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Planning for Decommissioning and Decontamination of Hanford Nuclear Facilities

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ABSTRACT

The 570-square mile Hanford Project contains facilities with varying degrees of radioactive contamination as a result of plutonium production operations. With the evolution of production requirements and technology, many of these have been retired and will be decommissioned and decontaminated (D&D). Planning for D&D at Hanford requires identification and characterization of contaminated facilities, prioritization of facilities for decommissioning, selection of D&D modes, estimating costs and other characteristics of D&D activities, definition of future scenarios at Hanford, and preparation and assessment of plans to achieve defined scenarios.

A multiattributed decision model using four criteria was used to prioritize facilities for decommissioning. A computer-based interactive planning system was developed to facilitate preparation and assessment of D&D plans.

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THE HANFORD RESERVATION

The Hanford Project was built during 1943 and 1944 by the Manhattan District of the U.S. Army Corps of Engineers to produce plutonium for nuclear weapons. Located on 570 square miles of shrub-steppe desert adjacent to the Columbia River in southeastern Washington State (Figure 1), the project originally included facilities for the fabrication of reactor fuel elements, three graphite-moderated plutonium production reactors, and three plants for separation of plutonium. Production reactors were located in self-supporting complexes ("100 Areas") adjacent to the Columbia River where the large volume of water necessary for reactor cooling was readily available. Separations plants were located in two complexes ("200 Areas") on a plateau near the geographical center of the site. Fuel fabrication facilities ("300 Areas") were located along the Columbia River near the southern boundary of the site, north of the project headquarters at Richland.

In the ensuing years, production was increased by process and equipment modification, and construction of additional production reactors and separations plants. At maximum production in the early 1960's, eight production reactors, one dual purpose production/power reactor (N-Reactor), and two separations plants were in operation.

