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A PRELIMINARY
SAFETY ANALYSIS OF THE
B-C CRIBS CONTROLLED AREA

H. L. Maxfield

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Environmental and Occupational Safety Section
Quality Assurance and Control Department
Operations Division

July 31, 1974

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A PRELIMINARY
SAFETY ANALYSIS OF THE
B-C CRIBS CONTROLLED AREA.

INTRODUCTION

Approximately 2,000 acres of land south of the 200 East Area in the center of the Hanford Reservation is contaminated with an estimated 14 curies of ^{137}Cs and 81 curies of ^{90}Sr associated with animal wastes. Approximately half of this activity is located on (or within) 2.5 centimeters of the ground surface. The source of the contamination was the B-C Cribs and trenches which were used as liquid radioactive waste disposal sites during the 1950's. The mechanism for movement of radionuclides from the disposal site to the ground surface is believed to have been burrowing by an animal (probably a badger) followed by use of the exposed material as a salt lick by rabbits and other animals. Although the exact time is unknown, the burrowing is believed to have occurred about 1959. When the radioactivity was discovered, the burrow was sealed, the contaminated site was classed as a radiation zone, and surveillance initiated. The contaminated site has not been a significant hazard to employees at the plant or to the public. The Atlantic Richfield Hanford Company, prime contractor to the U. S. Atomic Energy Commission - Richland Operations Office, has maintained control over the surface contamination by isolation, zoning and by continued surveillance. Methods of handling the contaminated area have been considered. Discussions of these alternatives and applicable safety analysis information are included in the document.

SUMMARY

The results of the Safety Analysis of the contaminated land south of the 200 East Area, designated as the B-C Cribs Controlled Area, show that none of the applicable federal regulations pertaining to either plant employees or the general public will be exceeded during normal or accident conditions, if current surveillance and control programs are maintained.

It will be necessary for the area that has surface or near-surface contamination to be maintained as a controlled area until it has been decontaminated. It should be noted that no criteria exists for release of contaminated soil at this time.

TABLE I
EVALUATION OF ALTERNATIVES
B-C CRIBS CONTAMINATED AREA PLANS

Plan*	Description	Percent Contamination Reduced	Percent Contamination Stabilized	Estimated Contamination Spread						Conceptual Costs	Surveillance Costs/Yr
				Normal Operation			Accident Conditions				
				Increased Acres/Yr	Onsite Movement Ci/Yr	Offsite Release Ci/Yr	Increased Acres	Onsite Movement Ci	Offsite Release Ci		
I	Control-as-is	0	0	0	None	None	4,000	24.0	4.0	\$ -0-	\$ 5,000
II	Vacuum 40 acres Scrape 5 acres	2	2	0	None	None	3,920	23.5	3.88	170,000	5,000
III**	Vacuum 400 acres Scrape 100 acres	20	20	0	None	None	3,200	19.2	3.2	1,121,000	5,000
IV	Scrape and vacuum all acres	99	99	0	None	None	None	None	None	4,742,000	-0-
V	Plow and reseed or stabilize	0	90	0	None	None	400	2.4	0.4	1,000,000	5,000
VI	Set up ecological reserve	0	0	0	None	None	4,000	24.0	4.0	-0-	5,000

* All plans assume fire protection capability.

** The implementation of Plan III would reduce by 50 percent or more the chance of detectable contamination reaching and crossing 4-S Highway.

HL Maxfield:mkm
May 17, 1974

ARH-3088

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Biological transport was responsible for the original spread of radioactive materials from the B-C trenches. However, very little transport by biological or meteorological mechanisms has been noted in or adjacent to the B-C Cribs Controlled Area during the past 13 years.

The greatest concern is the potential for surface contamination in the B-C Cribs Controlled Area to be spread by high winds, following a major range fire, beyond the present boundary. The contamination would be measurable, but low level and would signify an unacceptable lack of contamination control.

The construction of ten and one-half miles of combination firebreaks and graveled roads on section lines within the B-C Cribs Controlled Area has greatly reduced the potential of an uncontrollable range fire denuding the area. Other methods for the reduction of fire potential or damage subsequent to a fire should be given special consideration. Surveillance of the area against excessive soil surface erosion, animal burrowings, and biological radioactive transport must be maintained.

Various alternatives to deal with the surface contamination have been proposed and analyzed. Table I summarizes data from these proposals and includes conceptual cost estimates as an aid in cost benefit considerations.

HISTORY

In 1943 the Manhattan Project obtained land in southeastern Washington and constructed facilities known as the Hanford Works to produce plutonium for the war effort. The facilities were transferred to the jurisdiction of the AEC in early 1947. Nuclear-related activities have continued without interruption.

The site chosen for the radiochemical processing operations, near the center of the Hanford Works, has proven to be near-ideal for this type of activity. The radiochemical processing site is isolated, being about eight miles from the project boundary and 25 miles from the City of Richland, (Appendix K-1). The groundwater lies approximately 300 feet

below the ground surface and moves slowly toward the Columbia River. (1) Nearly all the precipitation which averages approximately seven inches per year evaporates; thus, percolation to the water table is near zero, (Appendix A). In addition, the soil has ion exchange properties and tends to sorb and hold most radioactive materials with which it comes in contact. Since start of plant operation, these favorable chemical processing site characteristics have been utilized to protect the environs outside the Hanford site from radioactive contamination.

From 1952 to 1958, wastes containing the uranium and the aged fission product wastes produced by the now obsolete bismuth phosphate separations process were removed from underground storage tanks. After the uranium was recovered, the cesium and strontium content of the effluent stream was reduced by precipitate scavenging, and the supernatant liquor released to ground in the B-C Cribs and trenches, (Appendix K-2). The specific volume of scavenged waste liquid which would be retained by the soil above the water table was transferred into the bottom of the unlined trenches, which were then backfilled with soil.

About 1959, animals (presumably a badger) burrowed into a backfilled trench and a salt layer was exposed. Rabbits subsequently used the burrow as a means of reaching radioactive materials in the trenches. These chemicals served as a "salt lick". After discovery of the burrow, it was filled with gravel and sealed over with asphalt. However, rabbits had ingested the contaminated salts and defecated over approximately four square miles of undisturbed sagebrush land depositing animal feces on the ground as far as two-and-one-half miles from the original site of the burrow, (Appendices K-3 and K-4). This contaminated land surrounds the B-C Cribs and trenches on three sides, extending primarily to the south and east and is the designated B-C Cribs Controlled Area.

In 1969, approximately 60,000 cubic yards of sand and gravel were used to cover and stabilize the area containing the B-C waste trenches to further isolate the radioactive material from the open environment.

HAZARDS REVIEW

CURRENT CONDITIONS

At present, the radioactivity in the B-C Cribs Controlled Area is associated with rabbit fecal pellets on the ground

surface. In addition, there is radioactivity in the sandy soil from four to nine inches deep as a result of radioactive urine and precipitation leaching radioactive materials from the pellets.(2) Additional radioactive material from the original source has not been detected since the burrow was covered. Although the soil is mainly sand, a heavy stand of shrubs, forbs, and grasses furnishes a buffer against surface winds.

Analysis of vegetation samples taken from the affected area indicate background radioactivity containing only trace amounts of ^{90}Sr and ^{137}Cs , (Appendix B-1). Onsite air monitoring studies by Sehmel (Appendix B-3) indicate airborne ^{137}Cs is roughly 1/1,000,000 of the guide values for radiation workers (AEC Manual Chapter 0524, Standards for Radiation Protection) and is not significantly different than general onsite environmental surveillance data.

For purposes of environmental management and planning for possible decontamination, the area has been divided into two zones according to the concentration of radioactive contamination present, (Appendix K-2). Zone A contains the most surface contamination and comprises approximately 560 acres with over 2,000 radioactive fecal pellets per acre. Aerial radiation surveys show surface contamination to be from one to ten microcuries per square meter. Zone B comprises approximately 2,000 acres* which contain a concentration of generally less than one microcurie per square meter of ground surface, (Appendix K-4). Total radioactivity on the ground surface and to a depth of 2.5 centimeters in Zones A and B is computed to be approximately 40 curies, of which 32 curies are ^{90}Sr and 8 curies ^{137}Cs , (Appendix B-4).

*The total acreage within the perimeter of Zone "B" is approximately 2,000 acres. There are, however, approximately 500 acres scattered within Zone "B" that are free of contamination.

Results of soil samples also indicate there is at least an equal amount of radioactivity below 2.5 centimeters to a depth of 20-30 centimeters (Appendix B-4), with cesium tending to remain nearer the soil surface and strontium to be separating and leaching downward. (2) Administrative control of the area during the past 13 years has been maintained without appreciable movement or spread of contamination and without detectable adverse effects to personnel, the public, or the environs. However, mechanisms which could make complete and finite control of the radioactivity difficult are as follows: (1) unauthorized entry into the zone by man, (2) biological transport mechanisms, (3) a major range fire through the area, (4) high velocity winds following a range fire, and (5) the effects of prevailing air currents.

FACTORS EFFECTING CONTROL OF CONTAMINATION

Unauthorized Entry by Man

During the past 12 years, many entries have been made by man to accomplish work in the B-C Cribs Controlled Area. Radiation monitors have continued to inspect and take vegetation and soil samples from the area; telephone and electrical line workers have routinely entered to do maintenance work; biological field research teams have entered the zone on numerous occasions; and construction forces used heavy earth-moving equipment to cut out and construct 10 1/2 miles of fire protection roads throughout the area. In all cases, radiation surveys for release from the zone showed personnel, tools and equipment to be free from radioactive contamination, (Appendix C). Gamma dose rates in the majority of "high" areas of the affected zone range from 300-700 mR/year, as compared with reading of 60-80 mR/year for non-radioactive zones at Hanford and in the City of Richland, (Appendix B-2).

From the above observations, it would appear there is an extremely low probability that any detectable injury would occur to man as a result of casual or accidental entry into the zone. The exception being a person inexperienced in radiation protection could inadvertently bring harm to himself or others in the event that individual or collections of pellets came into close contact with the skin for prolonged periods or if part (e.g., dust) of the pellets were accidentally inhaled or consumed.

The B-C Cribs Controlled Area in its present condition must be controlled as a radiation zone for over 100 years. Fortunately, long-term control is simplified because of site location within the Hanford Reservation.

Biological Transport Mechanisms

Biological transport was responsible for the original spread of radioactive materials from the B-C Cribs. However, very little transport by biological mechanisms has been noted for the B-C Cribs Controlled Area in the past 13 years, and only small amounts of radionuclides can be expected to be transported biologically from the area under existing environmental conditions, (Appendix D-1).

The lack of significant biological transport is consistent with the current state of biological knowledge relevant to the B-C Cribs Controlled Area. True biological accumulation is very rare where a terrestrial organism contains more radioactive materials than that found in the environment. The results of biological transport tend to produce a dilution effect over a long time period. Secondary long-term effects are redistributions within the site and among the biota. Two offsite biological transport modes are possible; one involves plants the other involves animals, (Appendix D-1). None of the plants or animals common to the B-C Cribs Controlled Area are ordinarily eaten by people.

It is possible that strong winds could transport plants like tumbleweeds offsite, but there are few tumbleweeds presently growing on the site. Plant tissue may contain as much ^{90}Sr on a per gram basis as the soil in which the plant is rooted, and plant uptake of ^{137}Cs is about 1/100 of that present in the soil, (Appendix D-1). The concentration of ^{90}Sr in the soil will decrease with time as precipitation results in some downward leaching. The location of ^{137}Cs in the soil will remain essentially unchanged, (Appendix J).

