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Land Requirements and Waste Management Policy at Hanford

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LAND REQUIREMENTS AND WASTE MANAGEMENT POLICY
AT HANFORD

By

D. J. Brown, J. H. Warren

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LAND REQUIREMENTS AND WASTE MANAGEMENT POLICY AT HANFORD

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INTRODUCTION

In 1943, the United States Government obtained approximately 2200 square kilometres of land in south central Washington State, designated as the Hanford Reservation, for siting nuclear plant facilities. Figure 1 shows the original boundary of the Hanford Reservation and the subsequent boundary lines which were established as segments of this property were released for public sale. The present boundary encompasses an area of approximately 1450 square kilometres. Near the center of the reservation, on an upland plateau 16 kilometres from the nearest point of unrestricted access, a site was selected for construction of a radiochemical separations complex, known locally as the 200 Areas (see Figure 1). The waste management plan adopted for this radiochemical plant provided for the release of certain liquid effluents and essentially all solid refuse to ground. According to the recommended IAEA waste categories suggested for use at this symposium, the highest activity liquid wastes discharged to ground at Hanford have been in the lower range of Category 4; 10 to 100 mCi/litre. Solid refuse buried in the ground at Hanford since the start of operations encompass all IAEA categories.

An extensive research and development program was initiated, early in Hanford's history, in support of ground disposal in the 200 Areas. Some of the specific disciplines included in this program are soil chemistry, soil physics, geology, hydrology, mineralogy, analytical chemistry, and process engineering. Much of the knowledge gained about the behavior of solid and liquid wastes in Hanford's sediments and

- A. LAND REQUIREMENTS FORESEEN FOR FUTURE GROUND DISPOSAL OPERATIONS IN THE 200 AREAS (GOAL ZONE)**
- B. ADDITIONAL LAND REQUIRED FOR PRESENT GROUND DISPOSAL OPERATIONS IN THE 200 AREAS**
- C. LAND NOT USED FOR OTHER SITE ACTIVITIES RELEASABLE WHERE WATER PONDING OR IRRIGATION ARE CONTROLLED**

Figure 1. Map of Hanford Reservation

the techniques and controls applied in ground disposal practices have been discussed in detail in previous international conferences and symposia at Geneva [1, 2], Monaco [3], Saclay [4, 5] and Vienna [6, 7].

At Hanford the policy is to limit the volume and activity of liquid effluents and solid refuse released to the environment to the lowest practical level. In this respect consideration is given not only to the related long-term safety of the human population, but also to plant and animal resources and to the efficient use of the land so that a minimum of land and water is restricted. Even though the early history of ground disposal in the 200 Areas attested to the safety and practicality of practice, by 1957 a program to reduce the volume and activity of the liquid effluents and solid refuse being discharged was in preparation. As suitable technology was developed to carry out this program it was incorporated into the respective plant systems.

Originally, the establishment of the perimeter boundary around the Hanford Reservation was a matter of prudent judgement by knowledgeable individuals and was based on the premise that there should be a sufficient distance between the operating facilities and the contiguous private land to assure safety of the general public. Experience during more than 25 years of plant operation has shown that the size of the land area originally selected was more than adequate to operate the nuclear facilities at Hanford. During this period, studies showed that nearly 750 square kilometres of land could be released and still assure the safety of the general public (see Figure 1). Studies were also made to determine specific land requirements for each of the various operations conducted at Hanford within the confines of the perimeter boundary.

In 1967 a special study was made to determine minimum specific land requirements in support of all operations in the 200 Areas. The scope of this study included consideration of all effluent streams and solid refuse, both contained in underground storage tanks and those released to the environment, and evaluated the land requirements for three situations; normal operation covering planned release of liquid effluents to the environment, abnormal plant operation covering periods of temporary loss of control when relatively small quantities of highly radioactive effluents are released (hereafter referred to as nuisance contamination), and credible accident situations of a disastrous magnitude. This study also undertook to investigate possible methods of reducing the land requirements identified by this study.

This paper discusses those aspects of the 1967 study related to evaluating land requirements for disposal of low and intermediate level liquid effluents and solid refuse to ground. Also discussed in this paper are the general liquid effluent reduction methods incorporated in the waste management program to reduce the amount of land needed for ground disposal practices. Data are presented showing the results achieved through 1969.