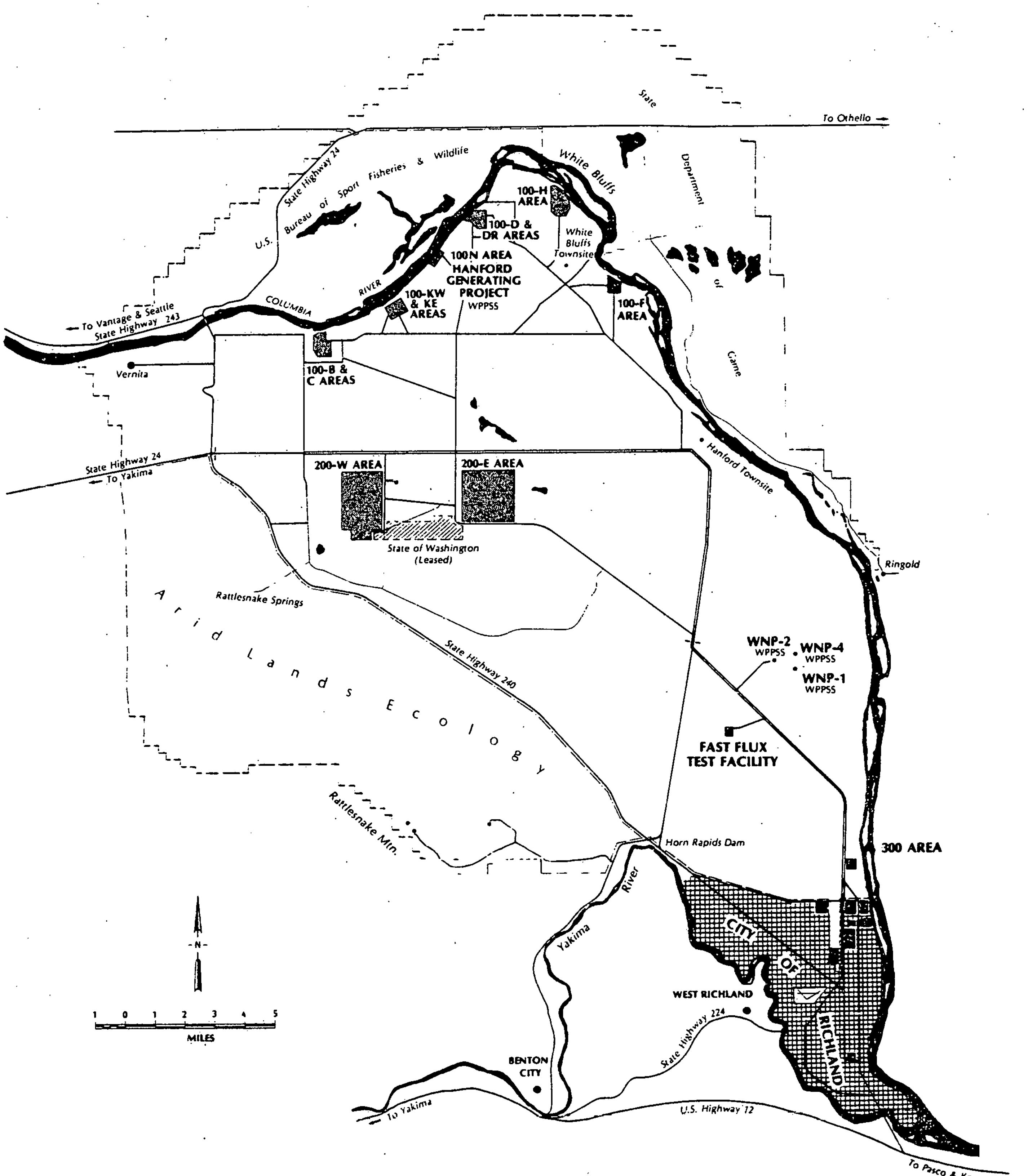

FIGURE 1. Map of Hanford Reservation

In 1964, a Presidential order to curtail plutonium production resulted in the gradual phasing out of Hanford production activities. At present, operation of all separations plants and all but one of the reactors has been terminated. N-Reactor remains in operation, supplying steam to the adjacent Washington Public Power Supply System (WPPSS) 860 MW generating plant. Four reactors are in standby status and four have been declared surplus. One separations plant (Purex) remains in "wet standby" status, while the remaining plants are either retired or are performing alternative functions. Ongoing activities center on management of the radioactive solid and liquid wastes that are the legacy of 30 years of Hanford Project operation.

With the curtailment of plutonium production, alternative uses of the Hanford Reservation have been sought. These presently include:

- Construction of three commercial nuclear power plants by WPPSS.
- Lease of 1,000 acres to the State of Washington for commercial nuclear waste disposal.
- Development of 86,000 acres lying north of the Columbia River by the U.S. Bureau of Sport Fisheries and Washington State Department of Games as a wildlife refuge and recreation area.
- Designation of a 120-square mile Arid Lands Ecology Reserve.
- Designation of the Hanford Reservation as a National Environmental Research Park.

Management responsibility for the Hanford Reservation is currently vested in the U.S. Energy Research and Development Administration (ERDA).

Retired Contaminated Facilities at Hanford[a/]

More than 600 radioactively contaminated facilities are found on the Hanford Reservation. These have been divided into eleven classes based on radiological, structural, and functional characteristics.

Uranium Facilities: These facilities are used to process material containing isotopes of uranium or thorium. Included are reactor fuel manufacturing and storage buildings and facilities for production of uranium trioxide from reprocessing plant uranyl nitrate product.

Reactors: Eight graphite-moderated, direct once-through cooling production reactors were built at Hanford to produce weapons-grade plutonium by exposing ^{238}U to a neutron flux. In addition, the dual purpose N-Reactor, which produces steam as well as plutonium, was commissioned in 1963 and is still in operation. An aerial view of a typical production reactor complex is provided in Figure 2. Five low-power test reactors were also constructed.

Reactor Gas and Exhaust Air Systems: These facilities were used to maintain an inert gas atmosphere in the graphite piles of the production reactors. Also included are the ductwork, filters, stacks, and monitoring facilities of the reactor ventilation systems. There are about 40 structures in the class. Reactor gas and exhaust air system facilities are visible in Figure 2.

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a/ Information on the number and types of radioactively contaminated facilities at Hanford has been taken from the Hanford D&D Resource Book.[1]

FIGURE 2. 100-F Production Reactor Complex Looking Southeast with the Columbia River on the Left. The 105-F Production Reactor (with the single stack) is to the upper right. The reactor gas recirculation building is to the right of 105-F. The retention basin is visible just above and to the left of the twin stacks.

