develop and operate LLRW disposal facilities need to be aware of these and other regulatory changes at all levels of government including those that deal with subjects that seem very remote from the regulation of LLW disposal. The paper provides a number of other examples of the types of permits required in California and implications for facility development in other states.

Introduction

Applicants, licensees and regulators are well aware of primary regulatory requirements associated with development of a LLW disposal facility - development and approval of a license application and in most cases development of some formal environmental document. However, those who have yet to undertake the process may be somewhat less aware of the myriad of other permits, approvals or actions that may be required by other state, federal or local entities which have an actual or perceived role in the development and approval process. The purpose of this paper is to discuss some of the approvals that were required of one specific project -- the Ward Valley low-level radioactive waste disposal facility; and to discuss some of the uncertainties, both regulatory and jurisdictional, associated with the permitting process.

Background

In 1985, after a prolonged competitive process, US Ecology, Inc. was named licensee designate for development of a low-level radioactive waste disposal facility for the State of California. This was the culmination of a decision by the state to develop and operate a disposal facility pursuant to the Low-Level Radioactive Waste Policy Act of 1980. California codified its responsibility under federal law by passing Senate Bill 342 in 1983. At its inception, the project was envisioned by the State to serve only the needs of California waste generators. Eventually, however, the project was expanded somewhat to serve also the needs of Arizona, North Dakota, and South Dakota in what is now the Southwest Compact pursuant to the passage, in 1988, of the Southwestern Low-Level Radioactive Waste Disposal Compact.

As licensee designate, US Ecology was tasked to undertake a comprehensive program of site screening and selection taking into account a myriad of geologic, hydrologic, climatological, demographic, cultural, and socio-economic factors both identified in regulation and specified by California as siting criteria. This screening process continued for several years and involved both rigorous technical studies and data analysis as well as a program of community screening and consensus building with the advise of citizens advisory groups. Detailed siting criteria led to the identification of 18 potential sites were identified in southeast California. Eventually, the list was narrowed to three sites with excellent potential for detailed site characterization, Ward Valley, Silurian Valley and Panamint Valley. All three sites shared the characteristics of closed basin hydrology, simple stratigraphy, arid climate and remoteness from population centers.

Based on a process of public participation and preliminary characterization carried out by US Ecology and its contractors, Ward Valley, 22 miles West of Needles, California, was selected as the preferred site for development of the LLW disposal facility with Silurian Valley as the backup. US Ecology undertook a comprehensive program of data collection and evaluation aimed at detailed site characterization, establishment of baseline environmental parameters that would allow for environmental monitoring both during and after facility operations, and development and integration of other data needed to prepare an application pursuant to California low-level waste regulations contained in Title 17 of the California Code of Regulations and prepare the Proponents Environmental Assessment (PEA) required by the California Environmental Quality Act (CEQA).

The application and PEA were submitted by US Ecology for review by the State Department of Health Services in December 1989. DHS and its contractors performed a rigorous review of the application and generated four rounds of interrogatories which in turn elicited additional information from US Ecology to supplement the license application. The interrogatory responses became part of the license application.

In response to the PEA, the State and the U.S. Bureau of Land Management (BLM) developed a joint Environmental Impact Statement/Report (EIR/S) to disclose the effects of the project and solicit public comment. (BLM currently manages the federal land on which the facility would be developed. Since the transfer of the land is a federal action, BLM elected to prepare an EIS.) Provisions contained in federal and California regulations allow for preparation of joint environmental documents. Therefore, DHS and BLM executed a Memorandum of Understanding in 1987 that merged the State and federal documents into a single EIR/S.

It is appropriate to note, at this point, that one of the main environmental considerations for this project is the desert tortoise (Gopherus agassizii). The desert tortoise is a State and federally listed "threatened" species. Many of US Ecology's efforts in environmental mitigation will include efforts to protect the tortoise, and mitigate not only impacts of the Ward Valley project, but other threats to its existence that have nothing to do with the Ward Valley facility. Efforts to date have included identification and tracking, through electronic means, individual tortoises for eventual relocation off site. Eventually, the project will include the construction of physical barriers to protect tortoises from one of their main predators -- the automobile. Many of the permits discussed or alluded to herein and required of US Ecology for this project are associated with mitigation efforts for the desert tortoise.

The Tortuous Path to Approval

The process of submittal and review of a license application is a necessary circumstance for the developer of a LLW disposal facility; and one which the authors who are former regulators are familiar. However, it became apparent that in California (as probably in other States) the process of developing a site is far more complicated. The license to receive and dispose of LLW is but one of 22 separate permits, licenses, approvals, or consultations that are or may be required by federal, state, regional, or local entities. These actions range from simple to complex; and inexpensive to expensive. Some of the requirements have explicit criteria for implementation, others have none at all. Furthermore, the applicability of some of these requirements is not clear even among authorities within the organization which is supposed to implement the requirement. The entities of which specific approvals are required are listed in Table 1.

