COMPLIANCE DETERMINATION STRATEGY

RR2003 POTENTIALLY ADVERSE CONDITION
HUMAN ACTIVITY AFFECTING GROUNDWATER [10 CFR 60.122(c)(2)]

PRIMARY REGULATORY CITATION:

10 CFR 60.21(c)(1)(ii)(B)

PASS ID OF THE COMPLIANCE DETERMINATION STRATEGY:

RR2003/NS0001

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analyses (Type 4)

RATIONALE FOR TYPES OF REVIEW:

Acceptance Review (Type 1) Rationale:

This regulatory requirement is considered to be License Application-related because, as specified in the License Application content requirements of 10 CFR 60.21 and the Format and Content Regulatory Guide -- DG-3003 (NRC, 1990), it must be addressed by the DOE in its license application. Therefore, the staff will conduct an Acceptance Review of the License Application for this Regulatory Requirement.

Safety Review (Type 3) Rationale:

This regulatory requirement is related to radiological safety and waste isolation. Because this requirement is in 10 CFR Part 60, Subpart E (Technical Criteria), compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31 (i.e., regulatory requirements in Subparts E, G, H, I and 10 CFR 60.21). Therefore, the staff will conduct a safety review of the license application to determine compliance with the regulatory requirement.

This regulatory requirement, concerning a potentially adverse condition (PAC), focuses on the potential for foreseeable human activities to adversely affect the groundwater flow system. These would include activities such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity, or construction of large-scale surface water impoundments. For most radionuclides of concern to geologic repository performance, groundwater is the principal transporting agent. Any process that serves to accelerate groundwater velocities has the potential to adversely impact the geologic barrier and repository performance. Human activities of the types described above clearly have this potential. The staff has

interpreted "foreseeable human activities" to mean those human activities that are typically occurring today and are likely to continue through the near and distant future. For example, groundwater is generally obtained by drilling wells and installing pumps to lift water to the surface. This basic approach is not expected to change, even in the distant future.

A number of other PACs are related to this regulatory requirement. For example, 60.122(c)(6) relates to the potential for hydrologic changes due to reasonably foreseeable climatic changes. Human effects on climate will be covered under that PAC and not under this requirement, even though such effects would not directly affect the groundwater flow system. The converse was considered by the staff, but because of the dry climate already existent, additional pumping due to a "dryer" climate was not thought to be likely. Climates changing to become wetter might raise the water table but would not be expected, considering current climate change scenarios, to significantly affect human activities. Another related PAC is 10 CFR 60.122(c)(22), which addresses the potential for the water table to rise high enough to saturate a repository located in a vadose zone. This analysis also assumes that rises in the water table would more likely be caused by long-term climatic changes (involving cooler temperatures and increased precipitation and recharge) rather than by human activities. Although unpredictable, at present, bounded long-term climatic change can be a part of scenario analyses of the performance objectives. Groundwater as an exploitable, naturally occurring material is addressed under 10 CFR 60.122(c)(17).

Perhaps the PAC of closest interrelationship to this regulatory requirement is 10 CFR 60.122(c)(5), which relates to hydrologic changes that would affect radionuclide migration by altering hydraulic gradients, groundwater velocities, hydraulic conductivities, etc. The nature of the hydrologic changes referred to under 10 CFR 60.122(c)(5), whether human- or naturally-induced, is not specified. This analysis proceeded based on the assumption that direct human-induced changes in the saturated zone will be addressed under this regulatory requirement. These human-induced changes would especially include groundwater pumping for irrigation or exportation of groundwater to satisfy urban demands. The consequences of a potential thickening of the vadose zone (i.e., lengthening of vadose zone flow paths) will be evaluated under 10 CFR 60.122(c)(5) and under 10 CFR 60.112.

