Supporting a Conservative Approach to Cleanup at Rocky Flats

FINAL REPORT

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A Technical Assistance Project of
the Rocky Mountain Peace and Justice Center
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Introduction

In March 2001 the Rocky Mountain Peace and Justice Center (RMPJC) of Boulder, Colorado, initiated a project to provide technical information on standards for cleanup of the contaminated site of the former Rocky Flats nuclear bomb factory. The project was supported in part by a technical assistance grant from the Citizens' Monitoring and Technical Assessment Fund.

The purpose of the project was to review, analyze, and disseminate information on the radionuclide soil action levels or cleanup standards being established for the Rocky Flats facility. The timeline of the project closely paralleled steps to revise the Rocky Flats Cleanup Agreement (RFCA) being taken by the DOE, the Environmental Protection Agency, and the Colorado Department of Public Health and Environment.

For assistance in this project RMPJC contracted for technical services with the internationally known Institute for Energy and Environmental Research of Takoma Park, Maryland. IEER provided detailed historical and scientific analysis of the subsistence farmer approach to cleanup, an approach that is far more conservative and protective of public health long term than the approach adopted by the government agencies of basing cleanup standards on the designation of Rocky Flats as a wildlife refuge after closure. .

The project entailed producing and distributing information in the form of technical reports, fact sheets, and guides on how to comment on the proposed RFCA revisions. Overall, the work was divided into several parts as shown in the table of contents printed on the following page.

Copies of this report are being made available to the RFCA Principals at DOE, EPA, and CDPHE, as well as to the Rocky Flats Citizens Advisory Board and the Rocky Flats Coalition of Local Governments.

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PART 1

Report summarizing the independent analysis
of radionuclide soil action levels for Rocky Flats
done by *Risk Assessment Corporation*
for the Radionuclide Soil Action Level
Oversight Panel

A Report on the Independent Analysis
of Radionuclide Soil Action Levels (RSALs) for Rocky Flats
Done by *Risk Assessment Corporation (RAC)*
for the Radionuclide Soil Action Level Oversight Panel (RSALOP)

Introduction

In 1996, DOE, EPA, and CDPHE established Radionuclide Soil Action Levels (RSALs) for Rocky Flats. Because of public unhappiness with the quantity of plutonium these RSALs would allow to remain in the Rocky Flats environment, the DOE agreed to fund an independent scientific assessment of the RSALs. To implement this task, the RSAL Oversight Panel (RSALOP) consisting of scientists and representatives of local governments and public interest groups was formed. In a competitive bidding process, the RSALOP contracted with *Risk Assessment Corporation* (*RAC*) to conduct the independent review. Throughout the review process, which began in October 1998, the RSALOP worked very closely with RAC. DOE, EPA, and CDPHE participated in an officio capacity. All work was peer-reviewed, and all parties realized that the study could produce a recommendation that the RSALs be revised to allow less plutonium in the soil. The project has now been completed, somewhat in advance of the terminal date of March 31, 2000.

RAC organized the project into eight tasks:

- Cleanup levels at other plutonium-contaminated sites.
- Computer models to determine RSALs.
- Key project inputs and assumptions.
- Methodology.
- Independent calculation of RSALs for Rocky Flats.
- Sampling protocol.
- Interaction with the Actinide Migration Panel.
- Public involvement.

What follows summarizes *RAC's* work for each of these tasks, reports briefly on the peer review process, then presents *RAC's* principal conclusion and the recommendation made by the RSALOP to DOE and the regulators.

Task One: Cleanup Levels at Other Sites

Completed in April 1999, the Task One report provided the RSALOP with a clear, unbiased evaluation and comparison of RSALs previously developed for Rocky Flats and other sites around the world. The evaluation found that the RSALs established for Rocky Flats are significantly higher than action or cleanup levels at other facilities, even when normalized to dose. However, the report provided a better understanding and clarification for the elevated levels and found that the calculation is strongly controlled by three basic parameters:

- dose conversion factor (solubility class of plutonium)
- mass loading (resuspension), and
- breathing rate (to a lesser degree).

In nearly every case, differences in RSALs between sites could be explained by the different assumptions made for one or more of these basic parameters. The Task 1 report identified the input model parameters that are of primary importance in determining RSALs so that this information could be used as the study evolves.

Task Two: Computer Models

The goal of the Task Two report, which was completed in July 1999, was to discuss and compare environmental assessment programs that might be used for developing soil action levels for Rocky Flats. *RAC* scientists evaluated the following five computer programs for use in the project: RESRAD, MEPAS, GENII, MMSOILS, and DandD. The report discusses the pros and cons of each program and provides information on the following four key elements that must be considered when developing soil action levels:

1. how radioactive material is transported in the environment to people;
2. how people might be exposed to the radioactive materials (exposure scenarios);
3. how radiation dose to a person is assessed (radiation dosimetry), and
4. how radiation protection guidelines fit in (annual dose limits).

Based upon extensive evaluation of the available computer codes, *RAC* representatives concluded that either the RESRAD or GENII program could be used. After further discussion with RSALOP members, it was decided to proceed with the use of the RESRAD program.

Task Three: Inputs and Assumptions

After months of discussion and input from RSALOP members, *RAC* personnel conducted a sensitivity analysis on the inputs and assumptions required for the use of RESRAD. Site-specific values were derived or uncertainty distributions were created for critical parameters emerging from the sensitivity analysis. The sensitivity of each parameter was then assessed using the built-in Monte Carlo-based sensitivity analysis packaged with the latest version of RESRAD. This

Task Four: Methodology
"Methodology" is a topic that encompasses the project as a whole through ongoing dialogue of *RAC* with the RSALOP and others from the community regarding proposed methodologies employed in the study. Methodologies that may be considered and/or decided upon are discussed within reports specific to project tasks. Therefore, no separate report was published on this task.

Task Five: Independent Calculation of RSALs
Although this item is identified as "Task Five," it is actually the final step in the study, completed after running the RESRAD program using the inputs and assumptions decided upon in Task Three. The Task Five report on Independent Calculation presents the results of *RAC's* independent assessment and describes the calculations and results of the RSALs for the seven exposure scenarios identified in the Task Three report.

Task Six: Soil Sampling Protocols
RAC released the draft final report for Task Six at the December 1999 meeting with the RSALOP. The report reviewed the current site sampling program and procedures as well as individual site sampling and analysis plans. It also provided recommendations to the RSALOP for consideration in developing a sampling protocol for the site and discussed the following ten key elements that should be a part of any sampling protocol:

- Data quality objectives
- Multiple radionuclide consideration;
- Classification of survey units;
- Soil sampling depth;
- Sample spacing and methods;
- Small areas of elevated activity;
- Surrogate measurements;
- Number of samples based on statistical methods;
- Independent confirmatory investigations;
- Soil sampling quality assurance.

The report concluded that the MARSSIM guidance provides the most comprehensive approach currently available for the development of radiological surveys and recommended that the final status surveys conducted at Rocky Flats follow the general principles contained therein.

Task Seven: Interaction with the Actinide Migration Panel
The Actinide Migration Panel is overseeing an effort begun by contractors at the Rocky Flats site in 1996. Comprised of a national task force, the group is drawing upon state-of-the-art knowledge throughout the scientific community on behavior and mobility of actinides in the environment. It is hoped that this group's efforts will help to provide information necessary to develop the best possible approach for the successful closure of the Rocky Flats site. *RAC* representatives, as well as numerous RSALOP members, attend regular Actinide Migration Panel meetings and are attempting to extrapolate any information gathered to assist in the independent review of the RSALs for the Rocky Flats site. No separate formal report has been generated for Task Seven.

Task Eight: Public Involvement
A public involvement strategy was developed and implemented to provide regular updates to the community on the progress of this study. Over the duration of the project, RSALOP members met the second Thursday of each month with *RAC* representatives to review project findings and to work with *RAC* to determine criteria for key components of the study. The general public was invited to participate in these regular monthly meetings. In addition, three special meetings were held at key points in the study so that input could be received from the community for all phases of the technical review. In addition, RSALOP members made themselves available to provide updates to community groups or other interested parties.

Peer Review
To enhance the quality and credibility of the independent study, the RSALOP formed a peer review team comprised of five nationally recognized specialists with backgrounds related to this project. Team members were tasked with reviewing and commenting on each draft final report as it was produced for this project. Their comments were then forwarded to *RAC*, who in turn reviewed and provided feedback on the peer reviewer's comments at the regular RSALOP meetings. RSALOP members then looked at both the peer review input and *RAC's* response (including possible revisions to draft reports) to ensure that RSALOP members concurred with how *RAC* resolved issues brought up by the peer reviewers.

***RAC's* Conclusion Regarding RSALs for Rocky Flats**
RAC's "Technical Project Summary" presented to the RSALOP in February 2000 concludes with these words:
"*RAC's* task was to evaluate the RSALs adopted for Rocky Flats in 1996, to develop a methodology for independently

At its February 2000 meeting the RSALOP agreed by consensus to recommend to DOE, EPA, and CDPHE that the RSAL for plutonium in the soil at Rocky Flats be 35 picocuries per gram of soil.

Prepared by LeRoy Moore of Rocky Mountain Peace and Justice Center, based on the February 2000 Project Update issued by the RSALOP of which he was a member

Supported by a grant from the Citizens' Monitoring and Technical Assessment Fund.

PART 2

Risk versus dose assessment in setting RSALs

Memorandum from Arjun Makhijani
of the Institute for Energy
and Environmental Research

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Memorandum

To: .LeRoy Moore, Tom Marshall

From: Arjun Makhijani
Subject: Risk versus dose assessmcnt in setting RSALs
Date: 11 June 2001

This memorandum on risk versus dose is part of the work that IEER is doing for RMP.JC 2on the Rocky Flats RSAL consulting contract.

Historically, radiation protection standards have been set in terms of radiation dose.

There is a consideration of cancer risk in the process of setting standards, but a limitation on the risk itself has not generally been used in the standard setting process. Thc rcason, of COl!rse, is that one can measure dose - i11 princjple, while risk is a more abstract concept~ even though it is thc one most directly linked to populatlon protection.

TIle issues in regard to whether risk or dose should be tile measw.e in setting residual soil action levels (RSAl...s) is a complex one. For instance, it is Ijkely that the stream of money available for clean up would dry IIp once the site has been taken nfTthe hook.of the party that owns it. This makes it quite different from worker protection in an operating factory, for instance. Moreover, it is impossible to actually measure dose to future populations. Therefore, if the goal is to protect generations a considerable time into the future, then it is pTudent to revisit tIle issue of risk verS1LS dose as the basis for sctting RSALs (as wcll as other clean-up standards).

There are several aspects to considering risk versus dose issues:

1. Tn general. risks depend on the organ exposed~ age at exposure, aIId for some kinds of canccr, gcndcr.
2. It is jrnportant to consider non-cancer risks and a simple dose approach often is not conducive to such asscssmcnt.
3. There may be synergistic effects between exposure to non-radioactive hazardous materials and radioactivity.
4. The same dose may result in a different risk to different sections of the population, since it is 1ike1y that sensitivity to radiation is highly variable in populations. even if thcy are otherwise homogeneous by age, class, ethnicity and gender.

5. The scientific evaluation of the risk of radiation may change with time, as it has in the past.

I will bricfly examine each *of* these issues.

1. Organ and population specific risks

A risk approach to soil action levels could deal with each onc of1he factors specified in item 1 above (organ, age, and gender), while a dose appToach usually considcrs a single canccr risk factor when setting the dosc limit. A risk approach to residual soil action means that the implications of the proposed RSALs tor various cancers (organ specific doses) and for difl'erent populations would need to bc cxamined. The RSAL would be set only after the doses assessed in these different ways have bccn cvaluated and thcir implicatjons for cancer risk have been calculatcd. Evidently, dose assessments arc all scenario-dependent. In general, the subsistence farmer or rancher (i.e., consuming local food and water only) ...scenario is the appropriate one to consjder in evaluating risks. IEER is prcparing a short report on this subject for tlle RMPJC a~ part of our consulting contract to address this crucial question.

2. Non-cancer risks

There are a variety of non-cancer rlf;ks, some of which are radionuclidc~dependent. The dose apppanch to regulation adds IIp all doses internal as well as external into a single effective dose equivalent and then applies a cancer risk factor. This approach docs not give adequate weight to adverse outcomcs such as miscarriagcs due to intake of tritiated water or developmental risks to chi Idren and fetuses from other radionuclides such as strontium-90, iodine-129, tritium, and cesiulll-137 which cross the placenta.

A risk-based approach allows the differentiation of internal from external radiation and hence allows for better organ, gcndcr, and age-specific evaluation of the consequences of clean-up rules. A recent study evaluating the risk of DNA abelTations in the children of Chcmobyl1iqu1dators found a surprising scven-tbld increase compared to children of the same people born before the exposure of the parent.! This high mutation rate is at considerable variance with the Hiroshima Nagasaki data. Thc laUeT data indicate a doubljng of mutations at doses of 100 to 200 fad. These arc considered high doses of radiation, when delivered in a short time, as, in fact, they were by the bombings. By contrast, Chemoby11iquidator doscs havc bccn estimated to be in the low-dose range -- 5 to 20 rad. No dose reconstruction was possible for the specific persons in the study. Still, the clear conclusion ofthc study is that low dose radiation, possibly an order of magnitllde or more less than the Hiroshima/Nagasaki doses cited above, could cause the samc mutation talc.

-1I H- Sh. Weinberg, A. B. Korol, Y.M. KlrL-bncr, A. Avivi, T. Fahima, Eviatar Nevo, S. Shapiro, G- Rennert, O. Piatak, E. I. StcpaJlova, and E. Skvarskaja, "VCI-Y H igll Mlilalioll Ralc: in OJIspring of Chernobyl Accident Liquidators." Proceedings oft!1e Royal Socic:ly u[Lundon, vol. 268, 2001, pp. 1001-1005.

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The Chemobyl study did not attempt to assign a cause of the high mutation rate other than to identify it with radiation dose. It *is* plausible that at least some of the difference may bc ~ue to ,internal expo~ure of the liquidators, The doses received by "Hirosh1ma Nagasakl survIvors were mauI1y external gamma alld neutron doses.

The large uncertainties in the area ofhcritable mutations can be factored in bettor using a nsk-based approach. A safety factor that corresponds to the uncertainty arising from the fact that exposures to future populations from radioactivity williarge1y be internal can be developed us1ng Chemoby111quidator data from tile above study, for instance.

3. Synergistic effects

Rocky Flats, like many other DOE sitcs. has hoth radioactivc aJld notl-radioactive pollution. Little is known about synergistic risks of toxic chemicals and radionuclides, particularly when considerations ofintemal dose d1scussed briefly above are taken into account. Chemicals may compromise immune and/or endocrine systcms in ways that may increase risks from radionuclide intake. The scicntific consideration of such issues is in its initial stages and it would be a surprise if there were no surprises as regards synergl~tlc health risks. A risk-based approach would include an cvaluation of what is known, the extent of the ignorance about syncrgistic effects and the implications of that ,. analysis for choosing a safety factor that would allow risks to be kept below specificd I!;~ levels. An approach that re1ies only on cancer risk deriving from radiation dose alone *b.y its nature* excludes these important considerations.

4. Differential population sensitivity

The occurrence of cancer appears to be mediated by the immune system. The immensc variation in al1ergic response among populations that are relatively homogeneous in other respects implies that there may be a large differential sensitivity to Tadiation between individuals. A risk-based or a dosimeu'ic approach to RSALs cuulll tak~ lhi!) into account, were the differential sensitivity known. Alternatively a satcty factor that would reduce allowable dose or risk may he !;elected. Tn any case, it is prudent to cxplicitly factor in some consideTation of possible differential population sensitivity to radiation within homogeneous population groups.

It is difficult to select a safety factor at the pTeSellt time since the factors that contributc to differential allergic response arc only now beginning to be understood. Typically, fuese factors arc genetic, devclopmcntal, and cnvtronmental, making the situation quite comp1ex.

A safety factor that acknowledges this ignorance is especially important in regard to long-lived residua1 radioactivity. The long half-lives mean that a variety of people are likely to CQme into contact with the Tesidual radioactivity over the ages. There is therefore a high likclihood that individuals who are among thc most sensitive in the population will at some time be exposed.

5. Future chan~es in the average dose to cancer-risk relationship

The past half-century has seen increascs in estimates of cancer risk per unit of dose based mainly on reassessments of Hiroshima and Nagasaki. Future asscssmentsiof these data mayor may not result in increases in risk, dcpending on such factors as whether the missing cohorts from the time immediately after the explosions are takcn into account and how neutron doses are evaluated and interpreted.

nlere are a nwnber of di fferences between the populations that would he exposed to residual radioactivity and Hiroshima/Nagasaki survivors. The recent study ofthc childrcn of Chemobylliquidators CTeates additjona! uncertainty about too heavy a reliance on Hiroshima Nagasaki data, thOUglI these should of course be included in risk evaluations. Reductions in cancer risk estimatcs for future populations exposed to residual radioactivity based on reassessments of Hiroshima Nagasaki data would be especially inappropriate at this time. For a variety of reasons, many of which are djscussed above, the uncertainties in regard to risk per unit of exposure to future populations aTe much grcater than those indicatcd by the analysis of Hiroshima/Nagasaki survivor data.

f; .,-,
r';';:'1 Conclusion

\~1 in sum, thcre are compelling reasons for using a risk-based approach to setting RSALs. t :t There arc strong reasons to llse dose standards in regulating the workplace. Dose can be ;:,\;-' measured and it providcs rcal (ime or near-real time data Telating to worker risk. Thi~ is ¥s;':t' important since it allows, for instance, workers who have been accidentally exposed to be l' moved to jobs tllat reduce thc risk of further exposure. But oven in the workplace there I"" has been far too li~le consideration. of factors ,such as. sytlergisti~ effects. ~ O~L T tJ I an the : well-known smokmg-radon SYIIerglsm) and dlfferentlal populatIon sensItIvIty.

f Sincc we cannot measure doses to future populations and we limit risk indirectly via approaches such as rcsidual radioactivity standards. A risk-based approach a1lows a more scientifically sound way to incorporate the various considerations to population protection discussed above.

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PART 3

Supporting Cleanup Standards to Protect Future Generations: The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels for Rocky Flats

by Arjun Makhijani and Sriram Gopal

A report prepared
for the Rocky Mountain Peace and Justice Center
by the Institute for Energy and Environmental Research

Setting Cleanup Standards to Protect Future Generations:

The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats

by

Arjun Makhijani, Ph.D.
and
Sriram Gopal

A report prepared for the Rocky Mountain Peace and Justice Center, Boulder, Colorado

by the

Institute for Energy and Environmental Research

December 2001

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Acknowledgements

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This report was prepared under contract with the Rocky Mountain Peace and Justice Center. The Rocky Mountain Peace and Justice Center was very helpful in pointing us to documents and keeping us current with ongoing developments regarding the standard setting process for cleanup at Rocky Flats.

This study required considerably more resources than were available to the Rocky Mountain Peace and Justice Center for it. Given the crucial national importance of the process of setting cleanup standards for sites contaminated by nuclear weapons production, we decided to use some of the funds we raise from foundations to complement locally available resources. As a result, funds for this study were also partly drawn from grants to IEER from the John Merck Fund, Stewart R. Mott Charitable Trust, Poughshares Fund, Public Welfare Foundation, Rockefeller Financial Services, Town Creek Foundation, and Turner Foundation. General support to IEER's nuclear work is provided by the Colombe Foundation, HKH Foundation, New-Land Foundation, and Rockefeller Financial Services for general support funding, part of which was used for this report. We deeply appreciate their generous support.

Arjun Makhijani, Ph.D.
Sriram Gopal
December, 2001.

Summary and Recommendations

Contamination of vast areas of land and huge amounts of water with dangerous long-lived radioactive and non-radioactive pollutants has posed a difficult problem for the generations of people who have created them. How can we ensure the health of future generations, of land and water resources, and of ecosystems thousands of years into the future?

The scientific tools at hand are relatively rudimentary, of recent vintage, and rife with uncertainties. The costs of cleanup of contaminated areas as well as their management, notably at the sites where processing of large amounts of nuclear materials has been done, are estimated to run into the hundreds of billions of dollars in the United States alone. Ensuring the effectiveness of public expenditures in ways that are compatible with health and environmental protection for thousands of years is a daunting task.

The nature of the problem requires the utmost care in the selection of the scientific tools that will be used to assess the health of future generations both in order to ensure a sound result and to promote effective expenditures. We have reviewed various approaches to protecting the health of people from radiation both in the present as well as in the long-term from the point of view of scientific defensibility. The scientific merits of any approach must take into account the historical experience that institutional memory about contamination is prone to fade in decades even in circumstances where very dangerous materials like chemical weapons have been handled and dumped. Laws can and do change, as do norms. Assessment of the risks of particular materials and of combinations of materials has evolved. Over the decades, the trend in official studies and evaluations has been to see radioactivity as more dangerous per unit of exposure than initially believed. In general, standards for environmental protection have become more stringent and support for such protection has increased.

Standard setting processes must take these fundamental considerations into account. A failure to do so is to risk the long-term health of both people and the environment.

Principal finding

Our principal finding is that the "subsistence farmer scenario," which assumes that people will live on the land and eat locally grown food, is a scientifically sound basis on which to base cleanup standards in general and regulations for residual radioactivity in the soil in particular. This finding is independent of any interim uses for which specific sites, such as the plutonium-contaminated Rocky Flats site near Denver, may be designated. *It is not appropriate to assume that site control, institutional memory, and legal land use restrictions will prevail for hundreds of years, to say nothing of thousands of years. There is little factual basis for such assumptions and much evidence that they are unwarranted.*

Choosing residual soil action levels based on the assumption that a wildlife refuge designation will endure for generations could result in residual radioactivity levels as high as several hundred picocuries of plutonium per gram of soil. This would be an unprecedented backward step in the history of the cleanup program.

Principal recommendation

Our principal recommendation for the Rocky Flats site is that, even if the site is designated as a wildlife refuge, the standard for residual radioactivity in the soil should be set assuming that at some time in the future the site will be used by a resident farmer or rancher.

One can derive a range of residual radioactivity levels for plutonium (and associated americium-241) based on the subsistence farmer approach, depending on details about groundwater use and future evolution of regulations in relation to groundwater. Current safe drinking water rules of the EPA for plutonium, americium, and other transuranic radionuclides have been set based on four-decade-old data, ignoring more recent data and calculation methods. They are also at variance with the State of Colorado limits for plutonium content of surface water, which are 100 times more stringent than current federal safe drinking water provisions for transuranic radionuclides. Drinking water rules for transuranics that are compatible with the Colorado rule for surface water or with the federal rule for most beta emitters would result in stringent residual soil levels toward the lower end of the range we recommend to be considered.

IEER recommends that residual soil action levels between 1 and 10 picocuries per gram be considered as the basis for the cleanup program at Rocky Flats, whether or not the site is designated as a wildlife refuge. This range is consistent with the approach we recommend. Soil action levels deriving from scenarios related to designation of the site as a wildlife refuge should be rejected.

There is official precedent for choosing a residual soil action level in this range. The preliminary recommendation for a remediation goal for industrial use of the Department of Energy's Lawrence Livermore National Laboratory site is 10 picocuries of residual plutonium per gram of soil. For a residential use scenario, the goal would be 2.5 picocuries per gram.

