

**Revised
Needs Assessment for Medical Surveillance of
Former Hanford Workers
Version 1.2**

Supplement to

**Phase I - October 18, 1997 Report
Version 1.1**

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March 31, 1998

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Cooperative Agreement # DE-FC03-96SF21-258/A000

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Note: Tables with “s” designation refer to previous Needs Assessment tables with supplemental information

Executive Summary

The Defense Reauthorization Act of 1993, Public Law 102-484, Section 3162 mandates, "The Secretary shall establish and carry out a program for the identification and ongoing medical evaluation of current and former Department of Energy employees who are subject to significant health risks as a result of exposure of such employees to hazardous or radioactive substances during such employment." This needs assessment responds to the cooperative agreement from the Department of Energy (DOE) Request for Application (RFA) soliciting applications for cooperative agreements to Support Medical Surveillance for Former Department of Energy Workers. The RFA calls for a two-phase approach. Phase I is directed at conducting a needs assessment, and Phase II is directed at providing medical surveillance for former DOE workers.

This supplement addresses additional exposures and populations at risk. It also augments the populations described in the October 1997 Needs Assessment by the use of an additional database, the Radiation Exposure System (REX). 79,726 individuals with unique social security numbers (SS#) were found in this database along with their radiation dosimetry collected by Batelle Pacific Northwest National Laboratory (PNNL). When combined with the databases described in the October 1997 Needs Assessment, the new combined file contains 117,819 workers adding 13,050 workers to the population.

Existing databases were used in this needs assessment to identify the population of workers and to characterize exposures for these workers on the Hanford Site. Review of records, building location and a job-exposure matrix were used to estimate the number of workers exposed to specific hazards. A review of the occupational health literature was used to identify exposures representing an important health hazard resulting in illnesses or health risks and where a medical intervention (specific intervention or notification) would be of benefit to the workers. Analysis of available health outcome data suggests that respiratory hazards (asbestos, welding fumes, and dusts such as silica) along with noise are important concerns. In addition, experience among beryllium exposed workers elsewhere supports the need for provision of medical surveillance for this hazard.

This revised needs assessment identified 117,819 individuals who worked at the Hanford site during the period of 1943 to 1997. Of these an estimated 97,887 are alive in 1998, 13,816 are current workers and another 11,460 are construction workers. This gives a total of alive and eligible workers of 72,611 (Table 1s). Of this population an estimated 29,002 have potential asbestos exposure, up to 14,870 potential beryllium exposure based on job title with 682 working at jobs and in buildings with potential beryllium exposure, and 36,698 have potential

noise exposure. This represents an underestimate because not all subcontractors are believed to be included. Among the limited proportion of the cohort with available health outcome data there are important decrements in lung function and hearing.

This supplement identifies former non-construction workers likely exposed to irritant gases (3566), solvents (19,640), heavy metals (14,915), welding fumes (5083), and metal working fluids (2765). Various radiation dose types are described, and doses given for 79,726 former workers with social security numbers (allowing linkage to other databases). For example, 3997 workers are identified with a cumulative shallow dose greater than 10 REM.

As in the October Needs Assessment, the number of workers identified as exposed in the Job Exposure Matrix (JEM), can be adjusted for proportion dead (13%), proportion who were solely construction workers (10%), inability to locate (10%), and declining to participate (50%) to arrive at an estimate of who might avail themselves to examinations. Using this approach, an estimated 1439 radiation exams, 1284 respiratory irritant plus 1830 welding fume evaluations, 7070 solvent exams, 5369 heavy metal exams and 996 evaluations for exposure to metal working fluids.

As noted previously, there are many limitations to this approach. The populations are not well characterized with respect to types of exposure, occupational and non-occupational (e.g. smoking), or health outcomes. Approximately 30% of those identified in the databases have no recorded job titles. This results in a likely underestimation of those exposed. In addition, not all of those workers whose job titles suggest possible or probable exposure would have actually been exposed, adding further uncertainty to the estimates. Despite these limitations, the finding of a substantial number of individuals in the population with respiratory abnormalities and impairment in hearing considered along with the widely recognized hazards of asbestos, beryllium, and noise exposure make the provision of surveillance to this population defensible. Detailed work history questionnaires will be used to fill in gaps in exposure estimates of the JEM.

While additional individuals and hazards are identified in this supplement, the question of which if any of these additional hazards warrants medical monitoring remains controversial. Consensus among the investigators taking into account the limited resources of the overall monitoring program will be required to prioritize additional monitoring. An ongoing iterative process is desirable to take into account new information on exposures and risk as they emerge from new data and the medical monitoring program itself.