Retention Basin Systems: Systems for returning reactor cooling water to the Columbia River include basins for temporary retention of water prior to discharge, river outfall structures and many thousands of feet of large diameter effluent piping (Figure 2). Also included in this class are basins for temporary retention of reprocessing plant cooling water prior to discharge to ponds. Approximately 40 facilities are in this class.

Fuel Storage Basins: These water-filled basins are used to store and age irradiated fuel elements before reprocessing. Twelve fuel storage basins were constructed at Hanford.

Fuel Reprocessing Facilities: These plants are for chemical separation of plutonium, uranium, and other products from irradiated reactor fuel. Each main-line reprocessing plant includes a heavily shielded process building ("canyon" building) and numerous ancillary facilities. A typical fuel reprocessing plant is illustrated in Figure 3. Five main-line reprocessing plants and one pilot plant were built at Hanford.

Transuranic Facilities: These facilities were used to process purified transuranic materials and hence are contaminated only with transuranic isotopes. Included are plutonium nitrate concentration and loadout facilities and plutonium finishing facilities. Fewer than ten of these facilities are at Hanford.

Waste Management Facilities: These facilities are for processing and storage of high-level radioactive wastes generated during fuel reprocessing operations. Included are 15 tank farms (plus 2 under construction) for storage of liquid and salt cake high-level wastes, 5 evaporator systems