The following *Technical Uncertainty* has been identified: "The ability to predict the locations and extent of foreseeable human activities that may adversely affect the groundwater flow system." The potential effects of groundwater withdrawals will be reviewed at the Type 4 level which is discussed later. For the purposes of this initial assessment of foreseeable human activities, only groundwater withdrawals were considered as having possibly significant effects on repository performance. Other future human activities are expected to have minimal effects on the groundwater flow system and repository performance, and each can therefore be reviewed at the Type 3 level. These other activities are discussed below. Other information to be reviewed at the Type 3 level would include assessments of current water resources in southern Nevada and projections

of future needs.

Irrigation is considered to be intimately linked to the issue of groundwater withdrawals. Generally, if groundwater is used for irrigation purposes, the wells are located close to the irrigation sites. The team has assumed that the extreme climate, poor soil conditions, and generally steep topography at the Yucca Mountain site will prevent it from being used for agricultural purposes in the foreseeable future. However, we still consider irrigation to be one of the key reasons for large-scale groundwater withdrawals in the region beyond the controlled area. This region would include Jackass Flats, Rock Valley, Amargosa Valley, and the Amargosa Desert.

Large-scale surface impoundments require perennial sources of surface water, which are not present at the site. The very high evaporation rates during most of the year in southern Nevada would also discourage the construction of large impoundments under present-day climatic conditions. Underground injection and pumped storage are considered to be unlikely events in this analysis. The authors concluded that these activities would have to occur at Yucca Mountain itself in order to have significant effects on repository performance. Military activity in the form of underground nuclear testing is presently occurring at the Nevada Test Site. DOE (1988a, p. 8.3.5.17-21) considered that the seismic effects of weapons testing are bounded by the scenario classes for tectonic disturbances. The ongoing testing reportedly causes only minor, transient effects on the groundwater system at Yucca Mountain. Strip charts at wells UE-25 B#1 and USW H-4 have measured responses to nuclear tests and very small earthquakes. The water level responses in these open holes were a small fraction of a foot (personal communication, Richard Luckey, USGS, November 1991). It is noted that packers were not used to obtain pressure responses. The issue of the effects of nuclear testing would have to be re-examined if testing should begin at sites closer to the Yucca Mountain site or if larger magnitude tests were undertaken. No other future human activities or combinations of activities that are expected to have significant adverse effects on the groundwater system and repository performance were identified.

Previous DOE evaluations of this PAC were reviewed as part of the analysis. In the Environmental Assessment for the Yucca Mountain Site, DOE (1986) gave preliminary evaluations of both favorable conditions and potentially adverse conditions. With regard to this PAC, DOE concluded that the Yucca Mountain site has very limited potential for large-scale development of water resources and that modification of the groundwater flow system is unlikely. In fact, DOE considered that any changes that may increase the thickness of the vadose zone are likely to favor waste isolation. Therefore, based on available data at the time, DOE considered that this PAC was not present at Yucca Mountain.

DOE's conclusion regarding the absence of this PAC was reiterated in the report on early site suitability (SAIC, 1992, p. 2-138). One of the reasons given for the PAC not being present was "great depth to groundwater." It is certainly true that beneath Yucca Mountain proper the

depth is great, ranging from about 500-700 m. Given this information, this analysis agrees with DOE's conclusion that large-scale development of groundwater resources at the Yucca Mountain "site" is unlikely. However, it should be noted that large-scale future development could occur in the Yucca Mountain vicinity because the water table is much shallower in surrounding areas beyond the controlled area. For example, borehole UE-29, about 11 km northeast of the site, has a water table depth of less than 30 m (Waddell *et al.*, 1984). At well J-12, about 15 km southeast of the site, the depth is less than 230 m (DOE, 1988b, p. 3-158). Well data from Amargosa Valley (formerly Lathrop Wells) indicate water table depths of less than 100 m (Waddell *et al.*, 1984). These depths are not so great as to preclude extensive exploitation, should the need arise. As discussed previously (personal communication, David Donnelly, May 1992), within less than 15 years the Las Vegas Valley will have to import groundwater from adjoining basins.