The normal pathway for the animal uptake of radioactive materials is through food sources. Essentially all of the ^{137}Cs consumed is taken in through the gut, whereas, only one-third of the ^{90}Sr may be absorbed. About 80 percent of the ^{90}Sr not absorbed across the gut will be excreted in the feces, and ^{137}Cs will be rapidly eliminated in urine. (3) However, only a small portion of animal's diet would be composed of plants containing radioactive materials taken up from soil.

It is difficult to conceive of biological transport mechanisms resulting in health hazards to man. Perhaps a contaminated road-kill animal could be picked up on the Hanford Highway and lead to a compromising situation. This, however, is unlikely to happen. Analytical results of samples taken from rabbit kills in the B-C Cribs Controlled Area and nearby roads taken during the past four years indicate the concentration of radionuclides in the animal tissue to be less than detectible levels for Geiger-Muller (GM) type field survey instruments, (Appendix D-2).

Dispersion by plants, mammals, birds, reptiles, or insects may eventually result in a slightly larger contaminated area. The new area would contain trace amounts of radioactive materials.

Major Range Fire Through the Area

It is postulated that the maximum credible spread incident concerning the control of radioactive contamination in the B-C Cribs Controlled Area would occur during and following a range fire. Such a fire burned 18,000 acres near the Fast Flux Test Facility Reactor site in 1970 and resulted in a 100 percent consumption of surface vegetation in most of the burned areas.

To assure the consequences of the involvement of the B-C Cribs Controlled Area in such a fire, a set of rather adverse conditions and assumptions are postulated. Mr. J. R. Houston assumes (Appendix E-1) all of the activity available that would become airborne to be within a cross-section of 2,000 meters, (maximum breadth of gross contamination) and all of the activity not in the soil would become airborne during the course of the fire which would last for two hours. As before stated, the amount of surface radioactivity to a depth of 2.5 centimeters is computed to be 32 curies of ^{90}Sr and 8 curies of ^{137}Cs . Of this amount, Mr. J. Mishima^(4,5) showed ten percent of the total surface activity to be associated with the combustible materials on the surface of the ground, thus 3.2 curies of ^{90}Sr and .8 curies of ^{137}Cs would become airborne.

It is assumed the fire would entrain the strontium and cesium uniformly in the first two meters of air above ground surface along the 2,000 meter cross-section, with one meter per second wind speed. In his study of this condition, Mr. J. R. Houston computes the rem dose to individuals on 4-S Highway (approximately 1,000 meters downwind from the fire) and to individuals on the Hanford Highway (approximately seven kilometers to the south of the fire) to be well below the respective rem value standards for internal exposure.

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However, this evident lack of contamination control would be counter to the desired objective of reducing to a practicable minimum the onsite movement and potential off-site releases of radionuclides.

The Effects of Prevailing Winds

If the B-C Cribs Controlled Area were completely denuded as was the case in the FFTF site range fire of 1970, the radioactive contamination remaining in the upper 2.5 centimeters of soil would be 36 curies, i.e., 40 curies less 4 curies dispersed by the fire. The question then becomes, "Is the 36 curie deposition a subject of concern with respect to persons working or residing downwind from the source?" In Appendix F-1, Mr. T. W. Horst has made a climatological assessment of this condition, assuming ten percent of the remaining source to be available at any given time for resuspension and diffusion by the prevailing winds crossing the B-C Cribs Controlled Area. He concludes the annual exposure at the FFTF Site would be 1.3×10^{-10} $\mu\text{Ci hr/cc}$ of air. The exposure at Richland would be even less due primarily to its greater distance from the source; but due also to the fact that Richland is downwind less than half the time the FFTF Site is downwind from the source.

In Appendix F-2, Mr. Houston shows that radiation doses resulting from 50 year inhalation exposure to 1.3×10^{-10} (1.04×10^{-10} ^{90}Sr and $.26 \times 10^{-10}$ ^{137}Cs) $\mu\text{Ci hr/cc}$ would be far less than the radiation that would be received by an individual from natural sources over the 50 year time span.

ANALYSIS OF THE PROPOSED ACTION ALTERNATIVES

In the previous discussions in this document with respect to hazards related to control of contamination in the B-C Cribs Controlled Area, it has been shown the amount of radioactivity that could reach man through the described transport mechanisms is well below applicable standards. Also, results of environmental air samples taken within Zone "A" of the B-C Cribs Controlled Area are in the range of 10^{-15} uCi/cc (Appendix B-3), which is in the same range as other environmental air samples taken near the chemical separations and waste management areas located on the 200 Areas plateau. Sample results from other sampling locations on the Hanford Reservation, exclusive of the 200 Area plateau, are in the range of 10^{-16} uCi/cc⁽⁷⁾ as are results from offsite locations surrounding the Hanford Reservation.⁽⁸⁾ From these observations, it is apparent the B-C Cribs Controlled Area with its heavy growth of protective vegetation is not contributing to airborne contamination to any other site, on or off the Hanford Reservation. However, a reduction of the quantity of radionuclides currently on or near the surface of the soil by any of the following proposed methods would further reduce the potential inhalation and biological transport hazards in direct proportion to the extent of the reduction of the source of radioactivity.

PROPOSAL I - PROVIDE FIRE PROTECTION ONLY

The major hazard contributing to the potential spread of contamination from this area has been identified as the consequence associated with a fire in the area. Thus, initial funds have been spent for the construction of ten and one half miles of combination firebreaks and graveled roads to deter fire and provide easy access for fire fighting equipment. In addition, a fire fighting plan, (Appendix G) has been prepared by the Hanford Fire Department to combat and control fires threatening or developing within the area. Water is available at two nearby locations on the perimeter of the 200 East Area.

While the fire fighting action taken has not reduced or eliminated the source of contamination from the ground surface, it has greatly reduced the probability of an uncontrolled fire sweeping the area in a total burn.

Because no cleanup of the area would be accomplished, the surface contamination would remain a potential for onsite spread to unrestricted areas following a fire, particularly along the 4-S Highway near the southeast corner of 200 East Area. Under

the worst conditions, high winds following a range fire could enlarge the present zone to include an additional estimated 4,000 acres, extending to the edge of the 200 East Area Plateau, and could cause the temporary closing of portions of the highway. Proposal I would not lessen requirements for continued surveillance.

PROPOSAL II - PROVIDE FIRE PROTECTION, VACUUM 40 ACRES,
STRIP 5 ACRES, LEAVE THE REMAINDER OF THE
AREA AS IT IS

Fire protection roads have been constructed with little adverse effect on the environs. The areas selected for decontamination would be part of the area between the highway and the east-west section line firebreak immediately south of the highway, (Appendix K-2). The rationale for cleaning this particular area is to remove the contamination closest to the highway with the objective to bring the contamination within the existing east-west firebreak for maximum fire control. The contaminated material removed from the acreage would be buried in a new excavation adjacent to the B-C Liquid Waste trenches (Appendix K-5), and would be covered with nine feet of clean soil.

The concentrating of radioactivity from a comparatively low density area into a burial pit of higher density may be considered a negative aspect of this proposal. This would add another zone requiring surveillance against radioactive plant growth and burrowing by animals.

During cleanup, repeated travel over shrubs, forbs, and grasses for radiation detection and release surveys, vacuuming, and transport to and from the burial site would have an adverse effect on the growth of ground cover plants. It could become necessary to do some revegetation for soil control against wind erosion, not only on the scraped five acres, but also on other sandy surfaces in the vacuumed area.

The vacuuming of 40 acres and the scraping of five acres would reduce the total source of radiation by approximately two percent. The acreage containing the remaining contamination would require continued surveillance as in Proposal I. Although the amount of contamination removed is considered insignificant, the purpose of this action is to demonstrate cleanup techniques. The risks involved in leaving the remaining area "as is" are the same as analyzed in Proposal I.

PROPOSAL III - CONSTRUCT FIREBREAKS AND ROADS; SCRAPE 100 ACRES OF ZONE A; VACUUM-CLEAN 400 ACRES OF ZONE B; PROVIDE WATER PLUS POWER TO THE AREA; AND LEAVE THE REMAINING ACREAGE AS IT IS

Zone A contamination is essentially continuous over the entire area. Although a vacuum cleaner could be used to pick up the contaminated soil and rabbit droppings in this area, the problem essentially becomes one of material handling which involves removal of about nine inches of top soil from the area. The removal of this large amount of earth could best be handled by large earth-moving equipment. Consequently, the proposal is to demonstrate this technique as a cleanup method for Zone A by scraping the top nine inches from about 100 acres of Zone A, (Appendix K-5). The area selected for scraping would be those portions of Zone A resting in sections 10 and 11, i.e., between the highway and the east-west section line firebreak. The vacuuming of the 400 acres in Zone B would remove the remainder of the contamination in the area between the highway and the first east-west firebreak to the south and all the contamination in the area which lies to the west of the western north-south firebreak. This would withdraw the perimeter of the contaminated zone to within the confines of the firebreak roads for maximum fire protection.

Contaminated soil from the cleanup would be buried in an excavation adjacent to the B-C Liquid Waste trenches, and would be covered with nine feet of clean soil. A new water line would be installed from the 200 East Area reservoir to a point across the highway to provide irrigation for reseedling the scraped area with drought-resistant grasses. At the proper time an irrigation system would be rented and installed to assure germination and growth until the grasses are adequately established to self-exist. An electrical supply line would be installed into the area to provide power for continuous environmental air sampling and for the operation of irrigation pressure booster pumps.

The removal of all contamination from the described acres in this proposal would reduce the total radioactive source by approximately 20 percent, which would be reflected in the amount of radioactivity available for transport through the various systems to man. It would also produce a half mile wide contamination free buffer zone south of 4-S Highway over which wind blown contaminated sandy soil could be checked before reaching the highway. Drought tolerant grasses, once established would offer good soil surface holding capacity, and unlike sagebrush, the grasses have rapid growth recovery following a range fire. In past practices, sheep and cattlemen have often taken advantage

of this fire recovery characteristic to produce new forage growth. However, drought-resistant range grasses are sometimes difficult to establish, especially on those areas of very sandy surface, (Appendix H).

Again, a possible negative aspect of the proposal is the re-concentration of radionuclides from a comparatively low-level activity per unit area into an AEC approved radioactive burial site of much higher activity per unit area. This would require long term surveillance against radioactive weed growth and burrowing by animals.

The acres remaining within the firebreaks would be left as is. To be directly exposed to the action of the elements, biota and man as they have been during the past 12 years. It is not expected that conditions would vary to any appreciable degree, excepting the construction of the firebreak roads has made the area less susceptible to range fires.

As in Proposals I and II, the major risk involved in Proposal III would be associated with high winds following a range fire. However, the cleaned area between the north section line road and 4-S Highway could be effectively used as a buffer zone in which to check the spread of contamination before it could reach the highway.

PROPOSAL IV - PROVIDE FIRE PROTECTION, WATER AND POWER;
COMPLETE CLEANUP AND RELEASE OF ALL ZONES,
AND REESTABLISH VEGETATION

The complete decontamination of the B-C Cribs Controlled Area would remove all potential for radioactive contamination reaching the public from that site. It would eliminate the necessity of continued surveillance other than that for the burial site. The area would be returned to a condition that could allow public access or use with a minimum of restrictions.

Fulfilling Proposal IV would require the greatest effort, and take the longest period of time for completion. Revegetation of the ground surface following decontamination could be very difficult in those areas where the soil is sandy. Moving the radioactivity from a comparatively low density area into a pit of high density concentration could make it more available for redistribution by plants and animals.

PROPOSAL V - OTHER PROPOSALS

Plowing Under the Surface Contamination

Assets. Deep plowing to a depth of two feet or greater would turn under as much as 90 percent of the radioactivity from the surface of the soil to where it would not be available for airborne spread to onsite or offsite locations. Plowing would dilute the concentration of nuclides in the soil, which would reduce the potential for biological recycling and plant uptake. No casual contact by man with radionuclides would occur as a result of unauthorized entry into the zone.

