Reclamation of Uranium Mill Tailings
Evolution of the Technical Basis for Regulations

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Introduction and History of UMTRCA

The Uranium Mill Tailings Radiation Control Act of 1978 (the UMTRCA), which amended the Atomic Energy Act of 1954 (the ACT), was enacted by the U.S. Congress in response to concern that uranium mill sites, active and inactive, may be hazardous to the public health and the environment. This concern resulted primarily from instances in Grand Junction, Colorado and Monticello, Utah where uranium tailings had been removed from nearby mill sites and were used as fill around residential building foundations.

Public use of the tailings was possible and problematic for several reasons. First, access to the radioactive tailings was possible because they were uncontrolled and unregulated and were located in or near towns. The potential for misuse of these tailings (as was the case at Grand Junction and Monticello) was therefore high. Second, there was a suspected enhanced cancer risk from exposure to radon gas for the impacted home owners. Third, it was apparent that substantial additional uranium milling would be required to fulfill fuel demand for the nuclear power plants that were forecast to come on line.

These issues, along with an increased public awareness of the environment and an increased fear of cancer and awareness of its potential link to radiation, caused legislative, regulatory, and public attention to be focused on uranium tailings and the attendant mill sites.

The primary purpose of UMTRCA was to ensure that every reasonable effort be made to provide for the stabilization and disposal of tailings in a safe and environmentally sound manner in order to prevent misuse, minimize the release of radiation into the environment and prevent or minimize other environmental hazards postulated to be associated with tailings.

UMTRCA directed the U.S. Nuclear Regulatory Commission (NRC) to develop and administer a comprehensive uranium mill tailings regulatory program. The ACT established two programs to regulate uranium mill tailings: Title I, required the closure of inactive sites (sites with no identifiable owner which would require funding and cleanup by Federal and State Governments), and Title II, which established a comprehensive regulatory program for the disposal and stabilization of uranium mill tailings at active mill sites. To establish a regulatory home for uranium tailings, Section I1.e.(2) of the ACT was amended to reverse the definition of byproduct material to include:

"the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content."

UMTRCA also directed the U.S. Environmental Protection Agency (EPA) to establish environmental standards of general application for NRC to use to promulgate regulations for decommissioning and reclaiming milling sites and uranium mill tailings.

As an initial step to promulgating regulations, UMTRCA required NRC to study the issues and the technical and scientific aspects related to uranium tailings management and to prepare a generic environmental impact statement (GEIS) to provide background and support for its regulatory program. Based on the information and conclusions developed in the GEIS, the NRC proposed regulations for the operational and post-operational control of both radioactive and non-radioactive hazards associated with uranium and thorium mill sites and tailings disposal facilities. Defined in this regulatory program was provisions for formal agency review of tailings disposal and decommissioning plans, financial surety to ensure sufficient funds for decommissioning and reclaiming mills and tailings, preopera-
UMTRCA thus spawned a new philosophy for site closure which required the integration of a multiplicity of scientific and technical disciplines. This philosophy has impacted the approach now applied to regulate other industry segments. Although this philosophical concept had been developing for some time in the U.S., the enactment of UMTRCA and the development of the GEIS and the Appendix A criteria was the first instance in which it became the clear, driving intent of a regulatory program.

Once in effect, the new regulations placed a significant burden on the operators, engineers, scientists and regulators responsible for compliance. Prior to UMTRCA, reclamation and final closure of a mill site was accomplished using more problem specific, narrowly focused methodologies. The norm had been to do what seemed “right” for a specific issue (e.g., provide stable slopes, establish vegetation) without regard for or the need to investigate other potentially related problems and define how they might impact other control facets of closure plans. Typically, if problems developed later, they were addressed as they arose.

This basis for operating and closure was rejected by UMTRCA and replaced with requirements to find comprehensive engineering designs and scientific solutions that could comply with the demand.

Out of the UMTRCA regulatory process and its attendant philosophical mandate has evolved predictive engineering and scientific methodologies that are generally better equipped to deal with the complex problems that confront us as we struggle with a wide variety of waste management and human and environmental impact issues. As a technical community we have learned the practical limitations to removing uncertainty from the decision process and have developed an evaluation process that integrates once divergent engineering and scientific disciplines into a comprehensive but flexible set of design tools.

Regulatory Objectives

The NRC regulations intended that site closure plans provide design features that would ensure the minimization or elimination of operational and post-closure risks. Furthermore, this was to be done with no active maintenance and essentially no reliance or institutional control needed after closure of a site. The closure of uranium and thorium mill and tailings sites, thus, had to be done in a manner that would minimize risk and not burden future generations.