Water Resources in Southern Nevada and Future Groundwater Needs. This analysis considers extensive groundwater withdrawals and lowering of water tables to be the most likely human effects on the groundwater system in southern Nevada. Historically, this has been the trend in large areas of the west where groundwater has been drawn in quantities that exceed recharge. The mid-western Ogalalla Aquifer is one of the best-known examples of the effects of extreme groundwater "mining." Local examples of smaller-scale groundwater mining in Nevada include previous groundwater overdrafts in the Las Vegas Valley, Amargosa Desert, Crater Flat, and Pahrump Valley. An overdraft of 3000 acre-ft/yr (3.7E06 cubic m/yr) exists in the Amargosa Valley. Crater Flat is overdrawn because of an appropriation for mining purposes (DOE, 1988b, p. 3-121). Groundwater overdraft in the Ash Meadows area of the Amargosa Desert resulted in water level declines in Devil's Hole, habitat for the endangered Devil's Hole pupfish. This resulted in court action to restrict groundwater withdrawals in a way that would maintain water levels in Devil's Hole (Dudley and Larson, 1976; DOE, 1988b, p. 3-123).

Water use in Nevada is currently governed by the Office of the State Engineer and the Division of Water Resources. If there is evidence that an aquifer overdraft is occurring, measures can be taken to regulate withdrawals. The Nevada State Engineer can designate groundwater basin boundaries in areas where groundwater resources are being depleted (DOE, 1988b, 3-134). Such designation orders have been issued in: (1) the Amargosa Desert groundwater basin; (2) the Pahrump Artesian Basin; (3) Oasis Valley West; and (4) Indian Springs Valley. Although groundwater mining is currently prohibited in Nevada (DOE, 1988b, p. 3-114, 3-121), the statutes allow overdrafts for minerals mining for periods less than five years.

The need for additional development of groundwater resources in southern Nevada will continue to grow in the foreseeable future. This conclusion is based on projected water demands in the Las Vegas area and on the finite allocation received by the State of Nevada from the Colorado River. Future water needs in southern California can also be expected to rise. The Las Vegas Valley Water District has already begun a serious effort to

find a regional approach to solving the water supply problem. Water Resources Management, Inc. (WRMI) refers to the magnitude and urgency of the water supply problem for the district (WRMI, 1992). It noted that without any action, projected development cannot be supported beyond the year 1995. Allocation of the rest of Nevada's Colorado River water will extend that time to the year 2002, and along with the imposition of a responsible program of water conservation measures will extend that time further to the year 2006. After 2006, additional water will be needed to support the region's projected needs. WRMI (1992) recommended that the Las Vegas Region aggressively pursue any possible new sources of water and immediately plan to construct facilities to import additional water to the region. Based on a personal communication with David Donnelly (May 1992), Chief Engineer with the Las Vegas Valley Water District, additional groundwater resources will have to be acquired from adjoining groundwater basins.

As discussed above, available predictions indicate the total utilization of available water resources in the Las Vegas Valley by ~2006. We can thus also foresee the need for the valley to import groundwater from basins to the north and west. The Yucca Mountain site and the Amargosa Desert lie about 120 km to the northwest of Las Vegas valley. Technically, groundwater mining is not legal in the State of Nevada. However, given that the only controls are statutory (i.e., political), it would be prudent to assume that future political decisions by the State, in the face of finite water resources and expanding needs, may result in renewed groundwater mining and overdrafts in this region. Such overdrafts would result in a lowering of water tables and the potential for increased hydraulic gradients. Such human activities would result in locally increased groundwater velocities in the saturated zone which, if they occurred near Yucca Mountain, could result in adverse effects on geologic repository performance with respect to the U.S. Environmental Protection Agency (EPA) radiation standards. Corresponding lowering of the water table beneath Yucca Mountain could actually be favorable with respect to isolation by artificially increasing the thickness of the vadose zone. However, it is not yet known whether the consequences of greater velocities in the saturated zone would be balanced by thickening of the vadose zone (i.e., lengthening of vadose zone flow paths). The consequences of a potential thickening of the vadose zone will be evaluated under 10 CFR 60.122(c)(5) and 60.112.