Other findings

1. **The concept of the hypothetical maximally exposed individual has been the basis for protecting the general population from radiation released by nuclear facilities.**

The hypothetical maximally exposed individual is a person at the site boundary who would receive the highest dose from a facility's operations. This is a hypothetical person in that it does not necessarily correspond to any actual person. The basis is that if the exposure of this hypothetical person is less than the maximum allowable then the rest of the population is also protected. Unlike radiation workers, the general population does not have radiation measuring equipment or monitoring, and this necessitates a conservative and more statistical approach to radiation protection that will ensure the health of the population to a high degree. An extension of this idea in time provides a part of the scientific basis for a subsistence farmer approach to protecting future generations.

2. **The concept of the subsistence farmer scenario has evolved as the long-term equivalent of the hypothetical maximally exposed individual in situations where contamination or waste disposal activities may put future generations at risk.**

Many radionuclides as well as other pollutants are very long-lived. Their fate in the environment over such long periods is very difficult to estimate with a high degree of precision. Long-term uncertainties are great on many fronts. Lifestyles, diet, population settlement patterns, land-use regulations, climate, environmental protection standards, future assessments of the risk of pollution or contamination, and future utility of specific resources are among the important factors that contribute to these uncertainties. The choice of a framework for cleanup cannot resolve these uncertainties as to what will happen, but it can address them in a manner as to make the cleanup standards relatively robust to changes that might occur.

The subsistence farmer scenario provides a reasonable, scientifically and historically defensible framework that is robust to a large variety of future uncertainties. Local use of land and water for farming and consumption is well founded. It is conservative in that there are few assumptions about future lifestyles that will result in much greater exposures. The remaining uncertainties are then in the parameters chosen for modeling future doses, such as those related to climate and hydrology and those related to mobility of contaminants through the environment. These can be addressed with reasonable conservatism in the subsistence farmer framework.

3. The wildlife refuge scenario does not provide an adequate basis for long-term public health protection.

The designation of a site such as Rocky Flats as a wildlife refuge does not address the many fundamental issues raised by the uncertainties as regards changing land-use, changing laws, lack of institutional memory, that are among the issues that are at the heart of the use of the subsistence farmer scenario as the method of choice for long-term population protection. The phasing of cleanup and issues related to keeping people out of a contaminated site should not be confused with the central concerns that give subsistence farmer scenario a robust character as the sound scientific choice for setting cleanup standards.

4. It is not clear that the integrity of wildlife will be protected over the long-term even if the designation of the site as a refuge can be sustained indefinitely.

Emerging understanding of genome-ecosystem interactions have led to the postulation of a genetic "uncertainty principle" according to which induced genetic changes that do not produce observable deleterious effects in individuals of a species may nonetheless be harmful to the entire species over the long-term. Understanding of genome-ecosystem interactions at the molecular level is still rudimentary at best. Radiation is one of the causes of genetic mutation. Some random mutations are harmful. It is therefore not at all clear that a designation of a contaminated site as a wildlife refuge will be protective of the integrity of species over the long-term even if it there is no observable harm to individual wildlife specimens in the short-term.

Other recommendations

1. **The designation of Rocky Flats as a wildlife refuge should not serve as a precedent for other sites or for reducing cleanup expenditures at other major DOE nuclear weapons sites.**

2. **The Department of Energy should adopt the subsistence farmer scenario as the basis for the cleanup program throughout its nuclear weapons complex.**

There is a considerable amount of literature supporting the idea of wildlife refuges at the major DOE weapons sites. The use of this designation as a way of avoiding cleanup expenditures would not be protective of future generations. While it is not desirable to release contaminated areas to the public, and site restrictions of various types may be adopted to achieve this goal in the short-term, that should not become the basis for avoiding the use of the subsistence farmer scenario as the basis for cleanup goals and standards.

1. Introduction

Historically, radiation standards were set in the context of worker protection, such as medical X-ray workers, radium-dial painters, and Manhattan Project personnel. These were situations where, in principle, the dose could be measured, via film badges for instance, or inferred, from urine data, for instance. There were no separate standards for public health protection. It was not until 1959, that the ICRP and NCRP recommended a maximum exposure limit of one-tenth of the occupational level of 5 rem per year for non-worker individuals (so the individual dose would be 0.5 rem per year) and one-thirtieth of the occupational level as an average for the entire population (0.17 rem per year).[1]

The extension of radiation protection to non-worker offsite populations created the problem of measuring dose because it was generally not practical to extend the same kind of measurement protocols to off-site populations as to workers. As discussed later in this document, this led to the idea of the hypothetical maximally exposed individual. The assumption was that if the dose to such an hypothetical individual were kept below a specified limit, then one would be sure that the rest of the population would have a lower dose and hence be protected relative to whatever standard was established for maximum allowable exposure. Of course, all of this is supposed to occur in the general context that the activity that imposes the risk upon people has some beneficial purpose, in order to guard against gratuitous imposition of risk (see below).

The protection of offsite populations from operations of nuclear facilities is complex enough, but the problem of protecting people far into the future from residual contamination of soil and water is far more complicated and difficult. A number of factors enter into the picture. For instance we know the diets of people who live near the facilities today. What about people far into the future? History is no help, other than to tell us that diets and preferences change.

When considering current operations, we know where the facilities are located and the approximate distribution of the pollutants. Even so, getting data that is precise enough for accurate dose determination for compliance can be a costly and difficult business.

When considering doses to populations far into the future, we do not know how the waste and residual activity will have migrated. We do not know what new activities might take place on the site. We do not know the population levels or distribution. We do not know what resources, other than water and food will be regarded as precious by society. We do not know how weather patterns will change or whether major geophysical disruptions will occur. Conditions that exist today will not endure indefinitely. Long-term waste management and long-term stewardship arising from residual radioactivity levels present some of the most conceptually difficult challenges for health protection. For instance, a few hundred years ago it would have been essentially impossible to predict that Las Vegas, Nevada, would become a bustling metropolitan area. Similarly, a hundred years ago the Midwest was being settled by then Europeans anxious to get a lot of land for farming. It would have been difficult to foresee the depopulation that is occurring in the Dakotas, for instance, outside of American Indian

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[1] Mazuzan and Walker, 1984, pg. 259; Walker, 2000, pp. 25-26. See also IEER, 2000 for a summary of worker dose regulations.

reservations, or that many parts of the Midwest now fit the nineteenth century definition of wilderness areas because their population density is below one person per square mile.

Some basic concepts have been put forth in radiation protection to meet the challenge of protection of populations far into the future. The International Commission on Radiological Protection describes three basic concepts:

a) the justification of a practice,
b) the optimization of a practice so as to minimize exposure, and
c) the development of dose limits.[2]

The first item, justification, means that no activity, including disposal, involving radioactive materials will be undertaken unless its benefits to society outweigh any potential detriments. Optimization is the process by which exposures to individuals and entire populations should be as low as reasonably achievable. Finally, dose and risk limits should be developed before the activity takes place so that no individual is faced with unacceptable risks resulting from the use of radioactive materials.

Two methods have been suggested to meet the goals of radiation protection implicit in these concepts.[3] One is the concept of limiting population dose or risk from any facility or activity and the other is to limit individual dose or risk. For estimating the dose to populations in the vicinity of the contaminated area of a disposal site, this approach requires a large number of assumptions about future population distribution patterns and overall resources use. It is difficult to justify specific assumptions about future lifestyles in general and even more difficult to predict demographics thousands of years into the future. The examples of the difficulty of prediction that we have already cited can be easily multiplied. However, there are some areas where population dose estimates are possible and desirable. For instance, releases of carbon-14 to the atmosphere in the form of carbon dioxide has radiobiological effects in terms of dose that are have been established, since carbon dioxide becomes part of the food chain. While uncertainties will remain as to transport of carbon-14 in the atmosphere, the uptake of carbon-14 by plants, and the exact diets in the future, there is no question that the basic food constituents, such as carbohydrates, proteins, etc. will remain in the diet. All of them are affected by the presence of carbon-14 in the atmosphere.

Such an approach cannot be used with ease or accuracy to estimate future local doses. For instance, in attempting to estimate population doses and cancer fatalities as a result of the operation of a high-level waste repository, the EPA calculated future doses based on world average statistics on food and water consumption, water flow, and a future population of ten billion people that consumes water and food at a rate that is three times greater than that of the present population. Using these averages and assumptions, EPA estimates the fraction of world river flow that is used for drinking and growing food, the retention of radionuclides in soil as a result of irrigation with contaminated water, and the uptake of these radionuclides into plants and animals.[4]

This approach was criticized by the National Academy of Science (NAS) Waste Isolation Systems Panel, in its *Study of the Isolation System for the Geologic Disposal of Radioactive*

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[2] ICRP, 1977, pp. 3, 28.
[3] See for instance NAS, 1983, Chapter 8
[4] Pigford, 1981; NAS, 1983, p.221.

Waste (1983). A part of the problem with the EPA approach was that it did not couple protection of local individuals who might be living in the area of the geologic repository with the global aim of keeping cancers to below 1,000 over a period of 10,000 years. Adopting such a global goal without sublimits may have permitted local doses to be huge. This was the central theme of the criticism of the repository standard proposed by the EPA in the early 1980s:

> "Because of the problems of making any meaningful estimates of numbers, locations, and eating habits of future populations, because of the many uncertainties in EPA's derivation of release limits to achieve its objective of population risk, because of the lack of justification of the EPA 10,000 year time limit for consideration of future releases of radionuclides to the environment, and because the population-dose-based release limits can allow individual radiation exposures greater than what we consider to be reasonable, we do not adopt population dose or activity release limits as an overall performance criterion for our study."[5]

The subsistence farmer scenario evolved over a period of time as a model by which the goals of radiological protection could be met in the context of long term waste management and disposal for local populations without recourse to assumptions about local lifestyles over very long time periods. If a future subsistence farmer, who used the local water supply and ate only locally grown food, were to be protected by radiation regulations, then all other people would have a risk of cancer lower than that of the subsistence farmer– and most people's risks would be much lower. The subsistence farmer concept has historically been coupled with defining a set of individuals called the "critical group" to which we now turn.

2. The concept of the critical group and the maximally exposed individual

The concepts of the critical group and maximally exposed individual originated from discussions regarding the disposal of high-level radioactive waste. According to T.H. Pigford, who has long been involved in discussions involving radioactive waste, projects for long-term disposal of high-level radioactive waste have been planned with the following ethical goals in mind:

A. Future people, of distant times, should be given the same health protection afforded to people living near nuclear facilities today.
B. Present generations should be responsible for safely disposing of the radioactive waste that we have created.
C. Future generations should not have to take conscious action to protect themselves from the radioactivity that we have created.
D. Disposal systems should provide long-term security against weapons proliferation.[6]

The principal basis for radiation protection until recently has been to set limits on the maximum allowable exposures to individuals from man-made sources. For example, the overall individual dose limit for the general population from all man-made sources of radiation (other than medical) is 100 millirem per year. The limit for exposure due to emissions from specific facilities is generally in the range of 5 to 25 millirem per year.

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[5] NAS, 1983, pp. 230-231.
[6] Pigford, 1999.

Both the individual and population dose concepts are incorporated into current standards codified in federal regulations 40 CFR 191, which apply to all high-level waste repositories except Yucca Mountain.

The "maximally exposed individual" is a hypothetical construct, corresponding to a set of "reasonable" assumptions about human needs and activities. People who may be unusually sensitive to radiation or who have unusual habits are not used for standard setting. For example, a British inquiry omitted people who subsisted mainly on clams from its definition of the affected population because this diet was considered unusual.[7]

For the purposes of calculating radiation dose, a small, homogeneous group of individuals is used to define a "critical group." The concept goes back to at least 1977.[8] The International Commission on Radiological Protection (ICRP) defines the critical group in the following manner:

> "When an actual group cannot be defined, *a hypothetical group or representative individual* should be considered who, due to location and time, would receive the greatest dose. The habits and characteristics of the group should be based upon *present knowledge* using *cautious*, but *reasonable* assumptions. For example, the critical group could be the group of people who might live in an area near a repository and whose water would be obtained from a nearby groundwater aquifer. Because the actual doses in the entire population will constitute a distribution for which the critical group represents the extreme, this procedure is intended to ensure *that no individual doses are unacceptably high*."[9] (emphasis added)

Since an actual group can never be defined far into the future, it is generally necessary to define such a critical group in order to consider issues related to protection of local populations who may live in the area at that time. Since the critical group must be both small and homogenous, the concept essentially extends the idea of a maximally exposed individual, that is used for current operations, to people far into the future.

A description of the critical group is included in ICRP 26. This provides an explicit link between the critical group and the maximally exposed individual:

> "It is often possible to identify population groups with characteristics causing them to be exposed at a higher level than the rest of the exposed population from a given practice. The exposure of these groups, known as *critical groups*, can then be used as a measure of the upper limit of the *individual doses* resulting from the proposed practice. When several practices may contribute significantly to the exposure of the same exposed population, either simultaneously or successively,

[7] NAS, 1995, p. 171.
[8] ICRP, 1977, p. 17.
[9] ICRP, 1985, p. 9.

> the definition of critical groups must take account of these separate contributions."[10] (emphasis added)

ICRP also recommends that critical groups be small so that they are homogenous with the upper limit to size usually being "up to a few tens of persons." They could be as small as only one person.[11]

> "In an extreme case it may be convenient to define the critical group in terms of a *single hypothetical individual*, for example when dealing with conditions well in the future which cannot be characterized in detail." (emphasis added)

In this specific instance, the congruence of the critical group with a hypothetical maximally exposed individual is complete.

Institutions in countries other than the United States have also adopted the ICRP recommendations on the critical group concept. The United Kingdom's National Radiological Protection Board (NRPB) says:

> "…it is appropriate to use hypothetical critical groups. For the purposes of solid waste disposal assessments, these are assumed to exist, at any given time in the future, at the place where the relevant environmental concentrations are highest, and to have habits such that their exposure is representative of the highest exposures which might reasonably be expected."[12]

The device of a small critical group is used to represent the maximally exposed individual for regulatory purposes. In practice, the maximally exposed individual should be in the critical group. Once the exposure scenario for the maximally exposed individual is selected, then it is possible to derive secondary standards for limiting concentrations of radionuclides in air, water, and soil. These secondary standards, if adhered to, would result in compliance with the primary dose standard.

The concept of the maximally exposed individual has existed for quite some time, although over time the terminology has changed. The roots of this concept can be traced back in part to the 1958 version of the Atomic Energy Commission's *AEC Manual* chapter 0524, where it was expressed in very rudimentary form, without the use of that expression.[13] It was in this document that the AEC discussed the idea that limiting doses near sites from its operations would be expected to produce lower average individual doses in the general population. This document was updated and renamed in 1963.[14] These documents first established radiation protection standards for populations located in uncontrolled areas outside of and around nuclear sites. To limit offsite doses, the maximum allowable concentrations of radionuclides were specified at the site boundary. This concept was also implicit in other regulations that were put into effect in the late 1960s and 1970s. *Regulatory Guides* 1.3 and 1.4 do not use the term

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[10] ICRP, 1977, p. 38-39.
[11] ICRP, 1984, p. 15.
[12] NRPB, 1992, p. 12.
[13] AEC, 1958, paragraph 12.
[14] AEC, 1963.

maximally exposed individual, but their assumptions for calculating potential doses after a loss-of-coolant accident are designed to assess the maximum theoretical dose an individual could receive.[15, 16] *Regulatory Guide* (revision 1) 1.109 of 1977 explicitly uses the term "maximum exposed individual." In this document, dose estimates are given to assess the dose to the hypothetical "maximum exposed individual" in the absence of hard data.

Regulatory Guide 1.109 reads:

> "…the NRC staff has made use of the maximum exposed individual approach."
>
> "Maximum [exposed] individuals are characterized as 'maximum' with regard to food consumption, occupancy, and other usage of the region in the vicinity of the plant site and as such represent individuals with habits representing reasonable deviations from the average for the population in general." [17]

It is inherent in these definitions that these individuals' doses would be higher, possibly far higher, than those of the general population. The basic concept of this hypothetical construct clearly pre-dated these documents. For example, the Hanford environmental and evaluation staff would sum exposures from various sources "in a manner which tends to maximize the total dose."[18] This is essentially calculating the exposure that the maximally exposed individual would receive. One can use documents such as this and the ones mentioned above to create a rough lineage of the model in regulatory literature.

The concept of the maximally exposed individual, which is at the heart of current radiation protection regulations for present populations, goes back to about the early 1960s and has come into general use. For example, it is used in the implementation of the Clean Air Act. A hypothetical person living at the site boundary for 24 hours a day and 365 days a year, without any building shielding factor is specified as the basis for compliance with the maximum allowable dose of 10 millirem per year. The reasoning is that if the hypothetical individual at the site boundary gets less than the maximum allowable dose, then every other person in the population would get less than that and therefore have a risk of cancer lower than that implicit in the standard.

But even a situation that seems straightforward – that of protecting offsite populations from radiation emitted by current operations – the actual problem is often more difficult than this scenario would make it appear. Implicit in such a scenario is the assumption that the location of the maximally exposed individual does not change during the year. Yet, changes of operations, accidents, sudden releases during cleanup operations, etc. could result in higher doses at other locations. There are examples when someone walking by a facility that has low normal emissions but is having an accident or an abnormal operation might receive a greater dose than a hypothetical maximally exposed individual whose location might be elsewhere based on routine operations. Hence, in order to determine who is really at risk requires a detailed knowledge not

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[15] AEC, 1970a.
[16] AEC, 1970b.
[17] NRC, 1977, p. 1.109-1.
[18] General Electric, 1963, p. 6.

only of routine operations but also of extraordinary occurrences, possible accidents, and unanticipated events.[19]

If protecting people to pre-specified levels is difficult for the present generation, matters are far more complex and uncertain for future ones. The concept of the critical group, which is an extension of the concept of the maximally exposed individual, was created as a minimal, essential tool to assist in what might otherwise become an arbitrary exercise in wishful thinking.

3. Description of the subsistence farmer scenario

How should the critical group be defined? What are the criteria that must be used? Here also the basic thrust of historical practice has been to take a conservative, but reasonable approach that corresponds to the idea of the maximally exposed individual. We seek to define such a group at a time when we cannot know whether there may be radiation doses from other sources. Lack of knowledge in this regard has always meant that the maximum dose limit be kept well below the allowable exposure from man-made sources.

When the main route of exposure over long time periods is uncertain, it is the general practice to use the subsistence farmer scenario for calculating risk, or the level of permissible exposure. This approach assumes that a person would unknowingly use contaminated water for drinking and farming and would grow all their own food. Further, it assumes that such exposure would last a lifetime, and not just a few years. The people in the critical group spend most of their time on the contaminated site. In addition, it assumes that the diets as well as food and water intake of future populations will be similar to those of today. People are considered protected if their lifetime exposure is less than an assigned limit. The reasoning is that in such a case all other people would be protected since their doses would be lower than that of the hypothetical subsistence farmer.

The assumption that the risk of illness to all individuals within a population will be below that of the hypothetical subsistence farmer is not a prediction, of course. It is an estimate that, with some unknown, but small likelihood, may turn out to be wrong. The subsistence farmer scenario is a conservative, stringent, and practically bounding approach to calculating future regulatory dose limits. However, it should be recognized that, in general, it excludes the most extreme doses that it is possible to calculate. For instance, it is common to exclude extreme diets consisting only of the most contaminated foods. While such diets cannot be ruled out, they may reasonably be considered as improbable, unless there is some evidence to the contrary. The subsistence farmer scenario is akin to and based on the maximally exposed individual concept that we have discussed above, but for the purpose of long-term calculations.

One concept within the subsistence farmer scenario is the notion that radionuclides, once in the environment, can move up the food chain. This food chain concept was incorporated into regulations in Table 2 of 10 CFR 20, a regulation of the Atomic Energy Commission. This table, which still exists today in updated form, deals with the possible exposure of people who may live near a licensed nuclear facility and was initially a regulation of the Atomic Energy Commission, the predecessor to the Department of Energy, and still exists today (in updated form). It codifies the permissible concentration of various radionuclides in air and water based upon the allowable

[19] Makhijani and Franke, 2000, pp. 4-5

quantity of each radionuclide in the body. In preparing this table the AEC assumed that the individual continuously breathes contaminated air and only drinks contaminated water. The subsistence farmer scenario is one step beyond this one in that food is grown using the contaminated water. The one exception in 10 CFR 20 is the maximum permissible concentration for iodine-131. This regulation takes into account airborne radioiodine being deposited onto the ground and taken up by grass which cows then eat. The iodine is then concentrated in cow's milk and consumed by an infant.[20]

Much of the development of the subsistence farmer scenario was done by Bruce Napier and William Kennedy at the Hanford Pacific Northwest Laboratory in the 1980s. The early version of this model was known as the "backyard farmer" scenario.[21] In their analysis of allowable residual contamination levels (ARCL) at Hanford, they assumed that restricted use of the site for 100 years, controlled use for another 300, and unrestricted use of the facilities afterward. All of their assumptions are based on the ingestion characteristics of the " standard Hanford maximally-exposed individual," a construct that fits the description of the average adult male.[22] For unrestricted use, they assumed that an individual would have "free access to any remaining facilities or radionuclides on the site."[23]

> "…for the far-term scenario, it may be assumed that people will eventually move onto the waste site. This is not intended to imply that future populations are unintelligent or technologically inferior, but only that records of the waste sites are forgotten or ignored."[24]

This individual is "assumed to raise a large fraction of his own fruits and vegetables for personal consumption."[25] Calculations were carried out to determine doses at ten kilometers from the site, one kilometer from the site, and on-site. It was assumed that the individual would live downwind and downstream from the site. Because doses were found to be much smaller offsite than on, the onsite exposure scenarios were deemed the most critical.[26]

By the late 1980s, this model had been refined even further into three different scenarios.[27] These are the resource-recycle scenario, the residential/home-garden scenario, and the agriculture scenario. The resource-recycle scenario bases its assumptions on an individual who recycles materials that were salvaged at a destroyed facility after institutional controls are lost.

The home-garden scenario is based on an individual who resides on-site and operates a home garden for 50 years. This person constructs a basement where the greatest contamination associated with a facility would occur. It is assumed that this person spends twelve hours per day outside where s/he is exposed to radiation from the soil and can inhale resuspended

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[20] Pigford, 2001.
[21] Napier, 2001.
[22] Napier, 1982, p. 34; Kennedy and Napier, 1985, p.155.
[23] Kennedy and Napier, 1985, pg.155.
[24] Kennedy, Napier, and Soldat, 1983, p. 106.
[25] Napier, 1982, p. 34.
[26] Kennedy, Napier, and Soldat, 1983 p. 106.
[27] Napier, *et al.*, 1988. p. 2.3-2.7.

contamination from the soil surface. Also, twenty-five percent of the individual's fruit and vegetable intake is assumed to come from a backyard garden that is located on contaminated soil.

The agricultural scenario, a slight variation of the home-garden scenario, was designed to assess exposure resulting from eating agricultural products whose roots come into contact with buried radioactive materials.[28] In common with the home-garden scenario, Napier, *et al.* assume that only twenty-five percent of the diet would be from food grown on-site. While the home-garden model is only designed for one person, the agriculture system assumes that a family of four would get twenty-five percent of its total fruit and vegetable supply from the land. As a result, it is assumed that the land would be 0.1 to 1 hectare in size. It is assumed that 50 square meters would be used for above ground vegetables, 200 square meters would be used for root vegetables and grains, and slightly more than 200 square meters would be used for fruit trees. Homegrown animal products are not included in this scenario because it is assumed that one hectare of land would not be enough to grow animals as well as crops.