Available Databases

Identification of the population has required stitching together multiple databases. Since award of the contract we have been working closely with the Department of Energy Headquarters, the local Richland DOE Office, Pacific Northwest National Laboratories, Fluor-Daniel Hanford Company, Oil Chemical and Atomic Workers (OCAW) and the Hanford Environmental Health Foundation to identify and gain access to key databases. These databases are characterized, when available, for the following information:

- A. Name
- B. Purpose
- C. Location / owner
- D. Number of individuals
- E. Years covered
- F. Types of data included (personal identifiers, job title, duration, exposures, health outcomes, etc.)
- G. Comment on data quality (validity, completeness, reliability etc.)

Each of the databases used or anticipated being used pending access is described below.

Flow Gemini is the Hanford Environmental Health Foundation medical examination and scheduling system. It contains 47,604 workers who have been scheduled for examinations since 1985. Flow Gemini contains exam data for Chemistry, Urinalysis, Hematology, Audiometry, Pulmonary Function, X-ray, ECG, Physical Exams, Immunology, Toxicology, Medical Monitoring Programs, and more. It also contains limited information from the Hanford PeopleCore and HSS systems. Diagnoses were not entered into Flow, and no lab normal values are available to compare test values. Information is not necessarily updated. Addresses and vital status are suspect. Documentation for Flow Gemini is limited. Many of the fields are empty or so sparsely populated as to be of limited value.

REMS is the central repository for Radiation Exposure Monitoring (REMS) at DOE-HQ. It contains 42,874 Hanford workers who have been gathered from the REX Radiological Exposure System. The records cover the years 1985 to 1996, but exposure records for 1985 and 1986 do not correspond to individuals. REMS contains very limited demographic information (i.e., birth year rather than birth date, first initial often instead of first name) and annual dose records. The dose records also have a job code associated with them, but not every exposure corresponds to a person, and not every person has

an exposure. Building or job location is not recorded in REMS. Internal dose records were calculated using Annual Effective Dose Equivalent prior to 1993,

and Committed Effective Dose Equivalent after.

OHH88 is the source file for the employment history data used to create the cohort for Ethel Gilbert's 1989 mortality study of workers who began working between 1945 and 1986. OHH88 includes 9758 workers who were excluded from the mortality study, bringing the total number of operators to 53,105 and construction workers to 13,740. Because 2,280 workers are included in both the operator and the construction worker files, the total number of individual workers from these files is 64,565. Some of these may be current workers, but the exact number has not yet been determined. Data include personal identifiers, date and place of birth, death year, gender, race, work history dates, job title text, and 1971 Bureau of Census job code. Data is fairly complete with 99.6%, 93.1%, and 94.1% of birth, ethnicity, and gender information available respectively. Work history data includes 531,012 records of which 422,587 contain beginning job date and 88,437 contain end work date. All workers have at least one job code and only 0.1% of the workers have no beginning date for their work history while 14.3% have no ending date.

The Radiological Exposure System (REX) maintains and reports individual Hanford worker, subcontractor and visitor radiological records since 1944 (except for some early Westinghouse employees). It is held by Batelle Pacific Northwest National Laboratories. REX contains internal dosimetry records, radiation badge readings, and limited demographic information. It augments the populations described in the October 1997 Needs Assessment by 79,726 individuals with unique social security numbers (SS#). An additional 74,868 workers have radiation records in REX, but are without SS#. Because of the vagaries of the identifiers for these records, it will be difficult to determine which of these are unique individuals, or whether they are in other databases we have previously described

Pending Database Access

Access to databases related to the Hanford site is difficult for many reasons including national security concerns, privacy considerations, protection of human subjects and the costs of access. We have received excellent cooperation from the Department of Energy's Richland Office, Hanford Environmental Health Foundation, Pacific Northwest National Laboratories and Fluor-Daniel Hanford management contractor at the site to systematically address these issues. As a result, we have gained access to a sufficient number of databases to cite 117, 820 individual non-construction workers. As discussed elsewhere, the conduct

of a needs assessment is an iterative process. We propose to continue these activities during Phase II in order to provide optimal identification of workers who will benefit from surveillance focusing on subcontractors who may not be

included in the four databases utilized here.

Access to three crucial databases has been delayed due to difficulties in securing approval and execution of a work order to provide the database. As a result access to two key databases for final population enumeration is still pending. These databases are:

PSCR+ (Personal Security Clearance Record) is the Hanford security badging system, held by B & W Protec, Inc. Complete records only go back to 1985 (since the inception of the Central Badging Office). Prior to 1985, each company maintained their own internal badging systems, and the quality and quantity of data dumped into PSCR+ is unknown. There are approximately 100,000 workers, subcontractors and visitors in the system. Perhaps some small number never worked at Hanford.

Hanford PeopleCore is the central repository of human resources data supplied by all the contractor HR systems, held by Lockheed Martin. Demographic information is supplemented by location, company and employment data for prime-contractor employees, subcontractors, vendors and agency personnel.

Assembly of the master database was described previously. As noted above, 13,050 additional workers from REX were added to reach the 117,819 figure. The standardized mortality ratio from the 1993 Hanford Mortality Estimates (Gilbert, et al) were utilized to produce the following mortality distribution by age and sex (Table 2s).