Based on current trends in the use of water resources in southern Nevada, this analysis considers that the region's groundwater flow system could be strongly influenced by future human activities. However, without more extensive site characterization data, this analysis cannot reliably determine the full extent to which large-scale groundwater withdrawals could adversely impact geologic repository performance.

Detailed Safety Review Supported by Analyses (Type 4) Rationale:

Of the various types of future human activities mentioned under this requirement, only those activities related to future groundwater withdrawals will require a Type 4 review. The staff considers that the

following Key Technical Uncertainty may pose a high potential risk of non-compliance with the performance objectives specified under 10 CFR 60.112. For this requirement, the analysts drew the conclusion that a safety determination could be made by evaluating information submitted by DOE in the License Application and by acquiring and using codes and models developed by DOE. We do not at this time believe that a Type 5 review will be necessary because the NRC's independent use of codes and models developed by the DOE should be adequate to analyze the effects of future human activities on the groundwater flow system.

Key Technical Uncertainty Topic: Adverse effects of future groundwater withdrawals on the groundwater flow system.

Description of Key Technical Uncertainty: It is impractical to predict the locations and extent of future groundwater withdrawals that may adversely affect the saturated leg of the groundwater flow system in the controlled area.

Performance Objectives at Risk and Associated REOP PASS ID: 10 CFR 60.112 Containment Requirements; 10 CFR 60.112 Individual Protection Requirements; 10 CFR 60.112 Groundwater Protection Requirements

Explanation of Risk: Future large-scale groundwater withdrawals near the site may accelerate the migration rates of radionuclides in the saturated zone along paths to the accessible environment. This may lead to violations of 10 CFR 60.112 and each of its three performance requirements shown above. All three performance requirements are at risk because of the Key Technical Uncertainty described above, even though they cover different time frames (e.g., the containment requirements applies over 10,000 years whereas the other performance requirements apply over a period of 1,000 years). This is true because all three requirements relate to conditions in the saturated zone, and because adverse human effects on the groundwater flow system may just as reasonably occur over the next 1,000 years as they may occur over the period between 1,000 and 10,000 years in the future. It should be noted that if "special sources" of groundwater are confirmed not to exist in the vicinity of Yucca Mountain, then there can be no violations of the groundwater protection requirements. Nuclear Waste Consultants, Inc. (1987), in a report prepared for the NRC, gave a preliminary assessment that no "special sources" of groundwater exist in the Yucca Mountain vicinity.

Although drawdowns in unconfined aquifers do not propagate laterally as fast as in confined aquifers, it is noted that the very small horizontal hydraulic gradients east and southeast of Yucca Mountain would require little perturbation to significantly change groundwater travel times. For example, DOE (1988b, p. 3-221) calculated particle velocities over two segments in the saturated zone along a line connecting wells UE-25b#1 and J-13. Different particle velocities were derived for the two segments because the water table occurs in different tuff units. For that segment in the Topopah Spring unit, a particle velocity of about 14 m/yr was obtained. The gradient for this segment, which has a length of 2 km, was found to be 1.1E-04. If the head difference over this 2 km distance were

to be increased by only ~0.2 m (less than 1 ft), the particle velocity would double and the corresponding groundwater travel time over this segment would be cut in half.

Thus, very small reductions in hydraulic heads southeast of the site could significantly accelerate groundwater fluxes away from the site.

Description of Resolution Difficulty: Apostolakis *et al.* (1991, p. 128) discuss why predictions about future human activity are very different from predictions of natural processes. Predicting the magnitude of future human effects on the groundwater flow system is linked to the impractical task of forecasting human behavior. However, it is possible to identify a range of groundwater extraction scenarios that would influence the water table beneath Yucca Mountain. Therefore, in this way, the Key Technical Uncertainty can be bounded and reduced. One approach was identified by Adrian Brown Consultants, Inc. (ABC), in a report prepared for the Center for Nuclear Waste Regulatory Analyses (ABC, 1989a). This report described a methodology for assessing groundwater resources as a potential source of human intrusion. They analyzed various scenarios, including open borehole pathways and effects on the hydraulic gradient caused by pumping. ABC analyzed the frequency of well drilling in the region and, considering practical aspects of groundwater exploration and exploitation, came to the conclusion that there is a very low probability of direct human intrusion due to drilling for groundwater. They also considered an active pathway scenario with one (single-family domestic) pumping well (400 gal/day), and concluded that there is little likelihood of groundwater pumping adversely affecting the performance of a repository. However, they did not consider the effects of a field of pumping wells used to extract water for transport to another part of the region (such as southern California or the Las Vegas Valley). In another report (ABC, 1989b), ABC cited a State of Nevada report (1971) that noted that the only area in southern Nevada that is expected to have a significant water deficiency in the future is the Las Vegas Metropolitan area.