These scenarios were eventually adopted as official protocol for the Hanford site.[29] This is apparent in DOE's 1987 *Final Environmental Impact Statement*: *Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes*. In appendix R, a description is given of a "full garden scenario" that is very similar to the agricultural scenario described above, the only difference being that it assumes a small two hectare farm instead of the smaller ones described above.[30] While none of the scenarios described here is exactly like the subsistence farmer model, the DOE's official analysis has been along the lines of a subsistence-farmer-like model for quite sometime.

As another example, the Yucca Mountain Project has, in the past, based estimated future doses on subsistence farmers using computer modeling in the biosphere scenario.[31] The U.S. Nuclear Regulatory Commission (NRC) has also performed calculations to assess the risk of exposure to future populations due to geologic disposal at Yucca Mountain. In its calculations, the NRC has used a hypothetical self-sufficient farm family of three who obtain all of their water from a contaminated well. This same water is used to grow the family's crops, and their meat and milk is obtained from farm animals raised on vegetation that is irrigated by it.[32] The NRC also did not restrict the location of the critical group to currently populated areas, but it is assumed to live at the boundary of the controlled area.[33] This is consistent with ICRP 43 recommendations for calculating doses from major sources because the recommendations do not specify occupancy parameters. They only state that the chosen parameters be "appropriate."[34]

Other projects that have used the subsistence farmer scenario or variants thereof include the Waste Isolation Pilot Plant (WIPP) and Sandia National Laboratories.[35] The WIPP project was

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[28] Napier, *et al.,* 1988, pp. 2.6 to 2.8.
[29] Napier, 2001.
[30] DOE, 1987, Appendices F (vol. 2) and R (vol. 3)
[31] EPA, 2000. The biosphere scenario is an exposure calculation that translates concentrations of radionuclides in environmental media to estimates of dose and risk to future populations, pp. 8-49 to 8-52.
[32] NRC, 1995, pp. 7-8, 7-10; Napier, *et al.,* 1988
[33] NRC, 1995, p. 7-10.
[34] ICRP, 1984, p. 15
[35] Sandia, 1995, Chapter 14; Pigford, 2001.

formed to dispose of transuranic waste in bedded salt, while Sandia ran an evaluation of spent fuel in a tuff repository. The Hanford repository program uses the subsistence farmer approach to calculate exposure when the locations and other traits of exposed individuals are unknown. So, a strong precedent has been set for the use of the subsistence farmer scenario when the location and lifestyles of the exposed population are unknown. Finally, in regulatory terms, the EPA in establishing Superfund regulations has used the subsistence farmer scenario.[36]

4. International use of the subsistence farmer approach

There is a considerable international consensus about the subsistence farmer approach, which has been used in Britain, Sweden, Finland, and other countries.[37] In Switzerland, the critical group is defined as a self-sustaining agricultural community that obtains no food and water from outside sources and is located in the area of highest potential concentration.[38] This concept includes estimates of doses from the food chain (i.e. through crops, cow's milk, etc.)[39]

The British National Radiological Protection Board (NRPB) uses similar language to define the critical group. They state the critical group (they replace the term critical group with "reference community") should be defined as "'typical' subsistence farmers, i.e., perhaps a few families who produce a range of food to feed themselves."[40]

The Finnish government defines their critical group as a:

> "…small self-sustaining community in the vicinity of the disposal site. They are assumed to be exposed e.g. through abstracting water from a shallow well for drinking water or for irrigation of plants, or through catching fish from a small lake."[41]

The International Atomic Energy Agency writes that:

> "…there may also be benefits to be gained from choosing one particular biosphere/critical group combination as an international benchmark. This should be selected in such a way that the calculated doses and risks would be representative of the highest likely to be received in the future. An example of one such possibility, a northern temperate inland biosphere with a hypothetical reference critical group of subsistence farmers …"[42]

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[36] Federal Register, 1998. See also EPA, 1989. Superfund regulations do not address very long periods of time and are oriented to allowing re-use of sites. They are therefore different in intent than regulations specifically created for long-term health protection. Superfund exceptions from the subsistence farmer approach allowing for industrial "brownfields" use do not address long-term health impacts or site use issues, which is the subject of the present report.
[37] NRPB, 1992, p.14; Charles and Smith, 1991, pp. 6 to 8; Ruokola, 1998, p.40.
[38] Switzerland, 1985; NAS, 1995, p. 164.
[39] Switzerland, 1985, chapter 12.
[40] NRPB, 1992, p. 14.
[41] Ruokola, 1998, p. 40.
[42] IAEA, 1999, p. 7

Norway used several different scenarios, all of which have some similarities to the subsistence farmer scenario to estimate dose calculations for areas around their proposed site for low and medium level waste at Himalden. Calculations were done for five scenarios that included the four critical groups of:

1. Smallholder farming community located close to the facility by a stream.
2. Smallholder farming community located by a river downstream of the facility.
3. Hunter-gatherers consuming wild game from the area around a lake near the facility.
4. Fishermen consuming fish caught in that same lake.[43]

The Finnish example shows clearly that there is some flexibility in determining what specific scenario should be used depending on local custom and diet. But in all cases, the scenarios are constructed with the idea that a plausible maximum dose should be estimated based on a model akin to the subsistence farmer. The fisherman and hunter-gatherer models are really local variants of the subsistence farmer model and the Arctic climate makes such scenarios plausible. Similarly, the Risk Assessment Corporation used a subsistence rancher scenario as a reasonable local variant of the subsistence farmer scenario in assessing Rocky Flats radionuclide soil action levels (RSALs).[44] These are the residual levels of radionuclides that would remain in the soil after it has been declared cleaned up by the DOE.

One reason for the international acceptance of the subsistence farmer scenario is that it complies with the recommendations made by the International Commission on Radiological Protection for exposure, risk estimation procedure, and definition of the critical group. ICRP 46 and 43 both recommend calculating the average dose from a repository to a homogeneous group that is expected to receive the highest dose equivalent.

ICRP 43 reads:

"It is clearly stated by the Commission … that the dose-equivalent limits are intended to apply to the mean dose equivalent in a reasonably homogeneous group. In an extreme case it may be convenient to define the critical group in terms of a single hypothetical individual, for example when dealing with conditions well in the future which cannot be characterized in detail."

ICRP 46 reads:

"Because the actual doses in the entire population will constitute a distribution for which the critical group represents the extreme, this procedure is intended to ensure that no individual doses are unacceptably high." [45]

The subsistence farmer scenario used by other countries where a small community is defined as the critical group meets these criteria. However, it is also valid for institutions to use a single subsistence farmer as their critical group because ICRP recommendations state that "it may be convenient to define the critical group in terms of a single hypothetical individual, for example when dealing with conditions well in the future."[46] The term "well in the future" is especially applicable in cases such as Rocky Flats or waste repositories because of the long time-frame at issue.

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[43] Sörlie, 1998, p.61.
[44] RAC, 2000, pp. 25 to 27.
[45] ICRP, 1984 p. 3,4,15; ICRP, 1985 p. 9.
[46] ICRP, 1984 p. 15.

The subsistence farmer also meets several other criteria that have been recommended by ICRP. First, the diet, habits, and dose response of the farmer "should be based on present knowledge using cautious, but reasonable, assumptions."[47] It is both cautious and reasonable to assume that such a subsistence lifestyle could be viable in the future. It is neither cautious nor reasonable to assume that institutional restraints preventing use of the property as farmland will be effective for thousands of years. Historical examples ranging from house construction on dumps containing radioactive materials and chemical munitions within the space of decades provide ample reason to base future long-term health protection on an approach that does not assume prolonged institutional memory or controls. The subsistence farmer scenario provides such an approach and is therefore supported by both scientific and historical considerations.

Finally, the subsistence farmer represents the upper bound of exposure and the extreme of the actual doses in the entire population. ICRP 46 states that "the critical group represents the extreme" and "is intended to ensure that no individual doses are extremely high."[48] It has already been argued that the subsistence farmer meets the definition of a critical group. But, the language here shows that it is acceptable to protect this hypothetical individual in order to ensure that no other individual doses are unacceptably high.

One argument against this model is that it is too stringent for proposed geologic disposal sites such as Yucca Mountain or nuclear facilities such as Rocky Flats. However, this argument against the subsistence farmer scenario is weak and may be mathematically unsound (see discussion below). Because the behavior of future people is unknown, using a bounding approach, an approach that maximizes the number of people that would be protected, will limit the number of arbitrary assumptions that can be made to change estimated doses and possibly put future generations at risk. Also, in relation to Yucca Mountain, it has been shown that the repository design adopted by the DOE would in future time exceed established performance limits. This does not mean that the subsistence farmer scenario is too stringent but rather that the repository design is weak. Rather than adopting less stringent regulations, the DOE should improve its designs in order to avoid unacceptably high doses.

5. Reasonableness of the subsistence farmer scenario on occupational grounds

Today the term subsistence farmer often connotes a poor person scratching out a meager living from the soil. But this is not the assumption in radiation protection regulations. They assume that a subsistence farmer will eat a good diet, which will be locally grown with local water supply. It is not at all fanciful to consider a future where people might choose to grow most of their own food and, thanks to advanced technology, be able to do so very efficiently and in a sustainable way. Such individuals may even be able to devote most of their time to other pursuits and might be economically well off even by today's U.S. standards. Yet they would fit the radiological description of a subsistence farmer scenario. The term "subsistence farmer" is a rather unfortunate one in that it usually connotes a poor person. A "self-sufficient" farmer might be more appropriate to describe the hypothetical person created by radiation protection regulations.

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[47] ICRP, 1985 p. 9.
[48] ICRP, 1985 p. 9.

It is not at all implausible that there may be significant numbers of people in the future who would choose to be self-sufficient farmers or something close to it, even in the context of rapid urbanization of populations. In fact, the adoption of lifestyles closer to the land is a trend that has emerged in reaction to the increasing distance from the production and reproduction of our own existence that characterizes modern lifestyles. It is not necessary for a majority or even a substantial minority to adopt a self-sufficient farmer lifestyle for it to be germane to future health protection. It should only be a *plausible* lifestyle for some people based on what we know of society today. Indeed, it is quite possible to imagine economic, social, and technological arrangements under which a large proportion of the population of the future would grow most of their own food or obtain it very locally.

Some recent trends point in the direction of preference for local food and reinforce the arguments for adopting the subsistence farmer scenario. There has been a boom in the demand for organic food and the large numbers of people who are willing to work long hours, days, and years as organic farmers to meet that demand. The markets for such very local products now amount to billions of dollars per year in the United States alone. This means that the numbers of people who may consume the kind of diet assumed in the subsistence farmer scenario could be far larger than a small local community living on contaminated land. While this larger population would not have direct gamma radiation doses from contaminated land, and may not have the same drinking water doses as the subsistence farmer, they may have a similar dietary dose. There are many circumstances in which the dietary component dominates the dose. Such considerations mean that the dose calculated for some of the people who are not part of the critical group may not be significantly lower than that of the subsistence farmer. This is another important reason for using the subsistence farmer scenario as the basis for a clean up standard. It is important therefore to not only use the subsistence farmer scenario as the basis for protecting future populations, but to set a stringent standard limiting risk to protect against the possibility of large population doses due to lifestyle changes that are foreseeable based on many people's preferences today.

In addition to being a reasonable scenario in general, it is also important to underscore the point that this is reasonable for the Rocky Flats site. Because the Denver-Boulder corridor is one of the fastest growing areas in the country, there is a great deal of pressure to develop open spaces. There are farms, businesses, and homes located just up to the boundary of the site. The reasons given for declaring Rocky Flats a wildlife refuge include preserving open space and limiting the costs of cleanup.[49]

However, declaring the site a refuge and limiting short-term expenditures should not be confused with long-term public health protection and clean up standards for the site. If a law can create a wildlife refuge out of a plutonium contaminated site in a few months time, a reversal of such a decision can also be made. The pressures of development makes such a reversal plausible, if not likely. Further, preserving open space is not at variance with the adoption of a subsistence farmer scenario. Indeed, such a scenario would not only be more protective of human health, it would also be more conducive for the same reasons in protecting the integrity of any wildlife on the site, should the area be designated as a refuge. The idea that leaving a place highly contaminated by human occupation standards would preserve the space for wildlife, such as the endangered Prebles Jumping Mouse, begs the question of what such contamination could do to

[49] Udall and Allard, 2001.

the long term health of the wildlife that is sought to be preserved. Finally, protection of the health of future generations should not be based on the budgetary convenience of the moment but on sound scientific arguments that take the context of clean up decisions into account. In other words, a soil standard should be set according to stringent public health standards that are independent of current and short-term designations of site use since the basic concept of a standard should be long-term public health protection.

6. Relation of the subsistence farmer scenario to Radionuclide Soil Action Levels (RSALs) at Rocky Flats

Health risks to people living near a site that has been decommissioned may arise from a number of different sources, such as:

- Direct gamma radiation from residual radionuclides, and in some cases also neutron and beta radiation
- drinking contaminated water
- eating food grown using contaminated water for irrigation
- eating contaminated soil or ingesting it during periods when the air is dusty or via food
- breathing air containing contaminated soil that has re-suspended due to high winds
- breathing contaminants entering the air during fires
- exposure *in utero* via the mother's diet

These sources of risk are not static or independent. One of the most important sources of the evaluation of total risk and the distribution of doses via specific pathways is the residual contamination in the soil. For instance, the contamination in the soil acts as a reservoir for potential contamination of water that would be used for drinking or irrigation. As another example, the amount of radioactivity that is present in the air during periods of heavy wind, such as those that occur commonly at Rocky Flats, depends directly on the residual soil contamination, as does uptake of radioactivity by plants. Both of course, depend on other factors as well.

These points were illustrated by the Risk Assessment Corporation (RAC) in their analysis of RSALs at Rocky Flats. Their conclusions were that the most important exposure pathway at Rocky Flats was the inhalation of contaminated soil that had been resuspended by gusts of wind.[50] In addition, their recommended RSAL of 35 pCi/g does not assume a 100% probability of a large grass fire that would enhance the resuspension of contaminated soil. If this were the case, the RSAL would be even lower than 35 pCi/g.[51] This analysis also admits shortcomings in its investigation into the groundwater exposure pathway.[52]

Because of the crucial connection of residual soil contamination to a number of dose pathways, the residual concentration of long-lived radionuclides in the soil is a parameter of central importance in assessing the efficacy of clean up in protecting future populations. A number of radionuclides, such as tritium and strontium-90 are known to migrate rapidly through the soil. It

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[50] RAC, 2000, p. 25.
[51] RAC, 2000, pp. 30-32.
[52] RAC, 2000, p. 34.

had been the conviction of the DOE and its contractors for several decades that plutonium would not migrate rapidly through the soil. However, evidence has been accumulating for over two decades that, under a variety of conditions, the ion-exchange property of the soil that would bind plutonium and greatly retard its migration is overwhelmed by countervailing phenomena: migration of plutonium in colloidal form, the mobilization of plutonium by natural organic materials in the soil and spilled or dumped solvents, and complexing of plutonium with compounds present in the soil.[53]

For instance, experience at Oak Ridge has shown that organic materials in the soil can mobilize plutonium by forming complexes with it causing rapid movement through the soil and into groundwater. The rate of plutonium migration under such conditions was estimated in an Oak Ridge National Laboratory report to be 100 to 1,000 times faster "than predicted from batch adsorption studies in the literature."[54]

Assumptions in the early years that insoluble forms of plutonium would remain that way in the environment for long periods of time or remain bound by ion exchange in the soil for hundreds of thousands of years are being shown to be contrary to actual experience under a variety of circumstances. One fundamental reason is that the chemistry of plutonium is extremely complex. According to a Los Alamos scientific evaluation of the properties of plutonium, "[n]o other element displays such a complex chemistry."[55]

Specifically, the Los Alamos paper describes, among other things, the behavior of plutonium in oxidation state IV, which is the oxidation state of plutonium dioxide. This is the most insoluble form of plutonium and it is also the form that has been found at Rocky Flats Pad 903.[56] But insolubility does not guarantee that plutonium will remain relatively immobile, an assumption that has been made in evaluations of Rocky Flats.
Insoluble plutonium can be mobilized and can move rapidly through the vadose zone into groundwater in colloidal form. This has been found not only at the Nevada Test Site as noted above, but has been noted to be a specific property of plutonium in the IV valence state found at Rocky Flats. According to the Los Alamos study:

> "In oxidation state IV, plutonium strongly hydrolyzes (reacts with water), often to form light green "sols," or colloidal solids that behave much like a solution. These intrinsic colloids eventually age, and the solubility decreases over time. These intrinsic colloids can also attach themselves to natural mineral colloids that have important consequences for the migration of plutonium in the natural environment."[57]

A growing body of careful research shows that the migration of plutonium in the environment is dependent not only on the oxidation state of plutonium but on the environmental conditions in

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[53] For instance Kersting *et al*., 1999, p. 58 and p. 59 have shown that plutonium has migrated in colloidal form at the Nevada Test Site from one of the test locations at a rate orders of magnitude faster than ion-exchange and other solute-solid interactions would lead one to expect. See below.
[54] ORNL, 1996, p. 4-20. See also Fioravanti and Makhijani, 1997, pp. 121-124, for a discussion.
[55] Clark, 2000, p. 364.
[56] RAC, 1999b, p. 9.
[57] Clark, 2000, p. 373.

which that oxidation state is present. A changing environment will change the potential for plutonium mobility. .

Even if almost all the plutonium were to be in this insoluble form today, there is no guarantee that it will remain so in the future. Complexing with carbonate ions, for instance, can mobilize plutonium. Use of Rocky Flats as a wildlife preserve may considerably increase the amount of vegetable, animal, and related organic matter over the decades at Rocky Flats, creating new and unforeseen mechanisms for complexing and mobilization of plutonium. Natural organic matter has been known to mobilize plutonium at least one DOE site (Oak Ridge).[58] Hence if the site is first used as a wildlife refuge and then as a residential site, a ranch or a farm, the potential for harm may actually increase in comparison to a cleanup of the soil to a level corresponding to a subsistence rancher or farmer scenario.

Further evidence explaining the rapid migration of plutonium in groundwater is illustrated by the work of Haschke, Allen, and Morales.[59] Their experiments have shown that the water-catalyzed oxidation of plutonium dioxide (PuO_2) in air yields PuO_{2+x} in which plutonium is in its Pu(VI) valence state and therefore in a soluble form. The increase in solubility would increase mobility in groundwater. This might further explain the rapid migration of plutonium (1.3 km in 30 years) described by Kersting, *et al.*

The current contamination of groundwater at Rocky Flats with americium-241 and plutonium-239/240 is generally regarded as minimal. For instance, the reported maximum contamination levels in the fall of 2000 were 0.0354 and .0193 picocuries per liter respectively.[60] On an annual basis, these concentrations would result in doses of 1.7 and 0.9 millirem per year from drinking water alone, using EPA Federal Guidance Report 11 dose conversion factors.[61] These add up to 2.6 mrem per year, or more than half of the drinking water limit of 4 mrem per year set for beta emitters.[62] A two-fold increase would result in the drinking water dose exceeding 4 mrem per year. A six-fold increase in transuranic contamination would result in a drinking water dose exceeding the 15 mrem per year limit used by RAC for its calculations.

For a 500 pCi per gram of soil residual plutonium level, plus the associated americium-241 of about 55 pCi per gram of soil, RAC analysis estimated a water pathway dose of 88 mrem/year, mainly from drinking water.[63] For the 35 pCi/gram suggested as the plutonium RSAL by RAC, the dose would be about 6 mrem/year, which is in considerably excess of the safe drinking water limit for most beta emitters. (See footnote 62.) . The RSAL based on a 4 mrem per year dose limit to the bone surface corresponding to this calculation would be about 1.2 pCi/gram, or about 30 times lower than that recommended by the RAC team.. While this is not the current way that

[58] ORNL, 1996, pp. 4-20 and 4-21. See also discussion in Fioravanti and Makhijani, 1997, pp. 121-124.
[59] Haschke, Allen, and Morales, 2000.
[60] Kaiser-Hill, 2001, Appendix A, table on radionuclides.
[61] EPA, 1988, Table 2.2.
[62] The Safe Drinking Water standard (40 CFR 141) of 15 picocuries per liter for alpha emitting transuranics like plutonium-238, plutonium-239, or americium-241 does not follow a 4 mrem per year dose limit. For reasons that are unclear, it allows doses on the order of a hundred times higher than the 4 millirem annual limit to the critical organ specified for most beta emitters. The RAC dose is a whole body effective dose equivalent. The individual organ dose to the critical organ, in this case the bone surface, would be about 20 times bigger.
[63] RAC, 1999b, p. 14. The dose is mainly from americium-241 associated with the plutonium contamination since a very low solubility was attributed to plutonium.

safe drinking water limits are defined, it is a reasonable to assume that limits for alpha emitters, which are today set according to dose estimation procedures that are 40 years old, will, in the future, be brought into line with the methods now used in all other regulations, or even more current methods.[64]

The RAC analysis used a low solubility assumption for plutonium and did not account for colloidal transport, which is the subject of ongoing investigations, which it cited. (Most of the RAC water dose is from the residual americium-241.) These calculations assume low plutonium mobility. RAC did recognize that plutonium may become more mobile than it assumed, but the complexity of the problem, the ongoing nature of the debate on plutonium migration, and the limited scope of the project that RAC undertook meant that a more sophisticated groundwater calculation was not done.[65] The RAC assumption about plutonium mobility was based on analyses of the present chemical form of plutonium in the 903-pad soil at Rocky Flats.[66] Corresponding to these assumptions, RAC concluded that plutonium would probably not reach groundwater within the calculation period of 1000 years and, hence, that plutonium would not be likely to contribute to the peak dose via the groundwater pathway. Only americium-241 would contribute to the groundwater dose.[67]

The assumption of low plutonium mobility cannot be supported for the long-term in the absence of a more detailed environmental analysis, as the RAC team recognized. The analysis above regarding the complexity of plutonium migration under real-world conditions in the natural environment indicates that the possibility that water pathway doses could be an order of magnitude or more greater in the long-term than estimated by RAC cannot be and should not be ruled out. Indeed, that possibility could be enhanced by the designation of Rocky Flats as a wildlife refuge. Yet no study to date has addressed the potential synergism between such a designation and the long-term water pathway dose.

This analysis of the water pathway dose indicates the crucial importance of using the subsistence farmer scenario as the basis for protection of future populations. It is unrealistic to assume that site control and specific current site uses will endure for long periods of time. The evolution of the contamination over time could result in far greater threats to future populations than if a thorough cleanup were carried out in the first place corresponding to a subsistence farmer scenario.

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[64]Federal Guidance Report No. 13 of the EPA (EPA, 1999) incorporates more recent scientific methods. The methods are not directly comparable. On approximate basis, an RSAL based on these methods would be about 3 picocuries of plutonium per gram of soil.

[65] RAC, 1999b, pp. 14 to 16.

[66] RAC, 1999b, p. 9. Note that RAC used the dose conversion factors from ICRP 70, while the calculations relating to the clean water act done using Federal Guidance Report No. 11 (EPA, 1988) imply dose conversion factors from ICRP Publication 30 (ICRP, 1979, *etc.*). We have used the latter, older factors, since they are still the basis of US regulations. The qualitative conclusions are unaffected by the change, however.