Examples of approvals included a California Department of Transportation encroachment permits for road construction and construction of a tortoise fence along its right-of-way; Bureau of Land Management requires a land use permit for changing the use of the land to which the tortoises are located. Also, an easement is required for the access road to the proposed facility. And, of course, since US Ecology is a waste producer as well as a waste disposer, permits are required for the disposal of routine non-hazardous waste. In addition, US Ecology had to meet the requirements of the State Office of Historic Preservation with regard to evaluation of potential historic sites pursuant to section 106 (36 CFR 800). Further, a stream bed alteration agreement with the California Fish and Game Department is required for the project. US Ecology may need an FCC license for radio communication. This requirement could be easy and inexpensive to meet if US Ecology is allowed to use an Arizona transmission frequency; however, if we are required to use a California frequency, the company may be required to construct a microwave tower.

It is implicit that all of these permits and approvals involve time and expense to obtain; that is a recognized cost of development. However, when regulatory uncertainty, instability and ambiguity are added to the equation as they are in many cases the process becomes muddled and the means for timely resolution unclear.

Regulatory Stability

Rather than bemoan all the various requirements and the ease or difficulty by which they can be implemented, we would like to discuss the process with respect to regulatory stability and certainty, because these concepts have a profound impact on the process. First, it is necessary to establish a benchmark for regulatory stability. In the development of the Ward Valley facility that benchmark has been and continues to be the DHS/NRC Part 61 Licensing Process. Throughout this process there was no question that the regulatory requirements of 10 CFR Part 61 as they were codified in California Title 17 were applicable. DHS provided US Ecology with clear guidance as to what these requirements were and how they were to be demonstrated. The task of meeting these requirements was arduous and resource intensive for the license designee but progress could be measured through each iteration of the interrogatories. Both regulator and regulated had the same guidance before them and only matters of interpretation of individual requirements had to be resolved.

Contrast the above process with several regulatory processes associated with other requirements and actions whose applicability and implementation are at best unclear.

<u>Clean Air</u>

Early on in the process it was determined that a National Emissions Standards for Hazardous Air Pollutants (NESHAP) permit was not required for the Ward Valley facility. However, given the specter of uncertainty regarding the potential future applicability of proposed NESHAP compliance requirements, US Ecology decided that it would be prudent to conduct modeling studies to demonstrate compliance. These studies were submitted to EPA for review. At first, EPA staff was reluctant to spend resources reviewing studies related to a permit that was not yet required for the project. However, US Ecology prevailed upon EPA to remember that the NESHAP requirements were only in abeyance. Therefore, they could theoretically take affect prior to beginning of operations at Ward Valley. It was desirable to have the determination of US Ecology's compliance status should the NESHAP requirement take affect. The uncertainty of this status could have a profound effect on project schedules EPA staff was cooperative and reviewed US Ecology's air quality modeling studies. Based on the review, EPA determined that US Ecology's modeling demonstrated that the Ward Valley facility as it was proposed in the license application would comply with the proposed NESHAP requirements should those requirements become effective.

<u>Resource Conservation & Recovery Act (RCRA)</u>

The Ward Valley facility is a low-level radioactive waste facility only. US Ecology has not applied for a RCRA Part B permit to allow for the disposal of hazardous mixed waste at the facility. Therefore RCRA requirements for a double liner leachate collection system do not apply to the Ward Valley facility. This fact did not keep certain EPA staff from trying an end run through the EIS process to interject the liner philosophy for the low-level waste disposal facility. EPA did this by commenting on BLM's draft EIS that liners should be required for disposal units. This comment put BLM in the awkward position of moderating complex technical discussions in which the agency had only peripheral interest as the current manager and potential transferror of the land. EPA Region IX concerns were resolved when BLM and DHS convened a panel of ground water protection experts to discuss and resolve the liner issue in the context of the real issue -- assurance of ground water protection. The panel concluded that there were monitoring techniques that addressed EPA's concerns better than a double-liner leachate collection system. The panel went on to recommend a comprehensive vadose zone monitoring program which US Ecology will essentially implement at the Ward Valley Facility. The program will include several mechanisms for monitoring movement of water, water vapor and gases within the vadose zone above, below and beside disposal units.

EPA LLW Standards

As most people are aware, EPA has for some time been developing environmental standards for LLW disposal. As currently drafted, the standards would be somewhat more restrictive than those developed by NRC. Given the protracted nature of the Ward Valley licensing process, US Ecology was concerned that these standards could supersede the NRC standards adopted by DHS shortly before a license was issued. Therefore, it was necessary to keep abreast of progress in the promulgation of these standards and the potential impact on the project. During the licensing process, US Ecology agreed to apply a 4 millirem ground water protection standard as a practical means of demonstrating compliance with the groundwater protection policy of the Colorado River Water Quality Control Board. By extension, this would also meet EPA's requirement for a Class II aquifer, which the water below Ward Valley decidedly is not. US Ecology's means of demonstrating this compliance is contained in the pre-operational environmental monitoring report published in December 1991.