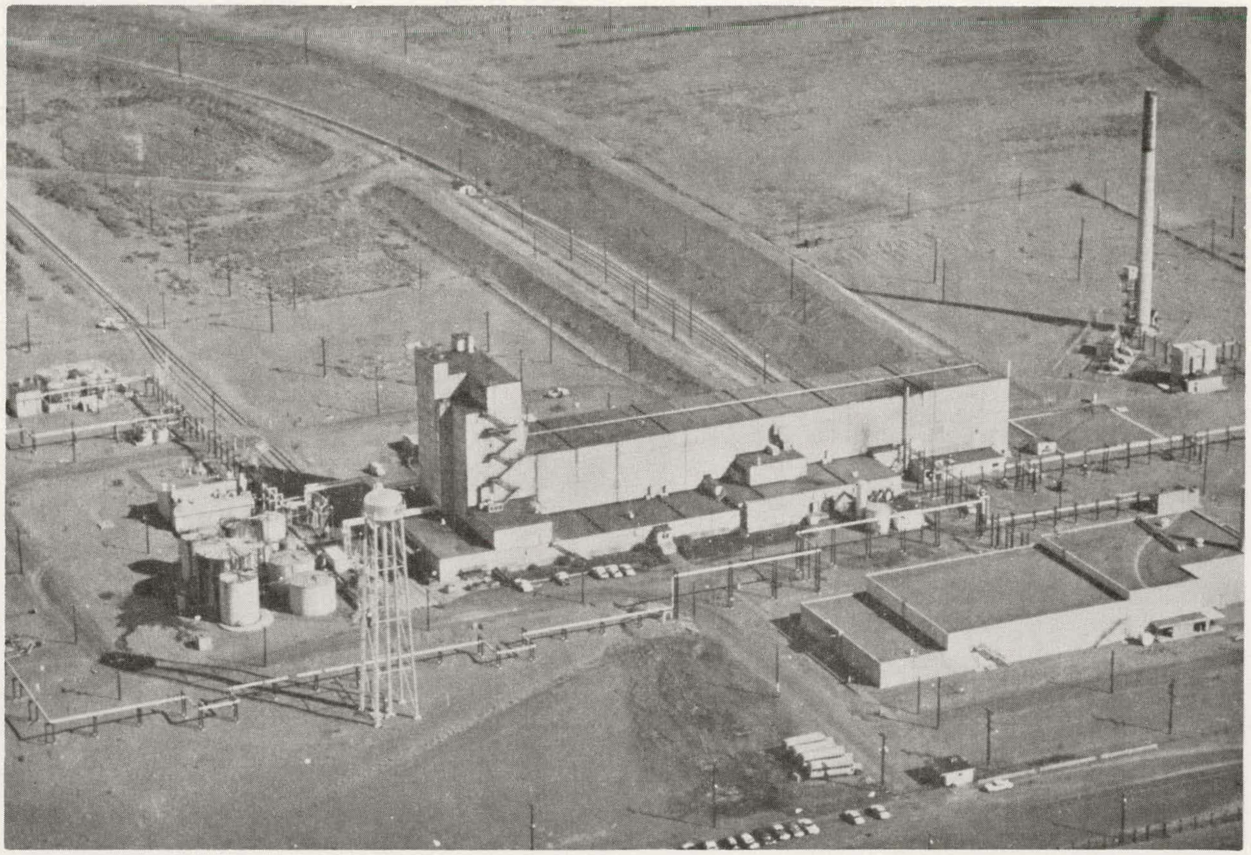

FIGURE 3. Redox Fuel Separations Plant

for waste concentration, and a waste transfer system consisting of vaults and diversion boxes connected by thousands of feet of encased underground transfer piping.[2]

Contaminated Liquid Disposal Sites: These facilities were used, in the past, for the disposal of low and intermediate level contaminated liquids to the soil column. Included are ponds, open and covered trenches, french drains, reverse wells and cribs (hollow or rock filled subsurface structures). In this facility class are more than 200 underground structures, 34 surface ponds, ditches and trenches, and 28 accidental release sites. A subclassification of contaminated liquid disposal sites has been established, based on their radionuclide inventory.

Contaminated Solids Storage and Burial Sites: These facilities are for disposal or intermediate term storage of contaminated solid wastes. A variety of structures are in use, including burial trenches, vaults, caissons, railroad tunnels, and surface storage. Approximately 70 contaminated solids storage and burial sites, occupying nearly 500 acres of land,[b/] are present at Hanford. A subclassification of contaminated solids storage and burial sites has been established, based on their radionuclide inventory.

Laboratories: These are various process monitoring and research facilities contaminated with all types of radioactive materials. About 25 contaminated laboratories are located at Hanford. One is visible in the foreground of Figure 3.

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b/ Commercial burial sites are not included.

NEEDS AND OBJECTIVES OF D&D AT HANFORD

As alternative uses for the Hanford Reservation develop, the need increases to place retired radioactively contaminated facilities into an acceptable decommissioned condition. Factors contributing to this need, in addition to the physical preemption of useful land by inactive facilities, include potential hazards presented by the radioactive inventories of these facilities to persons both on and off the Reservation. In addition, deterioration of shutdown facilities creates potential industrial safety hazards both to persons having authorized access, and to trespassers as well. These latter individuals are attracted by the recreational opportunities of the undeveloped Columbia shoreline and by the intriguing nature of the facilities themselves. An additional factor contributing to the need for decommissioning is the expense of ongoing maintenance and surveillance activities required to maintain facilities in a reasonably safe condition.

Decommissioning Methods

Four alternative decommissioning methods have been identified as generally applicable to retired Hanford facilities. Two, layaway and protective storage, are interim modes whereby the facility is placed in an acceptable condition for a number of years, but eventually requires permanent disposition. Two others, entombment and dismantle, are permanent alternatives requiring no major follow-up activities.

Layaway: This is a short-term (∿20 years) interim mode in which the facility is maintained in essentially its current state. Layaway may permit postponement of major D&D activities until acceptable terminal storage for radioactive wastes is developed. For facilities containing isotopes with short half-lives, radiation levels will be lower, reducing costs and occupational exposures at time of final D&D. Layaway, however, will require continuing expenditures for maintenance and surveillance of the facility and may require initial capital expenditures for structural renovation, containment, housekeeping, and fencing.

Protective Storage: This longer-term (50-100 years) interim mode has the objective of placing the facility in an acceptably safe condition long enough to permit substantial decay of the radioactive inventory. Ultimate disposition of the facility may then be accomplished at reduced cost and occupational exposure. Protective storage requires containment barriers designed for 50 to 100 year integrity with minimal maintenance and surveillance.

Entombment: This is a permanent D&D alternative in which the facility is enclosed with a barrier of sufficient integrity to contain the radionuclide inventory until it decays to a releasable level. Approximately 10 half-lives are required to transform a quantity of a given radionuclide to a concentration permitting general release to the environment. Thus, an inventory of ^{60}Co (5.26 y half-life) would require an entombment structure with expected integrity of greater than 50 years; ^{90}Sr (28 y half-life) and ^{137}Cs (30 y half-life) approximately 300 years; and ^{239}Pu (24,000 y half-life) a quarter of a million years. It may be reasonable to expect a 300 year lifetime for structures employing current technology; therefore, entombment may be a feasible mode for facilities containing mixed fission products such as ^{90}Sr and ^{137}Cs. It is unlikely that entombment would be considered a feasible mode for facilities contaminated with plutonium unless the plutonium was removed.