[67] See RAC, 1999b, pp. 12 and 14, where the parameters of migration of plutonium and americium on which RAC based these tentative conclusions are discussed. See also RAC, 1999c, p. 27.

7. Erosion of the subsistence farmer scenario[68]

An official recommendation to do away with the subsistence farmer scenario as the basis for public health protection first appeared in the *Technical Bases for Yucca Mountain Standards*. This report was prepared by an *ad hoc* committee of the National Research Council, the research arm of the National Academy of Sciences (NAS). That National Research Council (NAS-NRC) committee on Yucca Mountain standards, chaired by Robert Fri of Resources for the Future, recommended that the concept of establishing secondary measurable standards limiting releases of radionuclides from a repository be abandoned. In fact, the NAS-NRC committee is explicit that it does not include the current goal of protecting groundwater as a resource in its recommendations. The report states that the EPA regulation for high-level waste disposal,

> "40 CFR 191 includes a provision to protect ground water from contamination with radioactive materials that is separate from the 40 CFR 191 individual-dose limits. These provisions have been added to 40 CFR 191 to bring it into conformity with the Safe Water Drinking Act, and have the goal of protecting ground water as a resource. We make no such recommendation, and have based our recommendations on those requirements necessary to limit risks to individuals."[69]

The NAS-NRC committee recommended instead that the risk to a critical group be limited. It also recommended that this group would be defined in a new way. Professor Thomas H. Pigford (Emeritus, Nuclear Engineering, University of California, Berkeley), who was a member of that committee, disagreed and wrote a dissent.

If the recommendation of the majority were to be followed, there would be no explicit limits to the contamination of groundwater as such. It would be legally permissible for water to become highly contaminated, depending largely on the way the critical group was selected. The consequent radiation doses to some of the people using contaminated water could be very high.

The possibility of very high radiation doses, far above allowable limits, from consumption and agricultural use of water contaminated by a high-level waste repository at Yucca Mountain is real. Since water is scarce in the area, there is only a relatively small volume available (compared to other repository locations) to dilute leaking radionuclides.[70] The 1983 NAS study estimated that peak doses could range from a low on the order of one rem (perhaps less) to about 1,000 rem per year depending on the assumptions about the behavior of the waste and water travel time.[71] Subsequent studies by INTERA (1993) and Sandia (1994) lowered estimated peak doses at 30 and 20 rem per year, respectively.[72]

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[68] This section is an adaptation of a review of the 1995 NAS report by Arjun Makhijani entitled "Calculating Doses from Disposal of High-Level Radioactive Waste," *Science for Democratic Action*, vol. 4, no. 4, Fall 1995. It also draws on the dissent of Thomas H. Pigford from NAS, 1995 and his guest editorial entitled "The Yucca Mountain Standard: Proposals for Leniency," *Science for Democratic Action*, vol. 6, no. 1, May 1997.

[69] NAS, 1995, p. 121.

[70] NAS, 1995, pp. 27, 28.

[71] NAS, 1983, pp. 264, 278.

[72] Sandia, 1994; INTERA, 1993.

The controversy surrounding the proposed Yucca Mountain standards is illustrated by the disagreement between the NAS committee and its lone dissenter, Professor Pigford, . The questions that are at the center of this disagreement include the following:

1. Could the NAS committee's recommendation of limiting risk to individuals be compatible with allowing high doses of radiation to maximally exposed individuals, and in particular to subsistence farmers?
2. Are the committee majority's recommendations in conformity with those of the ICRP?

Insight into these questions can be gained through the analysis of Appendix C of the NAS-NRC report. Here, the majority outlines its eight-step process of determining the exposure of the critical group. The fundamental difference between this protocol and those that preceded it is that it defines the exposure limit for the critical group based on calculated risk from exposure rather than calculated dose. That is, it is recommended by the majority of the panel that dose calculations be made on the basis of hypothesized probabilistic distribution of future populations.

1. *Identify the population which contains the people at risk of getting the highest doses.* The example adopted by the committee is a farming community in the Amorgosa Valley. However, the term "farming community" could include many occupations, not just subsistence farmers. It could be a large, inhomogeneous group, which would be incompatible with ICRP's recommendation for a critical group, or a small, homogeneous group. For instance, it may consist of farmers, casino operators, and defense workers or it may have farmers only. These farmers may or may not be subsistence farmers.[73]
2. *Quantify the demographic and geographical characteristics of the population so as to determine what areas in the region "have the potential for farming and groundwater use." If possible, limit the area for exposure analysis by excluding some areas, such as those not likely to be farmed or where groundwater might be too deep.* On this basis, the area and groundwater in the immediate vicinity of the Yucca Mountain repository could be excluded from the calculations.
3. *Identify the intersections of those areas that might be farmed and those beneath which radioactively contaminated water would be present at some time.*
4. *Model the release of radionuclides from the repository and take into account that the plume of contamination passes through various areas at different times, limiting exposure in this way. Model various possible ways in which the contaminated plume of groundwater might travel (these are called "plume realizations"). People living in such areas before the plume is directly under them will be "at no risk" during these periods.*
5. *Calculate doses for a large variety of possible conditions and times, sampling from among the various plume realizations.* This step acknowledges, in contradiction to the one just above, that people "outside the area overlying the plume" could be exposed due to local export of water or food."
6. *Calculate the times at which the groundwater under various exposed populations would be most contaminated.*
7. *Divide the results of each plume realization into geographical subareas in which doses are to be arithmetically averaged. The population of each subarea should be large enough to "allow computation of a meaningful average dose." Then define a "critical subgroup" consisting of all subareas with average risks within a factor of ten of the "maximum*

[73] NAS, 1995, page 145.

average" subarea risk. The term "meaningful average" is not defined. This requirement could, in some cases, conflict with the ICRP recommendation that the critical group be small.

8. *Average the average doses for the critical subgroups in Step 7 for each plume realization.* This final average of averages is defined by the committee majority to be the "technically appropriate representation for the critical group risk."

The report implies that this new method is consistent with the ICRP's recommendations for the selection of a critical group, except that the committee uses risk in place of dose. The committee's definition of the critical group is very similar to that of the ICRP.

> "The critical group for risk should be representative of those individuals in the population who, based on cautious, but reasonable, assumptions, have the highest risk resulting from repository releases. The group should be small enough to be relatively homogenous with respect to diet and other aspects of behavior that affect risks."[74]

This definition is close to that of the ICRP except that it does not explicitly define the term "small."

Professor Pigford's dissent is given in Appendix E of the 1995 NAS report and his central arguments are that the majority's opinion is not consistent with ICRP recommendations, the majority's methodology for calculating exposure is not valid, and the standards would be too arbitrary and lenient. He argues that the committee majority abandoned the subsistence farmer scenario that is the most sure and most conservative method for protecting all future populations. This scenario is in conformity with the recommendations of the ICRP and is also consistent with the regulatory procedures of other countries and agencies within the United States itself. In addition, the probabilistic critical group approach recommended by the majority is "demonstrably less stringent in protecting public health than the subsistence farmer approach."[75] The example of the farming community in the Amorgosa Valley would contain part-time farmers, but the "full-time subsistence farmer will <u>not</u> be found on that distribution." (emphasis in original)[76] Therefore, this recommendation would not be in conformity with ICRP recommendations. Pigford also argues that the method is subject to manipulation because it allows for the arbitrary choices of parameters such as population characteristics and sizes of subareas. Such choices could lower the calculated doses that would provide "an illusion of safety, but with a serious loss of credibility."[77]

A major argument against the probabilistic critical group method as developed in the 1995 NAS report is that it is not mathematically valid. Pigford's claim is that the procedures set forth in Appendix C of the NAS report do not result in a critical group that corresponds to a critical group as defined by the ICRP. This is because step 7 of the calculation process divides the region into subareas where there is no necessity for homogeneity within the subarea. This means that doses to individuals within the subarea can be very different and a few individuals with high doses could be averaged with a large number of individuals with low doses. This

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[74] NAS, 1995, p. 53.
[75] NAS, 1995, p. 182.
[76] NAS, 1995, p. 168
[77] NAS 1995, p. 179.

would result in a low average dose to the entire area. These same inconsistencies were noted by Professor Peter Bickel in a letter to Dr. Bruce Alberts, President of the National Academy of Sciences. Professor Bickel noted that the procedure recommended by the majority "could be made arbitrarily discrepant – five times could be turned into 5000 times and more."[78]

ICRP recommendations require that the individuals with the highest dose be part of the critical group. In the probabilistic method, the averaging process over a subarea could result in the highest exposed individuals being in a subarea that has a low average dose. This could result in their exclusion from the critical group defined in step 8 of Appendix C because there may be many subareas with a higher average dose but that do not include the individuals with the highest dose.

EPA stated in its Background Information Document for Yucca Mountain that it did not accept the approach outlined in Appendix C of the NAS report.[79] It instead decided to use a scenario more along the lines of the subsistence farmer scenario outlined in Appendix D of the report. However in the final standards for Yucca Mountain, a vicinity-average dose has been introduced, which has the effect of introducing leniency into the calculation. According to the EPA rule water under Federal lands is exempt from safe drinking water rules, creating an unprecedented loophole for similar future exemptions. This extends to about 18 kilometers from the repository location. Drinking water and other doses are to be calculated outside this perimeter. Considerable dilution can be expected over such a distance and this would reduce the calculated vicinity average dose.

Another reason to adopt the subsistence farmer scenario is that it has been shown that the uncertainties associated with the subsistence farmer dose decrease over time.[80] This introduced leniency coupled with the decrease in dose uncertainties may lead to doses that are unacceptably high.

A proposal similar to the NAS-NRC majority has been put forth by the Electric Power Research Institute (EPRI). This is the vicinity-average dose model.[81] However, in this case there is no averaging of averages. Rather, the model converts "the results from calculations for a maximally exposed individual into an estimate of risk to an *average* individual in a *local population group*."[82] This method establishes a standard by calculating an average dose to a future population in the general vicinity of a geologic repository and allowing that average dose to be as large or larger than current exposure limits.[83] This would undermine the concept of the reasonably maximally exposed individual in much the same way that the NAS-NRC panel's plan does. The average dose may meet standards but there still exists a possibility that a small subset of the population could be exposed to very high doses while the remainder is exposed to very small ones. This would violate some of the basic tenets of radiological protection. The EPRI

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[78] Bickel, 1996. Dr. Alberts in turn reiterated the NAS-NRC majority position. Alberts, 1996.
[79] EPA, 2000, pp. 8-49 to 8-73.
[80] Pigford, 1999.
[81] EPRI, 1994, p. 3-20 to 2-23.
[82] EPRI, 1994, p. 3-20. Italics were used in original text.
[83] Pigford, 1999.

scenario was incorporated into legislation put before Congress to assess the performance of the Yucca Mountain disposal site.[84] This legislation did not pass.

The lowering of protection standards has led to degradation in other regulatory fields as well. A perfect example of this is the Department of Energy's (DOE) refusal to adopt clear national cleanup standards. The DOE remediation program has been operating under rules that allow it to impose site specific standards without any national standard upon which to base them. A process by which the EPA was setting cleanup standards for nuclear weapons sites was ended by a brief letter from an Assistant Administrator of the EPA.[85] The plan, which had consumed a great deal of time and energy, was abandoned without any plans for its resumption. The 1996 EPA draft 40 CFR 196 of 15 and 85 mrem/year dose limit (the variation depends on the chosen use of the site) was used to calculate Rocky Flats RSALs in 1996. A 15 mrem limit was used by the Risk Assessments Corporation in its calculations.[86]

The lack of clear standards is also illustrated by comparing the cleanup levels DOE has used at various sites across the country, summarized in Table 1. For example, at the Livermore site in California, the industrial preliminary remediation goal is 10 pCi/g and the residential goal is 2.5 pCi/g of soil.[87] Meanwhile, at the Mound site in Ohio, the cleanup guideline value is 55 pCi/g.[88]

Table 2 shows various nuclear sites around the country and the exposure scenarios they have chosen to adopt. These scenarios are generally less stringent than the subsistence farmer model. Table 2 illustrates this variation as it shows the soil action levels of various contaminated sites and the resultant doses that were estimated using a variety of scenarios.[89] This data was compiled by RAC. While it is up to the community to decide what scenarios and uses for the site to be used in determining cleanup levels, it is important to state that the process should be based on the same target dose/risk. That is, cleanup levels may be different, but the risks to individuals on site should be standardized. The table clearly shows that there is no clear mandate for clean up levels and that ratios given show the relationship between cleanup levels and the annual dose.

Table 1: Soil Cleanup Guideline Values at Lawrence Livermore National Lab (LLNL) and the Mound Site, Ohio

Source: EPA, 1998 and Mound, 2001

Site	**Radionuclide**	**Location**	**Scenario**	**Guideline Value** (pCi/g)
Mound	Pu-238	Onsite	Construction Worker	55

[84] U.S. Congress, 1999; Pigford, 2001.
[85] EPA, 1996.
[86] RAC, 2000, pp. 3,5;DOE, 1996, p. 6-6.
[87] EPA, 1998; Berg, 2001.
[88] Mound, 2001.
[89] RAC, 1999a.

Mound	Pu-238	Offsite*	Recreational	75
LLNL	Pu-239/240	Onsite	Commercial	10
LLNL	Pu-239/240	Onsite	Residential	2.5

*The only offsite removal action that has taken place was the Miami-Erie Canal for which this was the agreed upon cleanup level.

8. The Radioactive Wildlife Refuge

In the early 1990s, the DOE embarked on a cooperative process with the EPA to develop national cleanup standards, but it reneged on this process and has, since the mid-1990s attempted to proceed on a site-by-site basis. This has led to a welter of proposals for cleanup using various scenarios, with the wildlife refuge having emerged as one of the favorites of the DOE and its contractors. Proponents of this method argue that because nuclear weapons sites have been off limits to the public for so long, they have become havens to endemic species that would otherwise have been at risk due to sprawl and human intervention (see for example, *From Waste To Wilderness)*.[90] They also argue that up until now, the DOE cleanup program has been very expensive, ineffective, inefficient, and the costs will only increase. On the other hand, declaring them wildlife refuges would exempt the DOE from major cleanup and would also serve to protect the natural ecosystems that have flourished. The Chernobyl Exclusion Zone has been described by a scientist, Ron Chesser, from the Savannah River Ecology Laboratory run by the University of Georgia for the DOE, as "a beautiful place with thriving wildlife communities. Without a Geiger counter you wouldn't know you were in a highly contaminated place. "[91]

Five sites out of the more than 130 sites in the nuclear weapons complex are expected to account for the majority of cleanup costs. These sites are Oak Ridge in Tennessee, Hanford in Washington State, Savannah River Site in South Carolina bordering on Georgia, Rocky Flats in Colorado, and the Idaho National Engineering Laboratory. These same sites are now being proposed as wildlife refuges by proponents of this model.[92] Of these Rocky Flats is the only one located in the middle of a rapidly growing urban corridor. Congressional legislation is pending to designate Rocky Flats as a wildlife refuge.

Robert Nelson has argued for the wildlife refuge scenario for DOE sites based on the following four principles:[93]

A. Old DOE sites have a high ecological value in their current condition.
B. A wildlife refuge would minimize actual risk to off-site human populations by restricting access to the site, which would be done in case of its designation as a wildlife refuge. Indeed, he has cited "radiation danger" and site access restrictions as the basic reasons that

[90] Nelson, 2001.
[91] Ron Chesser as quoted in Cookson, 2000.
[92] Nelson 2001.
[93] Nelson, 2001, pp. 12-14.

wildlife is flourishing at several sites in the nuclear weapons complex as well as areas in other parts of the world.[94]

C. The technology for long-term cleanup to high levels is not available at present and it will require technological advances to accomplish such clean up.
D. Ecological values at DOE sites will be conserved by stewardship that would be implicit in a wildlife refuge and contribute in that way to protecting public health.

The second and fourth points are substantively the same. There is also a partial overlap of these points with the first one. The high bio-diversity at some DOE sites such as Savannah River and Hanford does not actually apply to Rocky Flats, which is a far smaller site and relatively homogenous ecologically. It is also already a part of the rapidly growing Denver–Boulder urban corridor, and therefore not a promising prospect as a long-term wildlife refuge. Further, the proposals for making contaminated sites into wildlife refuges have not taken into account the long-term evolutionary impacts on wildlife. For instance, synergisms of radioactive with non-radioactive contaminants have not been well studied even as they relate to human beings, much less wildlife.

[94] Nelson 2001, p. 11.

Table 2: Soil Action Levels (SAL), Resultant Doses, and Ratios for Comparison at Different Sites

Source: RAC, 1999a

		Soil Action Level (pCi/g)		**Dose from SAL** (mrem/year)		**Dose to SAL ratio** ([mrem/year]/[pCi/g])		**SAL to Dose ratio** ([pCi/g]/[mrem/year])	
Site	**Scenario**	Pu-239/240	Am-241	Pu-239/240	Am-241	Pu-239/240	Am-241	Pu-239/240	Am-241
Rocky Flats	Open Space	9906	1283	15	15	0.00	0.01	660.40	85.53
	Office Worker	1088	209	15	15	0.01	0.07	72.53	13.93
	Future Resident	252	38	15	15	0.06	0.39	16.80	2.53
	Future Resident	1429	215	85	85	0.06	0.40	16.81	2.53
Hanford	Rural Residential	34	31	15	15	0.44	0.48	2.27	2.07
	Industrial Worker	245	210	15	15	0.06	0.07	16.33	14.00
Nevada Test Site*	Rural Residential	162	13.2	10.7	1	0.07	0.08	15.14	13.20
	Rancher	162	13.2	42.6	3.56	0.26	0.27	3.80	3.71
	Farmer	162	13.2	20.1	1.84	0.12	0.14	8.06	7.17
	Child Rancher	162	13.2	16.7	1.61	0.10	0.12	9.70	8.20
	Industrial Worker	162	13.2	3.97	0.42	0.02	0.03	40.81	31.43
Johnson Atoll	Residential (inhalation)	17	N/A	20	N/A	1.18	N/A	0.85	N/A
Maralinga	Residential (inhalation)	280	N/A	500	N/A	1.79	N/A	0.56	N/A
Palomares	Residential (inhalation)	1230	N/A	100	N/A	0.08	N/A	12.30	N/A

*At Nevada Test Site the doses were calculated from assumed soil concentrations. They are not true SALs.

There is a more fundamental evolutionary argument against using highly contaminated sites as wildlife refuges. Proponents have argued that flora and fauna are thriving in radioactively contaminated environments. By leaving them contaminated, human beings will leave these contaminated areas to wildlife. Rather than the genetic abnormalities often attributed to radiation, Nelson cites radio-ecologist Ward Whicker's findings that wildlife is healthy and "absolutely thriving."[95]

Yet, it is well established that ionizing radiation is one of the causes of genetic mutation. It is also known that some of these mutations are deleterious. Even if we grant that all of the arguments about the health of individual wildlife specimens that have been observed are correct, one cannot therefore conclude that there is no danger to the genetic integrity of wildlife and hence to the ecosystem.

Diethard Tautz has argued, in the context of genetic engineering, that subtle genetic changes that do not result in readily observable effects upon individuals in a species may nonetheless have substantial and possibly devastating impacts upon the species in the long term. He has noted that "…genes or genetic functions that have only a very small effect on the fitness of an individual, but are nonetheless important for long-term fitness within a population," an adequate understanding may require "experiments that involve the whole population of the respective species." [96] This genetic "uncertainty principle" means that nearly the entire population would have to be changed to discover whether deleterious changes have occurred.

Understanding of gene-ecosystem interactions at the molecular level and their implications for evolution is an emerging science in which there are huge uncertainties.[97] Long-term considerations of the integrity of wildlife are simply not understood well enough to support the claims of wildlife refuge proponents that assigning contaminated areas to wildlife will be a boon to natural ecosystems and to life forms that are now endangered that society has decided to protect.

Further, the radiological pathways from animals to humans are being revealed as far more complex than is recognized in standard risk assessments. In recent years surprising problems regarding the spread of contamination have emerged. For instance, a garden in a private home near the Sellafield nuclear materials processing site in England was found to be contaminated with radioactive pigeon droppings to the point that the soil and the pigeons had to be declared a radioactive waste.[98]

The problem of non-availability of technology is at least in part a spurious one in regard to RSALs. There is no reason why highly contaminated soil cannot be removed and stored retrievably as radioactive waste. It is desirable to develop technologies to cleanup this soil in the long term to avoid the problem of shallow land burial, but soil removal and storage allows the contamination to remain concentrated which makes for easier long-

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[95] Whicker as cited and quoted in Nelson 2001, p. 9. See also footnote 93.

[96] Tautz, 2000.

[97] Makhijani, 2001. Additional references can be found in this publication, which is on the web at http://www.ieer.org/pubs/e&g-toc.html.

[98] Greenpeace, 1998.

term cleanup and also prevents the spread of radioactivity in the environment. Most importantly, soil removal and storage protects vulnerable populations from exposure by the various pathways that have been described in the RAC reports. While it is true that present technology will not return some portions of the site to near pristine conditions, there is no incentive for developing new technologies if standards are so loose that large amounts of residual contamination are left behind as a matter of routine, as would be the case with a wildlife refuge scenario.

The protection of public health by restricting site access can only be a temporary expedient, at best. It would be unreasonable to assume long-term site control or that site use will not be changed in the future due to loss of institutional control and institutional memory. A current example from Washington, D.C. is discussed in the next section. It shows that institutional memory may not endure even a few decades where military contamination is concerned even in the heart of the capital of the United States. Restricting site control can only be a temporary expedient for other purposes but cannot be justified on the grounds of public health protection over a period of decades, much less hundreds or even thousands of years. Therefore even if the Rocky Flats site is designated as a wildlife refuge at present, this is not an adequate basis on which to set RSALs. Stringent RSALs at the outset will not only ensure that public health is protected in the long-term, but also that resources will be set aside in order to ensure the protection of public health.

Finally, the DOE has done quite a bit to characterize the nature of the environmental problem in the weapons complex since the end of the Cold War. However, the actual process of cleanup has been limited by the fact that DOE has been unable to develop a coherent set of priorities. Much of the waste of money is not due to the difficulty of cleanup but the poor management that has plagued DOE projects. Poor institutional culture is at the core of the problem, as IEER has shown in a previous detailed study of the subject.[99] While even a well managed and coherent cleanup program would be expensive, one must look at these costs in context. The DOE estimate for partial environmental restoration, waste management and disposal is $227 billion over 75 years. Between 1940 and 1996, the United States spent 5.5 trillion dollars to construct and deploy nuclear weapons.[100] Cost internalization of environmental problems is an important principle that the government tries to impose when it creates regulations for private industry. Setting and meeting strict cleanup standards is a part of cost internalization for nuclear weapons. It is essential that the government set for itself the high standards it expects of the private sector. The costs of the cleanup program overall are estimated at about five percent of the total cost of nuclear weapons during the Cold War . This is hardly an excessive expense. Moreover, most of this expenditure is actually for materials management and safeguards, site security, and the like, which would have to be spent anyway. Actual cleanup costs are possibly on the order of a couple of percent of the total Cold War nuclear weapons expenditure even if it is done to exacting standards, if the money is well spent.

[99] Fioravanti and Makhijani, 1997, page 3.
[100] Schwartz, ed., 1998, page 4.

9. Enforcement for the eons

Short-term considerations such as availability of funds or priorities such as plutonium stabilization (as is the case at Rocky Flats) cannot detract from the reality that long-term site control is unrealistic and should not be the basis for cleanup plans. A failure to set stringent standards can result in increased risks to an unknowing and unsuspecting public in the future. This would not be the case were public health protection under a reasonably strict criterion undertaken from the very beginning.