Fortunately, the other major addition to the NRC requirements, the 25 millirem direct gamma restriction can be easily met in the Ward Valley facility through administrative limits. In fact, current administrative limits at the facility, while not set at the 25 millirem limit, are far below direct gamma limits set in 10 CFR Part 20. Ironically, the more significant compliance challenge with the 25 millirem limit comes not from radiation from the radiation controlled area, but from transportation vehicles in the parking lot awaiting receipt. The vehicles adhere to a DOT transportation standard that allows dose levels that are higher than the EPA standard. Thus, an individual could receive the same dose sleeping next to the truck in the US Ecology parking lot as they could receive sleeping next to the same truck parked in a motel parking lot anywhere along the nation's highways.

Control Through Political Fiat

The last example that we would cite is one of ersatz regulatory control through political fiat. In California this involves transfer of land from the federal government to the state for the development of a LLW disposal facility by means of indemnity selection. Briefly, this is a process whereby the federal government remunerates states for land not available for State School Lands due to prior federal commitments. This simple, straight-forward process of transfer by indemnity selection from BLM to DHS has turned into a practical impossibility because of the involved broker organization -- the California State Lands

Commission. In California, the State Lands Commission is responsible to effect transfer by the indemnity selection process of federal lands. In most cases this transfer is automatic and the role of the Commission is ministerial. However, in the case of the Ward Valley facility two members of the State Lands Commission have decided to use their authority to make a political statement with regard to the project, and thus have inserted themselves directly into the process. With limited technical expertise these commissioners have questioned and re-questioned the authority, expertise, and by implication, the integrity of the state agency (DHS) that is both technically qualified and authorized by state law to make the licensing determination. In the process, they have reopened issues that were closed early in the process regarding US Ecology's qualifications and the state's liability with regard to facility performance. This disruption of the land transfer by the State Lands Commission has significantly lengthened the process and added hundreds of thousands of dollars to the cost. There are other mechanisms for land transfer that may be used, but they will be time consuming.

Lessons Learned

What does this experience mean to those who are not as far along in the process as the Ward Valley Facility developer? As a result of the Ward Valley experience there are several recommendations that we would offer to developers or other facilities around the U.S.

1. Know who the regulator is and what regulations apply. Get clear guidance from the regulator wherever possible as to how the regulations will be implemented and the criteria by which implementation will be judged.

2. Remember that the process of licensing may last seven years. So keep track not only of current requirements, but also of any requirements that may be pending that would impact licensing.

3. Recalling the NESHAP experience, elicit from all potential regulatory agencies the applicability of their regulations. If certitude of regulatory applicability cannot be established, seek to demonstrate compliance notwithstanding applicability.

4. Develop a healthy sense of paranoia -- remember once the license is issued, you'll be sharing the black hat with the regulator, so it's in your best interest to help ensure that the regulator's process is bullet-proof. Remember the process of developing and licensing a facility with this much inherent controversy in it, is not merely <u>likely</u> to undergo a robust legal challenge. <u>It will with absolute certainty undergo such a challenge</u>. Therefore, all activities associated with the decision making process must be scrupulously documented and

without flaw. Remember the moral high ground belongs to project opponents, so they believe, and would have others believe. Theirs is the luxury of half truth, and sloppy, ill-thought out technical analyses. Developer and regulator alike must set a standard of near perfection for themselves, not only in technical analyses, but also public disclosure and documentation that supports the decision making process. Eventually, the record will be judicially scrutinized with little project specific knowledge, but with a legal mandate to determine the eventual fate of the project.

<u>References</u>

1. State of California Department of Health Services, U.S. Bureau of Land Management, State of California Indemnity Selection and Low-Level Radioactive Waste Facility, Draft Environmental Impact Report/Statement, June 1990.

2. US Ecology, Inc., California Low-Level Radioactive Waste Disposal Facility, License Application, December 1989.

3. State of California, California Code of Regulations, Title 17, Public Health, Division 7, State Department of Health Services.

TABLE 1

PERMITS, APPROVALS, CONSULTATIONS, AND ACTIONS POTENTIALLY APPLICABLE TO THE WARD VALLEY LLW DISPOSAL PROJECT.

AGENCY	PERMIT, APPROVAL, OR REVIEW
DHS	License to Construct and Operate LLRW Disposal Facility
BLM	Access Road Right-of-Way; Land Acquisition
Colorado River Basin Regional Water Quality Control Board	Waste Discharge Requirements
San Bernardino County	Dust Control Plan, Hazardous Waste Generator Permit, Class C Solid Waste Hauler Permit, County Business Plan, Fire Code Compliance Inspection
U.S. Environmental Protection Agency	National Emission Standards for Hazardous Air Pollutants
California Department of Fish and Game	Streambed Alteration Agreement, California Endangered Species Act, Biological Consultation
California Department of Transportation	Highway Encroachment Permit
State Office of Historic Preservation	Section 106 Consultation
U.S. Fish and Wildlife Service	Federal Endangered Species Act Biological Consultation

Source: Reference 1

APPENDIX A
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