Dismantle: This mode involves removal of radiaoctivity from the site to levels permitting unrestricted release. This may be accompanied by removal of non-contaminated structures as well. Dismantling will require transfer of the contaminated inventory to a storage facility or to ultimate disposal.

D&D PLANNING AT HANFORD

Because of the potential hazards and costs associated with retired contaminated facilities, and increasing interest in alternative uses of the Hanford site, ERDA has requested Battelle, Pacific Northwest Laboratories (PNL) to prepare comprehensive long range plans for D&D of surplus contaminated Hanford facilities. These plans include methods, budget requirements, and schedules required to achieve specific goals (scenarios) for future use of the Hanford Reservation. Because future scenarios for Hanford have not been firmly established, one product of this study will be a set of alternative future scenarios for the Hanford Reservation. A second product is alternative plans for achieving the goals established by each scenario. Assessments of the effects of proposed plans are also being provided. These assessments will enable ERDA to select a preferred scenario and a comprehensive D&D plan for achieving that scenario.

Scenarios

Alternative scenarios for the future of the Hanford Reservation are being proposed, each with an explicit statement of goals. Goals include future land use objectives for Hanford and dates by which the land use objectives are to be achieved. Because of the size of the Hanford Reservation and the scattering of contaminated facilities, it is likely that land use objectives will differ for various areas within the Reservation. Other goals specified in a scenario may include acceptable levels of residual onsite or offsite hazard; acceptable expenditures for surveillance and maintenance of decommissioned facilities; waste management assumptions; and future uses for specific facilities.

Three basic classifications of land use have been defined for purposes of describing future Hanford scenarios. These include: restricted, conditional, and unrestricted use.

Restricted Use: Under restricted land use conditions, future use of a site is limited to nuclear-related activities. Restricted use would probably be required if retired facilities are placed into a condition requiring continuous surveillance by radiological control or security personnel. Use of the layaway mode would generally require surveillance at frequent intervals and thus limit the site to restricted use only.

Conditional Use: For the conditional use alternative, certain non-nuclear activities would be permitted, subject to specified conditions on use of the site. The conditions imposed would be designed to prevent breeching of containments enclosing the radionuclide inventory of decommissioned facilities. Typical conditions might include prohibitions against disturbance of entombment or protective storage structures; prohibitions on disturbance of vegetative cover overlying a subsurface site; and restrictions of activities, such as drilling, which might violate containment of subsurface repositories of radionuclides. Conditions on use of the land would be recorded in the legal descriptions of the affected land and by use of on-site monuments to ensure notification of future users of the land. Periodic government inspections would probably be required to ensure compliance. Use of protective storage or entombment D&D alternatives would probably limit affected sites to conditional uses.

Unrestricted Use: Achieving unrestricted use of a site would require removal of radionuclides to release levels. Only the dismantle mode initially meets this criterion; however, entombment would eventually permit unrestricted use of a site after radionuclides decay to releasable levels.

Radiological criteria for the three categories of land use are presently under development.

Plans

One or more alternative plans for achieving each scenario are being developed. A plan includes:

- A schedule of D&D activities including each surplus contaminated facility;
- Identified D&D modes for each surplus contaminated facility; and
- Budget requirements to support decommissioning activities.

Subsequential D&D modes may be specified for certain facilities. For example, a reactor might be placed in layaway for five years, followed by fifty years of protective storage to allow decay of ^{60}Co, after which the facilities can be dismantled.

Effects and Implications

In addition to achieving the goals of the associated scenario, each plan will have numerous effects (in addition to cost) which are important in evaluating the merits of alternative plans. Important effects of each plan are being assessed as part of the Hanford D&D planning program. Significant effects include: volumes of contaminated and uncontaminated wastes generated by D&D activities; manpower requirements; occupational dose resulting from plan implementation; changes in levels of potential offsite and onsite hazards; and other environmental effects.