The problem of leaving sites with huge amounts of contamination has recently been dramatically illustrated in the capital of the United States in relation to abandoned chemical munitions in one of the most sought-after real estate locations in Washington, D.C. – the area near American University.

In 1986, the United States Army discovered that there were abandoned chemical munitions on the grounds of American University and parts of the environs of the campus, including some homes. The horribly confusing situation that has emerged in the course of just one century in a plush area of the capital of the country should, perhaps suffice to dispel any illusions regarding long-term site control, the vigilance of the authorities or even their use of common sense in informing people at risk. The following is based on an article in the Washington Post on July 25, 2001. There have been many news articles, official reports, and other documents around this problem in the past fifteen years.

The Army did not inform local authorities in 1986 when it found the problem. A pair of reports in 1995 by the Army, which had investigated its own conduct in 1986, came to the following confusing conclusions:

> "A report by the Army Audit Agency presented to the Army Corps of Engineers on June 6, 1995, concluded that the Army did not 'notify local authorities and third parties in accordance with laws and regulations in effect in 1986.'
>
> But the same agency's final review, dated July 27, 1995, found that 'the Army had no duty to notify local authorities or third parties in 1986, as the developer claimed.'"[101]

One of the serious problems arising from the Army's chemical dumping in the area has been high arsenic contamination of the soil, including the yards of many homes. In one such case, the high contamination was discovered in 1994 but officials covered up the discovery of the contamination, presumably for fear of the potential liabilities, even though it was high enough to designate the soil as hazardous waste. In the meantime the family that lived in the home used the garden, planted things. Children played in it. One of the people (the mother) got a brain tumor that was operated on, but there is now no way to tell whether it was caused by the arsenic. The family will live in fear that their children may develop diseases as a result of their exposure for the rest of their lives. This

[101] Vogel, 2001.

occurred despite the family's vigilance, since they did ask the authorities repeatedly whether they would face problems as a result of the contamination. The family was not informed of the contamination until 1999, when they demanded all the documentation. They were reassured by the government that all would be well, and no action was taken, despite the high levels of arsenic. In 2001, the family moved out of the house.

When the official purpose of an operation has been fulfilled and the funds have dried up, site control can be tenuous, and institutional memory even more so. The tendency to cover up even at possible cost to people's health is strong, and this is not the only case in which such tendencies can be seen. There are, after all, no designated funds to deal with it. It is an old operation whose benefit to the sponsoring institution has long since expired.

Besides the evolution of conditions on a site and of site use that may increase the risk to future generations, there is also possible evolution of the understanding of risk per unit of exposure. Historically, radiation protection standards have been set in terms of radiation dose. There is a consideration of cancer risk in the process of setting standards, but a limitation on the risk itself has not generally been used in the standard setting process. The reason, of course, is that one can measure dose, in principle, while risk is a more abstract concept, even though it is the one most directly linked to population protection.

The issues in regard to whether risk or dose should be the measure in setting residual soil action levels (RSALs) is a complex one. For instance, it is likely that the stream of money available for clean up would dry up once the site has been taken off the books of the party that owns it. This makes it quite different from worker protection in an operating factory, for instance. Moreover, it is impossible to actually measure dose to future populations. Therefore, if the goal is to protect generations a considerable time into the future, then it is prudent to revisit the issue of risk versus dose as the basis for setting RSALs (as well as other cleanup standards).

There are several aspects to considering risk versus dose issues:

A. In general, risks depend on the organ exposed, age at exposure, and, for some kinds of cancer, gender.
B. It is important to consider non-cancer risks, and a simple dose approach often is not conducive to such assessment.
C. There may be synergistic effects between exposure to non-radioactive hazardous materials and radioactivity.
D. The same dose may result in a different risk to different sections of the population, since it is likely that sensitivity to radiation is highly variable in populations, even if they are otherwise homogeneous by age, class, ethnicity and gender.
E. The scientific evaluation of the risk of radiation may change with time, as it has in the past.
F. The regulatory procedure by which standards are established may change.

A. Organ and population specific risks

A risk approach to soil action levels could deal with each one of the factors specified in item A above (organ, age, and gender), while a dose approach usually considers a single cancer risk factor when setting the dose limit. A risk approach to residual soil action means that the implications of the proposed RSALs for various cancers (organ specific doses) and for different populations would need to be examined. The RSAL would be set only after the doses assessed in these different ways have been evaluated and their implications for cancer risk have been calculated. Dose assessments are all scenario-dependent. In general, the subsistence farmer or rancher (i.e., consuming local food and water only) scenario is the appropriate one to consider in evaluating risks.

B. Non-cancer risks

There are a variety of non-cancer risks, some of which are radionuclide-dependent. The dose approach to regulation adds up all doses, internal as well as external, into a single effective dose equivalent and then applies a cancer risk factor. This approach does not give adequate weight to adverse outcomes, such as miscarriages due to intake of tritiated water or developmental risks to children and fetuses from other radionuclides, such as strontium-90, iodine-129, tritium, and cesium-137 which cross the placenta. While these particular radionuclides are not thought of as problems in the Rocky Flats environment, they have been present in the past. The main point here is that different radionuclides carry different risks.

A risk-based approach allows the differentiation of internal from external radiation and hence allows for better organ, gender, and age-specific evaluation of the consequences of cleanup rules. A recent study evaluating the risk of DNA aberrations in the children of Chernobyl liquidators found a surprising seven-fold increase compared to children of the same people born before the exposure of the parent.[102] This high mutation rate is at considerable variance with the Hiroshima/Nagasaki data. The latter data indicate a doubling of mutations at doses of 100 to 200 rad. These are considered high doses of radiation, when delivered in a short time, as, in fact, they were by the bombings. By contrast, Chernobyl liquidator doses have been estimated to be in the low-dose range -- 5 to 20 rad. No dose reconstruction was possible for the specific persons in the study. Still, the clear conclusion of the study is that low dose radiation, possibly an order of magnitude or more less than the Hiroshima/Nagasaki doses cited above, could cause the same mutation rate.

The Chernobyl study did not attempt to assign a cause of the high mutation rate, other than to identify it with radiation dose. It is plausible that at least some of the difference from the Hiroshima/Nagasaki data may be due to internal exposure of the liquidators. The doses received by Hiroshima/Nagasaki survivors were mainly external gamma and neutron doses. The main concern at Rocky Flats would be the internal exposure from alpha radiation. An internal dose of an alpha emitter would be more harmful than an external one.

The large uncertainties in the area of heritable mutations can be factored in better using a risk-based approach. A safety factor that corresponds to the uncertainty arising from the

[102] Weinberg, *et al.,* 2001.

fact that exposures to future populations from plutonium in the Rocky Flats environment will largely be internal can be developed using Chernobyl liquidator data from the above study, for instance.

C. Synergistic effects

Rocky Flats, like many other DOE sites, has both radioactive and non-radioactive pollution. Little is known about synergistic risks of toxic chemicals and radionuclides, particularly when considerations of internal dose discussed briefly above are taken into account. Chemicals may compromise immune and/or endocrine systems in ways that may increase risks from radionuclide intake. The scientific consideration of such issues is in its initial stages, and it would be a surprise if there were no surprises as regards synergistic health risks. A risk-based approach would include an evaluation of what is known, the extent of the ignorance about synergistic effects and the implications of that analysis for choosing a safety factor that would allow risks to be kept below specified levels. An approach that relies only on cancer risk deriving from radiation dose alone *by its nature* excludes these important considerations.

D. Differential population sensitivity

The occurrence of cancer appears to be mediated by the immune system. The immense variation in allergic response among populations that are relatively homogeneous in other respects implies that there may be a large differential sensitivity to radiation between individuals. A risk-based or a dosimetric approach to RSALs could take this into account, were the differential sensitivity known. Alternatively a safety factor that would reduce allowable dose or risk may be selected. In any case, it is prudent to explicitly factor in some consideration of possible differential population sensitivity to radiation within homogeneous population groups.

It is difficult to select a safety factor at the present time since the factors that contribute to differential allergic response are only now beginning to be understood. Typically, these factors are genetic, developmental, and environmental, making the situation quite complex.

A safety factor that acknowledges this ignorance is especially important in regard to long-lived residual radioactivity. The long half-lives mean that a variety of people are likely to come into contact with the residual radioactivity over the ages. There is therefore a high likelihood that individuals who are among the most sensitive in the population will at some time be exposed.

E. Future changes in the average dose to cancer-risk relationship

The past half-century has seen increases in estimates of cancer risk per unit of dose based mainly on reassessments of Hiroshima and Nagasaki survivors. Future assessments of these data may or may not result in increases in risk, depending on such factors as whether the missing cohorts from the time immediately after the explosions are taken into account and how neutron doses are evaluated and interpreted.

There are a number of differences between the populations that would be exposed to residual radioactivity and Hiroshima/Nagasaki survivors. The recent study of the children of Chernobyl liquidators creates additional uncertainty about too heavy a reliance on Hiroshima/Nagasaki data, though these should of course be included in risk evaluations. Reductions in cancer risk estimates for future populations exposed to residual radioactivity based on reassessments of Hiroshima/Nagasaki data would be especially inappropriate at this time. For a variety of reasons, many of which are discussed above, the uncertainties in regard to risk per unit of exposure to future populations are much greater than those indicated by the analysis of Hiroshima/Nagasaki survivor data.

F. **Future changes in regulatory procedure especially with respect to water**

Besides changes in regulations arising from changes in risk assessment, regulations may be changed due to other factors. Regulations generally result from a variety of historical, institutional, scientific, and political considerations. They can therefore have glaring inconsistencies that may be corrected at some future time when the political conditions are appropriate. Take, for instance, safe drinking water regulations in relation to transuranic radionuclides. These regulations allow total contamination by these radionuclides of up to 15 pCi per liter. At the same time, the doses for most beta emitters are limited to 4 mrem per year. The allowable concentrations are not specified but must be derived from prevalent dose conversion factors. It turns out that if the currently applicable dose conversion factors are applied to transuranics, the drinking water doses resulting from 15 pCi per liter would be roughly a hundred times greater than the 4 mrem allowed for most beta emitters. Contamination of water to just a fraction of a picocurie of plutonium-239/240 is sufficient to yield a drinking water dose of 4 mrem per year. It is quite possible that the public might demand both consistency and water purity in the future, given that the public places a very high value on water purity.

The State of Colorado already has a state standard for plutonium in surface water of 0.15 pCi/L and at Rocky Flats the standard is enforced at the downstream boundary of the site where 30-day moving average is calculated from streams exiting the site. For two separate 30-day periods in 1997, averages for Walnut Creek exceeded the standard.[103] Moreover, as noted above, the Colorado standard is a reasonable one based on the 4 mrem annual drinking water dose limit that applies to most beta emitters. There is no rational reason for that same limit not to be extended to alpha emitters.

The DOE has suggested changing the Colorado standard by changing the averaging period from one month to longer periods.[104] At the same time, a multi-year study concluded that cleanup to an RSAL of 10 pCi/g would not meet the 0.15 pCi/L water standard for the most contaminated areas downstream from the 903 Pad (the most contaminated part of the Rocky Flats facility).[105] This is one example of the uncertainty of regulatory issues.

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[103] RMRS, 1997, table 1.

[104] Rampe, 2001.

[105] Kaiser-Hill, 2000, pp. E-3, E-4.

Other changes may arise from the fact that there has been as yet no regulatory assessment, much less action, on possible synergisms between hormonally active compounds, like PCBs and dioxins, and radiation doses. Recent acceptance of the potential harm by hormonally active compounds for non-cancer end-points, such as developmental abnormalities, as well as advances in the biological effects of radiation at the cellular and sub-cellular level could lead to considerable changes in the regulatory system in the coming decade or two. It is not possible at this time to predict the magnitude of these changes, but some risk estimates may go up as these effects are considered for the simple reason that the present assumption is of zero synergisms in the absence of data and analysis.

10. Conclusions and Recommendations

There is sound scientific basis to use the subsistence farmer scenario, or its local equivalent such as the subsistence rancher scenario, as the basis for protection of future populations when long-lived contaminants are present on a site. Site use restrictions are, at best, a temporary expedient. If such restraints are assumed in the absence of a more stringent goal for clean up derived from the subsistence farmer scenario, the health and ecological damage that may result would likely be higher as would the cleanup costs if the site must be revisited. There is plenty of evidence that a revision of prior lax decisions is costly from every point of view – health, environment, fiscal, or public trust in the government.

Beyond the subsistence farmer scenario based on present day risk coefficients and understanding, a safety factor is also needed. The many uncertainties in estimating future risk and the many areas of science that have been relatively neglected that may result in increased risk estimates per unit of dose indicate the need for an substantial safety factor to obviate the necessity of revisiting cleanup due to changes in risk coefficients. The complexity of plutonium chemistry in the natural environment, notably in relation to possible water contamination, also points to the need for an adequate safety factor. These two safety factors combined would reduce the maximum RSAL at Rocky Flats that results from scenario calculations considerably. Such an approach can be justified because a new cleanup effort in the future that would be far more difficult and costly, and the temptation of government inaction or worse would be avoided.

The RAC team recommended an RSAL of about 35 picocuries per gram of plutonium, plus the associated TRUs in specified ratios. Though this RSAL is based on a reasonably conservative subsistence rancher scenario, it reduces the estimated dose from a fire probabilistically. The RAC analysis leads to an RSAL of 10 picocuries per gram if the probability of a fire is taken as 1. As we have discussed, this analysis potentially underestimates doses by the groundwater pathway, if site conditions evolve to allow much faster plutonium migration than assumed in the RAC study. The plausibility of such rapid migration has been discussed in this report.

In light of the fact that these factors and others, discussed above, may increase risk from residual soil contamination at Rocky Flats, it would be highly advisable to set an RSAL below 10 picocuries per gram. This implies a safety factor of about 3 or more relative to the RAC recommended RSAL of 35 pictures per gram. How much larger this safety factor should be is a matter for public debate.

IEER's recommendations can be summarized as follows:

- The subsistence farmer or subsistence rancher scenario should be used as the basis for setting a residual soil action level at Rocky Flats.
- The subsistence farmer or rancher approach should be adopted even if the site is designated as a wildlife refuge, since it is not reasonable to assume that such a designation will endure for hundreds of years.
- Careful investigations of the effect of high residual contamination on wildlife should be undertaken, before the site is actually so designated. Investigations of the potential for such a site designation to enhance the mobility of plutonium into the accessible environment, including groundwater, should also be undertaken.
- RSALs between 1 and 10 picocuries per gram should be considered for Rocky Flats. This range is compatible with a subsistence farmer scenario. At the upper end of this range, the groundwater doses would be downplayed, but a safety factor of about 3 relative to the RAC model would be built in. Such a safety factor is desirable for a variety of reasons discussed in this report. If doses from groundwater are factored in, it would be reasonable to set an RSAL at the lower end of this range. Such an RSAL would also be compatible with the dose implications of the current state of Colorado surface water standard of 0.15 pCi/liter of plutonium, should it be extended to groundwater in the future.
- The steps towards the achievement of the ultimate RSAL, and the institutional arrangements in the interim, are beyond the scope of this report. But any cleanup plan should specify how a standard based on the subsistence farmer or rancher scenario would be achieved, and how any interim steps would relate to this goal.

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PART 4

Guide to Rocky Flats RSALs

and proposed cleanup levels

Material prepared by the Rocky Mountain Peace and Justice Center and distributed to the public:

- Arjun Makhijani and LeRoy Moore, "Fed plan is weak; subsistence farmer scenario the way to go," *Denver Post*, August 12, 2001
- Who Gets Protected: Fact Sheet on RSALs for Rocky Flats (December 2001)
- Articles on Rocky Flats cleanup from *Science for Democratic Action* (May 2002), newsletter of the Institute for Energy and Environmental Research
- Risk from Plutonium in the Environment at Rocky Flats (November 5, 2002)
- Excess Cancers among Workers Exposed to Plutonium on the Job at Rocky Flats (January 2002)

http://www.denverpost.com/Stories/0,1002,75%257E96208,00.html

ROCKY FLATS CLEANUP: FED PLAN IS WEAK;
SUBSISTENCE FARMER SCENARIO THE WAY TO GO

Denver Post -- August 12, 2001

by Arjun Makhijani and LeRoy Moore

Sunday, August 12, 2001 - The cleanup of the radioactive mess left behind by decades of nuclear weapons production at Rocky Flats is at a critical juncture. The Department of Energy, the Environmental Protection Agency and the Colorado Department of Public Health and Environment are set to choose a standard for how much plutonium and other radionuclides can be left in the soil at Rocky Flats after cleanup. The quantity may be considerably higher than the amount allowed at other sites, such as the Marshall Islands, where nuclear tests occurred, or at the DOE's Livermore Lab in California.

Why are the levels of allowable residual plutonium so different in different places? The arbitrariness in the DOE's approach to cleanup arises from one central reality. Even though cleanup of the nuclear weapons complex will cost an estimated $300 billion, there are no national standards to guide the process because the DOE has resisted their development and argued instead for a site-by-site approach.

The trick that would allow higher residual contamination levels at Rocky Flats is to assume that the site will remain a wildlife refuge for thousands of years. There is a bill in Congress to designate it as such. Perhaps it should be done. But what is the life of a law compared to the half-life of plutonium? The former may last as little as an election cycle and, in any case, may not long endure in the face of mounting property values. Plutonium has a half-life of 24,000 years.

The peculiar issues posed by the longevity of certain radioactive pollution problems were recognized and addressed in a reasonable way long ago. The scientific community involved in radiological protection devised a way to protect future generations that does not depend on the vagaries of fashion, law, lifestyles or government departments. It created a simple construct called the "subsistence farmer scenario." This does not refer to a poor person scratching out a living from the soil, but rather to a hypothetical person who lives on the land, consumes local water and eats only locally produced food.

The rationale underlying this choice was that it is a reasonable possible future use well grounded in past human experience. If an individual who depended on local food and water was protected, then the rest of the population would be even better protected. Within the limits that human ingenuity can devise, this is a sound way to think about protecting people far into the future, since predicting future lifestyles and land-use is very likely to prove wrong.

As the bill for the environmental negligence of the Cold War has come due, pressure has increased to relax environmental protection regulations as they relate to waste management and cleanup. The most politically expedient way to relax standards and still pretend to uphold them is to fix the models to yield the desired numbers. Once the reasoning behind the subsistence farmer scenario is abandoned, then any lifestyle can be substituted by appeal to current vogue or legislation. In the case of Rocky Flats, the DOE, EPA and CDPHE have decided to use a worker on the putative wildlife refuge as the person to be protected. He will not eat local food. He will not bring his children to the site, so they will not be exposed to the soil. He will drink little, if any, of the local water. His time exposed to plutonium left in the soil will be a fraction of that of a permanent resident.

And how long will a wildlife refuge persist across the street from booming residential and commercial development? A decade? Two? How long will there be institutional memory of residual plutonium at the site? A recent report from the National Academy of Sciences suggests that assuming institutional control or memory for more than a few decades is rash.

Places like the Denver metro area that have been reluctant hosts to nuclear weapons plants during the Cold War deserve better than the DOE's shoddy approach to public health protection. At Rocky Flats, an expensive public process, funded by the DOE, has already reviewed this controversy and concluded that the standard adopted by DOE and the other agencies in 1996 was too lenient. This independent review endorsed a subsistence rancher scenario and proposed that the residual plutonium level of 1996 be reduced by about a factor of 20. The DOE and its regulators did not like the result. So now they are inventing new scenarios and doing more model runs to get numbers more to their liking.

The proposal for residual contamination at Rocky Flats based on a wildlife refuge is a disservice to the people of Colorado (and to its wildlife). It should be abandoned in favor of the scientifically rigorous approach that uses the subsistence farmer scenario, which has long been established and is still the generally accepted method.

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WHO GETS PROTECTED? FACT SHEET ON RADIONUCLIDE SOIL ACTION LEVELS (RSALS) FOR ROCKY FLATS

Background: From 1952 until 1989 the Rocky Flats plant produced the fissionable plutonium "pit" for every nuclear weapon in the U.S. arsenal. Nearly 40 years of bomb production punctuated by several major accidents and many minor ones left the site badly contaminated. In 1992 the facility's mission was changed from production to cleanup and environmental restoration. The facility was renamed the Rocky Flats Environmental Technology Site.

The site: The 6,500 acre Rocky Flats site is located 16 miles northwest of central Denver in an area undergoing rapid urban development. Almost 20 acres of the site are known to be contaminated with plutonium above 100 picocuries (a unit of radiation) per gram of soil (pCi/g). About 300 acres are contaminated above 10 pCi/g. The site has not been thoroughly characterized; there may be unknown hot spots. Hundreds of thousands of people live downwind and downstream from Rocky Flats. Some 2 million people live in the Denver area.

Plutonium: The principal contaminant at Rocky Flats, plutonium, has a half-life of 24,400 years; it remains dangerous for a quarter-of-a-million years. The alpha radiation it emits cannot penetrate skin, but tiny particles inhaled, ingested, or taken into the body through a wound can cause cancer, genetic defects, or harm to the immune system. One particle inside the body can penetrate more than 10,000 cells within its range. Columbia University scientists found that a single particle can induce mutations in cells of mammals. Particles of plutonium left in the soil can be resuspended in respirable size and transported by wind or water or by plant, animal or human actions. Left in the environment, it poses an essentially permanent danger. There is no guarantee plutonium in the soil will remain on the site. Winds at Rocky Flats are severe.

Cleanup goal: In 1995 both the Rocky Flats Future Site Use Working Group and the Citizens Advisory Board recommended that Rocky Flats be cleaned to average background levels when the technology allows this to be done in a cost-effective and environmentally sensitive manner. Average background for plutonium from global fallout in soil in Colorado is 0.04 pCi/g.

Radionuclide soil action level (RSAL): An RSAL stipulates that when the amount of radioactive material in soil exceeds a specified level, action must be taken to remove the material or to contain it. Amounts below the RSAL require no remedial action and can be left in place. The RSAL thus indicates how much radioactive material may remain in the soil. No single decision regarding Rocky Flats cleanup is likely to have greater long-term effect than the one establishing how much plutonium can remain in soil.

The original Rocky Flats RSALs: In October 1996 DOE, EPA, and the Colorado Department of Public Health and Environment adopted plutonium RSALs of **651 pCi/g**. (assuming the presence of other radionuclides). Developed with scant input from the affected public and strongly opposed during the period of extensive public review, these RSALs were adopted essentially as originally proposed. RSALs at other plutonium-contaminated sites range from 10 pCi/g for part of the Livermore Lab in California to 200 pCi/g for part of the Nevada Test Site. The RSALs for Rocky Flats are by far the least protective anywhere.

Independent review and recommendation: In response to persistent public opposition, DOE agreed in 1998 to fund an independent scientific review of the Rocky Flats RSALs. A broadly representative RSAL Oversight Panel was convened. In competitive bidding, the Panel hired *Risk Assessment Corporation* (*RAC*) to do a peer-reviewed study. Based on *RAC's* work, in February 2000 the Oversight Panel recommended by consensus that the RSAL for plutonium in soil be reduced about 95% from 651 to **35 pCi/g**. The agencies responsible for Rocky Flats cleanup never responded to this recommendation but conducted their own review instead.