TABLE 1s. AMMENDED ESTIMATION OF THE SIZE OF THE POPULATION

<u>Database</u>	<u>Number of Workers</u>
OHH88	64,565
REMS	42,874
FLOW GEMINI	47,604
REX	79,726
OHH88 and REMS overlap	10,342
OHH88 and FLOW GEMINI overlap	20,320
REMS and FLOW GEMINI overlap	21,968
REX and OHH88 overlap	52,226
REX and REMS overlap	23,634
REX and FLOW GEMINI overlap	40,387
REX, OHH88, REMS, and FLOW GEMINI Combined	117,819
Exclude Estimated Current Workers	-(13,816)
Total Former Workers	104,003
Estimated Solely a Construction Worker	-(11,460)
Total Estimated Deceased Workers	-(19,932)
Total Estimated Eligible & Living Former Workers	72,611¹

¹ Underestimate likely due to lack of information about subcontractor employees.

TABLE 2s. Estimated Survival of Workers by Gender and Age Group

Age	Number of Workers in Master Data Set	Percentage Alive in 1993 in CEDR OHH_OP Data Set	Number of Workers Assumed Alive in 1997 in Master Data Set	Number Assumed Dead in 1997
Males				
< 20	99	100.000	99	0
20-29	4,991	99.265	4,954	37
30-39	12,093	98.929	11,963	130
40-49	17,200	98.308	16,909	291
50-59	13,630	96.274	13,122	508
60-69	9,678	86.923	8,412	1,266
70-79	9,481	65.976	6,255	3,226
80-89	7,299	33.444	2,441	4,858
90-99	3,904	8.726	341	3,563
100 +	2,454	6.203	152	2,302
Age missing	1,164	79.981	931	233
Total	81,993	79.981	65,579	16,414
Females				
< 20	112	100.000	112	0
20-29	3,752	100.000	3,752	0
30-39	5,583	99.557	5,558	25
40-49	6,129	99.042	6,070	59
50-59	3,822	97.220	3,716	106
60-69	3,271	91.909	3,006	265
70-79	3,128	80.229	2,510	618
80-89	1,571	55.026	864	707
90-99	675	26.161	177	498
100 +	237	11.017	26	211
Age missing	320	91.199	292	28
Total	28,600	91.199	26,083	2,517
Gender Not Available				
< 20	21	100.000	21	0
20-29	205	99.730	204	1
30-39	433	99.200	430	3
40-49	433	98.540	427	6
50-59	348	96.530	336	12
60-69	104	88.530	92	12
70-79	18	69.640	13	5
80-89	5	37.820	2	3
90-99	2	11.340	0	2
100 +	0	6.640	0	0
Total	7,226	21.104	1,525	5,701

TABLE 2s. (cont.) Estimated Survival of Workers by Gender and Age Group

Age	Number of Workers in Master Data Set	Percentage Alive in 1993 in CEDR OHH_OP Data Set	Number of Workers Assumed Alive in 1997 in Master Data Set	Number Assumed Dead in 1997
Age and Gender Not Available				
	5,657	83.083	4,700	957
Overall Total	117,819	83.083	97,887	19,932

Table 2s key

Percentages for Age missing are the weighted average of the respective gender category.

Percentages for Gender Not Available are weighted averages of Male and Female.

Percentages for Age and Gender Not Available is the overall average.

Estimation of Exposures

Retrospective estimation of exposures for individual workers has been difficult. To estimate exposures we have:

- Reviewed documents describing hazards on site
- Created a job exposure matrix
- Used building location as a proxy for possible exposure to beryllium
- Accessed the Radiation Exposure System (REX) database.

Pending resources for exposure estimation:

- Employee Job Task Analysis
- Individual Worker Exposure Questionnaire

Review of documents

Documents cataloguing exposures on the site were reviewed. The documents reviewed include:

- Office of Technology Assessment. Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production. US Congress OTA-O-484. US Govt Printing Office, Washington, DC, 1991.
- Epidemiologic Surveillance Data Center and Office of Epidemiology and Health Surveillance, US Dept of Energy. Epidemiologic

Surveillance 1992: Annual Summary for Hanford Site.