Liabilities. This alternative would present those problems associated with plowing and reseedling of uncleared land, such as:

- disposal of large volume of sagebrush,
- reestablish soil stabilization,
- create a dust source, and
- difficult revegetation.

Plowing would result in irreversable action with respect to decommissioning of the site at a later date. The volume of contaminated soil would be at least triple the present affected volume. Continued surveillance would be required until decay to an innocuous level had occurred.

Fixation of the Soil Surface Against Wind Erosion

There is not enough information presently available to evaluate the overall effects of surface soil fixation methods on sagebrush covered Hanford rangelands.

Establishment of a Ecological Reserve

Those acres resting in sections 13, 14, 22, and 23 would be set aside as an ecological reserve for the study of the movement of radionuclides in a naturally contaminated ecosystem, and for the testing and development of environmental waste management practices. Information gained from such a study could be far reaching in effect and could have national and international application.

The major risks involved would be those associated with high winds following a range fire, as previously delineated. The present radiation zone would enlarge by smearing toward the north and east and would become a nuisance as it reached or crossed the 4-S Highway.

This plan would require continued surveillance, which would be incorporated into the research and study program.

- (1) BNWL-1739 (unclassified), 1973, K. L. Kipp, et al., "Hanford Wells."
- (2) ARH-SA-176 (unclassified), March 1974, L. E. Bruns "Aerial Gamma Survey by Helicopter to Measure Surficial Contamination."
- (3) International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation, ICRP Publication 2, Pergamon Press, Ltd., Oxford, 1959.
- (4) BNWL-B-303 (unclassified), December 1973, J. Mishima, "Potential Airborne Release of Surface Contamination During a Range Fire in the B-C Controlled Area."
- (5) BNWL-B-337 (unclassified), April 1974, J. Mishima, "Distribution and Potential Release of Surface Contamination, ^{137}Cs in Zone 1, B-C Control Area Interim Report."
- (6) BNWL-1605 (unclassified), June 1972, W. A. Stone, et al., "Climatology of the Hanford Area."
- (7) BNWL-B-336 (unclassified), 1973, W. L. Nees and J. P. Corley, "Environmental Status of the Hanford Reservation."
- (8) BNWL-1811 (unclassified), 1973, W. L. Nees and J. P. Corley, "Evaluation of Radiological Conditions in the Vicinity of Hanford."

APPENDIX A

APPENDIX A

Abstract From: Soil Moisture Transport in
Arid Site Vadose Zones
ARH-SA-169- (SM-182/6)

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E. L. Roetman

January 1974

Average annual precipitation at Hanford is about 16 centimeters per year [11]. The total annual rainfall ranges from about eight centimeters to about 28 centimeters, of which about 70 percent occurs during fall and winter months. Residual moisture in the Hanford sediments below a depth of 10 meters ranges from about 1.5 to about 4 percent with a mean value of about 2 percent, by weight. Water content retained by capillarity ranges from 8 to 10 percent, by weight. Based on these data, a full year of precipitation of 16 centimeters would satisfy the soil moisture deficiency to a depth of less than 3.0 meters if no loss to the atmosphere or redistribution other than capillary transport occurred. Soil drainage predictions would give a somewhat greater depth of penetration. Because of the complexities of soil moisture movement in the vadose zone of arid sites, in-depth soil moisture transport studies were initiated at Hanford in 1969.

APPENDIX B-1

APPENDIX B-1

222-S ANALYTICAL REPORT			
SERIAL NO. ES-117 and ES-118		SUBMITTER'S SAMPLE NO. #1 and #2	
SAMPLE DESIGNATION			
SAMPLE SITE B.C. CRIB			
REQUESTED BY H.L. Maxfield	AREA 200-E	BLDG. 2704 - W	PHONE 22286
DATE-TIME SAMPLED 2-26-74	DATE RECEIVED 2-26-74	DATE COMPLETED	
ANALYSIS REQUESTED GAMMA ENERGY ANALYSIS ON VEGETATION SAMPLES FROM B.C. CRIB			

<u>SERIAL NO.</u>	<u>CUSTOMER'S DESCRIPTION</u>	<u>SAMPLE SIZE</u>	<u>ISOTOPES FOUND BY GEA</u>
<u>LAB</u> <u>CUSTOMER</u>			
ES-117 1	Plant growing in soil.	5.72g	¹³⁷ Cs 2.34 E-04 μ Ci/gram of dried plant
ES-118 2	Sage Brush from ground surface south of trench area.	10.96g	¹³⁷ Cs 1.63E-05 μ Ci/gram of dried plant

REW:jld

Prepared by:

*Ronnie Wheeler*Supervisor
Environmental Laboratory

cc: RE Wheeler

APPENDIX B-1

222-S ANALYTICAL REPORT			
SERIAL NO.		SUBMITTER'S SAMPLE NO. 1 through 11	
SAMPLE DESIGNATION			
SAMPLE SITE Zone A BCP Controlled Area			
REQUESTED BY H. L. Maxfield	AREA 200-East	BLDG. 2704-E	PHONE
DATE-TIME SAMPLED June 14, 1974	DATE RECEIVED	DATE COMPLETED July 15, 1974	
ANALYSIS REQUESTED 89,90Sr, 137Cs on Vegetation Samples			

1. Vegetation samples were wet ashed using nitric acid, strontium and cesium carriers and strontium-85 spike were added to dried samples prior to digesting with nitric acid. Strontium was separated from cesium via a carbonate precipitation.

The cesium fraction was further purified by a silicotungstic acid precipitation followed by a tetraphenolboron precipitation. The tetraphenolboron precipitate was mounted and beta counted for cesium-137 determination.

The strontium fraction was purified using fuming nitric acid and re-precipitated as a carbonate. The strontium carbonate was mounted and beta counted for strontium. The gamma from strontium-85 was used for recovery determination.

2. Results are given in picocuries per gram of air dried vegetation.

CLT:cam
7/17/74

Prepared by:

Supervisor
Environmental Laboratory
Analytical Laboratories

Approved by:

Manager
Analytical Laboratories

SAMPLE POINT: ZONE A BCP CONTROL AREA

DATE COLLECTED: JUNE 14, 1974

<u>Sample Number</u>	<u>^{89,90}Sr Results in pCi/gram</u>	<u>¹³⁷Cs Results in pCi/gram</u>
1) Bitter brush	3	3.2
2) Poa secunda (desert blue grass)	244	---
3) Artemisia tridentata (sage brush)	55	4.3
4) Comandra pallida (bastard toadflax)	30	3.1
5) Salsolia Kali (Russian thistle)	181	4.9
6) Lomatium greyi (desert parsley)	30	4.6
7) Psoralea (scurfpea)	39	4.4
8) Chrysothamnus viscidiflorus (green rabbit brush)	25	1.9
9) Bromus tectorum (sheet grass)	< 1	1.3
10) Grayia spinosa (hop grass)	43	2.8
11) Franeria acanthocarpa (tomato plant)	11	*6.8

*Gamma analysis prior to HNO₃ digestion: 8.1±1.3 pCi/g ¹³⁷Cs

APPENDIX B-2

APPENDIX B-2

Date: May 9, 1974
To: H. L. Maxfield
From: L. E. Bruns *LEB*
Subject: DOSE RATE STUDIES IN THE BC-CRIBS
CONTROLLED AREA - MAY & JUNE 1973

This letter is in reply to your request for results of dose rate studies conducted in the BC-Cribs Controlled Area. You may use this information as a reference for your safety analysis statement.

Aerial gamma dose rate measurements showed the average gamma dose rate to be 60 mR/yr, the highest, in the H area being 1640 mR/yr. This compares fairly close with the Reuter-stokes argon dosimeter readings which showed a range of 100 to 1200 mR/yr. The majority of the high areas are 300 to 700 mR/yr. Where the roadways and firebreaks have been made there is a definite drop in activity, e.g., in the concentrated zones, the mR/yr value has dropped from 300 - 700 to 100 - 150 mR/yr. Background is about 60 - 80 mR/yr.

LEB:ah

APPENDIX B-3

Battelle

Pacific Northwest Laboratories

Battelle Boulevard

Richland, Washington 99352

Telephone (509)

Telex 36921

March 12, 1974

Harold L. Maxfield
2704-E Bldg., 200-E Area
Atlantic Richfield Hanford Company
Richland, Washington

Dear Mr. Maxfield:

PARTICLE RESUSPENSION AT B-C AREA

You requested a brief note to document radioactive air concentrations at B-C area that we have determined in our resuspension research. This note is to serve as a reference for your environmental impact statement.

Airborne radioactivity concentrations have been determined at B-C area during four representative time periods in 1973. The periods were from June 1 to 5, August 30 to September 14, September 14 to October 17, and October 17 to November 2. Air concentrations were determined using high volume air samplers mounted on towers. Eleven towers at 100 feet north-south spacing were near the east side of Zone 1 and were located to sample prevailing westerly winds which came across Zone 1 into these "downwind" towers. Three "upwind" towers were located west of Zone 1. Air samplers were located at 1, 6, and 20 foot heights on the towers. All sampler sites and towers were not used in each time period. Samplers collected airborne material for all windspeeds and wind directions.

The first resuspension experiment at B-C area this spring (March to April, 1974) will determine airborne radioactivity concentrations as a function of three windspeed increments, and at 1 and 6 foot sampling heights. Wind direction and wind speed instrumentation will turn-on the samplers only when westerly winds are blowing from the three upwind towers to the eleven downwind towers.

Airborne concentrations have been calculated for both ^{137}Cs and ^{90}Sr . Data analysis is continuing. All measured concentrations are orders of magnitude lower than MPCair concentration of $2 \times 10^{-8} \mu\text{Ci}/\text{cm}^3$ ^{137}Cs and $10^{-10} \mu\text{Ci}/\text{cm}^3$ ^{90}Sr for continuous exposure.

Analyses have been made for both ^{90}Sr and ^{137}Cs for the June and the August to September runs. In general, results indicate airborne ^{90}Sr and ^{137}Cs concentrations are comparable (i.e., usually within 50% in the value of $\mu\text{Ci}/\text{cm}^3$). ^{90}Sr concentrations were usually within the magnitude of $10^{-15} \mu\text{Ci}/\text{cm}^3$ except for two samples of greater concentration, which were 1.3×10^{-14} and $1.5 \times 10^{-14} \mu\text{Ci}/\text{cm}^3$. In comparison, ^{137}Cs concentrations for the four time periods were

March 12, 1974

<u>Period</u>	<u>Range, $\mu\text{Ci}/\text{cm}^3$ ^{137}Cs</u>
1. June 1 to June 5	2×10^{-15} to 2.8×10^{-14}
2. Aug. 30 to Sept. 14	1.9×10^{-15} to 1.1×10^{-14}
3. Sept. 14 to Oct. 17	9.5×10^{-15} to 1.4×10^{-15}
4. Oct. 17 to Nov. 2	2.9×10^{-15} to 7.8×10^{-15}

Relative airborne ^{137}Cs concentrations during the August 30 to September 14 experiment were largest near a road which had been built through B-C area. Airborne concentrations near the road were up to about 50% higher than at a distance from the road. The possible effect of the road on increased airborne concentrations was not observed in the succeeding time period.

We have also measured near U-pond area the concentration of airborne dust as a function of wind speed and respirable particle size. The data indicate that above approximately 10 mph that the respirable concentration of airborne dust increases approximately as wind speed to the third power. If the resuspension of respirable radioactive particles follows the same general wind dependency, airborne activity also probably increases rapidly with wind speeds above 10 mph. It is recommended that human activity in the B-C crib area could be limited or restricted to windspeeds less than approximately 10 mph if respirable exposure is to be minimized during clean-up operations. Nevertheless, human activity for higher wind speeds in B-C area could probably still be within MPC_{air} for the undisturbed soil. At present, we do not know the extent to which potential respirable exposure will be increased by disturbing the soil during B-C area clean-up operations.