It should be noted that there would be some conditions under which a Type 4 review may not be necessary and a Type 3 review would be adequate. For example, if the vadose zone at Yucca Mountain is subsequently found to have very favorable isolation characteristics, then the effects of a thickened vadose zone would outweigh accelerated groundwater velocities in the saturated zone. Based on estimates of groundwater travel time described in the DOE's Site Characterization Plan, travel time for the saturated zone is less than 200 years, and ranges from 9,000 to 80,000 years for the vadose zone (DOE, 1988b, p. 3-219). The authors consider the numbers for the vadose zone to be highly uncertain at this time. The DOE analysis assumes that all flow occurs within the rock matrix, and that no fracture flow occurs.

There is evidence to suggest that enhanced flow paths can and do exist in unsaturated tuffs. Russell *et al.* (1987) and Clebsch (1960) describe analyses of tritium data from a groundwater sample collected in the U12e Tunnel in Rainier Mesa. Results indicated a residence time of eight months to 6 years. These results were duplicated using a sample from a

spring near the northern end of Rainier Mesa. The sampling sites were believed to be sufficiently far from nuclear testing sites to prevent tritium contamination from such testing. The presence of rapid flow paths in unsaturated tuffs has also been detected at the Apache Leap site in Arizona. Bassett *et al.* (1992) note that the travel time for water from Queen Creek seepage through fractures into the Never Sweat Tunnel is on the order of 1 to 3 months. If enhanced flow paths of this type are discovered at Yucca Mountain, it may be necessary for DOE to place greater reliance on the sorptive characteristics or the travel-time in the saturated leg of the groundwater flow path.

In evaluating this regulatory requirement, this analysis considered the implications of 10 CFR 60.121 as it relates to DOE's future acquisition of water rights in the vicinity of Yucca Mountain. In accordance with 10 CFR 60.121, DOE shall "exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation." The NRC staff considers that 10 CFR 60.121 imposes a postclosure, institutional control of finite duration. This institutional control should not be assumed to exist for a significant period beyond closure of a repository, and thus cannot serve to mitigate potential adverse effects on the groundwater system caused by foreseeable human activities. For example, as discussed by the EPA (1985), active institutional controls cannot be relied upon to isolate waste for more than 100 years after disposal.

To summarize, the following assumptions have been made in developing this review strategy:

(1) For purposes of developing this strategy, the current regulatory position in 40 CFR Part 191 is assumed. Human activities and human intrusion must be considered when evaluating compliance with the "Containment Requirements" of 40 CFR Part 191. The regulation does not exclude human activities from consideration of the "Individual Protection" and "Groundwater Protection" requirements, even though human intrusion is excluded from these requirements

(2) With respect to groundwater resources, foreseeable human activities are those typical human activities that are occurring today and are likely to continue through the near and distant future

(3) Large-scale groundwater withdrawals are the only reasonable, future human activities affecting groundwater that may adversely affect waste isolation

(4) Although future human activities and their effects cannot be reliably predicted, it is possible to identify and evaluate the effects of a range of such activities which could adversely affect the groundwater flow system. Within 15 years or less, the Las Vegas Valley will have to import large amounts of groundwater from adjoining sub-basins. Water resource needs will also continue to

grow in southern California

(5) DOE may have to rely upon the isolation potential of the saturated zone between the repository and the accessible environment in addition to the isolation potential of the vadose zone

(6) Conditions at the Yucca Mountain site will preclude future agriculture on any significant scale

(7) Future nuclear testing will not occur at magnitudes much larger than recent tests, or at locations significantly closer to the site

(8) The consequences of a potential thickening of the vadose zone (i.e., lengthening of vadose zone flow paths) will be evaluated under 10 CFR 60.122(c)(5) and 60.112.