- National Research Council. Building Consensus through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program Commission to Review Risk Management in the DOE's Environmental Remediation Program. National Academy Press, Washington, DC, 1994a.
- BEMR. Volume I. Estimating the Cold War Mortgage. DOE, March 1995. DOE/EM-0232.
- BEMR. Volume II. Site Summaries. DOE, March 1995. DOE/EM-0232.
- The Blush Report. Blush SM, Heitman TH. March 1995. Train Wreck along the River of Money: An Evaluation of the Hanford Cleanup. A report for the US Senate Committee on Energy and Natural Resources.
- Building Consensus through Risk Assessment and Management. National Resource Council (NCR), 1994.
- CERE Report. Health and Ecological Risks at the US Department of Energy's Nuclear Weapons Complex: A Qualitative Evaluation. March 1995.
- CERE (Xavier). Inventory of Public Concerns. Xavier University. Draft, 1995.
- Chemical Safety Vulnerability Working Group Report. DOE, September 1994. DOE/EH-0396P. Volume 1 of 3.
- Closing the Circle on the Splitting of the Atom. DOE, January 1995.
- Committed to Results. DOE, April 1994. DOE/EM-0152P.
- Confederated Tribes Reports. Scoping Report. Nuclear Risks in Tribal Communities. Confederated Tribes, 1995.
- Environmental Management 1995. DOE, February 1995. DOE/EM-0228.
- Plutonium Vulnerability Management Plan. DOE, March 1995. DOE/EM-0199.
- Hanford Environmental Dose Reconstruction (HEDR), Technical Steering Panel. Summary: radiation dose estimates from Hanford radioactive materials releases to the air and Columbia River. Richland, WA: HEDR PNNL, 1994
- Hanford Thyroid Disease Study (HTDS), Pilot Study Final Report. Seattle, WA: Fred Hutchinson Cancer Research Center, 1995.

- Archived Industrial Hygiene Records. Richland DOE Office. Reviewed by Kathy Ertell.
- Archived Exposure Records Collected by Field Industrial Hygienists. Richland DOE Office. Reviewed by Kathy Ertell.
- U.S. Department of Energy, Office of Environmental Management. Linking Legacies: connecting the Cold War nuclear weapons production processes to their environmental consequences.

The Job-Exposure Matrix

A method of linking individual former workers to their potential past exposures is an integral part of designing and implementing an effective occupational health surveillance program. Exposures that individual members of the workforce have had should determine who is enrolled in such a medical surveillance program, and which medical tests are appropriate. Furthermore, some independent information about the past exposures of the individual is required for the physician to appropriately interpret any medical test results with respect to the individuals' history, and any possible work-relatedness of conditions identified. In addition, accurate assignment of exposures is important for any epidemiologic analysis that might take place using the information developed during the surveillance project.

Past work exposures to individuals can be identified in several ways, including direct measurements, exposure questionnaires, work history questionnaires or through linkage of a work history to exposures through the use of a Job Exposure Matrix (JEM) (Kauppinen 1994). JEMs can be effective means of identifying exposures histories for groups of workers, especially in cases such as Hanford where the exposure is rare, and closely linked with specific jobs (Goldberg M, et al. 1993; Kauppinen, et al. 1992).

The complete JEM is demonstrated and described in detail in the October Needs Assessment. Briefly, the 73 existing Common Occupational Classification System (COCS) Codes developed by the DOE were examined by our industrial hygienists and grouped within the more broad COCS categories resulting in the development of 42 distinct occupational exposure categories. Each of the occupational exposure categories represents a group of job categories likely to

have been exposed to the same hazards at Hanford. A job-exposure matrix was then constructed such that an estimate of exposure could be assigned for each of the 42 hazards to each occupational category for each of five decades (1943-1990) of Hanford operations.

A group of four certified industrial hygienists was assembled to develop estimates for the qualitative exposure estimates of the matrix. Exposure categories were: “probably not exposed” (0), “possibly exposed depending on location and specific tasks” (1), and “probably exposed” (2). Adding the 13,050 new individuals from REX who have job title information gives 4,378 additional workers to JEM for a total of 82,771 individuals (Table 3s). This number includes deceased workers because current databases are not adequate to determine vital status. As noted previously, this estimate does not include many lower tiered sub-contractors, and for workers with multiple job titles it relies upon the last job title in the data base. Except for deceased workers, each of these weaknesses would tend towards under estimation of workers at risk, since sub-contractors often have significant exposures and workers tend to move from more exposed jobs to less exposed jobs. In estimating number of workers alive in any given exposure category a factor of 0.9 is used, i.e. the assumption that 10 % of the workers have died.

The qualitative process used to develop these data also contributes to uncertainty in the estimate. During Phase II, two additional sources of information will be gathered on an on-going basis and integrated into the Phase I JEM in order to increase its sensitivity and specificity. In addition, the three level categories will be translated into an estimated probability of exposure. Probability-based JEMs have been shown to help control the bias associated with measurement error in the application of JEMs (Gilks and Richardson, 1992).

The Phase I JEM will first be converted to a database structure. The three level exposure scale will be converted to a probability, initially using 0.10 for unlikely, 0.50 for possible, and 0.9 for likely exposure. These a priori exposure probabilities can be adjusted as additional information becomes available.

The former worker exposure questionnaires will be used as the first set of additional information to add to the a priori matrix. Questionnaire information will provide the only individual-level assessment of exposures, but can also be used to develop a probability of exposure within each job. As questionnaire results are assembled, three fields (variables) will be updated: the number of individuals responding that they held the job in the time period, the number indicating the exposure occurred in that job and time period, and their ratio, the percentage, or probability of having the exposure given that you worked the job.