Very truly yours,

G. A. Sehmel, Ph.D.

Particulate & Gaseous Waste Research
ATMOSPHERIC SCIENCES DEPARTMENT

GAS:lb

cc: L.E. Bruns, ARHCO

APPENDIX B-4

APPENDIX B-4

Date: July 11, 1974

To: H. L. Maxfield

From: L. E. Bruns, Staff Engineer *L.E. Bruns*
Physical and Life Sciences TechnologySubject: STATUS OF BC CRIB SURFACE CONTAMINATION DEVELOPMENT
WORK

1. Aerial Survey - The results indicate that there are 7 curies of Cesium-137 on the surface if all the activity were in the top 1 cm of soil. Any activity below the surface that registers on the helicopter's NaI(Tl) gamma system must be multiplied by an attenuation factor, e.g., at 2 cm multiply by about 1.2, at 5 cm by about 1.6 and at 7.5 cm by about 2.0. (If there were 1 curie of activity at a depth of 7.5 cm, the instrument would see it as 0.5 curie on the ground surface.) The aerial survey can estimate the X-Y plane but the depth distribution, the Z direction, must be attained by soil depth analyses (see item 3). Based on scattered soil depth analyses, an initial estimate can be made of the Cesium-137 in the BC-Crib area.

<u>Depth (cm)</u>	<u>Curies Cesium-137</u>
0 - 1.0	5
1.0 - 2.5	3
2.5 - 5.0	2.5
5.0 - 10.0	2.0
10.0 - 20.0	1.5
20.0 - 30.0	0.5
	<u>14.5</u>

To be conservative it is recommended that the high side of the accuracy be used, i.e., the 0 - 1.0 cm depth would be 7.5 curies. Isopleths maps resulting from the aerial surveys can be used to study the distribution of activity throughout the affected area.

The average gamma dose rate throughout the affected area was 160 mr/yr, the highest being 1640 mr/yr. This compares fairly close with the Reuters-Stokes argon dosimeter (see next item).

2. Gamma Dosimeter - These studies show a range of 100 to 1200 mr/yr. The majority of the high areas are 300 to 700 mr/yr. Where the roadways of firebreaks have been made there is a definite drop in activity, e.g., in the concentrated zones, the mr/yr value has dropped from 300-700 to 100-150 mr/yr. Background is about 60-80 mr/yr.
3. Soil Sampling and Analyses - The ratio of Strontium-90 activity to Cesium-137 activity is shown below,

H. L. Maxfield
 Page 2
 July 11, 1974

Depth	Ratio Strontium/Cesium
0 - 5.0 cm	4.5
5.0 - 20.0 cm	8.0
20.0 - 30 + cm	15.0

The highest value of Strontium-90 taken in the top sand plus rabbit pellet mixture was 7×10^{-8} ci/cc or 70 nanocuries/cc of soil. Almost all analyses to date have come from the higher concentrated areas. Several hundred samples taken in areas of varying levels are awaiting analyses. The highest laboratory Cesium-137 value was 2.5×10^{-8} ci/cc.

The variation with depth based mainly on analyses made from samples from the concentrated areas follows approximately the percent activity of the total with depth as given below.

Depth (cm)	Percent Activity	
	Strontium-90	Cesium-137
0 - 2.5	47.0	60.0
2.5 - 5.0	31.0	25.5
5.0 - 10.0	17.5	12.2
10.0 - 15.0	3.5	1.8
15.0 - 20.0	0.9	0.4
20.0 - 30.0	0.1	<0.1
	100	100

Many more samples are needed to confirm these percentages with depth. It can be concluded that there is very little activity beyond the 15 cm depth. Activity beyond the 15 cm depth in the cleanup process might better be handled by a vacuum system, even that beyond a 10 cm depth.

The BC-Crib area was checked for all radionuclides by an approximation in the aerial survey for gamma emitters and by laboratory analyses. The results are associated with the high activity surface soils and are tabulated below.

$^{239}\text{Pu} + ^{240}\text{Pu}$ <0.1 to 1.3×10^{-10} g/g soil

^{155}Eu 6.0×10^{-11} ci/g (max.)

^{60}Co 7.0×10^{-12} ci/g (max.)

^{241}Am 1.0×10^{-10} ci/g (max.)

Others found were ^{154}Eu , ^{238}U , ^{235}U , ^{103}Ru , ^{238}Pu , ^{106}Ru ,

H. L. Maxfield

Page 3

July 11, 1974

^{106}Rh , ^{57}Co , ^{125}Sb , ^{226}Ra , ^{51}Cr , ^{185}Sr , ^{152}Eu , ^{135}Cs , ^{141}Ce ,
 ^{228}Th , ^{40}K , ^{228}Ra .

From the aerial survey and the laboratory analyses the total curies of activity are estimated to be:

Total Curies BC-Crib Area Activity

Depth (cm)	^{137}Cs	^{90}Sr	
0 - 1.0	5.0	20.0	
1.0 - 2.5	3.0	13.5	
2.5 - 5.0	2.5	12.5	
5.0 - 10.0	2.0	16.0	
10.0 - 20.0	1.5	12.0	
20.0 - 30.0	0.5	7.5	
	14.5	81.5	Total 96 Ci (-60 + 40%)

This number is based on only about 25 Strontium-90/Cesium-137 ratios and is believed to be on the high side since some of the Strontium-90 numbers averaged in were suspected to be on the high side. A range of total curies is estimated to vary from about 40 to 140 curies.

4. Leaching Studies - Leaching studies for Cesium-137 and Strontium-90 indicate that for 50 column volumes show the following laboratory results and the results applied to the crib area.

Leaching of BC-Crib Surface

		<u>Laboratory</u>	
	<u>Column Volumes</u>	<u>Water</u>	<u>0.1M NH NO</u>
^{137}Cs	50	5%	41%
^{90}Sr	50	8%	48%

BC-Crib Area
 (Assume rainfall averages 7-in./yr)

Maximum Amount Leached Downward Since 1960

^{137}Cs

From	0.0 to 2.5 cm	30 - 60%
	0.0 to 5.0 cm	20 - 45%
	0.0 to 10.0 cm	10 - 20%

H. L. Maxfield
Page 4
July 11, 1974

⁹⁰Sr

From	0.0 to 2.5 cm	40 - 75%
	0.0 to 5.0 cm	30 - 50%
	0.0 to 10.0 cm	15 - 40%

These values are considered maximum because equilibrium conditions in the soil may be attained sooner than a simulated laboratory column. Also, evaporation and capillary effects may tend to put the actual in situ leaching lower than the values shown. However, actual soil analyses and a noticeable drop in surface activity from initial measurements show that both Strontium-90 and Cesium-137 are being leached downward with rainwater.

LEB:pm

cc: G. E. Backman
G. Burton
R. D. Fox
R. E. Isaacson
C. W. Malody
B. J. McMurray
G. C. Oberg
B. J. Saueressig
A. E. Smith

APPENDIX C

**RADIATION MONITORING SURVEY RECORD OF PERSONNEL,
MATERIALS AND EQUIPMENT**

[illegible]

APPENDIX C

RADIATION MONITORING SURVEY RECORD OF PERSONNEL, MATERIALS AND EQUIPMENT

D	PO	XYZ	FUNCTIONS												REPORTS												RADIATION OCCURRENCE	INJURY				
			12-8	8-4	4-12	BURIAL	CONTROL PROGRAM	DECONT	FOLLOW-UP	INSP	LAB	MAINT.	PERSONNEL SURVEYS	PROCESS WORK	RAIL MOVEMENT	RELEASE	SAMPLING	SHIPMENT	VEHICLES	CONTAM CLOTHES	CONTAM SKIN	MONTHLY REPORT	NASAL SM. AND IRRIG.	REPORTED TO RPO								
C			TIME		RADIATION SURVEY												SURVEY NUMBER 08400												PUREX			
B			TIME JOB STARTED		NO														RESPIRATORY PROTECTION WORN												S	
A			TIME		0815														N R A C FA												T	
✓	DAYS		LOCATION		210 East & West												INSTRUMENT(S) USED G.M., PAM, CP												U			
31			JOB DESCRIPTION		Car 20 activities																								Z			
30																													TANK FARMS			
29																													200 GENERAL			
✓	28		ITEM OR LOCATION AND REMARKS		① 234-5 Personnel takes neutron readings at 21 Swamps. Bldg < 2 m/yr "F"																								CONST.			
27																													LAB			
26					② Pick up air & water samples at East area - normal																								INST. & TECH.			
25																													CONTAM.			
24					③ Personnel & equip survey at B-C Bldg < det. c/m																								CONTAM. & DECONT.			
23																													RECLAMATION			
22					④ take 216-Z-19 Water samples (2) < det. c/m																								SER. & DECONT.			
21																													OTHER			
20																													1969			
19																													1970			
18																													1971			
17																													1972			
16																													1973			
15																																

* DOSE RATE - WHOLE BODY, NORMALIZED TO WHOLE BODY, OR BODY EQUIVALENT

SIGNED R. Smith

DAY MONTH

RADIATION MONITORING SURVEY RECORD OF PERSONNEL, MATERIALS AND EQUIPMENT

PO	D	XYZ	TIME	FUNCTIONS															X46245X	REPORTS										RE INJURY
				BURIAL	CONTROL PROGRAM	DECONT	FOLLOW-UP	INSP	JAB	MAINT	PERSONNEL SURVEYS	PROCESS WORK	RAIL	MOVEMENT	RELEASE	SAMPLING	SHIPMENT	VEHICLES		CONTAM CLOTHES	CONTAM SKIN	MONTHLY REPORT	NASAL SM AND IRRIG	REPORTED TO RPO	RADIATION OCCURRENCE					
	C			☐ SWP ☐ RWP NO. _____		RADIATION SURVEY										SURVEY NUMBER 03870														
	B			TIME JOB STARTED 0800		TOTAL TIME 8hrs										RESPIRATORY PROTECTION WORN N R A C F A														
	A			LOCATION 200 Areas		INSTRUMENT(S) USED GM & Poppy																								
	✓ DAYS			JOB DESCRIPTION Can 20																										
	31																													
	30																													
	29			ITEM OR LOCATION AND REMARKS		DOSE RATE		WC		DIST		c/m		u/h																
	28			216-Z-19 234-5 ditch water sample																										
	27			B-C creek check out personnel & equip																										
	26			U Pond personnel surveys																										
	25																													
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	AUG.																													
	JULY																													
	JUNE																													
	MAY																													
	APRIL																													

APPENDIX D-1

Pacific Northwest Laboratories

APPENDIX D-1

Project Number _____

Internal Distribution

Date March 19, 1974
To Harold Maxfield
From William H. Rickard
Subject BIOLOGICAL TRANSPORT OF RADIONUCLIDES
FROM THE B-C CRIB AREA

File
Lb

Because of the short time span, I am sending this to you today. If you think this is valuable information, more data can be obtained from various sources in BNW.

A brief summarization of the state of biological knowledge of the important plant and animal species common to the B-C Crib area is presented in tables 1, 2 and 3. Only small amounts of radionuclides can be expected to be transported biologically from the B-C Crib area under existing environmental conditions. One transport mechanism is through plants and the other through animals.