To the policy makers and the environmentally concerned public this was an appropriate and sound goal, especially when considering the depth of concern that was prevalent over the long-lived radioactive tailings constituents. Without entering into debate about the absolute or relative level of risk posed by uranium and thorium tailings, there is no question that it is desirable to design and implement a reclamation and closure plan that will meet stringent performance goals over extended time periods.

We believe that the current NRC regulations and guidelines generally achieve these objectives in a fundamentally sound manner. While these objectives can and usually do cause extreme, and sometimes seemingly unnecessary,
measures to be used in closure design, the imposition of these objectives on the design process has caused the engineering and scientific community to improve predictive methodologies, integrate natural science and engineering disciplines in evaluating design performance, and become rather innovative in the development of operational and closure plan designs. It is our belief that this evolutionary process has substantially improved industry’s overall ability to develop effective closure and reclamation designs, and, in that regard, has contributed in a positive way to the advancement of our technical capabilities. This has resulted in the development of a comprehensive and interdisciplinary approach to operational and reclamation design and performance analysis. It has required innovation, adaptation and basic research to provide the engineering and scientific basis needed to achieve the objectives set out by the regulations. In so doing, this process has generally improved our overall capability to effectively and efficiently achieve the broad societal objectives protection of the environment and public health.

**Evolution of Closure Objectives**

Initially, the NRC concluded that three meters of cover, maximum 5h:1v slopes and 100,000 years were the appropriate design-life objectives for reclamation plan designs because of the long-lived nature of the perceived radioactive hazard present. This very long-term design life objective, along with the requirement that performance could not rely on active maintenance or institutional control, created two interesting conditions.

First, it was clear that, for perhaps the first time in a comprehensive design sense, natural processes, such as erosion and geomorphic land form development, had to become an integral element of development and analysis of design solutions. Furthermore, because of the very long time frame being considered, extreme and unlikely natural events, such as the Probable Maximum Precipitation event (PMP), were appropriate conditions to consider in design in the closure plan. Second, it was clear that traditional engineering performance evaluation techniques were generally inadequate and/or unable to project performance predictions as far into the future as required by the new regulations. In addition, very few soil-based structures could serve as models to demonstrate the long-term effectiveness of engineered designs.

It was immediately clear that new design evaluation and analysis processes were needed and that to facilitate the development of these processes, several evolutionary things had to occur. First, in the GElS, the NRC evaluated several evolutionary things had to occur. The 100,000 year design-life was in the realm of geologic time and a time period in the realm of historic time was more appropriate. Therefore the design-life was reduced to 1,000 years to the extent practical but not to be less than 200 years. This time frame has allowed more realism to be introduced into design performance analyses but has not removed the necessity to design to accommodate extreme natural events.

For example, a design-life of 200 years does not mean that the design flood is the 200 year flood. For an allowable probability of occurrence of even 0.01 some time within the 200 year period the design flood would have a recurrence interval of about 20,000 years (Nelson, et al., 1983). Extrapolation of short-term hydrologic data bases to such long-term periods is not reasonable and therefore, a design flood based on the PMP was recommended. Thus, reducing the design life did not reduce the design flood for the reclamation plan.

The design and analysis process related to reclamation surfaces has also

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**This obvious and serious gap between need and ability was bridged by a generally productive undertaking by all parties involved.**

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evolved into a system that can reliably determine what can be accepted as a final land form. The ability to establish that a reclamation surface achieves the long-term stability performance criteria has thus progressed to the point where little controversy now exists. This evolution of design and performance analysis has evolved from application of the relatively qualitative judgements possible by the application of classical geomorphic interpretation of land-form stability and the Universal Soil Loss Equation (USLE) to much more highly refined, and at least, semi-quantitative analytical methodologies. The basis for now accepted analytical process is presented in the NRC's Final Staff Technical Position, Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites (NRC, 1990). One very important tenet of this process is that to be effective, a design must accommodate natural weathering processes without failure of the features which encapsulate the tailings. In addition and corollary to this process, analysis methodologies and design approaches for control of radon emanation have been extensively investigated, reviewed and debated and a final methodology established.

Finalization of the ground water protection element of closure designs is pending, NRC publication of a guidance document (Staff Technical Position) for establishing alternate concentration limits (ACL's) for ground water constituents that cannot be reasonably controlled to achieve background or established regulatory limits. The NRC has written a draft ACL guidance document (NRC, 1992) that is currently being reviewed. However the technical and scientific elements of the process, that is geohydrologic and geochemical evaluation and prediction, have been thoroughly addressed and developed to a high level of technical proficiency and reliability. It is fair to state that the uranium industry has been responsible for advancing this general scientific area significantly, particularly where partially saturated flow and contaminant migration geochemistry applied to practical design and performance evaluation. As stated above, final ground water guidance protection acceptance waits for regulatory policy decisions which seem to always lag our scientific and technical understanding of a situation.