REVIEW STRATEGY:

Acceptance Review (Type 1):

In conducting the acceptance review of the potentially adverse condition [Human Activity Effecting Groundwater -- 10 CFR 60.122(c)(2)], the reviewer should determine if the information presented in the license application and its references for demonstrating compliance with respect to this potentially adverse condition are complete in technical breadth and depth as identified in DG-3003 (NRC, 1990). Appropriate information should be provided to enable the staff to: (1) determine the presence (or absence) of the potentially adverse condition; and (2) review the effects of human activities, if any, on the groundwater system with respect to the overall system performance objective (10 CFR 60.112).

The information in the license application should be presented in a manner such that the assumptions, data, and logic leading to a demonstration of compliance with the requirement are clear and do not require the reviewer to make extensive analyses and literature searches. The reviewer should also determine that controversial information and appropriate alternative interpretations and models have been adequately described and considered.

Finally, the reviewer should determine if DOE has either resolved all the documented NRC staff objections to the license application that apply to this requirement or provided all the information requested in Section 1.6 of DG-3003 for unresolved objections. The reviewer should evaluate the effect of any unresolved objections, both individually and in combinations with others, on: (1) the reviewer's ability to conduct a meaningful and timely review; and (2) on the Commission's ability to make a decision regarding construction authorization within the three-year statutory period.

Safety Review (Type 3):

In conducting the safety review, the reviewer will, as a minimum, determine the adequacy of the data and analyses presented in the license

application to determine DOE's compliance with 10 CFR 60.122(c)(2). Specifically, DOE will need to: (1) provide information to determine whether and to what degree the potentially adverse condition is present; (2) provide information to determine to what degree the PAC is present, but undetected; (3) assure the sufficiency of the lateral and vertical extent of data collection; and (4) evaluate the information presented under Items (1) and (2), with assumptions and analysis methods that adequately describe the presence of the PAC and ranges of relevant parameters. In general, the reviewer will assess the adequacy of DOE's investigations of future human effects on the groundwater flow system in the manner outlined in 10 CFR 60.122(a)(2). Those specific aspects of the license application on which a reviewer will focus are discussed in DG-3003, and the acceptance criteria will be identified in Section 3 of the License Application Review Plan.

The first step in the staff review will be to evaluate the DOE analysis to determine if the basic review assumptions have been met. These are:

(1) For purposes of developing this strategy, the current regulatory position in 40 CFR Part 191 is assumed. Human activities and human intrusion must be considered when evaluating compliance with the Containment Requirements of 40 CFR Part 191. The regulation does not exclude human activities from consideration of the "Individual Protection" and "Groundwater Protection" requirements, even though human intrusion is excluded from these requirements

(2) With respect to groundwater resources, foreseeable human activities are those activities that are occurring today and are likely to continue through the near and distant future

(3) Large-scale groundwater withdrawals are the only reasonable future human activities affecting groundwater that may adversely affect high-level waste isolation

(4) DOE may have to rely on the isolation potential of the saturated zone between the repository and the accessible environment

(5) Conditions at the Yucca Mountain site will preclude future agriculture on any significant scale

(6) Future nuclear testing will not occur at magnitudes much larger than recent tests, or at locations significantly closer to the site.

If these assumptions have not been met, the reviewer will have to assess the potential impacts with respect to the PAC. Modifications to the *Review Strategy* and the *Review Methods* may be needed. The nature of such modifications will have to be determined based on the professional judgement of the review team. If the assumptions are met, the review will proceed as outlined. Examples of specific review activities that will be required include: (1) confirmation that the applicant has fully considered the most recent projections of population growth and water resource needs

in southern Nevada; and (2) confirmation that an appropriate range of future human activities that could adversely affect the groundwater flow system has been considered.