LAND REQUIREMENT GUIDES

To provide a basis upon which to judge the amount of land actually required for all operations conducted within the 200 Areas, local guides were established. For normal operation guides related concentrations

of radioactive and chemical materials that would be acceptable in the environment on a long-term basis to recognized authoritative health and safety standards. Reasonable safety factors were taken into consideration to assure that the authoritative standards would not be exceeded. These guides are stated in a general way as follows:

- Members of the general public should not have uncontrolled access to land where it is probable that they will receive ten percent or more of the allowable annual radiation dose (equivalent to one-hundredth of the 168-hour week concentration guides listed in Table 1 of ICRP Publication 2 [8]) as a result of inhaling or ingesting any single radionuclide via any one mode of exposure; nor receive more than ten percent of the allowable annual radiation dose from any single external source that is generated by operations within the 200 Areas.
- Members of the general public should not have uncontrolled access to land where the concentrations of chemical substances released from operations within the 200 Areas will reach noxious levels either in drinking water or in air.

The guides established for nuisance contamination and credible accident situations permit higher concentration levels of radioactive and chemical materials in the environment on a short-time basis and are, therefore, less restrictive with respect to land requirement needs. Because these guides are directed towards radioactive contamination associated with high level liquid wastes and gaseous effluents they are not presented in this paper.

All of the guides developed during the 1967 study were intended solely for use in evaluating land requirements and were not intended to be used as a basis for action or judgement in relation to actual conditions that might arise as a consequence of any operating condition within the 200 Areas.

LAND REQUIREMENTS FOR NORMAL PLANT OPERATIONS

An evaluation was made to determine land requirements for planned release of solid refuse and liquid effluents to ground in the vicinity of the 200 Areas. The word "requirements" as used in this paper refers to the outer control boundary necessary around the 200 Areas due to all foreseeable releases of radiochemical pollutants. Land requirements for each individual disposal site are not discussed in this paper because they are included within the overall control boundary.

The results of this evaluation confirmed that solid wastes buried in the ground are essentially immobile under the existing site climatic conditions and that no additional land surrounding these burial sites is required other than that needed for future expansion. Recently, a storage drum that had been buried in the ground for approximately ten years was dug up to evaluate its physical condition. Figure 2 is a sequence of four photographs showing this drum: A) when it was first encountered during excavation; B) the lid removed while it was still in place; C) after it had been removed from the ground; and D) after the inner container had

A **B** **C** **D**

Figure 2. Retrieval of Solid Waste After Burial for ~10 Years in Hanford Sediments

been removed. The condition of the inner container, which contains the radioactive material, is essentially the same as when it was originally placed in the ground.

Determinations of water potential distribution in Hanford sediments indicate that natural precipitation, averaging about 16 centimetres per year, seldom if ever penetrates to the depths where the solid wastes are buried. Studies show that this moisture is drawn back up out of the ground during the hot dry seasons. With no percolation of precipitation through the vadose zone to the underlying water table, the solid wastes stored in the ground remain immobile.

Land requirements for ground disposal facilities receiving liquid effluents that are essentially free from contamination, IAEA Categories 1 and 2, were determined to be the same as those for solid refuse. These liquid effluents are presently discharged into natural depressions on the ground surface, several kilometres from other waste facilities and operating plants. These effluents infiltrate into the ground and percolate to the underlying water table. Concentrations of contaminants in the groundwater beneath these disposal sites are below the guide limits used for establishing land requirements. The only land consideration is for future expansion of the facility.

Liquid wastes containing concentrations of radionuclides approaching 100 mCi/litre (middle range of IAEA Category 4) are discharged to underground structures called cribs if the waste is shown to be compatible with Hanford sediments. Because of the relatively higher concentrations of radionuclides in these wastes, pollutants with poor ion exchange properties reach the water table in concentrations exceeding the land requirement guides. These include ruthenium-106, tritium and nitrate ion. These pollutants, having reached the water table, move down the hydraulic gradient thus restricting the use of the groundwater along the path of the flow. Because of this restriction, the land surface above the zone of groundwater contamination must be regulated to assure that this water is not used for drinking or other domestic purposes. On the basis of our knowledge of the Hanford groundwater flow system and the concentrations of ruthenium-106, tritium and nitrate ion in the groundwater, a zone extending approximately 13 kilometres southeast of the 200 East Area and about 5 kilometres wide would have to be regulated. Tritium and ruthenium concentrations in the groundwater are above 1/100 ICRP 168-hr week MPC_w; nitrate ion concentration is above noxious levels, 45 ppm. The areas designated by letters "A" and "B" in Figure 1 are involved.

LAND REQUIREMENTS DICTATED BY NUISANCE CONTAMINATION

As stated above, the land requirement guides for nuisance contamination are less restrictive than those established for normal plant operation. The only land restrictions identified, relating to ground disposal, were those dictated by pollutant concentrations in the groundwater where equivalent to IAEA Categories 3 and 4. In these instances only the immediate area surrounding the facility required control ($\pm$ 0.5 kilometres).