Plants

Two kinds of plants ordinarily break off at ground level and are transported for long distances by wind. These are Russian thistle (tumbleweed) and tumble mustard (Table 1). The plants can extract ^{90}Sr and ^{137}Cs from contaminated soil within the rooting zone of these annual plants. The discrimination factor from soil concentration (expressed in dry weight) to plants (expressed as dry weight) is in the order of 1:1 for ^{90}Sr and 100:1 for ^{137}Cs . This, of course, varies with the growth stage of plant development, placement of radionuclides in the soil, and the root distribution of the plant. None of the plants growing in the B-C Crib area are used as food by people. With strong winds it is possible for some of the tumbling plants to be transported off the reservation area.

Under the present land use, i.e., without livestock grazing, control of off road vehicular traffic, and the absence of fire, the existing vegetation can be expected to maintain itself for many years. It is also expected that in the absence of disturbances that Russian thistle will tend to decline in abundance on the site and be replaced by the more competitive winter annuals and perennials.

Animals

The common animals associated with the B-C Crib area are shown in Table 2 and a general description of their mobility is shown in Table 3. None of these animals is ordinarily eaten by people. Only a few individuals can be expected to visit the B-C Crib area and then have the ability to leave the reservation area. These are the coyote, badger, Swainson's hawk, meadowlark, and the migratory grasshopper (Melanoplus sanguinipes).

Harold Maxfield

Page 2

March 19, 1974

Current data on the ^{90}Sr content of jackrabbit bone show values in the range between 80 and 224 picocuries per gram (personal communication--Harold Maxfield) while ^{137}Cs values in rabbit muscle range between 1 and 7 pCi/gram fresh weight. The cesium values are much like levels expected from worldwide fallout. The ^{90}Sr values are higher than expected from worldwide fallout. Once incorporated into bones, ^{90}Sr is generally not available for further transfers in biological systems for a long time, but bones are occasionally eaten by rodents. The levels of ^{90}Sr in rabbit bones suggests more detailed sampling program is needed for the plants and animals in the B-C Crib area to elucidate more clearly the ecological pathways involved in radionuclide transfers.

The transfer coefficients between herbage and tissues of herbivorous animals is not known for the plants and animals characteristic of the B-C Crib area. However, a short-term experiment using a common goat and alfalfa raised in soil contaminated with ^{90}Sr and ^{137}Cs showed that muscle tissues had 200 times less ^{90}Sr than alfalfa when expressed in dry weight for plants and fresh weight for muscle; however, the muscle had only ten times less ^{137}Cs than the alfalfa when expressed on the basis described above. Cesium-137 could not be detected in goat bones. Strontium-90 in bone in this short-term goat experiment showed about the same 1:200 ratio as seen for muscle.

WHR:bjr

TABLE 1. Features of the vegetation growing in the B-C Crib area applicable to waste management.

Common Plants in the B-C Crib Area	Soil to Plant Discrimination		Plant Dispersal by Tumbling	Found in Diet of Rabbit	Sprouts After Burning
	⁹⁰ Sr	¹³⁷ Cs			
<u>Shrubs</u>					
*Big Sagebrush	Unknown	Unknown	No	Yes	No
Spiny Hopsage	Unknown	Unknown	No	No	Yes
Rabbitbrush	Unknown	Unknown	No	Yes	Yes
<u>Perennial Grasses</u>					
*Sandberg Bluegrass	Unknown	Unknown	No	Yes	Yes
Needle-and-Thread	Unknown	Unknown	No	Yes	Yes
Indian Ricegrass	Unknown	Unknown	No	No	Yes
<u>Annual Grasses</u>					
*Cheatgrass	1	170	No	No	Seeds
Sixweeks Fescue	Unknown	Unknown	No	No	Seeds
<u>Perennial Forbs</u>					
Yarrow	Unknown	Unknown	No	Yes	Yes
Balsam Root	Unknown	Unknown	No	No	Yes
Scurf Pea	Unknown	Unknown	No	No	Yes
<u>Annual Forbs</u>					
*Tansy mustard	0.2	25	No	Yes	Seeds
*Tumble Mustard	Unknown	Unknown	Yes	Yes	Seeds
Cryptantha	Unknown	Unknown	No	Yes	Seeds
*Tumbleweed (Russian thistle)			Yes	No	Seeds
Borsage	Unknown	Unknown	No	No	Seeds
<u>Crop Plant¹</u>					
Alfalfa	1	100	No	No	Yes

*Important plant contributor to biomass.

¹Growing in experimental plot at 100 F Area.

TABLE 2. Food categories of common herbivorous and carnivorous animals in the B-C Crib area.

	Food Categories			
	-Herbage-	-Seeds-	-Belowground Parts-	
<u>Herbivorous Animals</u>				
(6) Black-tailed Jackrabbit	X	---	---	
(5) Townsend Ground Squirrel	X	---	---	
(4) Deer Mouse	X	X	---	
(3) Pocket Mouse	---	X	---	
(2) Grasshopper	X	---	---	
(1) Darkling Beetles (larvae)	---	---	X	
	-Mammals-	-Birds-	-Reptiles-	-Insects-
<u>Carnivorous Animals</u>				
(5) Coyote	X	X	X	X
(6) Badger	X	X	---	---
(3) Gopher Snake	X	X	X	X
(4) Swainson's Hawk	X	X	X	X
(1) Side-blotched Lizard	---	---	---	X
(2) Meadowlark	---	---	---	X

The numbers in parenthesis indicate the relative ranking in abundance of animals, i.e., rank 1 = most abundant.

TABLE 3. Relative mobility of the most abundant animals in the B-C Crib area.

A. Animals with restricted range in movement ~ 0.1 mile

Townsend ground squirrel

Pocket mouse

Deer mouse

Side-blotched lizard

Darkling beetle

B. Animals with short range of movement. Animals resident to B-C Crib area probably will not leave the Hanford Reservation. Range ~ 5 miles.

Black-tailed jackrabbit

Gopher snake

C. Animals with medium range movements can be expected to wander off the reservation after a visit to the B-C Crib area.

Coyote

Badger

D. Animals with long range migratory movements. Leave the Hanford Reservation seasonally.

Grasshopper

Swainson's hawk

Meadowlark

Proposal I - Fire protection only--

Fire protection can provide for the continued existence of sagebrush on the B-C Crib site. Sagebrush provides a measure of protection from wind to the smaller herbaceous plants associated with the shrubs. Together the shrubs and herbaceous plants have been able to retard wind erosion. In the event of a wide spread fire, considerable soil erosion can be expected in this habitat. The habitat would also be difficult to revegetate.

Proposal II - Fire protection, vacuum 40 acres, strip five acres--

This plan would remove the radioactive jackrabbit pellets from the most heavily contaminated zones. It also has the advantages of experimenting with stripping and vacuuming techniques on a small scale to assess their effectiveness and also provides a chance to experimentally revegetate the stripped acres.

Proposals III and IV should not be fully considered until the effectiveness of Plan II was demonstrated.

APPENDIX D-2

Battelle

Pacific Northwest Laboratories

Battelle Boulevard

Richland, Washington 99352

Telephone (509)

Telex 36921

March 22, 1974

Mr. Harold Maxfield
Atlantic Richfield Hanford Company
2407E/24
Richland, Washington 99352

Dear Mr. Maxfield:

I am enclosing the analytical results for three (3) rabbits which were sampled at your request from the BC Crib on February 25:

Units of pCi/gram

	D.L.	No. 1		No. 2		No. 3	
		Muscle	Bone	Muscle	Bone	Muscle	Bone
K-40	1.3	3.09		2.56		2.71	
Co-60	0.08	*		0.089		*	
Zn-65	0.15	*		*		*	
Sr-90	2.9		222.		221.		77.8
Cs-137	0.08	1.90		5.52		1.98	

*Indicates the result was less than the analytical limit.

The Cs-137 is slightly high and the Sr-90 in bone is definitely high by comparison of other small mammals sampled on the Hanford project. The other results are not unusual.

Sincerely,

Peggy Blumer
Environmental Evaluations Section
Building 318; 300 Area

PB/pv

Analytical Results from Battelle Pacific Northwest Laboratories,
 Richland, Washington
 of
 Rabbit and Coyote Kills on or near the Highways
 having proximity to the B-C Cribs Controlled Area.

Units of pCi/gram

<u>Date</u>	<u>Species</u>	<u>Location</u>	<u>40K</u>	<u>65Zn</u>	<u>89+90Sr</u>	<u>137Cs</u>	<u>239Pu</u>
05-07-70	Rabbit	South of the muscle B-C Cribs Area bone	3.2 9.1	0.68 7.0	* --- 641.	2.3 4.4	* *
01-27-71	Rabbit	Wye Barr.	1.8	---	.015	1.04	*
01-29-71	Rabbit	Rt. 4-S, Mile 5	0.83	---	.98	2.8	*
12-17-71	Rabbit	B-C Cribs	3.1	* .01	* .002	.99	---
01-20-72	Coyote	Rt. 4-S, Mile 20	3.4	* .16	* .0003	.18	---
07-31-72	Rabbit	200 East	3.2	.14	.02	1.3	---

* Less than Analytical Limit

APPENDIX E-1

BC CONTROLLED AREA HAZARD ANALYSIS

J. R. Houston

To assess the consequences of the involvement of the BC controlled area in a range fire, a set of rather adverse conditions and assumptions were postulated.

To begin with, all of the activity available to become airborne was assumed to be within a cross-section of 2000 meters and all of the activity not in the soil was assumed to become airborne during the course of the fire which lasted for two hours. Analysis⁽¹⁾ indicates that roughly 90% of the 32 curies of ⁹⁰Sr and 8 curies of ¹³⁷Cs in the area are in the soil and would not be available for involvement in a range fire. The quantities assumed available to become airborne are then, 0.1 x 32 Ci ⁹⁰Sr or 3.2 Ci ⁹⁰Sr and 0.1 x 8 Ci ¹³⁷Cs or 0.8 Ci ¹³⁷Cs.

The fire was assumed to entrain the Sr and Cs uniformly in the first two meters of air above the ground surface along the 2000 meter cross-section. With a 1 meter per second wind-speed this would produce during the course of the postulated range fire a contaminated air volume of:

$$2000 \text{ meters} \times 2 \text{ meters} \times 1 \text{ meter/sec} \times 7200 = 2.9 \times 10^7 \text{ m}^3$$

which leads to an average air concentration of:

$$\frac{8 \times 10^5 \text{ } \mu\text{Ci } ^{137}\text{Cs}}{2.9 \times 10^7 \text{ m}^3 \times 10^6 \text{ cm}^3/\text{m}^3} = 2.8 \times 10^{-8} \text{ } \mu\text{Ci } ^{137}\text{Cs}/\text{cm}^3$$

and

$$\frac{3.2 \times 10^6 \text{ } \mu\text{Ci } ^{90}\text{Sr}}{2.9 \times 10^7 \text{ m}^3 \times 10^6 \text{ cm}^3/\text{m}^3} = 1.1 \times 10^{-7} \text{ } \mu\text{Ci } ^{90}\text{Sr}/\text{cm}^3$$

A man working and breathing hard (350 cc/sec) near the fire (within a thousand meters or so) downwind would inhale:

$$2.8 \times 10^{-8} \mu\text{Ci } ^{137}\text{Cs}/\text{cm}^3 \times 350 \text{ cm}^3/\text{sec} \times 7200 \text{ sec} \\ = .071 \mu\text{Ci } ^{137}\text{Cs}$$

and

$$1.1 \times 10^{-8} \mu\text{Ci } ^{90}\text{Sr}/\text{cm}^3 \times 350 \text{ cm}^3/\text{sec} \times 7200 \text{ sec} \\ = .28 \mu\text{Ci } ^{90}\text{Sr}.$$

The Hanford highway (approximately 6.8 Km to the south of the controlled area) constitutes the point of closest exposure to the public to the radioactive cloud from the postulated fire. If the fire were able to somehow entrain in the cloud, all of the radionuclides not in the soil and atmospheric conditions were rather adverse (very stable atmospheric conditions and 1 meter/sec windspeed) and assuming a point source, the quantity inhaled by someone located on the centerline of the plume at the highway would be as follows:

Quantity released =

$$Q = .8 \text{ Ci } ^{137}\text{Cs}, 3.2 \text{ Ci } ^{90}\text{Sr}$$

Normalized time integrated air concentration =

$$(E/Q) = 1.5 \times 10^{-4} \frac{\mu\text{Ci}/\text{cc}}{\text{Ci}/\text{sec}}$$

Ventilation rate =

$$\text{VR} = 350 \text{ cc/sec}$$

Quantity of Cs inhaled =

$$I_{\text{Cs}} = (E/Q) \times \text{VR} \times Q = 1.5 \times 10^{-4} \times 350 \times 0.8 = .042 \mu\text{Ci } ^{137}\text{Cs}$$

Quantity of Sr inhaled =

$$I_{\text{Sr}} = 1.5 \times 10^{-4} \times 350 \times 3.2 = .17 \mu\text{Ci } ^{90}\text{Sr}$$

The preceding analysis constitutes a maximum hypothetical situation. Resultant internal organ doses from inhalation of these quantities of radionuclides are shown in Tables 1 and 2.