The second source of information will be the employee job-task analyses (EJTAs). These data are the only data generated by close observation and intimate knowledge of specific work activities, but independent of the worker-respondent. However, EJTA data are also limited in two important ways: they are only available for the current time period, and they are only evaluating

exposure to a small subset of the potentially interesting agents. These data will be incorporated only for those relevant categories, but may be used in a modeling context to infer exposure during earlier periods. Similar to the questionnaire data, the EJTA information will be incorporated into the JEM as a number of persons in a job, the number exposed and the ratio, or probability of exposure.

Having assembled these three sources of exposure information, the a priori Phase I JEM, the individual questionnaire results, and the EJTA observation results, an exposure probability based on all three pieces of information can be integrated to form a best possible estimate of exposure probability. The following scenario is suggested for this integration:

Assuming no information beyond the a priori JEM is available, then that assignment will be used. If information from the a priori JEM, the questionnaires and EJTA's are available, then they will be integrated as a weighted average:

$$EP_{jt} = EP_{jem} (1 - (w_q + w_{EJTA})) + EP_q (w_q) + EP_{EJTA} (w_{EJTA})$$

where EP_{jt} is the exposure probability for job j and time period t . EP_{jem} is the probability derived from the a priori JEM, EP_q represents that derived from the questionnaire and EP_{EJTA} is the probability derived from the EJTA. w_q and w_{EJTA} are weights assigned to each EP (Table 4). These are calculated as the number of questionnaires or EJTA's addressing the given job divided by 100. If the number of questionnaires and EJTA's are 0, then full weight will be given to the questionnaire based information. If the numbers exceed 50, then 0.5 weight is given to each, and the a priori information receives 0 weight. Although this weighting scheme is arbitrary, it provides a mechanism to combine the three sources of information, in general proportion to the amount of information received, and relying on the JEM in other cases. The weighting scheme for the three information sources may be altered if needed.

Table 3. Variables to be included in the JEM Database

Variable	Definition
Job	COCS-based job group as defined in the Phase I JEM
Decade	Decade during which work was conducted
Agent	Exposure agent as identified in the Phase I JEM
JEM Rating	Consensus rating as 0, 1, 2 given in Phase I JEM
EPjem	Exposure probability assigned based on JEM Rating: initially 0.1, 0.5, 0.9, respectively
Numq	Number of questionnaires with information concerning this job, decade and agent
Expoq	Number of questionnaires indicating that this exposure occurred
EPq	Exposure probability based on questionnaire responses
Numq	Number of EJTA's with information concerning this job, decade and agent
Expoejta	Number of EJTA's indicating that this exposure occurred
EPejta	Exposure probability based on EJTA information

Table 4s. Exposure assessment based on all job records by JEM
Number of Workers Exposed by Hazard

	Possibly Exposed	Probably Exposed	Total
Noise	11234	25464	36698
Gamma radiation *	24970	9134	34104
Asbestos	19608	9394	29002
Lead	19447	8572	28019
Plutonium *	24644	2852	27496
Uranium *	24644	2852	27496
Other isotopes *	24644	2852	27496
Vibration	8591	18848	27439
Stack Gas	25770		25770
Chlorinated Solvents	18370	7194	25564
Fuels, greases, oils	11612	11126	22738
Toluene and Ketones	14282	8447	22729
Sodium dichromate	21467		21467
Pesticide	20613		20613
Paints/Thinners	16757	1026	17783
Silica	16921		16921
Irritant Gases	12715	3566	16281
Herbicide	15977		15977
Other solvents	12248	3412	15660
Other Acids/Caustics	13022	2512	15534
Welding fumes	8665	5083	13748
Uranyl nitrate hexahydrat	12737	880	13617
Uranium tetrafluoride	12737	880	13617
Tributyl phosphate	12737	880	13617
NPH (kerosene)	12737	880	13617
Beryllium	12988		12988
Nitrates	12911		12911
Acetonitrile	8874	2994	11868
Nickel	4738	6281	11019
Zirconium/Zircalloy	10927		10927
Chromium	5612	4968	10580
Hydrazine	10417		10417
PCBs	8730	1626	10356
Mercury	9874	403	10277
Other/Unknown Metals	8114	1518	9632
Metal working fluids	6494	2765	9259
Formaldehyde	8331	511	8842
Lithium hydroxide	7778		7778
Glycol ethers	2814	4006	6820
Cadmium	4062		4062
RF or Microwave radiation	989		989
Laser Light	980		980

* see Radiation Exposure System (REX) Tables

Building Information

For some of the hazards, job category will be less predictive of exposure than will building assignment. This is why many of the job categories were assigned a "1" for "possibly exposed" in the job matrix. Workers with the same job title who worked in different buildings might have very different exposures. Thus, we must also consider estimating numbers of exposed individuals by location rather than by job.