In considering land requirements for nuisance contamination from each specific ground disposal operation in the 200 Areas, an arbitrary control zone was assigned. Each zone extends 0.8 kilometres in every direction from each ground disposal site and on each side of all related transportation routes within the 200 Areas. The rationale for this recommendation was based on the assumption that control should be maintained in the area over which accidental contamination could reasonably be expected to spread. Past experience at Hanford indicates that contamination originating within such a zone does not spread beyond the proposed 0.8 kilometre distance. The aggregate extent of all these individual control zones results in an overall zone of control about 5 kilometres from any 200 Area fence.

LAND REQUIREMENTS DICTATED BY CREDIBLE ACCIDENTS

No credible accidents could be postulated in connection with ground disposal practices at Hanford that would indicate need for additional land requirements over those already specified above for normal release and for nuisance contamination. Studies indicated that an eight-kilometre control zone around sites within the 200 Areas, where major credible accidents could occur, would be a reasonable buffer to protect the public. The aggregate plot of these control zones coincided reasonably well with the zone dictated by the nuisance contamination considerations.

ACTION REQUIRED TO REDUCE LAND REQUIREMENTS

When the actual land requirements for ground disposal practices within the radiochemical separations complex were determined during the 1967 study, consideration was given to possible courses of action whereby these land requirements could be reduced. Because the land requirements dictated by nuisance contamination and credible accident situations coincided reasonably well, this zone was selected as a "goal zone" and studies were made to determine the changes required to permit land release to the goal zone perimeter. This is the area designated by the letter "A" in Figure 1 and is established primarily in consideration of surface contamination control. The only ground disposal practice which required modification to meet this objective involved the release of intermediate level liquid wastes (IAEA Categories 3 and 4). Calculations showed that in order to reduce the concentrations of ruthenium-106, tritium, and nitrate ion in the groundwater to this goal, the respective concentrations of these pollutants in the waste being discharged to ground would have to be reduced by factors of 2, 10, and 10 respectively.

WASTE REDUCTION METHODS

Various approaches were considered in selecting the methods for reducing ruthenium-106, tritium and nitrate ion concentrations in the wastes discharged to underground cribs. The effluent reduction scheme adopted involved a stepwise approach, i.e., the streams contributing the major quantities of pollutants to the environment were treated first. Initially, the cost of achieving a reduction in pollutants discharged to ground was low. As the quantity of pollutants discharged to ground decreased it became increasingly more difficult and expensive to achieve additional reductions.

A number of methods have been utilized to reduce the volume and radioactivity in 200 Area liquid effluents. They are:

- Installation of new process equipment with higher operating efficiency resulting in reduced waste stream volume containing less radioactivity.
- Evaporation and/or segregation of liquid effluents containing high concentrations of radionuclides (IAEA Category 4) and solidification of the concentrates.
- Diversion of selected effluent streams through appropriate ion exchange materials to remove radioactivity. Treatment of used ion exchange material as solid waste, or removal of activity from ion exchange material.
- Recycling of selected liquid waste streams back into the plant system for reuse.
- Monitoring effluent streams continuously for early detection of off-standard conditions. When detected, these are rerouted back into the plant for decontamination or containment.
- Steam stripping organic wastes followed by tank storage.
- Analyzing effluent samples with the best analytical techniques available. In extremely high volume effluent streams (10^{10} litres/year), where the average concentration is multiplied by the total volume discharged, the estimated quantity of pollutant released may be several orders of magnitude higher than that which is actually released.

As a result of incorporating methods such as those described above into the waste management program at Hanford, significant reductions in both the volume and radioactivity in liquid effluents released to ground were made. To illustrate the effectiveness of these methods a comparison is made in Table I between the volume, curies, and radionuclide concentration in liquid effluents discharged to ground in 1966 and 1969. The organic wastes were recycled back into the plant, passed through a steam stripper, and/or contained in underground storage tanks. Laboratory and decontamination wastes were evaporated. The concentrates from the evaporator were sent to underground storage and the condensate was discharged to ground. Using this method the concentration of activity in these wastes was reduced three orders of magnitude and the volume was reduced slightly. The noted reduction in activity in the process condensate was accomplished largely by installation of new process equipment. There was a slight increase in activity in the tank farm condensates during this period because of the increased volume of waste liquid of higher activity levels sent to these tank farms. The radionuclide concentration in the steam condensate was about the same in 1969 as it was in 1966. A significant decrease in volume accounted for the reduction in curies released during 1969. There was a marked decrease in radioactivity in the process cooling water. This was largely due to improved analytical procedures which provided lower detection levels. On the basis of analytical results, using these improved procedures, measured concentrations were more than an order of magnitude lower than those previously reported.