Based on the studies of Mishima^(1,2) on the potential airborne release of material from the BC controlled area during a range fire, less than 0.1% of the radioactive material in the area would be made airborne. This constitutes a release 2 orders of magnitude smaller than the maximum hypothetical case postulated previously, yielding correspondingly smaller inhalation and internal doses to persons exposed. Analysis of the internal deposition and doses for a release of this magnitude were also conducted and correspond to the results labeled "max probable" in Tables 1 and 2.

The internal doses shown in the Tables were calculated using both the initial ICRP lung model and the recently adopted Task Group Lung Model (TGLM) since the older model is still in use. The bone and whole body doses were assessed on the basis that the material inhaled was "soluble", (class "D" in the TGLM), and the lung doses on the basis of the strontium being "insoluble", (Class "Y" in the TGLM). Naturally both the bone and the lung doses cannot be maximized at the same time in a real situation, but are shown to indicate the maximum for both conditions. The whole body and bone doses would actually be lower than those shown by a factor of 3 if the strontium were of an "insoluble" form.

Mishima also indicates that as much as 4% of the active material above the mineral soil could be made airborne immediately following the fire. Under the right set of circumstances then, soon after the fire, dose commitments a factor of 4 greater than those shown in Tables 1 and 2 for the "max probable" case during the fire could be incurred.

Suspension of material, in the mineral soil near the surface, in a high wind following a fire could result in redistribution of the material, but it is not likely to result in even as much as 10% being suspended in a cloud and available for inhalation. Thus the maximum hypothetical case for the range fire represents the so called "worst situation".

Reduction of the quantity of radionuclides currently on and near the surface of the soil would reduce the potential inhalation hazard in more or less direct proportion to the extent of the reduction.

DOSE COMMITMENTS FROM INHALATION EXPOSURE
DURING BC AREA RANGE FIRE
 (Using the Task Group Lung Model)

		<u>FIRST YEAR DOSE</u> (rem)		
		<u>Whole Body</u>	<u>Bone</u>	<u>Lung</u>
Max Hypothetical	At Perimeter	.04	.16	.67
	At Hanford Highway	.024	.096	.41
Max Probable	At Perimeter	.0004	.0016	.0067
	At Hanford Highway	.0002	.001	.0041

		<u>50 YEAR DOSE COMMITMENT</u> (rem)		
		<u>Whole Body</u>	<u>Bone</u>	<u>Lung</u>
Max Hypothetical	At Perimeter	.87	3.6	1.6
	At Hanford Highway	.53	2.2	.96
Max Probable	At Perimeter	.0087	.036	.016
	At Hanford Highway	.0053	.022	.0096

T A B L E 2
 (Revised 4/3/74)

JR Houston
 Senior Development Engineer

DOSE COMMITMENTS FROM INHALATION EXPOSURE

DURING BC AREA RANGE FIRE

(Using the initial ICRP Lung Model)

		<u>FIRST YEAR DOSE</u>		
		(rem)		
		<u>Whole</u>	<u>Bone</u>	<u>Lung</u>
		<u>Body</u>		
Max Hypothetical	At Perimeter	.034	.12	.51
	At Hanford Highway	.020	.072	.31
Max Probable	At Perimeter	.00034	.0012	.0051
	At Hanford Highway	.0002	.00072	.0031

		<u>50 YEAR DOSE COMMITMENT</u>		
		(rem)		
		<u>Whole</u>	<u>Bone</u>	<u>Lung</u>
		<u>Body</u>		
Max Hypothetical	At Perimeter	.68	2.7	.98
	At Hanford Highway	.44	1.8	.59
Max Probable	At Perimeter	.0068	.027	.0098
	At Hanford Highway	.0044	.018	.0059

T A B L E 1

(Revised 4/3/74)

R E F E R E N C E S

1. BNLW-B-337, J. Mishima.
2. BNWL-B-303, J. Mishima.

APPENDIX E-2

APPENDIX E-2

BC-CRIB AREA HAZARD ANALYSIS

N. P. Nisick

To further assess the consequences of a range fire involving the BC-Crib controlled area, the dose commitments shown in Tables 1 and 2 were converted to percents of the AEC Appendix 0524 Radiation Protection Standards for internal exposure. The perimeter of the BC-Crib contaminated area is well within the controlled area; and, therefore, the standards for individuals in controlled areas were used in making the percentage dose commitment calculations. Conversely, the Hanford Highway (approximately 7 km to the south of the contaminated area) is accessible to the public; and the more conservative standards for individuals in uncontrolled areas were used. These percentages, Tables 1A and 2A, show that for the maximum probable exposure neither the first year nor the fifty year dose commitments would exceed 1% of the applicable standards. Even the very unlikely maximum hypothetical first year Task Group lung model dose commitment of 0.41 rem is only 27% of the 1.5 rem standard for individuals in uncontrolled areas, and this same 0.41 rem dose does not exceed the 0.5 rem standard for groups in uncontrolled areas.

NP Nisick
Radiation Staff Engineer

3/14/74

DOSE COMMITMENTS FROM INHALATION EXPOSURE
DURING BC-CRIB AREA RANGE FIRE
EXPRESSED IN PERCENT OF AEC APPENDIX 0524
RADIATION PROTECTION STANDARDS
(Using the Initial ICRP Lung Model)

FIRST YEAR DOSE

		<u>Whole Body</u>	<u>Bone Marrow</u>	<u>Lung</u>
Max Hypothetical	At Perimeter*	0.7%	2%	3%
	At Hanford Highway**	4%	14%	21%
Max Probable	At Perimeter	<0.01%	0.02%	0.03%
	At Hanford Highway	0.04%	0.1%	0.2%

FIFTY YEAR DOSE

		<u>Whole Body</u>	<u>Bone Marrow</u>	<u>Lung</u>
Max Hypothetical	At Perimeter	0.3%	1%	0.1%
	At Hanford Highway	2%	7%	0.8%
Max Probable	At Perimeter	<0.01%	0.01%	<0.01%
	At Hanford Highway	0.02%	0.07%	<0.01%

*Standards for individuals in controlled areas used at perimeter of BC-Crib Area.

**Standards for individuals in uncontrolled areas used at Hanford Highway.

TABLE 1A

(Revised 4/9/74)

DOSE COMMITMENTS FROM INHALATION EXPOSURE

DURING BC-CRIB AREA RANGE FIRE

EXPRESSED IN PERCENT OF AEC APPENDIX 0524

RADIATION PROTECTION STANDARDS

(Using the Task Group Lung Model)

FIRST YEAR DOSE

		<u>Whole Body</u>	<u>Bone Marrow</u>	<u>Lung</u>
Max Hypothetical	At Perimeter*	0.8%	3%	4%
	At Hanford Highway**	5%	19%	27%
Max Probable	At Perimeter	<0.01%	0.03%	0.04%
	At Hanford Highway	0.04%	0.2%	0.3%

FIFTY YEAR DOSE

		<u>Whole Body</u>	<u>Bone Marrow</u>	<u>Lung</u>
Max Hypothetical	At Perimeter	0.3%	1%	0.2%
	At Hanford Highway	2%	9%	1%
Max Probable	At Perimeter	<0.01%	0.01%	<0.01%
	At Hanford Highway	0.02%	0.09%	0.01%

*Standards for individuals in controlled areas used at perimeter of BC-Crib Area.

**Standards for individuals in uncontrolled areas used at Hanford Highway.

TABLE 2A

(Revised 4/9/74)

APPENDIX F-1

Pacific Northwest Laboratories

Battelle Boulevard

Richland, Washington 99352

Telephone (509)

Telex 32-6345

March 26, 1974

Mr. Harold Maxfield
Atlantic Richfield Hanford Company
Richland, Washington 99352

Dear Harold:

Enclosed is a climatological assessment of the downwind diffusion of material from the BC crib site. This is being provided in support of your contribution to the Hanford Environmental Impact Statement.

Very truly yours,

A handwritten signature in cursive script that reads "Tom Horst".

Thomas W. Horst
Atmospheric Physics Section
Atmospheric Sciences Department

TWH/lp

Enclosure

MEAN ANNUAL DIFFUSION FROM THE BC CRIB SITE

T. W. Horst

In order to determine a realistic estimate of the downwind exposure to radioactive materials resuspended from the BC crib site, 16 years (1955-1970) of hourly weather observations from the Hanford Meteorological Tower have been analyzed. This analysis used the standard Gaussian plume diffusion model⁽¹⁾ to calculate probability distributions of the normalized air concentration χ/Q as a function of wind direction and source-receptor separation. Here χ is an air concentration in curies/m³ and Q is the source strength in curies/sec. When the source and receptor are both at ground level, this model reduces to

$$\chi/Q = (\pi \sigma_y \sigma_z \bar{u})^{-1} e^{-y^2/2\sigma_y^2}$$

where $\bar{u}$ is the mean wind speed and σ_y and σ_z are the standard deviation of the plume spread in, respectively, the crosswind and vertical directions. y is the horizontal distance from the plume centerline, measured in the crosswind direction. For this climatological assessment of diffusion as a function of wind direction, the average air concentration is found by distributing the crosswind-integrated air concentration uniformly over the wind sector within which the wind is blowing. Hence, dividing the possible wind directions into the standard 16 points of the compass (N, NNW, NW, etc.),

$$\bar{\chi}/Q = \frac{8}{\pi x} \frac{1}{\pi \sigma_y \sigma_z \bar{u}} \int_{-\infty}^{\infty} e^{-y^2/2\sigma_y^2} dy = \frac{32}{(2\pi)^{3/2} \sigma_z x \bar{u}}$$

where x is the source-receptor separation. This expression has been evaluated using the hourly observations of mean wind speed and direction at the 50 foot

level of the Hanford Meteorological Tower. σ_z has been calculated from the correlation of experimental diffusion data proposed by Briggs,⁽²⁾ Table I, where the stability class is determined as in Table II. A typical result is given in Table III which shows the cumulative percent frequency of occurrence of $\bar{X}/Q$ values for each wind direction at a distance of 20 km from the source. This tabulation shows, for example, that $\bar{X}/Q$ is less than or equal to 4×10^{-7} sec/m³ 69 percent of the time that the wind blows from the south. Table IV shows that the wind blows from the south 3.2 percent of the time and hence $\bar{X}/Q$ is less than or equal to the above value 2.2 percent of the time at a receptor 20 km north of the source.