Interdisciplinary/Multidisciplinary Decision Approach

One of the most significant contributions that the UMTRAP process has provided are its interdisciplinary or multidisciplinary approaches to regulatory evolution and problem solution development. The National Environmental Policy Act (NEPA) of 1969 preceded UMTRCA by about 10 years. NEPA clearly mandates an interdisciplinary approach to environmental impact analysis which extends to impact mitigation and solutions development. It was clear to the framers of this law that environmental impact analysis required a broadening of the traditional focus of problem analysis. This philosophical approach is embodied in the EIS process.

Significant advancements in mine and tailings closure technology have come as a result of the very practical realization that reliance on a single science or engineering discipline, as was historically the practice, no longer was feasible. That is, it was not possible to support conclusions about the long-term performance of a reclamation design solely on the basis of a single, traditional engineering analysis. The available period of actual performance testing and functional experience with engineered designs was far too short to provide the confidence required by the new regulations. We believe that a large part of this regulatory paradigm shift resulted from the UMTRCA process, wherein the multidisciplinary approach became an accepted element of regulatory decision making and the application of the concepts of such relatively obscure disciplines as geomorphology became an integral element of stability analysis and design justification. The new regulatory paradigm also required a shift in the mindset of those engineers designing reclamation plans because multiple objectives were not normally integrated in these traditional design approaches and in actual fact were sometimes not compatible in terms of objective fulfillment. The most easily recognized example of contradictory closure objectives lies in the design of tailings covers. The tailings cover is required to control radon, be erosionally stable for long periods of time and reduce moisture infiltration to levels necessary to protect long-term ground water quality. Much debate has ensued as to the most appropriate design of a cover system. The universally accepted conclusion that no one design is appropriate for all sites and situations. Further, the objectives, if pursued independently, very often result in contradictory designs. For example, long-term surface stability is most easily achieved by construction of either a very flat cover surface or by covering steeper surfaces with rock. The result of both of these designs with respect to infiltration is to maximize (compared to a steep, vegetated soil surface) the amount of infiltration that can be predicted to occur.

The outcome of these designs are not the most appropriate when one considers the requirement to protect ground water quality for the long-term. This can be a frustrating dilemma. The solutions
lie in the integration of many, varied cover designs. And the basis of these designs and the performance analyses used to prove their acceptability have almost always been based on understanding and adequately predicting performance based on application of several different scientific disciplines. For example, if rock cover is needed to provide surface erosional stability, the geomorphology shape of the surface may become less important, but the

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long-term durability of the rock then becomes an integral element of the design analysis. In addition, since a rock cover acts as a mulch and increases infiltration especially when compared to a soil/vegetation cover system the analysis of the plan must also demonstrate that the increased amount of water that might infiltrate will not mobilize contaminants in unacceptable qualities.

The resolution of this quandary may rely on integrated understanding of how the chemical environment evolves in the tailing mass once it is covered, the geochemical interaction that will occur beneath the impoundment between the chemistry of the seepage and the chemistry and physical nature of the subsurface geologic materials which lie along the flow path, and the rate (quantity) at which seepage will leave the tailing impoundment over the long-term. In the end, the final resolution is likely a compromise or balance between the competing objectives, optimizing performance within the limits imposed, and using scientific disciplines and procedures to evaluate and analyze the balance sought. With all of the factors considered, the final design might employ a vegetated rock mulch which applied and the adaptation of technologies to provide a compatible decision framework has not been without its challenges. Happily, this integration has been successfully achieved and has allowed the uranium industry to proceed with reclamation design in a somewhat sensible manner and to pass along this integration to other waste disposal and reclamation problems.

Regulatory Continuity and Growth — The Desired State

It is interesting and instructive, and an element of the regulatory process worthy of commendation, to note in closing, that the evolution of the UMTRA process has been very open and amenable to change and modification as the state of our understanding of uranium tailings closure technology has developed. Many of the "truths" that characterized the initial regulatory posture have been overturned in a positive sense for new truths. At the head of the list of modified truths is the three meter cover and the "absolute" Sh to Iv and 10h to Iv side slope requirements. It is not likely that a three meter cover will ever be constructed, or, that the NRC would require a 5h to Iv slope just because the regulations say 5h to Iv. What has developed is regulatory objectivity that allows licensees to demonstrate, by employing a range of accepted analytical approaches without prescribing specific design requirements, that a design achieves the desired performance of objective. We feel that this has been possible because the regulations are based on performance objectives rather than static, inflexible numeric standards. This approach to regulation imposes a heavy responsibility on both the regulator and the operator to not only to conduct business on the basis of mutual respect and professional competence, but an open exchange and, acceptance and understanding of original ideas and new, innovative approaches. The industry, NRC and the Agreement State personnel are to be commended for nurturing and allowing this environment to prevail. The authors feel that this type of approach would well serve other elements of the regulatory arena.

References