Unfortunately, most of the building information comes from a single database, Flow Gemini. We have used Flow Gemini to identify workers in specific buildings in order to construct populations of workers exposed to targeted substances. Due to the limitations of Flow Gemini, it is difficult to reach conclusions regarding total numbers of people exposed as a result of building assignment based on this database alone. Another source for this information will be an individual exposure questionnaire.

We will continue to use building assignment as a possible surrogate for beryllium exposure. As we gather additional information about the prevalence of beryllium sensitivity in various job categories, we will make a determination as to whether the JEM or the building assignment is the best predictor of exposure.

Radiation Exposure

Because radiation exposure was measured at Hanford and quantitative data exists for this hazard, we will not need to rely on the JEM, questionnaires, and EJTA's for exposure information in this case. We currently have external radiation exposure information from REX for 79,726 individuals and 19,240 from REMS all with social security numbers for tracking between databases. We hope to obtain additional information regarding internal exposures to radioactive materials and will maintain this information for each individual in our master database for whom it is available. This will allow physicians providing medical surveillance for beryllium and asbestos-exposed individuals to consider a possible interactive effect between radiation and other lung toxins in addition to any direct radiation effects.

Utilizing the available radiation data is complex because of the variety of methods used to record dose since 1943. The most complete data relies upon badge dosimetry with several inherent problems (Gilbert, et al, 1990, Fix, et al). Prior to 1989, the dose resulting from penetrating ionizing radiation (external dose) and that resulting from the uptake of radionuclides (internal dose), was reported separately. Internal dosimetry is available on a limited number of Hanford workers but though requested, was not included in REX data we received from PNNL except for 320 workers from recent years who had Total Effective Dose Equivalent calculated. For discussion purposes we have therefore constructed a summary measure of all external doses. This Sum External Dose = deep dose + shallow dose + ring dose + eye dose + neutron dose + xray dose. The Sum External Dose does not reflect biological effectiveness, but does provide a range

of exposures in the 79,726 former workers in REX (Table 5). A breakout by each of these dose categories is also provided below (Tables 6-11).

Table 5. Dose Category for Sum External Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing values	17171	21.5
0-5000	50070	62.8
5001-10000	5033	6.3
10001-20000	3280	4.1
20001-30000	1393	1.7
30001-40000	791	1.0
40001-50000	486	.6
50001-60000	335	.4
60001-70000	249	.3
70001-80000	237	.3
80001-90000	161	.2
90001-100000	118	.1
100001-110000	86	.1
110001-120000	74	.1
120001-130000	48	.1
130001-140000	55	.1
140001-150000	39	.0
150001-380479	100	.1
Total	79726	100.0

7573 workers with > 10 REM cumulative dose.

If a high dose radiation monitoring program is established for Hanford workers further consideration of what dose summary to use will need to account for the variability in data collection over the 55 year history of radiation exposure to the workers and should include internal dosimetry when available. As suggested in Figure One showing internal depositions in CEDR, most of the worker dose at the site occurred in the early history of the site. Because of latency of radiation related disease, particularly for cancer, these early doses may be significant. Age of the worker at the time of exposure may also be important because older workers appear to be more susceptible to radiation effects. Once optimal dose estimates are determined, a prioritization scheme might include age at exposure as a factor in the risk analysis.

Figure One. Data from Hanford Section of Comprehensive Epidemiologic Repository (CEDR) For Internal Depositions

Table 6. Distribution of Sum Shallow Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing	17504	22.0
.0001-5000	54689	68.6
5001-10000	3536	4.4
10001-20000	2129	2.7
20001-30000	860	1.1
30001-40000	458	.6
40001-50000	258	.3
50001-60000	148	.2
60001-80000	124	.2
80001-100000	20	.0
Total	79726	100.0

3997 workers with > 10 REM cumulative dose.

Table 7. Distribution of Sum Deep Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing Values	19844	24.9
.0001-5000	54310	68.1
5001-10000	2686	3.4
10001-20000	1657	2.1
20001-30000	612	.8
30001-40000	333	.4
40001-50000	145	.2
50001-60000	82	.1
60001-80000	54	.1
80001-100000	3	.0
Total	79726	100.0

2886 workers with > 10 REM cumulative dose.

Table 8. Distribution of Sum Neutron Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing Values	70198	88.0
.0001-62.5	5193	6.5
62.6-125	1247	1.6
126-250	999	1.3
251-500	773	1.0
501-1000	579	.7
1001-2000	345	.4
2001-3000	128	.2
3001-4000	87	.1
4001-5000	56	.1
5001-6000	34	.0
6001-8000	37	.0
8001-10000	18	.0
10001-20000	29	.0
20001-50000	3	.0
Total	79726	100.0

121 workers with > 5 REM cumulative dose.