In order to conduct an effective review, the reviewer will rely on his own expertise and independently acquired knowledge, information, and data in addition to that provided by the DOE in its license application. Therefore, it is incumbent upon the reviewer to have acquired a body of knowledge regarding current and projected water resources in southern Nevada and the types of current and future human activities that could reasonably occur and have adverse effects on the groundwater flow system. This would include the review of references relevant to water resources in southern Nevada, such as Malmberg and Eakin (1962), Miller (1977), Walker and Eakin (1963), and WRMI (1992), as well as other relevant publications which may be published in the future.

Evaluations of future human effects on the groundwater flow system will contribute to performance assessment calculations under 10 CFR 60.112. Although such future scenarios cannot be predicted in a statistical sense, it is possible to examine a range of reasonable conditions to evaluate how they might affect waste isolation. The decision as to how great those effects might be will require the use of professional judgement.

Detailed Safety Review Supported by Analyses (Type 4):

Both detailed reviews and modeling should be conducted for the Key Technical Uncertainty concerning the potentially adverse effects of future groundwater withdrawals on the groundwater flow system. A detailed review will be needed only for future human activities involving large-scale groundwater extraction. This will ensure that DOE has adequately demonstrated Items (1) through (4) listed in the previous section ("Safety Review," paragraph 1).

With respect to repository performance, an adverse scenario would occur if the saturated zone within the controlled area contained elevated concentrations of radionuclides and if extensive pumping outside the controlled area caused an increase in lateral hydraulic gradient. Such a change could accelerate contaminant transport of radionuclides along pathways to the accessible environment. To properly evaluate such conditions, the NRC staff will need to independently use codes and models developed by DOE. This effort will include an evaluation of boundary conditions and other input parameters. It will also examine whether the DOE has reasonably examined possible locations and magnitudes of future groundwater withdrawals in the region around Yucca Mountain. The results from the analysis of this PAC will be used to develop and condition a group of human-activity scenarios to be evaluated under 10 CFR 60.112.

In order to properly review DOE's conclusions regarding future human activities and their effects on the groundwater flow system, the NRC staff will need to independently model the flow system using codes and models developed by DOE. Simple, "back-of-the-envelope" calculations will not be adequate to properly evaluate the results of complex numerical models of

groundwater flow and transport. The need for independent NRC development of codes and models to accomplish this work is not foreseen.

NRC's independent use of DOE's codes and models should evaluate the statistical reasonableness of model parameters and boundary conditions, perform sensitivity studies of input parameters, and determine whether discretization is adequate. The staff may also simulate alternate scenarios of large-scale groundwater pumping that may be deemed appropriate. For example, it will be important to simulate the possible future existence of pumping fields in the region surrounding the Yucca Mountain site. It should not be necessary to evaluate radionuclide transport. Instead, for this regional analysis, it should be adequate to evaluate groundwater fluxes based on saturated flow modeling. The modular saturated flow codes developed by the USGS should be appropriate. An example of a two-dimensional code that has the necessary capabilities is MODFE (Torak, in press). This is a finite element code, and as such can be used to develop models with complex geometric boundaries. A determination will have to be made whether two-dimensional models will be adequate, or whether vertical flow components in the region are large enough to justify the use of three-dimensional models. In particular, the deep carbonate aquifer system that underlies Yucca Mountain may introduce vertical flow components that require the use of three-dimensional models. A decision regarding the appropriateness of two- vs. three-dimensional modeling will have to be made well in advance of DOE's submittal of a license application.

Contributing Analysts:

NRC STAFF: Neil Coleman, Harold Lefevre, James Park

CNWRA STAFF: Michael Miklas, Ronald Green

Date of Analysis: June, 1992

RATIONALE FOR REVIEW STRATEGY (OPTIONAL):

Not applicable.

APPLICABLE REGULATORY ELEMENT OF PROOF:

Type 3:

RR2003/EP0100

Type 4:

RR2003/EP0100

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