Starting anew: After a year-and-a-half of working with some of the affected public, the agencies will soon propose new RSALs. Because Rocky Flats is a Superfund site, cleanup must comply with guidelines of Superfund law (CERCLA, the Comprehensive Environmental Response, Compensation, and Liability Act). Of all the variables that can affect what the agencies propose, two of the most important are the level of risk they decide to permit and the future-use scenario they employ for their calculations.

Risk level: CERCLA allows risk from exposure to radiation to fall between one-in-ten- thousand excess cancers (10^{-4}) and one-in-a-million (10^{-6}). Most members of the public from whom the agencies have heard, including the Citizens Advisory Board, have called for RSALs at the most protective end of this range (10^{-6}). To date, the agencies have not indicated how they will respond.

A short-term future-use scenario: protect the wildlife refuge worker: Because Rocky Flats is expected to be designated a National Wildlife Refuge, the government agencies intend to propose RSALs designed to protect a wildlife refuge worker – that is, someone who will spend 40 hours a week on site for maybe 14 years, possibly half of this time outdoors. This is a reasonable choice for the short term. But the one thing that can be said with certainty about the future use of Rocky Flats is that the site will cease being a wildlife refuge long before plutonium ceases being dangerous. The whole of recorded human history is brief by comparison to the half-life of plutonium. Plutonium left in the environment will pose a danger long after fences fall and memories fail. Cleaning the site only to the refuge worker level means institutional and engineered controls (e.g., fences and earthen caps) will have to be used. Controls are likely to fail; they are no substitute for cleanup.

A long-term alternative: the subsistence farmer scenario: Because we do not know what will happen at Rocky Flats in the future, we should assume that eventually people will live on the site. The most protective residential scenario is that of a subsistence farmer- a hypothetical person who lives a lifetime with a family on the land, eats homegrown food, and consumes local water, a way of life steeped in human experience. If the subsistence farmer is protected, then all other site users, including the refuge worker, will be even better protected.

Open space and development: Most stakeholders want Rocky Flats as open space, with no urban development on the site. Making Rocky Flats a wildlife refuge prevents development. It also provides a rationale for cutting cleanup costs by adopting an RSAL calculated to protect a wildlife refuge worker. Leaving some removable quantity of plutonium in the environment as the price for open space, however, is a Faustian bargain if ever there was one. While a wildlife refuge designation can prevent onsite development for the near term, cleaning the site only to the refuge worker level provides poor protection for unsuspecting future residents of the site.

Cost: One argument against a more restrictive RSAL is its higher cost. Cost estimates are insufficient, but Kaiser-Hill's preliminary estimate for cleanup of the 903 Pad area (the most contaminated part of the site) show that the difference between cleaning this area to the 1996 RSAL of 651 pCi/g and the 35 pCi/g recommended by the RSAL Oversight Panel is about $48 million, not a great amount by comparison to the present annual Rocky Flats budget of $657 million. The community and the agencies need to work together to explore cost-saving options.

Precedent: Rocky Flats is a flagship site in DOE's effort to clean contaminated sites. Cleaning to the level of a wildlife refuge sets the bad precedent of increasing risk by cutting cost. We have the opportunity, and indeed the responsibility, to set a good precedent for other sites by establishing the best possible protection at Rocky Flats.

Prepared by LeRoy Moore, Ph.D., Rocky Mountain Peace and Justice Center, Box 1156, Boulder, CO 80306; 303-444-6981; Fax 303-444-6523 <leroymoore@earthlink.net> (December 2001)

Articles on Rocky Flats cleanup from
***Science for Democratic Action* (May 2002)**
Newsletter of the Institute for Energy and Environmental Research
On line at: http://www.ieer.org/sdafiles/vol_10/sda10-3.pdf

Setting Cleanup Standards to Protect Future Generations

The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats

By Arjun Makhijani and Sriram Gopal

Vast areas of land and huge amounts of water remain contaminated with dangerous long-lived radioactive and non-radioactive pollutants from operations of nuclear weapons facilities. This poses a difficult enough problem for the generations of people who have created them, but how can we ensure the health of future generations, of land and water resources, and of ecosystems thousands of years into the future?

The nature of the problem requires the utmost care in the selection of the scientific tools that will be used to assess the health of future generations in order to both ensure a sound result and promote effective expenditures. The scientific merits of any approach must take into account the historical experience that institutional memory about contamination tends to fade in a matter of decades. Laws change, as do norms. Assessment of the risks of particular materials and of combinations of materials has evolved. Over the past several decades, the trend in official assessments has been to conclude that radioactivity is more dangerous per unit of exposure than initially believed. In general, standards for environmental protection have become more stringent and public support for such protection has increased.

The U.S. Department of Energy (DOE) is embarked on a process of setting standards for cleanup at its Rocky Flats nuclear weapons plant near Denver, Colorado that could result in unprecedented levels of plutonium being left at the site. The DOE's approach could affect people in the future in a variety of ways, for instance by inhaling resuspended plutonium or other radioactive particles during windstorms, or by using contaminated water, which can become polluted both by runoff into surface water and transport of contaminants into groundwater as rainwater percolates down.

The Institute for Energy and Environmental Research (IEER) was commissioned to provide technical assistance to the Rocky Mountain Peace and Justice Center of Boulder, Colorado, in that group's effort to secure more protective cleanup levels at Rocky Flats. As part of that work IEER prepared the report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats* (December 2001).[106] This article is based on that report. References can be found in the report, which is available in its entirety on IEER's web site at www.ieer.org/reports/rocky/toc.html.

The subsistence farmer approach

[106] The work was supported in part by a grant to the Rocky Mountain Peace and Justice Center from the Citizens' Monitoring and Technical Assistance Fund.

The approach to protecting people far into the future must be based on the assumption that any institutional controls put in place today will lapse with time, that institutional memory will not endure as long as the hazardous lifetimes of some of the contaminants, and that people may live on the land, farm it and use the water on it not knowing that it was contaminated. If a cleanup or waste management program can be devised to protect self-sufficient farmers, it is reasonable to conclude that the rest of the population will also be protected. This is the basis of the "subsistence farmer" approach to setting radiation cleanup standards.

This general approach was developed by scientific advisory bodies, notably the International Commission on Radiological Protection, as well as by governmental authorities, such as the U.S. Atomic Energy Commission and its successor agency, the U.S. Department of Energy. The DOE used this approach in the 1980s to evaluate options for the management high-level wastes at its Hanford site.

Using the subsistence farmer approach for setting standards makes scientific sense because it minimizes a large number of the uncertainties (though not all of them) that are associated with estimating the impact of contamination on people's health far into the future. More information on the development, use and scientific basis of the subsistence farmer approach is attached.

In addition to being a reasonable scenario in general, the subsistence farmer approach is reasonable for setting cleanup standards at the Rocky Flats site. Because the Denver-Boulder corridor is one of the fastest growing areas in the country, there is a great deal of pressure to develop open spaces. Also, farms, businesses and homes are located at the boundary of the site. The sound scientific basis of the subsistence farmer scenario is independent of any interim uses for which specific sites may be designated.

Some current official proposals for radioactive waste management and cleanup of contaminated sites are discarding the subsistence farmer scenario. They argue that if public access to the contaminated site is prevented, then there will be no need to establish conservative cleanup standards because no one will be exposed. But it is not realistic to assume that institutional control and public memory will exist long enough to prevent unnecessary exposure to the future public. Some of the contaminants in question have half-lives of thousands of years.

Rocky Flats' radionuclide soil action levels[107]

From 1952 until 1989 the Rocky Flats plant produced plutonium pits for U.S. nuclear weapons. Routine operation plus accidents contaminated surrounding water and soil with plutonium, americium and other radionuclides, as well as with nonradioactive toxic substances. Now, Rocky Flats is a "flagship" site in DOE's attempt to clean and close some nuclear weapons production sites. Rocky Flats is slated for closure in 2006.

Plutonium (along with the associated americium-241) is the contaminant of principal concern at Rocky Flats. To deal with plutonium in the soil, DOE and the regulators set radionuclide soil action levels (RSALs) for the site. An RSAL indicates how much radioactive material may remain in the soil. When the amount of radioactive material in the soil exceeds the RSAL, action must be taken to remove or contain the material. Contaminant concentrations below the RSAL require no remedial action. No single decision regarding Rocky Flats cleanup is likely to have

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[107] Some information presented in this section draws from the statement of LeRoy Moore of the Rocky Mountain Peace and Justice Center at the IEER press conference on the report *Setting Cleanup Standards to Protect Future Generations* on December 11, 2001, online at www.ieer.org/reports/rocky/lerstmt.html.

greater long-term effect on human health and the environment than the one establishing how much plutonium can remain in soil.

In 1996, federal and state government agencies proposed an RSAL for plutonium at Rocky Flats of 651 picocuries per gram of soil (pCi/g), a level higher than the action level adopted at any other plutonium-contaminated site anywhere. In addition there would be associated radionuclides, mainly americium-241. (See the table below for examples of the differing levels of residual radioactivity in soil assumed or measured at DOE and other sites, and the resultant doses estimated using a variety of scenarios.)

Soil Action Levels and Resultant Doses for Different Sites and Varying Scenarios

		Soil Action Level (pCi/g)		**Dose from SAL** (mrem/year)	
Site	**Scenario**	Pu-239/240	Am-241	Pu-239/240	Am-241
Rocky Flats	Open Space	9906	1283	15	15
	Office Worker	1088	209	15	15
	Future Resident	252	38	15	15
	Future Resident	1429	215	85	85
Hanford	Rural Residential	34	31	15	15
	Industrial Worker	245	210	15	15
Nevada Test Site*	Rural Residential	162	13.2	10.7	1
	Rancher	162	13.2	42.6	3.56
	Farmer	162	13.2	20.1	1.84
	Child Rancher	162	13.2	16.7	1.61
	Industrial Worker	162	13.2	3.97	0.42
Johnson Atoll	Residential (inhalation)	17	N/A	20	N/A
Maralinga	Residential (inhalation)	280	N/A	500	N/A
Palomares	Residential (inhalation)	1230	N/A	100	N/A

*At Nevada Test Site the doses were calculated from assumed soil concentrations.They are not true Soil Action Levels.

Source: *Final Report: Task 1: Cleanup Levels at Other Sites.* Radionuclide Soil Action Level Oversight Panel. (RAC Report No. 6-RSALOP-RFSAL-1999-Final), Risk Assessment Corporation, April 1999.

Note: The IEER recommended range for Radionuclide Soil Action Levels at Rocky Flats is 1 to 10 pCi/gram, with the lower end of the range recommended when water use considerations are taken into account.

This RSAL was met with public opposition and the DOE eventually agreed to fund an independent scientific review of the matter, which was done by the Risk Assessment Corporation (RAC). The RAC report is available online at www.racteam.com/Experience/Projects/RSALS.htm.

The RAC team recommended an RSAL of about 35 pCi/g plutonium, plus the associated americium-241in a specified ratio. RAC used a subsistence rancher scenario as a reasonable local variant of the subsistence farmer scenario in assessing Rocky Flats RSALs. A 15 millirem (mrem) annual dose limit (whole body effective dose equivalent) was used in RAC's calculations.

The RAC analysis admittedly did not consider the issue of groundwater doses in detail. Yet contamination in the soil acts as a reservoir for potential contamination of water that may eventually be used for drinking or irrigation. Thus if site conditions evolve to allow much faster plutonium migration than assumed in the RAC study, which is plausible given the results of recent government research on plutonium mobility in soil, the analysis may underestimate doses by the groundwater pathway.[108]

The agencies responsible for Rocky Flats cleanup never formally responded to this recommendation but conducted their own review instead. This raised the possibility that the findings of the independent review would be rejected implicitly or explicitly and that lax RSALs might be proposed again, especially in view of the target date for completion of December 15, 2006 to declare the site cleaned up.

A "target fee" of about $340 million to the contractor, Kaiser-Hill, is at stake in meeting this deadline. This amount decreases, to a set minimum, for each day the project goes beyond the target date. By contrast, it increases if the project is completed early and below target cost, reaching a maximum of $460 million.[109] Since the RSALs were not defined at the start, there is a built-in incentive for the contractor to want more lax rules.

Protecting water resources

An analysis of the water pathway dose indicates the crucial importance of using the subsistence farmer scenario as the basis for protection of future populations.

The current contamination of groundwater at Rocky Flats with americium-241 and plutonium-239/240, alpha-emitting radionuclides, is generally regarded as minimal because it is far below the current U.S. Environmental Protection Agency (EPA) standard for transuranic radionuclides[110] of 15 picocuries per liter. However, that does not take into account the fact that the EPA standards for transuranic radionuclides are far more lax than the health risk based limit of 4 mrem per year to the critical organ that applies to most beta emitters.

Safe drinking water limits for transuranic radionuclides, most of which are alpha emitters, are not currently defined the same way as those for most beta-emitting radionuclides. EPA limits for alpha-emitting transuranics are set according to dose estimation procedures that are 40 years old. For the purposes of long-term planning, it is reasonable to assume that limits for transuranic radionuclides will eventually be brought into line with the current dose estimation procedures.[111] (For further discussion of the inconsistencies in safe drinking water regulations as regards radionuclides, see the box.)

At Rocky Flats, the reported contamination level in groundwater in the fall of 2000 for americium-241 was 0.0354 picocuries per liter (pCi/liter). This sample also contained 0.00624 pCi/liter of plutonium-239/240. When added together, these amount to only about 0.3 percent of

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108 See p. 25 of the IEER report for more information about plutonium migration.

109 Email correspondence with Tod Anderson, DOE-Rocky Flats, March 22, 2002, and Kaiser-Hill Contract, No. DE-AC34-00RF01904, Feb. 1, 2000 to Site Closure (Dec. 15, 2006), viewed online March 22, 2002 via www.rfets.gov.

110 The term transuranic refers to elements with an atomic number greater than 92 (the atomic number of uranium), which are essentially man-made elements. (A few transuranic radionuclides occur in nature in extremely tiny concentrations.)

111 Reg. Guide 13 of the EPA incorporates more recent scientific methods but the methods are not directly comparable. On an approximate basis, an RSAL based on these methods would be about 3 picocuries of plutonium per gram of soil. [Full citation is: Eckerman, et al. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, (Federal Guidance Report No. 13) (EPA Report Number EPA-402-R-99-001) Oak Ridge, TN: Oak Ridge National Laboratory; Washington DC: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, 1999.]

the current safe drinking water limit. But if someone drank water with these concentrations all year, the dose would be about 2.1 mrem per year to the bone surface (the critical organ[112] for these radionuclides) using the dose conversion factors that the EPA now normally requires for risk dose estimation.[113]

For the 35 pCi/g suggested as the plutonium RSAL by RAC, the estimated water pathway dose would be about 6 mrem per year (whole body effective dose equivalent). The corresponding bone surface dose would be about 110 mrem per year. The RSAL corresponding to a 4 mrem per year dose limit to the bone surface alone would be about 1.2 pCi/g, or about 30 times lower than that recommended by the RAC team.

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[112] The critical organ is that which is most affected by a radionuclide due to its chemistry. For instance, the critical organ for plutonium-239/240 and americium-241 is the bone surface. The dose to the critical organ is only one part of the dose received due to inhalation or ingestion of a radionuclide. Limiting doses to the critical organ to a certain number is more protective than the same dose to the whole body. In other words, the level of contamination required to produce a whole body effective dose equivalent of 4 millirem is considerably greater in most cases (including plutonium and americium) than that which produces the same dose to the critical organ.

[113] Federal Guidance Report No. 11: Eckerman et al., *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Spine title: *ALIs, DACs & Dose Conversion Factors*), EPA 520/1-88-020, Oak Ridge, TN: Oak Ridge National Laboratory; Washington, DC: U.S. Environmental Protection Agency, Office of Radiation Programs, September 1988. Online at www.epa.gov/radiation/assessment/pubs.html.

Radionuclides in water: Possible future changes in regulations

Federal safe drinking water regulations contain glaring inconsistencies as regards radionuclides. Stipulated in 40 CFR 141[†], the regulations allow total contamination by alpha-emitting transuranic radionuclides, like plutonium-238, plutonium-239 and americium-241, of up to 15 picocuries per liter (pCi/liter).

At the same time, the regulations limit doses for most beta-emitting radionuclides, for instance cesium-137 and iodine-129, to 4 millirem (mrem) per year to the critical organ. The allowable concentrations are not specified but must be derived from prevalent dose conversion factors.

It turns out that if the currently applicable dose conversion factors[‡] are applied to alpha-emitting transuranics, the dose to the critical organ of an adult male who regularly drinks water contaminated with 15 pCi/liter of plutonium-239/240 or americium-241 would be about 180 times greater than the 4 mrem per year allowed for most beta emitters. (The critical organ for plutonium and americium is the bone surface.) Contamination of water to just a fraction of a picocurie of plutonium-239/240 is sufficient to yield a drinking water dose of 4 mrem per year. In the case of neptunium-237, the dose corresponding to a 15 pCi/liter contamination would be almost 280 times higher than 4 mrem per year to the bone surface.

The State of Colorado has a state standard for plutonium in surface water of 0.15 pCi/liter. At Rocky Flats the standard is enforced at the downstream boundary of the site where 30-day moving average is calculated from streams exiting the site. For two separate 30-day periods in 1997, averages for one of the streams, Walnut Creek, exceeded the standard.

The DOE has suggested changing the Colorado standard by changing the averaging period from one month to longer periods. At the same time, a multi-year study, done by the site contractor Kaiser-Hill and funded by DOE, concluded that cleanup to an RSAL of 10 pCi/g would not meet the 0.15 pCi/liter limit for the most contaminated areas downstream from the 903 Pad (the most contaminated part of the Rocky Flats facility). On the other hand, a standard that is enforced for a thirty day period would produce an annual average that, in most cases, would be less than 0.15 pCi/liter.

In the case of plutonium-239/240, the Colorado limit would result in a dose to the bone surface of about 7 mrem per year, compared to the 4 mrem per year federal drinking water dose limit that applies to most beta emitters. If the standard were set for a maximum four mrem per year to the bone surface for americium-241 or plutonium-239/240, the annual average maximum allowable concentration would be about 0.08 pCi/liter (rounded to one significant figure). The concentration limit for each radionuclide would be lower if there is more than one contaminant present.

Federal safe drinking water standards in effect today are a hundred times less strict in regard to plutonium concentration than the State of Colorado's standards for surface water purity. There is no rational reason for the federal transuranic radionuclide limit to be as high as it is and at such variance with maximum allowable doses from most radionuclides.

[†] U.S. Environmental Protection Agency, *Code of Federal Regulations,* Title 40, Part 141, 7-1-00 Edition. Online at www.epa.gov/safewater/regs.html

[‡] In Federal Guidance Report No. 11 (see footnote 8)

The radioactive wildlife refuge

In the early 1990s, the DOE embarked on a cooperative process with the Environmental Protection Agency to develop national cleanup standards, but the DOE pulled out of the process abruptly in the mid-1990s without any plans for its resumption. Since then, the DOE has proceeded on a site-by-site basis. This has led to a welter of proposals for cleanup using various scenarios, with the wildlife refuge having emerged as one of the favorites of the DOE and its contractors.

Five sites out of the more than 130 sites in the nuclear weapons complex are expected to account for the majority of cleanup costs: Oak Ridge in Tennessee, Hanford in Washington State, Savannah River Site in South Carolina bordering on Georgia, the Idaho National Engineering Laboratory, and Rocky Flats. These same sites are now being proposed as wildlife refuges.

In December 2001 President Bush signed into law the bill designating Rocky Flats as a National Wildlife Refuge.[114] It stipulates that the site will be transferred from DOE to the Department of the Interior following cleanup (as defined by the Rocky Flats Cleanup Agreement) and closure.

The DOE, EPA, and the Colorado Department of Public Health and Environment plan to use the wildlife refuge designation to set RSALs at Rocky Flats. Specifically, the agencies intend to calculate the RSALs to protect a wildlife refuge worker, a less protective scenario than the subsistence farmer scenario. They expect to propose RSALs in May 2002. Following a 60-day comment period, they will make a final decision.

Proponents argue that a wildlife refuge would minimize actual risk to off-site human populations by restricting access to the site. They also argue that the DOE cleanup program has been very expensive, ineffective, inefficient, and the costs will only increase, while declaring them wildlife refuges would exempt the DOE from major cleanup and would also serve to protect the natural ecosystems that have flourished. They argue that because nuclear weapons sites have been off limits to the public for so long, they have become havens to endemic species that would otherwise have been at risk due to sprawl and human intervention. (See, for example, *From Waste To Wilderness.*[115]) They also argue that technology for long-term cleanup to high levels is not available at present and it will require technological advances to accomplish such cleanup. We have assessed these arguments, at least as regards Rocky Flats, and conclude that they do not stand up to scrutiny.

Whether a site is designated a wildlife refuge in order to preserve open space and reduce the access of people to contaminated areas in years to come is an issue that is quite distinct from how doses to people far into the future should be assessed. Institutional memory tends to be short compared to the time frames we are considering. Laws change as do patterns of land use. Rocky Flats is already a part of the rapidly growing Denver-Boulder urban corridor, and there can be no *a priori* assurance that this open space will not fall prey to development pressures as has happened elsewhere. Thus, the wildlife refuge designation should not be used to assess how the site may be used centuries from now.

Further, the proposals for making contaminated sites into wildlife refuges have not taken into account the long-term evolutionary impacts on wildlife, the increases in organic matter on site

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[114] The Rocky Flats National Wildlife Refuge Act of 2001, Title XXXI, Subtitle F of the National Defense Authorization Act for Fiscal Year 2002 (Public Law No. 107-107).

[115] Robert H. Nelson, *From Waste To Wilderness: Maintaining Biodiversity on Nuclear-Bomb-Building Sites.* Washington, DC: Competitive Enterprise Institute, 2001.

that may cause more rapid radionuclide migration, and complex pathways to humans due to the interaction of wildlife and people in a densely populated area. Finally, the problem of non-availability of technology is at least in part a spurious one in regard to RSALs. There is no reason why highly contaminated soil cannot be removed and stored retrievably as radioactive waste.

The protection of public health by restricting site access can only be a temporary expedient, at best. It cannot be justified on the grounds of public health protection over a period of many decades, much less hundreds or even thousands of years. Therefore the Rocky Flats' wildlife refuge designation should not be used to set RSALs.

Institutional and cost considerations

The Department of Energy has done quite a bit to characterize the nature of the environmental problem in the weapons complex since the end of the Cold War. However, the actual process of cleanup has been limited by the fact that DOE has been unable to develop a coherent set of priorities. Much of the waste of money is not due to the difficulty of cleanup but the poor management that has plagued DOE projects. Poor institutional culture is at the core of the problem, as IEER has shown in a previous detailed study of the subject.[116]

Cost is often cited as a factor in setting more lax standards. But the DOE has historically chosen to use waste management methods that have been expedient in the short-term but turn into far more costly and difficult problems of cleanup in the long-term. Not doing the job of cleanup right in the first place allows contamination to spread both through the forces of weather and, it is becoming increasingly apparent, by fauna that pass through the site but do not stay on it. Expedient solutions may appear cheaper now but they have been a central part of the reason that the United States is faced with immense cleanup costs in its nuclear weapons complex today.

While even a well managed and coherent cleanup program would be expensive, one must look at these costs in context. The DOE estimate for partial environmental restoration, waste management and disposal is $227 billion over 75 years. This is about 4 percent of the total of 5.5 trillion dollars that the United States spent between 1940 and 1996 to construct and deploy nuclear weapons.[117] Moreover, most of this expenditure is actually for materials management and safeguards, site security, and the like, which would have to be spent anyway. Actual cleanup costs may be on the order of a couple percent of the total Cold War nuclear weapons expenditure even if it is done to exacting standards, presuming the money will be well spent.