Table 9. Distribution of Sum Eye Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing	76346	95.8
.0001-125	2140	2.7
125-250	359	.5
250-500	326	.4
501-1000	289	.4
1001-2000	177	.2
2001-3000	56	.1
3001-4000	20	.0
4001-10000	13	.0
Total	79726	100.0

13 workers with > 4 REM cumulative dose.

Table 10. Distribution of Sum Ring Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing	68833	86.3
.0001-60	1138	1.4
61-120	864	1.1
121-240	992	1.2
241-480	1214	1.5
481-960	1313	1.6
961-1920	1319	1.7
1921-3840	1393	1.7
3841-7680	1129	1.4
7681-240000	1531	1.9
Total	79726	100.0

Table 11. Distribution of Sum Xray Dose

Dose Range (mREM)	Number of Workers	Percent of Total
Missing	72035	90.4
.0001-5	10	.0
5.1-10	1470	1.8
10.1-15	2	.0
15.1-20	1606	2.0
26-30	1211	1.5
31-40	673	.8
41-50	508	.6
51-100	988	1.2
101-200	451	.6
201-8000	772	1.0
Total	79726	100.0

In 1993, a change in the internal dose calculation methodology from Annual Effective Dose Equivalent (AEDE) to the 50 year Committed Effective Dose Equivalent (CEDE). The total effective dose equivalent TEDE then became the sum of the CEDE and the Deep Dose Equivalent (DDE). TEDE would best represent cumulative radiation risk, but considerable work is needed to extend this dose calculation for the early years of dosimetry. REX has only 320 workers with TEDE, of those 70 have SS# (Table 12).

Table 12. Distribution of TEDE

Range	Number of Workers	Percent of Total
.00001-.00025	9	12.9
.0051-.01	9	12.9
.011-.1	39	55.7
.11-.5	7	10.0
.51-1	6	8.6
Total	70	100

The data presented here is meant to provide a crude description of dose distribution in the Hanford former worker population. Establishing a population at high risk will require additional data collection and analysis along with a consensus about dose levels and types which should trigger effective monitoring.

Employee Job Task Analysis (EJTA) Data

The Hanford Occupational Health Process (HOHP) is developing a systematic hazard-based surveillance program. The identification of hazards is through the employee job task analysis (EJTA). This program will assess hazards for each worker on the site. In a separate project we are validating EJTA's being performed by facility supervisors and industrial hygienists. Although the EJTA's are being done only on current workers, they will provide valuable information regarding exposures by job and building for the more recent decades during which clean-up work has become the primary focus.

Occupational History and Exposure Questionnaire

Once workers have been contacted and have signed a consent form to participate in our study, they are sent a follow-up questionnaire eliciting the details of their work history at Hanford, specific information about the hazards to which they were exposed, and what personal protective equipment was used for each job held at the facility. The questionnaire is composed of two parts: Part 1 is the Job History and General Health Form; Part 2 is the Job Specific Information Form. Workers will receive five copies of Part 2 and may request

additional copies as needed to complete their job history. The questionnaire has been piloted and is under revision. We propose to augment the JEM with the

questionnaire using the formula described above.

The information gained from this questionnaire will be particularly useful in understanding exposure potential in the early years of Hanford operations as none of our industrial hygienists were on the site prior to the 1980s. Information gathered from questionnaire responses will also be used to assign individual workers to specific medical surveillance programs as defined in Phase II.

How Additional Hazards May Affect Estimates of Need for Medical Surveillance

The term medical surveillance is used in the context of this report to include identification of workers at an increased risk, provision of medical screening, provision of recommendations to the worker for further testing, treatment, workers compensation when appropriate, preventive measures, and a summary of findings and recommendations to DOE to assist them with future hazard reduction. In many cases (e.g. beryllium and asbestosis), periodic monitoring for latent diseases is anticipated, but not included in the proposed estimates at this time.

The Federal Register notice put forth the goals of medical surveillance as:

1. Identify groups of workers at significant risk for occupational diseases;
2. Notify members of these risk groups; and
3. Offer these workers medical screening that can lead to medical interventions.

As noted in the October Needs Assessment, monitoring assignments were based upon these goals. Medical literature on occupational hazards and potential surveillance programs was reviewed to provide a justification for medical surveillance for former workers exposed to noise, asbestos, and beryllium. Additional exposures are considered here. Ionizing radiation, solvents, heavy metals, metal working fluids, welding fumes and other respiratory irritants were raised by the NIOSH reviewers as potential hazards which "could significantly change the anticipated nature and severity of the overall health effects in the target population".

Table 13. Hazards Under Consideration for Additional Monitoring Programs
Number of Workers from JEM

	Possibly Exposed	Probably Exposed	Total
Silica	16921		16921
Irritant Gases	12715	3566	16281
Solvents	13437	19640	33077
Heavy Metals (all)	18402	14915	33317
Welding fumes	8665	5083	13748
Metal working fluids	6494	2765	9259

Solvents include: Chlorinated Solvents; Fuels, greases and oils; Toluene and Ketones; Paints and Thinners; Other Solvents.