As of the writing of this paper, preparation and assessment of scenarios and plans for D&D at Hanford were not yet complete. Consequently, it is not possible to present a fully developed set of alternative scenarios and plans resulting from the planning process. However, the planning methodology is fully developed and supporting computer models are operational and will be described in the following sections of this paper. Available results are used to illustrate the planning methodology. Many of the results are preliminary in nature and subject to change.

PLANNING APPROACH

The development of plans for D&D of Hanford is being achieved through a seven-step planning approach. These steps in approximate order of completion are as follows.

- Facility Characterization
- Information Management
- Facility Prioritization
- D&D Mode Selection
- D&D Activity Characterization
- Scenario Definition
- Integrated Planning and Plan Assessment

These steps are discussed in the following section with emphasis on integrated planning activities.

Facility Characterization and Information Management

Facility characterization information was compiled in the initial phase of the Hanford D&D planning program. Surplus contaminated facilities were identified: locational, historical, physical, and radiological characteristics of each facility were documented.

Information is compiled on both computerized and conventional data management systems. The computer-based information system utilizes Computer Sciences Corporation's Data Management Language (DML). Currently over 90 data elements are maintained on each of about 550 Hanford facilities. Additional facilities are being added as characterization information becomes available. The computer-based information system facilitates predicting costs, manpower requirements, project duration, and other characteristics of D&D activities using mathematical models.

Information is also maintained in the Hanford D&D Resource Book.[1] The Resource Book contains a description of the Hanford Reservation, generic descriptions of each of the facility classes, and a discussion of D&D techniques and plans. An information sheet is provided for each facility containing administrative, historical, and locational information and descriptions of functional, physical, and radiological characteristics.

Facility Prioritization

One of the three major elements of D&D plans is a schedule of D&D activities, including planned starting and completion dates for D&D of each surplus contaminated facility. Creation of a schedule requires assigning a priority for disposition to each retired contaminated facility. Because of the large number of facilities, it was necessary to adopt a structured decision analysis methodology to establish a reasonably consistent priority index. A multiattribute decision methodology[3] was chosen to integrate several distinct facility characteristics into this priority index. A generalized example of this methodology is shown in Figure 4. Structuring the prioritization methodology helped to identify specific data requirements necessary to establish priorities, and to document the prioritization process.

CRITERIA	REL IMPT WEIGHTS	FACILITY PERFORMANCE	PRIORITY INDEX
OFFSITE	W_1	P_1	W_1P_1
ONSITE	W_2	P_2	W_2P_2
COST	W_3	P_3	W_3P_3
COMPATIBILITY	W_4	P_4	W_4P_4

PRIORITY INDEX $= \Sigma W_i P_i$

FIGURE 4. Priority Model

Implementation of this method first requires definition of relevant criteria for judging priority for D&D action. Second, it is necessary to establish relative importance weights on each of the prioritization criteria. Third, each facility is scored to determine the "performance" of the facility relative to each criterion. Finally, performance data and relative importance weights must be integrated to determine the priority for D&D action.[c/]

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c/ One approach to prioritizing facilities for D&D would involve evaluation of the merits of decommissioning alternative facilities. This would have required, however, predetermination of the D&D mode to be used, thus making the priority of a facility dependent upon the mode selected. An alternative approach was selected which establishes priority for D&D independent of mode, based on existing negative facility characteristics.

Criteria Definition: A comprehensive set of mutually independent criteria are used to estimate the priority for D&D action. It was of importance that these criteria be relevant to the Hanford D&D decision-making process and that the criteria selected could be quantified. To assure relevance, knowledgeable individuals representing the Energy Research and Development Administration plus four Hanford contractors[d/] were assembled to identify suitable criteria. As a result of several meetings of this group, four criteria were developed as a basis for determining the priority for D&D of each facility.

- Potential offsite radiological hazard
- Potential onsite radiological and industrial safety hazards
- Cost of continued maintenance and surveillance
- Compatibility with projected future uses of the site

The first two of these criteria relate to the potential physical, chemical, and radiological hazards within Hanford boundaries and to individuals off-site. These two criteria are intended to identify facilities potentially posing industrial and radiological safety problems and establish them as high priority.