Cost internalization of environmental problems is an important principle that the government tries to impose when it creates regulations for private industry. Setting and meeting strict cleanup standards is a part of cost internalization for nuclear weapons. It is essential that the government set for itself the high standards it expects of the private sector and that it do so based on long-term public health protection criteria.

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[116] Marc Fioravanti and Arjun Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, Takoma Park, MD: Institute for Energy and Environmental Research, 1997.

[117] Stephen I. Schwartz, (ed.), *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*. Washington, DC: Brookings Institution Press, 1998.

The Subsistence Farmer Scenario
Its Development, Use and Scientific Basis

The principal scientific basis for radiation protection has been, and continues to be, to set limits on the maximum allowable exposures to individuals at greatest risk from man-made radiation sources. Historically, radiation standards were set in the context of worker protection, such as medical X-ray workers, radium-dial painters, and Manhattan Project personnel. Worker exposures are measured or inferred through the use of film badges, urine monitoring, and other methods. (See *Science for Democratic Action* vol. 9 no. 1, December 2000, for a summary of worker dose regulations.)

The general public outside of nuclear facilities does not have the same protective monitoring. As a result, conservative approaches to estimating doses have been developed to protect people off-site, which also serve to limit population dose in most cases. In the late 1950s and early 1960s, the Atomic Energy Commission, a predecessor of the U.S. Department of Energy (DOE), established the first regulations designed to protect off-site populations. Over time, it has become established practice to limit the maximum allowable concentrations of radionuclides at the site boundary so that a hypothetical maximally exposed individual is not exposed to more than a specified radiation dose. For long-term dose calculations, the concept of "critical group" has also been established.

The **maximally exposed individual** is a hypothetical off-site person, usually located at or near the site boundary, who would receive the maximum dose from a facility's operations. The maximally exposed individual concept was implicit in U.S. regulations as early as the late 1960s and is now at the heart of current radiation protection regulations for present populations.

The **critical group** is a small, homogenous subset of the general population with characteristics such as lifestyle or diets that would cause them to have higher exposures than the rest of the population. In practice, the maximally exposed individual is a member of the critical group whose exposures are the highest of the group, and therefore of the entire general population.

The critical group and the maximally exposed individual are necessarily statistical concepts and do not cover all possible contingencies, but they are tools which prevent, with a high degree of probability, the general population from getting higher radiation doses than the limits specified in regulations. (See the box below for further discussion of these concepts.)

The maximally exposed individual joins the critical group

For the purposes of calculating future radiation dose and setting cleanup standards (or repository performance standards), a small homogeneous group of individuals is used to define a **critical group**. The International Commission on Radiological Protection (ICRP) Publication 46 (1985) defines the critical group in the following manner:

When an actual group cannot be defined, a hypothetical group or representative individual should be considered who, due to location and time, would receive the greatest dose. The habits and characteristics of the group should be based upon present knowledge using cautious, but reasonable assumptions. For example, the critical group could be the group of people who might live in an area near a repository and whose water would be obtained from a nearby groundwater aquifer. Because the actual doses in the entire population will constitute a distribution for which the critical group represents the extreme, this procedure is intended to ensure that no individual doses are unacceptably high.

ICRP recommends that critical groups be small so that they are homogenous with the upper limit to size usually being "up to a few tens of persons." They could be as small as only one person. In this specific instance, the congruence of the critical group with a hypothetical **maximally exposed individual** is complete.

In an extreme case it may be convenient to define the critical group in terms of a *single hypothetical individual*, for example when dealing with conditions well in the future which cannot be characterized in detail. (emphasis added) (ICRP Publication 43, 1984)

The **subsistence farmer scenario** was developed as an extension of the maximally exposed individual in situations where contamination or waste disposal activities may put future generations at risk of cancer or other disease outcomes. When the main route of exposure over long time periods is uncertain, it is the general practice to use the subsistence farmer scenario for calculating risk or the level of permissible exposure to radiation. If the predicted dose and risk of the subsistence farmer is estimated to be less than allowable limits with a high degree of confidence, then it is reasonable to assume the rest of the public is protected as well.

The choice of a framework for cleanup cannot resolve all the uncertainties -- future lifestyles, diet, population settlement patterns, land-use regulations, climate, environmental protection standards, future assessments of the risk of pollution or contamination, future utility of specific resources -- but it can address them in a manner as to make the cleanup standards relatively robust to changes that might occur. Correspondingly, the subsistence farmer approach assumes that institutional memory of contamination will be lost and that some people would unknowingly use contaminated water for drinking and growing all of their own food. Further, it assumes that such exposure would last a lifetime, and not just a few years. It is conservative in that there are few assumptions about future lifestyles that will result in much greater exposures. The remaining uncertainties are then in the parameters chosen for modeling future doses, such as those related to climate and hydrology and those related to mobility of contaminants through the environment.

It is not at all implausible that there may be significant numbers of people in the future who would choose to be self-sufficient farmers or something close to it, even in the context of rapid urbanization of populations. Indeed, it is quite possible to imagine economic, social, and technological arrangements under which a large proportion of the population of the future would grow most of their own food or obtain it very locally.

The assumption that the risk to all individuals within a population will be below that of the hypothetical subsistence farmer is an estimate that, with some unknown but small likelihood, may turn out to be wrong. For instance, the subsistence farmer approach assumes that the diets as well as food and water intake of future populations will be similar to those of today. It is common to exclude extreme diets consisting only of the most contaminated foods. While such diets cannot be ruled out, they may reasonably be considered as improbable, unless there is some evidence to the contrary.

Use of the subsistence farmer scenario has a strong precedent. DOE analyses of allowable residual contamination levels have used a subsistence-farmer-like model since the 1980s. The Yucca Mountain Project, in the past, estimated future doses based on subsistence farmers. The U.S. Nuclear Regulatory Commission and projects at the Waste Isolation Pilot Plant and Sandia National Laboratories also have used the subsistence farmer scenario or variants thereof. In regulatory terms, the U.S. Environmental Protection Agency in establishing Superfund regulations used the subsistence farmer scenario. There is also considerable international consensus supporting the subsistence farmer approach: it has been used in Britain, Sweden, Finland, Norway, Switzerland and other countries, and is consistent with recommendations of the International Commission on Radiological Protection. (See the IEER report for quotes and references from international sources.)

One argument that has been used against the subsistence farmer scenario is that it is too stringent for proposed geologic disposal sites such as Yucca Mountain or nuclear facilities such as Rocky Flats. However, this argument is weak. In relation to Yucca Mountain, it has been shown that the repository design adopted by the DOE would in future time fail established performance limits. It could not meet currently established safe drinking water limits near the repository footprint. This does not mean that the subsistence farmer scenario is too stringent but rather that the repository location and design are poor.

In sum, the subsistence farmer scenario is a conservative, stringent, and practically bounding approach to calculating future regulatory dose limits. It provides a reasonable, scientifically and historically defensible framework that is robust to a large variety of future uncertainties.

This centerfold draws from the IEER report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats* (December 2001). References can be found in the report, which is available on IEER's web site at www.ieer.org/reports/rocky/toc.html.

Recommendations

IEER's recommendations for setting cleanup standards to protect future generations are summarized in the box below.

IEER RECOMMENDATIONS

for setting cleanup standards to protect future generations

- The U.S. Department of Energy (DOE) should abandon its attempt to use the wildlife refuge designation as the basis for setting RSALs. It should adopt the subsistence farmer scenario as the basis for the cleanup program throughout its nuclear weapons complex. It is the scientifically sound approach and it is far less likely to result in future damage of a kind that could cause future suffering, loss of trust and expenditure should problems crop up.
- The subsistence farmer or subsistence rancher scenario should be used as the basis for setting a residual soil action level at Rocky Flats, regardless of the site's designation as a wildlife refuge.
- The designation of Rocky Flats as a wildlife refuge should not serve as a precedent for other sites or for reducing cleanup expenditures at other major DOE nuclear weapons sites.
- Careful investigations of the effect of high residual contamination on wildlife should be undertaken. Investigations of the potential for the wildlife refuge designation to enhance the mobility of plutonium into the accessible environment, including groundwater, should also be undertaken.
- A residual soil action levels (RSAL) between 1 and 10 picocuries of plutonium per gram of soil should be considered as the basis for the cleanup program at Rocky Flats, regardless of the site's wildlife refuge designation. Our evaluation indicates that, if groundwater pathway doses are taken into account, a choice in the 1 to 3 picocuries per gram range would be more appropriate. Such an RSAL would also be compatible with the dose implications of the current State of Colorado surface water standard of 0.15 picocuries per liter of plutonium, should it be extended to groundwater in the future. Soil action levels deriving from scenarios related to designation of the site as a wildlife refuge should be rejected.
- The steps towards the achievement of the ultimate RSAL, and the institutional arrangements in the interim, are beyond the scope of the IEER report. But any cleanup plan should specify how a standard based on the subsistence farmer or rancher scenario would be achieved, and how any interim steps would relate to this goal.

For the full set of recommendations, see the report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats,* online at www.ieer.org/reports/rocky/toc.html.

Risk from Plutonium in the Environment at Rocky Flats

Prepared by LeRoy Moore, Ph.D., Rocky Mountain Peace and Justice Center (303-444-6981)

November 5, 2002

- Plutonium 239, the material of principal concern at Rocky Flats, has a half-life of 24,400 years. It remains dangerously radioactive for more than a quarter-of-a-million years. Left in the environment, it poses an essentially permanent danger.

- The alpha radiation emitted by plutonium cannot penetrate skin like gamma radiation or x-rays. But minuscule plutonium particles inhaled, ingested, or taken into the body through an open wound may lodge in the lungs or migrate to the liver or to the surface or marrow of bone. For as long as it resides in the body it continues to bombard surrounding tissue with radiation, possibly resulting in cancer, genetic defects, harm to the immune system. The latent period of cancer is likely to be 20 to 30 years.

Lung Tissue exposed to alpha rays emitted from a single particle of plutonium-239.

"The black star in the middle of this picture shows the tracks made by alpha rays emitted from a particle of plutonium-239 in the lung tissue of an ape. The alpha rays do not travel very far, but once inside the body, they can penetrate more than 10,000 cells within their range. This set of alpha tracks (magnified 500 times) occurred over a 48-hour period" (Robert Del Tredici, *At Work in the Fields of the Bomb* [1987], plate 39; photographed at Lawrence Radiation Laboratory, Berkeley, California, 9-20-82).

- A single microgram of plutonium is "a potentially lethal dose" (F. Albert Cotton & Geoffrey Wilkinson, *Advanced Inorganic Chemistry*, 2nd ed., 1966, p. 1102). One microgram = 1/millionth of a gram. One ounce contains 31.1 grams, or 31.1 million micrograms. Particles of plutonium weighing 10 or less micrograms can be inhaled.

- Internal alpha emitters like plutonium are much more harmful per unit dose than penetrating gamma radiation. To account for the difference, the International Commission on Radiological Protection (ICRP) and other bodies refer to the "relative biological effectiveness" (RBE) of alpha emitters. Looking at the potential harm to different organs and for different disease end-points, ICRP comes up with an average RBE for alpha emitters of 20. This means that, on average, internal alpha emitters are 20 times more harmful than external gamma radiation of the same dose. But because 20 is an average, for some body organs and for certain cancers as well as for some individuals the actual

RBE is higher than the average, sometimes much higher. Those who calculated the proposed cleanup levels for Rocky Flats used 20 as the RBE for plutonium. This approach underestimates the harm that may result from plutonium exposure to certain organs of the body or to given individuals. Doubling the plutonium RBE to 40 would reduce the amount of plutonium allowed to remain in the surface soil by half from 50 to 25 picocuries per gram of soil. (On the RBE for plutonium, see Helen A. Grogan et al, *Assessing Risk of Exposure to Plutonium*, February 2000, [Risk Assessment Corporation], pp. 6-27 – 6-39).

• A British research team headed by Eric Wright concluded that the RBE for chromosomal damage from plutonium exposure is essentially "infinite" -- because the extent of harm to the human gene pool is incalculable (Khadim et al, *Nature*, vol. 355, no. 20 [2-92], pp. 738-740).

• Tom K. Hei and colleagues at Columbia University demonstrated that a single plutonium alpha particle induces mutations in mammal cells. Cells irradiated by very low doses of alpha radiation were more likely to be damaged rather than destroyed. Replication of these damaged cells constitutes genetic harm, and more such harm per unit dose occurs at very low doses than would occur with higher dose exposures. "These data provide direct evidence that a single alpha particle traversing a nucleus will have a high probability of resulting in a mutation and highlight the need for radiation protection at low doses" (*Proceedings of the National Academy of Sciences*, 94 [April 1997]: 3765-3770). In a follow-up study, they found that "a single alpha particle can induce mutations and chromosome aberrations in [adjacent or bystander] cells that received no direct radiation exposure to their DNA" (*Proceedings of the National Academy of Sciences*, vol. 98 [4 Dec. 2001], pp. 14410-14415).

• The resultant genomic instability may also, they believe, account for illnesses other than cancer, illnesses so elusive that epidemiology is "powerless" to detect any relationship between their incidence and exposure to radiation (see M. A. Kadhim et al, *Nature*, vol. 355, 20 February 1992, pp. 738-740; and Rob Edwards, *New Scientist*, vol. 11, October 1997, pp. 37-40).

• In 1987 Gregg S. Wilkinson of DOE's Los Alamos Lab published results of his study showing that some exposed Rocky Flats workers with internal plutonium deposits well below DOE's purportedly safe permissible lifetime body burden developed a variety of cancers in excess of what was normal for workers who had not been exposed (*American Journal of Epidemiology*, vol. 125, no. 2 [1987], pp. 231-250).

• Diethard Tautz, a specialist on genetic effects, says that effects of radiation exposure on a given species of wildlife may not be readily apparent in the individuals of that species until the passage of several generations. He calls this a "genetic uncertainty problem" (*Trends in Genetics*, vol. 16 [11-00], pp. 475-477). His work suggests that the wildlife for which Rocky Flats will provide a refuge could in the long term be hurt more than helped by conditions at the site. Such hurt, of course, woud not be contained within the bounds of the Rocky Flats site.

• Historically, while certain parts of the Rocky Flats site were more heavily contaminated than others, the whole of the site was contaminated to some extent. Samples taken by Prof. F. Ward Whicker of Colo. State Univ. at the Flatiron Vista Trailhead, an offsite predominantly upwind location about three miles northwest of the site's industrial area, showed plutonium deposits slightly more than twice the average background concentration from fallout. Elevated deposits in a predominantly upwind direction suggest that the whole of the buffer zone must contain levels of plutonium above background. One could reach a similar conclusion from the work of Prof. Harvey Nichols of the Univ. of Colo., who, in the winter of 1975-76, at the height of production at Rocky Flats, found that plutonium in the air as a result of routine emissions was brought to earth in the northwest portion of the site during snowfall. His finding, like Whicker's, suggests that there must have been similar deposits laid down across the whole of the site. The site's own 1999 map of plutonium distribution in surface soil does not refute this view and in fact seems to support it.

• The government agencies responsible for cleanup of Rocky Flats have not thoroughly "characterized" the Rocky Flats site to determine the full extent of contamination in the environment, and they have no plan to do so. They also have no intention of cleaning the site to the maximum extent possible. They plan to leave some plutonium and other toxins in the environment.

• Plutonium left in the Rocky Flats environment will be in the form of very fine particles that can be inhaled or ingested but that also can migrate. They can be picked up and transported by wind, and they can be moved by water, by plant processes, or by the actions of worms, insects, birds, animals. In the long-term future, human or animal activity or geophysical changes could bring to the surface plutonium left below the surface in the Rocky Flats environment. There is no guarantee that plutonium left in the Rocky Flats environment will remain on the site.

Excess Cancers among Workers Exposed to Plutonium on the Job at Rocky Flats The Wilkinson Study

by LeRoy Moore, Ph.D., Rocky Mountain Peace & Justice Center (January 2002)

In 1987 Gregg S. Wilkinson of DOE's Los Alamos Lab published results of a study of Rocky Flats workers that presented the first epidemiological findings suggesting that exposure to plutonium produced adverse health effects.[i] Wilkinson divided the 5,413 workers he studied into three groups: the *more exposed* (those with a plutonium body burden of 5 or more nanocuries [nCi]), the *less exposed* (those with a body burden of from 2 to 4.9 nCi), and the *unexposed*. Both the less exposed and more exposed workers showed no significant increase in cancers of the liver, bone and lung -- organs of the body where plutonium is known to accumulate. But both groups showed surprising increases in a wide range of other cancers. Excess brain cancers were found among both the less exposed and more exposed.

DOE's occupational standard for plutonium is a maximum permissible body burden of 40 nCi. Many of the workers Wilkinson studied had body burdens considerably below this level. Because 2 nCi -- a mere 5% of DOE's standard for permissible exposure -- was the lowest level his instruments could detect with certainty, Wilkinson classified as unexposed all workers with a body burden of less than 2 nCi. Any cancers among workers burdened at this very low level were not counted as possibly due to occupational exposure. Wilkinson thus thought his study underestimated the true effect of plutonium exposure.

As soon as his results began to be known, his study created a firestorm of controversy within DOE. A physician on the Los Alamos staff told him that his findings, if true, "would shut down the nuclear industry!"[ii] His supervisor at Los Alamos urged him to modify his findings prior to publication to please "the customer"[iii] -- that is, DOE. When he published his results without change in the *American Journal of Epidemiology* in 1987, his Los Alamos work was downgraded and subjected to increased levels of internal review, making future research more difficult and publication less likely. In response, he resigned.[iv] His colleague George Voelz, one of the eight co-authors of the Wilkinson study, was moved into the position Wilkinson vacated.

In a recent article in *Los Alamos Science*, Voelz presents what purports to be a comprehensive review of what is now known about risk from exposure to plutonium. Wilkinson's study of Rocky Flats workers, he says, showed "no evidence of statistically increased rates of lung, liver, and bone cancers."[v] While this is true, Voelz makes no mention of what made the Wilkinson study so controversial in the first place, namely, the finding of elevated levels of other cancers among workers with plutonium exposure at very low doses. Voelz brings the scandal surrounding Wilkinson's work right up to date. Wilkinson now chairs the Department of Epidemiology and Biostatistics at the University of North Texas at Fort Worth.

Having heard Wilkinson's Rocky Flats study dismissed as inadequate because he did not consider data on the use of tobacco among the workers he studied, I asked Wilkinson about this. He pointed out, first, that data on tobacco use would be pertinent for lung cancer but not for other cancers. Second, "the potential relationship between smoking, plutonium lung burden and lung cancer should be studied." In fact, while he was at Los Alamos he had drafted a proposal to seek National Cancer Institute funding for research in this area, but DOE officials "would not allow the proposal to be sent to the NCI for review."[vi]

PART 5

Commenting on the proposed revisions to the Rocky Flats Cleanup Agreement

Material prepared by the Rocky Mountain Peace and Justice Center and distributed to the public:

5. Fact Sheet on the Proposed Cleanup for Rocky Flats (November 26, 2002)
6. Rocky Flats: Your local radioactive Superfund site: How clean is clean? Your comments can help decide.
7. Comments, Questions, & Recommendations on Proposed Changes to RFCA (December 17, 2002)

FACT SHEET ON THE PROPOSED CLEANUP FOR ROCKY FLATS

Prepared by Rocky Mountain Peace & Justice Center, Box 1156, Boulder, CO 80306; 303-444-6981
(November 26, 2002)

Time and money trap, or why we're not getting a better cleanup: In 1996 the Department of Energy (DOE) made an arbitrary decision to close Rocky Flats in 10 years, by the end of 2006, without first figuring out the requirements for a real cleanup. Soon after they decided that cleanup and closure will occur according to a fixed-sum. The $7 billion budgeted covers everything from removal of weapons-grade material and bomb-production waste to site security and decommissioning and demolition of buildings. Environmental remediation, or cleanup of soil, air, and water, gets done with funds left over – $470 million, or only 7% of the $7 billion total. We're in a time and money trap in which public health and environmental integrity are being sacrificed to a partial cleanup and closure by an arbitrary date. DOE now says the site may close in 2005, with a resultant saving of about $210 million. They are unwilling to spend any of this saving on better cleanup of the Rocky Flats site.

The proposed cleanup in context: The DOE, Environmental Protection Agency (EPA), and Colorado Department of Public Health and Environment (CDPHE) propose a surface soil cleanup for Rocky Flats that will leave behind up to 50 picocuries of plutonium per gram of soil. This is a 93% reduction from the 651 picocuries level these same agencies adopted in 1996 despite strong public opposition. A surface soil cleanup level of 50 signifies a major victory for those who have sought a better Rocky Flats cleanup. But, as is explained below, this is not good enough. Moreover, in exchange for this better cleanup on the surface, the government agencies intend less cleanup of the subsurface environment. What follows indicates problems with the agencies' proposal and recommends an alternative.

What the public says it wants: In 1995, after a year of work, the broadly representative Rocky Flats Future Site Use Working Group recommended by consensus that Rocky Flats be cleaned to average background radiation levels (0.04 picocuries per gram for plutonium fallout from atmospheric tests) when it is technologically possible to do this in a manner that is fiscally and environmentally responsible**.** Calling for research to develop the technology needed to reach this goal, the Working Group said, "We are willing to wait as long as is necessary, but no longer than necessary, to see the site cleaned up." The Rocky Flats Citizens Advisory Board and Rocky Flats Local Impacts Initiative as well as several public interest organizations subsequently endorsed this recommendation. Cleanup now should move as far as possible toward this ultimate goal.

Key problems with the proposed Rocky Flats cleanup:

- Cleanup is geared to an arbitrary closure date of December 2006.
- All closure activities are being done for a fixed sum, with cleanup done for about 7% of the total. DOE and the regulators say we are getting the best possible cleanup for the limited sum available.

8. DOE, with the consent of EPA and CDPHE, does not intend to clean Rocky Flats to the maximum extent possible, though various groups have repeatedly recommended this.

1. Neither areas under buildings nor along the 7 miles of buried (and sometimes ruptured) process waste lines that carried toxic and radioactive waste have been fully examined or "characterized" to determine the actual extent of contamination. Ditto for the surface soil itself. Hence, no one really knows how dirty Rocky Flats is. DOE has no plan for full site characterization, and the regulators are not requiring it.

- Cleanup is limited to the short-term goal of protecting a wildlife refuge worker (see below).

The plutonium danger: Among the variety of toxins in the Rocky Flats environment, plutonium is the contaminant of principal concern. With a half-life of 24,400 years, plutonium remains dangerously radioactive for a quarter-of-a-million years. An alpha emitter, it can be harmful in very tiny amounts if inhaled, ingested, or taken into the body through an open wound. Once lodged in the body, it constantly bombards surrounding cells with radiation, potentially damaging cells hit directly as well as nearby "bystander" cells. The result can be cancer, immune system damage, or genetic aberrations that get passed on to future generations. Any quantity of plutonium left in the environment thus constitutes an essentially permanent danger. (On cellular damage that may be caused by a single plutonium particle, see Hei et al, *Proceedings of the National Academy of Sciences*, vol. 94, Ap. 1997; Kadhim et al, *Nature*, vol. 355, 20 Feb. 1992; and Edwards, *New Scientist*, vol. 11, Oct. 1997).