Metals include: Lead, Mercury, Chromium, Cadmium, Plutonium, Uranium .

For workers no longer exposed (former workers), the additional exposures hazards characterized here have only inference to support medical surveillance. Clearly the medical literature is supportive of attribution of adverse health effects with these exposures. Level of exposure (dose) is an important predictor of adverse effect, and we will continue to improve the exposure characterization for these hazards. However, we question whether medical monitoring specifically for these hazards in workers who are no longer exposed has proven benefit. Table 13. describes estimated number of workers in these categories, and Table 14. an estimate of those alive and likely to avail themselves to medical monitoring for each category.

An additional unresolved issue of importance is multiple exposures which interact to modify adverse effects. A prioritization scheme or pilot programs might be a reasonable approach in the context of longterm surveillance needs for USDOE workers. For example for noise, beryllium and asbestos we have suggested a tiered approach, with those workers with the highest likely exposures monitored first. For the additional exposures listed here, one strategy would be to use the JEM "probable" category, leaving the "possible" category for further refinement based upon questionnaire data or any new data discovered through archives. Applying this strategy to the additional exposures yield the results in Table 14.

The potential for substantial uncertainties in projections of who will avail themselves to examination is again acknowledged. The factors contributing to the uncertainties include: 1) difficulties in ascertaining all who worked on the site; especially subcontractors; 2) difficulties in identifying the jobs and job titles for workers (over 40% missing in some databases); 3) limitations in exposure assessment; 4) uncertainties with respect to who is still a current worker (10%) or was solely a construction worker (10%); 5) survival estimates (90%); 6) ability to locate (90%); and 7) likely participation (50%). Based on our analyses we have used the factors above to be applied to the number exposed to get an estimate of the number of exams which could be offered. These factors estimate the number likely to participate by the following equation:

Likely to participate =
 {current worker (0.9) x (Alive (0.9))} x {able to locate (0.9)} x
 {likely to participate (.5)}

Likely to participate = 0.36 x total number exposed

The numbers likely to participate in each of the additional medical surveillance programs have been calculated and are presented in Table 14. The number exposed is likely conservative given the extensive proportion missing job titles and the likely undercounting of subcontractors. For this reason the numbers proposed are felt to be very conservative with a caveat that the exposure assessment used in the job-exposure matrix is likely to over-estimate the total number exposed. This is balanced, however, by the lack of job titles for 25% of workers. As discussed later an iterative process where the needs assessment is updated annually based on new information including the incidence of positive screening examination is strongly favored.

Table 14. Estimated Need for Additional Medical Surveillance

Additional Hazard	Probably Exposed by JEM *	Total Eligible & Likely to Seek Exam
Radiation *	3997	1439
Silica		0
Irritant Gases	3566	1284
Solvents	19640	7070
Heavy Metals (all)	14915	5369
Welding fumes	5083	1830
Metal working fluids	2765	996

*For discussion purposes radiation based upon REX cumulative shallow dose greater than 10 REM (Table 6.)

Table 15. describes a further refinement of a prioritization scheme for workers exposed to multiple solvents the scheme could be applied to heavy metals or combinations of other exposures as well. Years at a particular job, a surrogate for cumulative exposure, could also be used for prioritization.

Table 15. Example of Possible Prioritization Strategy for Multiple Solvent Exposures:

Number of Solvent Categories of Worker Exposure	Number of Workers Probably Exposed in JEM	Percentage of Total Workers in JEM N= 82,771
1	12,984	15.7
2	2,983	3.6
3	2,449	3.0
4	1,212	1.5
5	12	0

Solvents categories are: Chlorinated Solvents; Fuels, greases and oils; Toluene and Ketones; Paints and Thinners; Other Solvents.

As noted previously, clear medical benefit for monitoring many of these additional hazards has not been well demonstrated. For example more study is needed of the benefit of cancer surveillance for workers with ionizing radiation exposure. Despite the existence of such a program for “high dose” USDOE workers at Rocky Flats and elsewhere for over a decade, an improvement in health outcome for workers in this program has not yet been demonstrated. Former USDOE workers with exposures such as those found at Hanford are an excellent population to study such questions, but considering the significant funding constraints for the surveillance programs with more likely benefit (noise, asbestos and beryllium), we question whether this program’s resources should be so directed. These prioritization issues which are affected by available resources should be resolved in consensus with the program partners and NIOSH reviewers.

Acknowledgments

This Phase I Needs Assessment could not have been done without the advice and support of many organizations and, importantly, the many employees and members related to the Hanford site. The assistance and counsel of those at the Oil, Chemical, and Atomic Workers Union, the Department of Energy, Richland Office, the Department of Energy Office of Health Studies, The Hanford Environmental Health Foundation, Fluor-Daniel Hanford, and Pacific Northwest National Laboratory.

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