The source strength due to resuspension is found by multiplying the quantity of material available for resuspension G (curies) by the resuspension rate λ (sec⁻¹). This assumes that the quantity of material resuspended per unit time is directly proportional to the amount available. A very limited number of measurements of resuspension rates have been made. Healy and Fuquay⁽³⁾ obtained a rate of 10^{-7} sec⁻¹ at a wind speed of 3 m/sec for resuspension from several different environmental surfaces at Hanford. Sehmel,⁽⁴⁾ using a similar tracer on an asphalt road, found resuspension rates of 5×10^{-9} to 6×10^{-8} sec⁻¹ at wind speeds of 1-4 m/sec. A value of 10^{-7} sec⁻¹ will be used here as a realistic upper limit.

An assessment can now be made of the potential climatological hazard of the BC crib site. The WPPSS Hanford No. 2 - FFTF site is probably the closest public population to the BC crib area. It is at a distance of about 20 km and is downwind when the wind blows from the northwest. From Tables III and IV we find that the average annual $\bar{X}/Q$ value for these conditions is 4×10^{-8} sec/m³. The annual exposure can then be calculated from

$$E = \lambda G(\bar{X}/Q)T$$

where T is the time of exposure. It has been estimated that the maximum amount of radioactive material available for resuspension following a fire

at the BC crib site would be 3.6 curies. Thus the annual exposure at the FFTF site would be calculated to be 1.3×10^{-10} μ curie hr/cc. The exposure at Richland would be even less due primarily to its greater distance from the source (30 km), but due also to the fact that it is downwind only when the wind blows from the north-northwest. The average annual $\bar{X}/Q$ value calculated from Tables III and IV for this wind direction is one-half of that for the northwest wind direction.

TABLE I, σ_z as a function of stability

<u>Stability Class</u>	<u>σ_z (m)</u>
A	0.20x
B	0.12x
C	$0.08x (1 + 2 \cdot 10^{-4} x)^{-1/2}$
D	$0.06x (1 + 1.5 \cdot 10^{-3} x)^{-1/2}$
E	$0.03x / (1 + 3 \cdot 10^{-4} x)$
F	$0.02x / (1 + 3 \cdot 10^{-4} x)$

TABLE II, Stability as a function of wind speed and time of day

<u>Time of Day</u>	<u>Wind Speed (mph)</u>			
	<u>0-3</u>	<u>4-7</u>	<u>8-12</u>	<u>>13</u>
Day	A	B	C	D
Night	F	E	D	D

TABLE III, Cumulative Percent Frequency of Occurrence of $\bar{X}/Q$ for Each Wind Direction at a Distance of 20 km from the Source

Wind Dir	<u>$\bar{X}/Q$ less than or equal to</u>							
	1×10^{-8}	2×10^{-8}	3×10^{-8}	4×10^{-8}	5×10^{-8}	7×10^{-8}	1×10^{-7}	2×10^{-7}
NNE	.00	31.75	55.89	66.20	66.92	77.56	83.28	85.36
NE	.00	33.24	59.34	65.74	67.29	80.36	83.83	85.13
ENE	.00	33.31	59.25	63.85	64.27	76.25	77.94	79.26
E	.00	31.77	56.49	60.52	60.55	70.63	71.52	74.07
ESE	.00	32.26	55.00	59.35	59.35	66.60	67.63	70.06
SE	.00	28.12	46.64	51.98	52.06	58.53	60.82	65.19
SSE	.00	23.07	37.79	43.60	44.04	51.45	57.21	65.89
S	.00	22.00	37.33	43.36	44.97	55.12	61.43	66.24
SSW	.00	16.38	28.59	39.95	44.99	59.27	69.88	74.70
SW	.00	12.28	22.31	33.23	40.65	56.61	71.06	77.71
WSW	.00	9.66	17.89	28.00	31.33	43.48	59.61	73.85
W	.00	10.19	17.30	23.18	24.02	29.81	42.45	62.08
WNW	.00	8.95	15.33	23.18	25.62	36.89	56.32	75.94
NW	.00	14.22	23.71	34.62	38.51	52.23	67.19	79.14
NNW	.00	30.34	47.82	55.45	55.58	61.92	65.10	70.20
N	.00	33.12	56.12	63.62	63.83	73.62	77.28	79.70

Wind Dir	<u>$\bar{X}/Q$ less than or equal to</u>							
	3×10^{-7}	4×10^{-7}	5×10^{-7}	7×10^{-7}	1×10^{-6}	2×10^{-6}	3×10^{-6}	4×10^{-6}
NNE	85.36	86.31	87.74	91.24	91.24	96.21	96.21	100.00
NE	85.13	85.70	86.59	90.15	90.15	95.93	95.93	100.00
ENE	79.26	80.16	81.68	87.29	87.29	94.46	94.46	100.00
E	74.07	75.46	77.53	83.58	83.58	92.83	92.83	100.00
ESE	70.06	72.17	74.97	82.25	82.25	93.13	93.13	100.00
SE	65.19	67.55	70.87	80.24	80.24	93.19	93.19	100.00
SSE	65.89	69.62	74.29	84.03	84.03	94.74	94.74	100.00
S	66.24	69.07	73.41	83.34	83.34	94.42	94.42	100.00
SSW	74.70	77.16	80.65	88.79	88.79	96.11	96.11	100.00
SW	77.71	81.06	84.90	92.05	92.05	97.38	97.38	100.00
WSW	73.85	79.78	85.15	92.90	92.90	97.95	97.95	100.00
W	62.08	70.81	79.40	91.17	91.17	97.25	97.25	100.00
WNW	75.94	82.14	87.36	94.59	94.59	98.45	98.45	100.00
NW	79.14	83.09	87.25	93.82	93.82	98.21	98.21	100.00
NNW	70.20	72.90	76.86	86.59	86.59	95.00	95.00	100.00
N	79.70	80.62	82.03	87.04	87.04	94.60	94.60	100.00

TABLE IV, Percent of the time that the wind blows from each wind direction

NNE	3.6	SSW	4.1
NE	3.4	SW	7.2
ENE	2.1	WSW	8.5
E	2.4	W	9.8
ESE	2.6	WNW	16.0
SE	3.7	NW	16.6
SSE	2.8	NNW	4.9
S	3.2	N	4.5

REFERENCES

- (1) Gifford, F. A., Jr., "An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere," ch. 3, Meteorology and Atomic Energy (D. Slade, ed.), USAEC - TID-24190, 1968.
- (2) Briggs, G. A., Diffusion Estimation for Small Emissions, U. S. Dept. of Commerce, NOAA-ERL-ARATDL contribution no. 79 (draft), Oak Ridge, Tennessee, May, 1973.
- (3) J. W. Healy and J. J. Fuquay, "Wind Pickup of Radioactive Particles from the Ground," Progress in Nuclear Energy Series XII, Health Physics, Pergamon Press, London, pp. 291-295, 1958.
- (4) G. A. Sehmel, "Tracer Particle Resuspension Caused by Wind Forces Upon an Asphalt Surface," Pacific Northwest Laboratory Annual Report for 1971 to the USAEC Division of Biology and Medicine, Volume II: Physical Sciences, Part 1: Atmospheric Sciences, BNWL-1651-1, Battelle, Richland, Washington, December 1972.

APPENDIX F-2

APPENDIX F-2

CALCULATED DOSE TO PERSONNEL RESULTING FROM DOWNWIND DIFFUSION OF RADIOACTIVE MATERIALS

J. R. Houston

To evaluate the long-term effect of wind erosion on the BC controlled area the calculated average annual exposure to airborne ^{90}Sr and ^{137}Cs at the FFTF site, 1.04×10^{-10} $\mu\text{Ci-hours/cc}$ and 0.26×10^{-10} $\mu\text{Ci-hours/cc}$, respectively*, were multiplied by the quantity of air breathed over a 50 year time span. No correction for decay of the radionuclides during the period of intake was made. The total quantities inhaled over the 50 year period are then:

$$\begin{aligned} 1.04 \times 10^{-10} \frac{\mu\text{Ci-hours}}{\text{cc}} \times 8.28 \times 10^5 \frac{\text{cc}}{\text{hour}} \times 50 \text{ yr} &= 4.3 \times 10^{-3} \mu\text{Ci } ^{90}\text{Sr} \\ &= 4.3 \times 10^{-9} \text{ Ci } ^{90}\text{Sr} \end{aligned}$$

$$\begin{aligned} 0.26 \times 10^{-10} \frac{\mu\text{Ci-hours}}{\text{cc}} \times 8.28 \times 10^5 \frac{\text{cc}}{\text{hour}} \times 50 \text{ yr} &= 1.1 \times 10^{-3} \mu\text{Ci } ^{137}\text{Cs} \\ &= 1.1 \times 10^{-9} \text{ Ci } ^{137}\text{Cs} \end{aligned}$$

These quantities were then used to calculate the 50 year dose to several organs of the body using the initial ICRP lung model (ILM) and the Task Group Lung Model (TGLM). The results of these calculations are shown in the following table.

The assumptions used in the dose calculations are the same as those used for the accident cases previously considered. An assumption used both here and in the earlier work, although not stated, is that the particle size of the airborne material was assumed to be 1 micron for the Task Group Lung Model dose calculation.

*Provided by Tom Hbrst, BNW Meteorology

The doses shown in the table are far less than the radiation that would be received by an individual from natural sources over the fifty year time span.

DOSE IN REM FROM 50 YEAR INHALATION AT THE
FFTF SITE FROM WIND EROSION OF THE BC CONTROLLED AREA

(Using the Task Group Lung Model)

<u>WHOLE BODY</u>	<u>BONE</u>	<u>LUNG</u>
.0089	.036	.026

(Using the Initial ICRP Lung Model)

<u>WHOLE BODY</u>	<u>BONE</u>	<u>LUNG</u>
.0069	.027	.0056

JR Houston
Senior Development Engineer

APPENDIX G

APPENDIX G

 DAYS PLATOON

PREFIRE PLAN
600 AREA

8/23/73 DATE

B-C CRIB

OCCUPANCY: Atlantic Richfield Hanford Company

Technical Services Section

AREA DESCRIPTION: B-C Crib with contaminated area south and east extending two miles by two miles is immediately adjacent to the roadway on the south side of 200-East Area. Area is relatively flat with gradual depressions and rises easily negotiated by the Fire Department tank trucks. This area has a moderate ground cover of cheat grass and sagebrush.

EXPOSURES: Nuclear Engineering facilities and burial pit is located to the northwest and west of designated crib area plus extension of grass and brush east, west and south.

HAZARDS: Contamination spread either during a fire or after a fire when particles could become airborne in high or gusty winds; respiratory protection is required.

WATER AVAILABILITY: 120 GPM at fill pipe south across highway from the 200-East Area Main Gate; 200 GPM from hydrant east of 2720-E and 2400 GPM from hydrant southwest of 284-E.

EQUIPMENT RESPONSE: First response: T-2, T-22 and S-1 plus Car 42. Additional equipment to be called if the fire is beyond minor stage. Second response: T-1, T-11 and Engine 1. Move ups and call outs to be according to the running cards. Available earthmoving equipment to be called as necessary.

PLAN OF ATTACK: When fires are outside the four-square-mile area, the initial attack will be to keep fire from entering the B-C Crib area general, which will employ the use of water or foam or earthmoving equipment or any combination

Prefire Plan - B-C Crib

necessary to accomplish the job and extinguish the fire. When a fire occurs within the area, first priority will be to confine and extinguish as rapidly as possible with top priority on Zone 1, second priority on Zone 2 and third priority on Zone 3. Back fire should be considered on areas outside Zones 1, 2 and 3. On a second alarm to this area, one man from one of the tank trucks, preferably T-11, should respond with Engine 1 and park it at a safe location near the fire area for immediate response to a building alarm, if necessary, before backup companies are available. During periods other than the normal 40-hour day shift, both the 100 Area and the 200 Area Stations will be empty and the next readily available personnel are located at the 300 Area Station. Call-out personnel will be one to two hours before they are in service. Should a fire be in the crib area, a Radiation Monitor representative should be available in the immediate area for surveying personnel and equipment in and out of the area.