The third criterion is an economic one. Significant long-term economic savings may accrue to ERDA if facilities requiring high-cost

d/ Contractors involved included Atlantic Richfield Hanford Company (ARHCO) (Fuel Separations and Waste Management Operations); United Nuclear Industries (UNI) (Fuel Fabrication and Reactor Operations); Hanford Engineering Development Laboratories (HEDL); and Battelle, Pacific Northwest Laboratories (PNL). ARHCO responsibilities have since been assumed by the Atomics International Division of Rockwell International Corporation.

maintenance and surveillance can be placed in a condition requiring reduced maintenance and surveillance. For this reason, a "high-cost" facility would be higher priority than an otherwise similar facility with relatively low maintenance and surveillance costs.

The fourth criterion is designed to identify facilities which are incompatible with existing or projected future uses of the site. Here, emphasis is placed on physical interference. A facility that is incompatible with existing or projected future uses will be of higher priority for D&D action that if the same facility was compatible with those uses.

Weighting the Criteria: For this application the constant relative importance weights of Figure 4 were replaced with composite utility functions. A four-stage approach was used to estimate these functions. The first stage involved establishing the expected range of performance of each of the four criteria and constructing a hypothetical facility demonstrating the maximum level of performance on each of the four criteria. In the second stage, the relative importance weights of the four criteria were derived assuming the maximum level of performance on each criterion (Figure 5). The third stage involved derivation of four importance functions, reflecting the variation of importance over the expected range of performance for each criterion (Figure 6). Finally, four composite utility functions (Figure 7) were derived by multiplicative combination of the relative importance weights and the importance functions.[4,5] Both the relative importance weights and the importance functions were derived from the group responsible for identification of prioritization criteria, using a modified Delphi approach.[6] Estimates

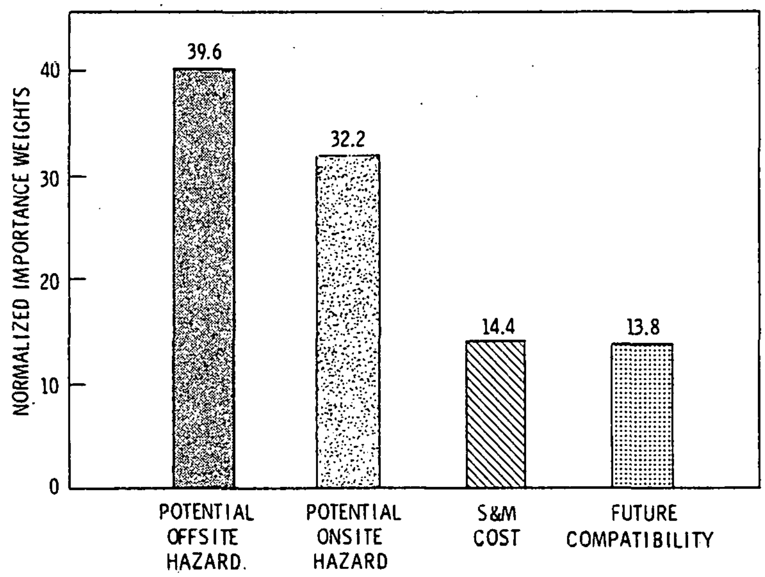

FIGURE 5. Relative Criteria Importance Weights

of criteria performance for each facility are transformed through the composite utility functions to determine a utility value for each of the four criteria. The priority index of the facility is determined by summing the utility of the four criteria.

Performance Estimates: To implement the prioritization system it was necessary to develop estimates of performance of each facility on each criterion. Because of the large number of estimates (600 facilities x 4 criteria = 2400 estimates), it was necessary to develop computer models to aid estimating criteria performance. The computerized data base was used to provide basic information for the criteria performance models and to store the completed estimates. In cases where insufficient data exists to estimate performance by use of models, comparisons with similar facilities were made to estimate criteria performance.