TABLE I. LIQUID EFFLUENTS DISCHARGED TO GROUND IN 200 AREAS IN 1966 AND 1969

EFFLUENT TYPE	VOLUME, 10 ⁻⁶ LITRES		CURIES		RADIONUCLIDE CONCENTRATION, (MILLICURIES/LITRE)		IAEA CATEGORY	
	1966	1969	1966	1969	1966	1969	1966	1969
Organic	0.12	NONE	129	NONE	1.1	---	4	---
Lab-Decontamination	40	30	14,581	9	4×10^{-1}	3×10^{-4}	4	2
Process Condensate	324	176	77,354	3,161	2×10^{-1}	3×10^{-2}	4	3
Tank Farm Condensate	62	122	299	336	5×10^{-3}	3×10^{-3}	3	3
Steam Condensate	629	348	2,059	359	3×10^{-3}	1×10^{-3}	3	2
Process Cooling Water	12,838	18,902	675	34	5×10^{-5}	2×10^{-6}	2	2

The extent of ruthenium-106, tritium and nitrate ion contamination in groundwater above their respective land requirement concentration guide is shown in Figure 3 for 1966 and 1969. Since 1966 the area of tritium contamination increased slightly, while the area of ruthenium-106 and nitrate ion contamination shows a significant reduction in size. During this three-year period a major reduction in the quantity of ruthenium-106 and nitrate ion in the waste liquids was achieved. While considerable attention was given to improving the technology for reducing the concentration of tritium in waste liquids, no specific method for removing tritium was introduced into the waste management program during this period. The zone where tritium concentration in the groundwater is above drinking water limits is also shown in Figure 3. This area is similar in size to the 1969 zones shown for ruthenium-106 and nitrate ion.

RESTRICTIONS ON RELEASABLE LAND

From the above discussion it might be concluded that the land outside the eight-kilometre goal zone might be released for other uses. The preceding discussion, however, has not considered the effects that use of the land by others could have on liquid waste disposal practices to ground.

The 200 Areas were purposely built in an area where the water table is deep, 60-70 metres beneath the ground surface. The sediments above the water table are essentially dry and have excellent sorption properties for many long-lived fission products. These sediments have been used for 25 years to confine radionuclides. Significant increases in the groundwater level under the 200 Areas would tend to inundate the dry sediments progressively, thereby reducing the distance between the confined radionuclides and the water table. Studies made of the distribution of long-lived fission and activation products in terminated liquid disposal sites have shown that the major fraction (more than 99.99 percent) of the activity is held on the sediments immediately below the disposal facility [7]. Studies have also shown that moderate increases (10 metre rise) in the water table elevation could be tolerated. Additional increases in elevation of the water table would require a more quantitative determination of the fission and activation product distributions in the sediments beneath the waste disposal sites.

A flow model of the Hanford groundwater flow system has been developed and provides a significant insight into its behavior. It is now possible to predict the behavior of the regional unconfined water table for any given change in water potential, such as that which might result if the surrounding land were irrigated. A computer controlled data display system was also developed to provide a three-dimensional view, simulating the Hanford groundwater flow system. Within hours following input of data into this system, observations can be made on a video screen of the shape of the water table surface as a function of time. To illustrate the type of output obtained from this computer controlled data

Figure 3. Changes in Groundwater Contamination Patterns Resulting from Waste Management Practices in the 200 East Area

display system, photographs of the videoscope were taken at different times during evaluation of a particular model. These photographs are presented in Figure 4. The first photograph, A, shows the initial conditions prior to discharge. The next two photographs show the transient solution at one day and thirteen days following discharge. The last photograph, D, shows the conditions reached at steady state. With this capability a prompt evaluation can be made of the feasibility of permitting land to be used where ponding of water or irrigation is contemplated.

It now appears technically feasible to release some land within the Hanford Reservation for uses requiring the addition of water onto the ground. Such land releases would likely be made in increments, with enough time to evaluate the effects of rising groundwater before releasing the next increment.

CONCLUSION

The Hanford Reservation is situated in a uniquely favorable position with respect to the climate, topography, population density, and types of underlying sediments. Conditions at this site have proved to be favorable for the disposal of both solid and liquid wastes to the ground. Experience has shown that this practice is safe and that the amount of land required to carry on these operations and practices can be reduced. Studies show that while some land could be made available for other use, some restrictions might be required to preserve the favorable natural environment at this nuclear plant site where radioactive wastes are stored in the ground pending a national decision regarding ultimate disposal of this material.

A **B** **C** **D**

Figure 4. Flow Model Showing Progressive Change in Water Table Resulting from Discharge of Water to Ground Above Site X

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