FACILITY REPRESENTATIVE

FIRE PROTECTION REPRESENTATIVE

TYPE Preliminary Scope		MEETING NO. 1	DATE 8/16/73												
PROJECT OR WORK ORDER NO. AND TITLE 216 BC Crib Contamination Removal		DISTRIBUTION Attendees RT Haley DR Nelson JF Nelson Central File DE Anderson													
REFERENCES															
ATTENDEES															
<table border="0"> <tr> <td><u>ARHCO</u></td> <td><u>Vitro</u></td> </tr> <tr> <td>BJ McMurray</td> <td>LB Ufkes</td> </tr> <tr> <td>HL Maxfield</td> <td>MH Piskadlo</td> </tr> <tr> <td>J. Davis</td> <td>PF Pritchard</td> </tr> <tr> <td>DR Gustavson</td> <td></td> </tr> <tr> <td>CA Caldwell</td> <td></td> </tr> </table>		<u>ARHCO</u>	<u>Vitro</u>	BJ McMurray	LB Ufkes	HL Maxfield	MH Piskadlo	J. Davis	PF Pritchard	DR Gustavson		CA Caldwell			
<u>ARHCO</u>	<u>Vitro</u>														
BJ McMurray	LB Ufkes														
HL Maxfield	MH Piskadlo														
J. Davis	PF Pritchard														
DR Gustavson															
CA Caldwell															

MINUTES

The purpose of this meeting was to outline the project and the now proposed solution as developed by ARHCO.

BJ McMurray described the background history and described the concentration of the contamination consisting mainly of animal dung together with some bleaching into the ground.

Contaminated Area

Approximately 2-1/2 miles square, immediately across the road south of 200 East Area. By helicopter survey, the main contaminated area of approximately 600 acres has been defined. This area will require the removal of 6 - 9 inches of topsoil for burial. Stabilization of the soil will be accomplished by planting grass which will require an irrigation system.

Phase I, Fire Protection

Due to the potential spread of contamination by a fire and the wind after the fire, it is imperative that the area be protected from fire and rapid access for fire fighting equipment be made available.

Fire breaks, 50 feet wide will be made on section lines. So as not to disturb the section monuments, the fire breaks will be constructed south and west of the section lines, with a 20 foot gravel road adjacent to the section line. Approximately 8-1/2 miles of roads will be required.

Gravel for the roads to be removed from an existing rock pit west of the 200 East Area.

PAGE 3 of 5

PRE FIRE PLAN B-C CRIB AREA

PREPARED BY L.B. Ufkes	APPROVED BY
TITLE: Project Manager	TITLE:

MINUTES OF MEETING - CONTINUED

TYPE	MEETING NO.	DATE
Preliminary Scope	1	8/16/73
PROJECT OR WORK ORDER NO. AND TITLE	PAGE NO.	
216 BC Crib Contamination Removal	2 of 2	

MINUTES CONTINUED

Phase II - Soil Removal & Stabilization

The top 6 - 9 inches of top soil covering 600 acres will be removed by earth moving equipment and buried in the existing rock pit which has been enlarged during Phase I graveling of the roads.

An irrigation system will be required for planting grass on this stripped area. Two 10-inch invasion pipe lines will be laid from 200 East reservoir to a centralized pond (approximately 1 mile in length). Pumping will be from the pond. Irrigation is to be over a 12 hour period with water being supplied over a 24-hour period. It is expected that the entire area be sprinkled each day.

Phase III - Specialized Pickup

Individual pre-marked spots will be vacuumed with a truck-mounted vacuum source and collection bins. Vitro would not have any design responsibilities at this time in regard to this phase.

Vitro will provide a marked-up print so JAJones can begin the fire break by August 23.

ARHCO will provide criteria for design of irrigation system and the roads. Design schedule will depend upon ARHCO priority of projects now in design.

ARHCO requested irrigation use by April 1, 1974.

A drive over the entire area will be made on Monday, August 20.

LBU:er
8/20/73

PREPARED BY

L. B. Ufkes

APPROVED BY

PREFIRE PLAN

B-C CRIB AREA

APPENDIX H

APPENDIX H

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

257 Johnson Hall, WSU, Pullman, Washington 99163

SUBJECT: FM - Seeding AEC Lands, Hanford, WA

DATE: December 3, 1973

TO:

Earl L. Hart, District Conservationist
Soil Conservation Service
Pasco, Washington

Your comments and recent suggestions are good. Gene Shaw offers the following:

1. Seed should be applied before mulching.
2. A disc - with concave blades - probably will not anchor the mulch material properly. A mulching disc (with straight blades) is the only tool which will effectively anchor the mulch, and yet leave it in a condition to control soil movement.

3. Irrigation is not a consideration, but it should be. This is dry country.

My additional comments are:

1. Alternate stripping of sprinkler width areas at right angles to the prevailing wind is first choice. There will be some blowing from the edges but less than if the entire 100 acres is stripped at one time.
2. Irrigation is essential to control blowing and to guarantee establishment. Only if the soil 12" profile is full to carrying capacity at the time of winter or early spring seeding, could irrigation be dispensed with.
3. If the entire 100 acres is stripped in one operation irrigation should follow close behind soil removal.
4. The travel road at right angles to the strip should be gravelled and outside of the stripped area.
5. The large burial site covered with sand will need a cover of gravel 6" deep to stop blowing.

John L. ~~Forrester~~
Plant Materials Specialist

cc: Frank Dickson, Jr. SC, Spokane, WA
J. Cleaton, Prosser, WA

4. Use a brush shredder to remove the existing brush on every other strip. Scalp every other strip during the late June thru early August low wind velocity period. Do not clear more strips than water is available for and wet to 18" before seeding.
5. Apply fertilizer as recommended by the soil test and distribute $1\frac{1}{2}$ tons of cereal or grass seed straw per acre and disc it in to anchor it against the wind. With a hydro mulcher both straw and fertilizer can be applied in one operation. If Silva mulch or other commercial fiber mulch is used it should be applied after seeding.
6. Fall seeding should be done in early September thru March 15 but may be extended into June if sufficient water is available. Avoid seeding during the heat of July and August.
7. Seed with a regular or semi deep furrow drill. Place the seed not more than 1 inch deep. On the other hand too shallow or surface seeds dry out too fast to become established.
8. Drill 5 lb per acre of Siberian wheatgrass or Nordan crested wheatgrass with not more than 20 lbs of winter wheat or cereal rye.
9. After wind erosion resisting cover is adequately established, about 2 months after planting work can proceed on the remaining strips.

If sufficient water, sprinkler system, mulch, machinery, manpower, etc are available the entire 100+ acres can be done in one fall. Otherwise a two season operation is suggested.

John L. Schwendiman

Plant Materials Specialist

cc: Frank Dickson, SO
Don Nanson, Yakima
Earl Hart, Pasco

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

257 Johnson Hall, WSU, Pullman, Washington 99163

SUBJECT: PM - Seeding AEC Lands, Hanford, WA

DATE November 9, 1973

TO: Jim W. Gleaton, District Conservationist
Soil Conservation Service
618 8th St
Prosser, WA 99350

The suggestions for stripping, irrigation and seeding summarized in my letter of March 2 to Harold Maxfield, AES, are still applicable. These were about as rigid as engineering specs for construction of a concrete steel bridge. They will insure success.

Hanford is a critical area. Elevation 400 ft., rainfall less than 8" average annual (varies from 4.6" to 12.2"), temperatures over 100°F in each of the months May thru September with a maximum of about 110°F, and a light sandy soil subject to wind erosion with a water holding capacity of less than 1" per ft. Evaporation exceeds precipitation about 5 to 1. The chances of success without irrigation are about 1 in 10. Seeding establishment on other parts of the reservation have been difficult even with irrigation.

Including Mr. Rosenoff's engineering suggestion, yours and mine, the specifications for successful establishment are:

1. Develop a water supply either by well or pumping from the river or one of the plants.
2. Take soil samples just below the area to be scalped and determine fertilizer needs and moisture holding capacity.
3. Lay out the area to be scalped in north and south strips approximately 118 ft wide (4000 ft = 34 strips) two sprinkler lines per strip. Design the system to get the seeded area, 17 strips wet once every 24 hours after seeding.

APPENDIX J

APPENDIX J

Date: April 2, 1974
To: H. L. Maxfield
From: K. R. Price *KRP*
Subject: FATE OF RADIONUCLIDES IN SURFACE SOILS

In response to your inquiry regarding the fate and longevity of radionuclides in soil following surface deposition, my experience has been similar to others, as well as that reported in the literature. For example, if soluble forms of strontium or cesium are contacted with a soil surface, the immediate reaction is sorption to the soil particles. A time dependent trend of downward movement is always observed as water percolates through the soil. The rate of movement, however, is different for various radionuclides. The net effect of downward movement, from a biological viewpoint, is dilution. Because biological uptake is a function of concentration, plant uptake can be expected to be reduced with the passing of time.

The best local evidence of this phenomenon was reported by Cline and Rickard¹. Experimental plots were contaminated near 100F Area, and after 8 years 70% of the added ¹³⁷Cs remained in the upper inch of soil, whereas, after 16 years ⁹⁰Sr was distributed throughout the upper 10 inches with maximum concentration at the 5-6 inch depth. Data shows a drop in the percent of total ⁹⁰Sr uptake by plants from 0.35 to 0.06 over the 15 year cropping sequence. Moreover, less than 2% of the estimated loss of ⁹⁰Sr from the plots, was through plant uptake mechanisms. The major loss was attributed to physical decay.

¹ Cline, J. F. and W. R. Rickard, 1972. Radioactive strontium and cesium in cultivated and abandoned field plots. Health Physics 23:317-324.

KRP:kea

APPENDIX K-1

APPENDIX K-2

200 EAST AREA

APPENDIX K-2

CONTAMINATED AREAS

ZONE - A

ZONE - B

APPENDIX K-3

FIGURE 1. Ecological Survey Transects Superimposed on an Aerial Photograph Mosaic of the B-C Cribs, 200 East Area. Measurements of activity are presented in counts per minute (cpm): white areas on radii indicate background levels; black areas indicate measurements in excess of 500 cpm; white circles represent activity in excess of 100,000 cpm.

APPENDIX K-4

NOTE THAT THIS DIRECTION IS
REFLECTED IN THE PATTERN OF
DUNE TRAILS IN THE BOTTOM OF
THE FIGURE.

CONTINUOUS SCALE

SECTOR LABEL	137CS SURFACE CONCENTRATION MC/G	137CS GAMMA EXPOSURE AT 1 METER LEVEL MR
A	13	11
B	18	19
C	16	24
D	14	40
E	49	59
F	57	84
G	28	13
H	13	7.8
I	30	3.8
J	39	45
K	45	67
L	67	161

UNITED STATES ATOMIC ENERGY COMMISSION
HANFORD RESERVATION
BC CRIB 1973

137CS EXPOSURE CONTOUR
CESIUM 137

AREA D & CRIB

DATES OF SURVEY 29 May-1 June 1973

LAS VEGAS AREA OPERATIONS
EG&G INC. 4901 S. SUNSET RD.
LAS VEGAS, NEV 89101

APPENDIX K-5

200 EAST AREA

MAIN HIGHWAY 4-S

BC
CRIBS

100
ACRE
PLOT

TRENCHES

TERMINUS FOR WATER LINE
AND ELECTRICITY

10

11

13

14

50' FIREBREAK
ROAD (TYP)

DIRT ROADS (TYP)

22

23

CONTAMINATED AREAS

ZONE - A

ZONE - B

APPENDIX K-5