Evolutionary effects of plutonium exposure on wildlife: It has been known since the 1920s that ionizing radiation can cause genetic mutation and that some mutations prove harmful. In a recently published study, Diethard Tautz, a specialist on genetic effects, says that genetic changes within a given species may not be readily apparent in individuals of that species until the passage of several lifetimes. Genetic alterations may be so subtle that they cannot be readily detected until generations later when their effects are manifest in an entire population and the change is irreversible. Tautz calls this a "genetic uncertainty problem" (see *Trends in Genetics*, vol. 16, Nov. 2000). His work suggests that the wildlife for which Rocky Flats provides a refuge may in the long term be hurt more than helped by conditions at the site. Such hurt, of course, would not be contained within the bounds of the Rocky Flats site. What Tautz suggests about wildlife has implications as well for humans.

Regulatory compliance: Cleanup of plutonium in surface soil to 50 picocuries per gram meets major regulatory requirements. But an August 2000 Actinide Migration Evaluation study concluded that cleaning surface soil at Rocky Flats to as low 10 picocuries would not guarantee compliance with the Colorado standard for plutonium in surface water (0.15 picocuries per liter of water). But the state surface water standard itself may be insufficiently protective. According to a report prepared for RMPJC by the Institute for Energy and Environmental Research (IEER), the Colorado standard for plutonium in surface water allows for a dose to bone surface about double the federal drinking water limit (see *Science for Democratic Action*, vol. 10, no. 3, p. 4 [attached]). The agencies thus should clean Rocky Flats to a level more protective than mandated by major regulatory standards both because they can and because leaving so much plutonium in the soil is unsafe, especially in the long-term.

Cleanup for what future use: Rocky Flats will become a wildlife refuge at closure. The law designating Rocky Flats as a refuge says that this designation should not be used to determine site cleanup levels. Yet this is precisely what is happening. The site will be cleaned to provide a modest (not the most stringent) protection for a wildlife refuge worker who spends 2000 hours per year on site for perhaps 15 years. But Rocky Flats will cease being a wildlife refuge long before plutonium left behind ceases to be dangerous. At some future time, after fences fall and memory fails, Rocky Flats is likely to be inhabited by families who eat homegrown food and for generations spend up to 8400 hours per year on the site, much of this time outdoors. Who will protect them from what's been left in the environment? Our August 2001 Freedom-of-Information-Act request for documentation on who made the decision to clean the site only to protect a wildlife refuge worker has received no substantive reply.

Questionable subsurface pathway analysis: DOE, EPA, and CDPHE say that the plutonium left in the subsurface environment at Rocky Flats will lack a pathway to humans who use the site. This analysis, however, is based on several dubious assumptions, including a) that the environment will remain basically unaltered by human or natural activity; b) that the incomplete characterization of the site hasn't missed hot spots that should be removed; and c) that institutional or engineered controls put in place to contain residual contaminants will not fail. A recent National Academy of Sciences report says that reliance on engineered barriers and institutional controls is "inherently failure prone" (NAS, "Long-term Institutional Management of U.S. Department of Energy Legacy Waste Sites," 2000).

Rocky Mountain Peace and Justice Center recommendations:

- We recommend that Rocky Flats be cleaned to protect the family of a resident subsistence farmer (on this topic see IEER, *Science for Democratic Action*, vol. 10, no. 3, pp. 1-6, 8-9 [attached]).
- The resultant cleanup level for plutonium in surface and subsurface soil would be 5 or less picocuries per gram, with subsurface cleanup depth determined by the depth of contamination. Cleanup to this level will make the site safer for all other uses.
- We further recommend removal of all process waste lines in the subsurface environment.
- We also recommend thorough characterization of the whole site and cleanup to the maximum extent now possible.
- We call on DOE to apply the full $7 billion dollars allocated for closure of Rocky Flats on cleanup and closure activities at the site.
- If the above cannot be accomplished with funds currently available, the government agencies should estimate the cost and seek public support to get the requisite funding from Congress.
- Finally, if he agencies reject the foregoing recommendations in favor of the partial cleanup they have proposed, we recommend that as a condition of moving ahead they work with the affected public to establish a rigorous long-term stewardship program that includes a plan to research technology needed for better site cleanup as well as assured and dedicated funding to cover all long-term stewardship costs, including contingencies.

ROCKY FLATS

YOUR LOCAL RADIOACTIVE SUPERFUND SITE

HOW CLEAN IS CLEAN? YOUR COMMENTS CAN HELP DECIDE

FINAL ROCKY FLATS CLEANUP PLAN RELEASED: On Tues, November 12, DOE and the regulators released for public comment their final plan for cleanup of Rocky Flats, site of the former nuclear weapons plant. Their document shows how much contamination they intend to leave in the Rocky Flats environment at closure in 2006 when the facility becomes a National Wildlife Refuge. There's a 60-day comment period, ending on January 13, 2003. The Citizens Advisory Board and RMPJC have asked that the comment period be extended until January 31, but to date there's been no reply.

COMMENTS NEEDED: The government agencies say they will not clean Rocky Flats to the maximum extent now possible. Because of the long-lived danger of some of the contaminants, especially plutonium, the "cleanup" done now will affect people in the Denver metro area essentially forever. Hence, your comments are very much needed. Public opposition to the cleanup standards adopted in 1996 made a huge difference in what the government has been able to do. We can have this sort of effect again.

WHAT ARE YOU COMMENTING ON? The Rocky Flats Cleanup Agreement (RFCA), the legally binding document that defines the nature and extent of "cleanup" at Rocky Flats, was originally adopted in 1996. The just-released final cleanup proposal takes the form of additions to and revisions of RFCA. The documents for public comment can be found at the Rocky Flats Reading Room, Front Range Community College, 3705 W. 112th Ave., Westminster, or online at www.rfets.gov under the Public Meetings link. All the proposed changes in the cleanup plan are detailed in the 27-page Part 1, Technical Basis Document, which is not exactly light reading but is probably clear enough for a careful reader and is sufficient for knowing what is being proposed.

RMPJC RESOURCES:

- Fact Sheet on the Proposed Cleanup for Rocky Flats summarizes the problems with the cleanup plan and provides our recommendations.
- Fact Sheet on Risk from Plutonium in the Rocky Flats Environment.
- *Science for Democratic Action* (May 2002), newsletter of the Institute for Energy and Environmental Research, summarizes a technical report IEER did for us that recommends cleaning Rocky Flats to protect a subsistence farmer who may some day live on the Rocky Flats site (this would entail a far more stringent cleanup than the government plan to protect only a wildlife refuge worker).

HOW TO COMMENT

You can comment either verbally or in writing, as follows:

Public meeting: Verbal and/or written comments can be submitted at a public meeting, 6-9 PM, Tues, Dec 17, at the Westminster Recreation Center, 10455 Sheridan Blvd (west side of Sheridan just north of W. 104th Ave). Carpool from RMPJC at 5:15 PM.

Mail: Comments postmarked not later than Jan 13, 2003, can be submitted to Rick DiSalvo, DOE Rocky Flats, 10808 Highway 93, Unit A, Golden, CO 80403-8200.

Prepared by Rocky Mountain Peace and Justice Center, Boulder
If you have questions or comments, please call 303-444-6981

COMMENTS, QUESTIONS, &

RECOMMENDATIONS

ON PROPOSED CHANGES TO RFCA

(ROCKY FLATS CLEANUP AGREEMENT)

LeRoy Moore, Ph.D., December 17, 2002

Rocky Mountain Peace and Justice Center

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Plutonium in the environment

- Plutonium, the contaminant of principal concern at Rocky Flats, has a half-life of 24,400 years; it remains dangerous for a quarter-of-a-million years.
- The alpha radiation that plutonium emits cannot penetrate skin, but tiny particles inhaled, ingested, or taken into the body through a wound can cause cancer, genetic defects, or harm to the immune system.
- One particle inside the body can penetrate more than 10,000 cells within its range. Columbia University scientists found that a single plutonium particle can induce mutations in cells of mammals.
- While some portions of the Rocky Flats site are more heavily contaminated than others, the whole of the site is contaminated to some extent.
- Particles of plutonium left in the soil can be resuspended in respirable size and transported by wind or water or by plant, animal or human actions.
- Genetic harm to wildlife may not be apparent for generations.
- Plutonium in the environment poses an essentially permanent danger.

(For more information on risk from plutonium, see Attachment A.)

Radiation risk in perspective

9. After the 1969 fire at Rocky Flats, NCAR physicist Ed Martell found Pu up to hundreds of times background at various locations off the Rocky Flats site. This is how the Colorado state government and the public learned about the Pu released into the environment from accidents at Rocky Flats.

- A lifelong student of radiation, Martell emphasized that humans had evolved in a symbiotic relation to natural radiation, which itself could be harmful, even fatal. But due to global fallout since 1945, we no longer live in an environment of natural background radiation. We all are now exposed to more radiation than evolution prepared us for. In Martell's view, incalculable harm is the likely effect. Thus, where we have the choice, we should not add to the burden of risk we have already created. Martell was working on a book on this subject when he died in 1995.

- Andrei Sakharov, the Soviet bomb designer who became his country's best-known dissident, believed that global fallout from bomb tests would result in millions of premature deaths. He bemoaned the fact that those harmed by what we now call background would not understand the source of their ailment and that perpetrators of this evil would not be brought to justice.

Rocky Flats cleanup: The public history

- The public has repeatedly said it wants the best cleanup possible at Rocky Flats. In 1995 the Future Site Use Working Group and other bodies said that the ultimate goal should be cleanup to average background levels, which for Pu from fallout is 0.04 picocuries per gram of soil (pCi/g).

- In 1996 the RFCA set the action level for Pu at 651 pCi/g.

- Because the 651 level was rejected by the public, DOE funded an independent review out of which came a recommendation of 35 pCi/g. The agencies never made a formal response to this recommendation.

- In June 2000 the agencies convened the RFCA Focus Group, a non-advisory body that over the next 22 months until April 2002 served as the principal body for public participation on cleanup issues.

- Meanwhile, an Actinide Migration Study of June 2000 said that a Pu action level of 10 pCi/g would not guarantee ability to meet the state standard for Pu in surface water of 0.15 pCi/L.[vii] This led to speculation that meeting the water standard would become the real driver for Rocky Flats cleanup.

Rocky Flats cleanup: The hidden history

To get assured funding from Congress for cleanup and closure of Rocky Flats, DOE and Kaiser-Hill agreed to meet three conditions:

- *Close the site by the arbitrary date of December 2006.*
- *Complete all closure activities for the fixed sum of $7 billion.*
- *Curtail conflict in the community.*[viii]

COMMENT: This agreement was made without consulting the affected public and without determining the requirements of a real cleanup (for instance, the site has never been thoroughly characterized and there is no plan for this).

- The first two items above put all parties involved in a time and money trap in which public health and environmental integrity are sacrificed to a partial cleanup and closure by an arbitrary date.
- Priority in spending has gone to security, removal of weapons material and bomb-production waste, and demolition of buildings. It is only the funds left over - $473 million, or not quite 7% of the $7B total – that are designated for cleanup of soil and water.
- Community conflict has been dealt with by involving the engaged public heavily in rearranging details of a plan devised without their input.

Rocky Flats cleanup: More hidden history

Two other key decisions were made without consulting the affected public:

- *Clean Rocky Flats to protect a wildlife refuge worker, though the law making the site a refuge says the refuge designation shall not define cleanup.*

COMMENT: The RFCA Focus Group spent much time on the cleanup scenario issue because several participants believed the refuge worker scenario was not sufficiently protective. In June 2001 we finally were told that the decision to use the refuge worker scenario had already been made. We'd been wasting our time. I asked who made the decision. Was it done locally or in Washington? I thought the public was entitled to know, so we could address concerns to actual decision-makers. Getting no answer, I sought the truth via a Freedom-of-Information-Act request. Months later I received some irrelevant documents already in our possession. The question remains unanswered.

- *Budget cleanup costs at the 651 Pu level rejected by the public, even though DOE was funding a technical review expected to produce a lower number.*

COMMENT: This fact illumines the tradeoff the public is asked to accept of getting better surface cleanup in exchange for less subsurface cleanup. Given a fixed sum, spending more on surface cleanup means less for the subsurface.

Aspects of the proposed cleanup: Future use and federal control

Because the immediate future use of Rocky Flats after closure will be as a wildlife refuge, the agencies assume permanent federal control of the site and propose a cleanup designed to protect a wildlife refuge worker (at the middle of the Superfund risk range –- 10^{-5} -- rather than at a more stringent level).

> **QUESTIONS**: Can the agencies guarantee that Rocky Flats will be a wildlife refuge in 200 years? in 500 years? in 2400 years (10% of the half-life of plutonium)? Will the site remain in federal hands through these periods? Can agency personnel imagine a time when fences fall and memory fails? If so, what provision are they making for this eventuality?

Aspects of the proposed cleanup:
The tradeoff

The agencies say they will clean or remediate Pu in surface soil at the 50 pCi/g level, which is a much better surface cleanup than the 651 level of 1996. But in exchange they plan less subsurface cleanup, an example being the intended incomplete characterization and limited removal of several miles of original process waste lines. *The Denver Post*, in a November 16 editorial, said the plan for these waste lines invites skepticism.

> **QUESTIONS**: Can the agencies guarantee that all the Pu they leave on the surface will remain stable and undisturbed on the site for 200 years? 500 years? 2400 years? Can the agencies guarantee that the much larger amounts of Pu they intend to leave below the surface will remain undisturbed by human or natural actions for these same periods or for, say, a mere 25% of the half-life of Pu? Recognizing uncertainties, for how long would they venture to say that the surface and subsurface Pu and other contaminants will remain undisturbed?

Aspects of the proposed cleanup: Controls

Because they plan to leave contaminants behind, the agencies intend to contain the residual contamination with institutional controls (restrictions on land use) and engineered controls (such as, covers, groundwater barriers, treatment cells, monitoring systems).

QUESTIONS: A recent National Academy of Sciences study concluded that reliance on institutional and engineered controls to contain residual contamination at DOE sites is "inherently failure prone."[ix] What provisions are the agencies making to meet this likelihood of failure? If their original controls fail, what will be put in their place? What new kinds of controls are anticipated, what will they cost, and how will they be paid for and by whom? Have the agencies estimated the potential long-term cost of controls replacing controls and requiring ongoing maintenance and monitoring? Have they compared an estimate of this sort with what they think they are now saving by instituting a plan that requires controls? Is their present plan cost-effective in the long-term?

Aspects of the proposed cleanup: Surface water

Meeting the state's standard for Pu in surface water (0.15 pCi/L) did not become the driver for cleanup. But the issue continues to be troubling. The state has agreed to change the period for averaging samples taken on site to determine compliance from the 30-day period used at the site boundary to a 365-day period for onsite water. This makes compliance easier, since most spikes may be averaged away, but it also underscores the fact that the problem of contaminated onsite surface water has not been solved.

> **COMMENT**: Some seem willing to leave some Pu in the soil and to limit cleanup to what is required to protect a wildlife refuge worker because this would ensure open space at Rocky Flats. A better cleanup, they fear, would result in free release and development of the site. But the fact of contaminated water at Rocky Flats means that there can be no free release of the site even if Pu in the soil is cleaned to a very stringent level. If the water issue doesn't drive cleanup it does ensure open space.

Aspects of the proposed cleanup: Regulatory compliance

A slogan often used regarding the proposed cleanup is that it will be "safe and compliant." The latter term refers to the simple fact that the finished job will meet all applicable legal requirements.

> **COMMENT**: One could spend much time criticizing the applicable laws for their inadequacy. CERCLA, or Superfund, for instance, has a risk range so broad that a thousand trucks of good or bad intent could be driven through its vast reaches, and it's one of the best laws we have. Risk assessment, itself an internal ingredient of the various regulations, is typically based on the averages of bodily effects or of population groups rather than on protecting the most sensitive organ or most vulnerable individual. Average people don't get sick and die so readily as vulnerable ones. It is the latter we need to protect. Being "compliant" is not necessarily a badge of honor. Legality and safety are not identical.

Aspects of the proposed cleanup: Funding, closure, and cleanup

The agencies say we are getting the best cleanup possible for the limited sum available. DOE now says cleanup and closure are ahead of schedule and that the site may close early, with a possible savings of $210 million. This sum, we are told, is not available to get a better Rocky Flats cleanup.

> **COMMENT**: Several times over the past two years the agencies have been urged to seek the funding required to accomplish a better cleanup. This proposal has been met with scorn. It was not until June 2001 that the DOE explicitly revealed to the RFCA Focus Group that cleanup was limited by the fixed sum available and that this necessitated tradeoffs. Bringing this out in the open, a DOE person later said, was like "throwing a dead rat on the table."[x] Had DOE worked with the public in 1995-96 to determine the cost of a real cleanup and then secured public support to seek the requisite funding from Congress, the resultant cleanup would be an object of pride and a fit model for other sites. It would also be the outcome of a more democratic public process. As is, public participation in the present plan has been reduced to tinkering.

RMPJC recommendations

1. Perform a thorough characterization of the whole site.

2. Clean Rocky Flats to protect the family of a resident subsistence farmer, a scenario that is both conservative and not improbable (see attachment B for the full justification for this recommendation). The resultant cleanup level for Pu in surface and subsurface soil would be 5 or less pCi/g, with subsurface cleanup depth determined by depth of contamination. Cleanup to this level will make the site safer for all other uses.

3. Remove all process waste lines in the subsurface environment.

4. Apply the full $7B allocated for closure of Rocky Flats on cleanup and closure activities at the site.

5. If the above cannot be accomplished with funds currently available, DOE should estimate the cost and seek public support to get the requisite funding from Congress.

RMPJC recommendations

6. If the agencies reject the foregoing recommendations in favor of the partial cleanup they have proposed, as a condition of moving ahead they should work with the affected public to establish a legally-binding long-term stewardship program that includes but is not limited to the following:
   - public participation and oversight;
   - comprehensive environmental monitoring;
   - surveillance and maintenance of all controls;
   - information management systems;
   - ongoing education of the public regarding the condition of the site;
   - research on better cleanup technology that can be applied at the site;
   - research for evidence of adverse health effects in plant, animal, and human life, with particular attention to genetic effects;
   - assured and dedicated funding to cover all long-term stewardship costs, including contingencies.

We expect to elaborate on the above points or to make additional recommendations during the comment period on the proposed cleanup.

NOTES

[1] Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site (August 2000).

[1] See Theresa Satterfield and Josh Levin, "Risk Communication, Fugitive Values, and the Problem of Tradeoffs at Rocky Flats," a Report prepared for the U.S. DOE Low Dose Radiation Research Program (Eugene, OR: Decision Research, Nov. 9, 2002), p. 26.

[1] Long-term Institutional Management of U.S. Department of Energy Legacy Waste Sites (Washington, DC: National Academy of Sciences, 2000).

[1] Satterfield and Levin, p. 29.

PART 6

Public forums where RMPJC presented results of technical reviews and other information relating to the Rocky Flats cleanup

PUBLIC FORUMS WHERE RMPJC PRESENTED RESULTS OF TECHNICAL REVIEWS AND OTHER INFORMATION RELATING TO ROCKY FLATS CLEANUP

October 30, 2001: Meeting with the Principals (decision-makers) from DOE, EPA, and CDPHE. As one of three invited speakers, LeRoy Moore made a presentation on Radionuclide Soil Action Levels for Rocky Flats: Points for the Principals. Though this meeting was convened by DOE, EPA, and CDPHE, the idea of a meeting between the public and the Principals had been initiated by RMPJC, and our publicizing of the event helped attract a quite large crowd for what proved a very valuable exchange. At this meeting we presented for the first time to the Principals the IEER report advocating that Rocky Flats be calculated to protect a hypothetical subsistence farmer living on the site at some future time.

January 25-26, 2002: Plutonium and Risk: A Workshop for Rocky Flats Workers and Community Residents. Presenters included Steve Wing of the University of North Carolina School of Public Health, James Ruttenber from the University of Colorado Health Sciences Center, Abel Russ of the Community-Based Hazard Management Program at Clark University, with responses from a Rocky Flats worker and two persons from the staff of the Rocky Flats Citizens Advisory Board. Topics covered were how radiation exposure standards are set and whether they're protective, what is known and what is controversial regarding research on plutonium health effects, where plutonium goes in the body and what it does, current research on Rocky Flats workers exposed to plutonium on the job.

September 12, 2002: Workshop led by LeRoy Moore to update the public on key issues regarding Rocky Flats cleanup, contrasting what was then known about the plan being developed by DOE, EPA, CDPHE with recommendations made in the past by the Future Site Use Working Group and RMPJC. This event emphasized the rationale for cleaning the site to protect a subsistence farmer rather than a wildlife refuge worker.

November 13, 2002: Workshop on Rocky Flats cleanup in relation to the wildlife refuge the site will become at closure. This evening's work served both to inform people about the cleanup and to prepare them to participate in Fish and Wildlife Service scoping meetings for their Environmental Impact Statement on the wildlife refuge. Resource persons included Prof. Harvey Nichols from the University of Colorado, who has done primary research on plutonium in the Rocky Flats environment, and LeRoy Moore.

December 11, 2002: Workshop conducted by LeRoy Moore to prepare people for commenting on the draft amendments to the Rocky Flats Cleanup Agreement, which had just been released for public comment.

December 17, 2002: DOE sponsored public comment meeting on the proposed changes to the Rocky Flats Cleanup Agreement. As one of three invited presenters, LeRoy Moore offered Comments, Questions, and Recommendations on Proposed Changes to RFCA.

In addition to the above, on November 12, 2002, we at RMPJC sent a letter to the Principals inviting them to attend a public meeting we would convene to enable them to hear directly from persons from the affected public regarding the proposed cleanup. Our letter emphasized that such a meeting was needed because the decision-makers have very little direct contact with the concerned public. Only one of the three Principals, the DOE manager at Rocky Flats, responded, and he declined the invitation. When the government agencies held their sole public comment meeting on the cleanup proposal on December 17, the DOE Rocky Flats manager was the only one of the three Principals present.

This work is supported by a grant from the Citizens' Monitoring and Technical Assessment Fund.

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[i] Gregg S. Wilkinson et al, "Mortality among Plutonium and Other Radiation Workers at a Plutonium Weapons Facility," *American Journal of Epidemiology* 125, 2 (1987): 231-250.
[ii] Wilkinson, "Seven years in search of alpha: The best of times, the worst of times," *Epidemiology*, 10 (1999).
[iii] Keith Schneider, "Panel Questions Credibility of Nuclear Health Checks," *The New York Times*, February 28, 1990.
[iv] Wilkinson, "Seven years in search of alpha," *Epidemiology*, 10 (1999).
[v] George L. Voelz as told to Ileana G. Buican, "Plutonium and Health: How great is the risk?," *Los Alamos Science*, No. 26 (2000), 85.
[vi] Wilkinson to Moore, April 26, 2001.

NOTES

[vii] Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site (August 2000).

[viii] See Theresa Satterfield and Josh Levin, "Risk Communication, Fugitive Values, and the Problem of Tradeoffs at Rocky Flats," a Report prepared for the U.S. DOE Low Dose Radiation Research Program (Eugene, OR: Decision Research, Nov. 9, 2002), p. 26.

[ix] Long-term Institutional Management of U.S. Department of Energy Legacy Waste Sites (Washington, DC: National Academy of Sciences, 2000).

[x] Satterfield and Levin, p. 29.