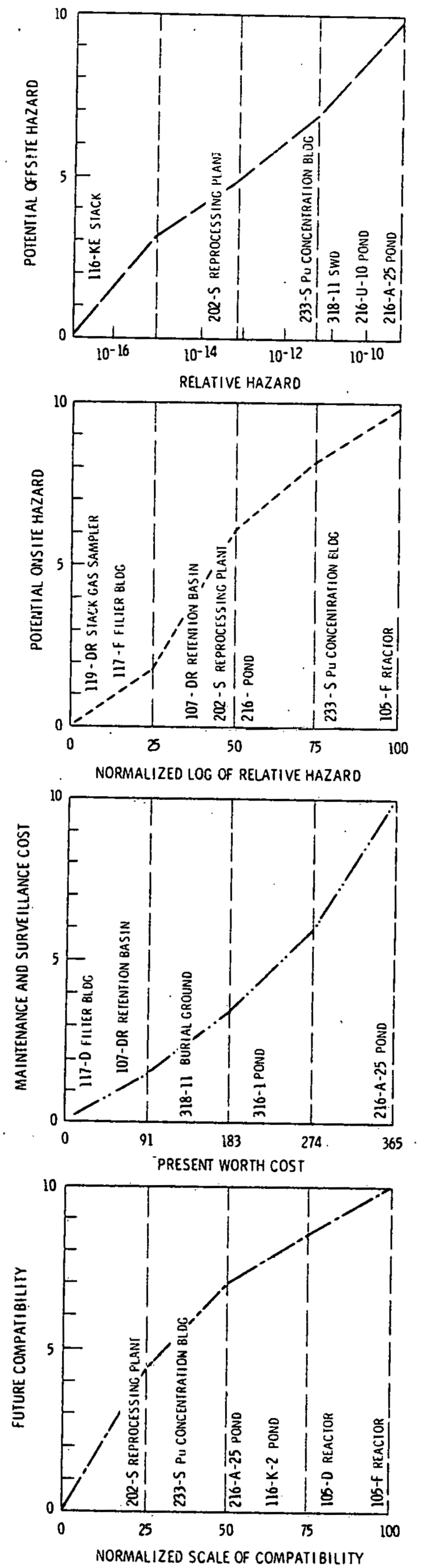

FIGURE 6. Importance Functions

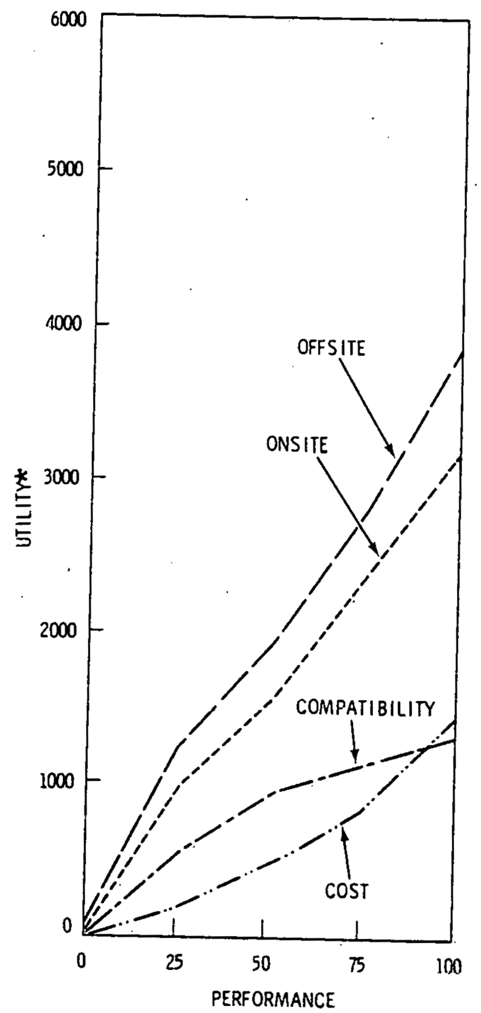

FIGURE 7. Composite Utility Functions

*Summed to give priority index.

Prioritization Results: As of this writing the final set of priorities for D&D at Hanford have not been established. However, a preliminary list of 25 surplus facilities having the highest priority for D&D is shown in Table 1. This listing is representative of the results of the prioritization process using the composite utility functions shown in Figure 7 and the best information currently available on each facility. Normalized performance estimates for each facility on each of the prioritization criteria are also shown in Table 1.

This prioritization methodology permits consistent incorporation of additional facilities as information on those facilities becomes available. It provides a basis for discussion and permits revision of the relative importance weights and subjective estimates if necessary. It also facilitates incorporation of expert opinion in the prioritization process. The resulting prioritization is an organized, documented, and replicable system, supporting the development and analysis of comprehensive D&D plans for Hanford.

Because of limited and imperfect information and the large number of facilities, it is unrealistic to assume that a prioritization methodology such as our could comprehensively examine all factors impacting on an ultimate D&D priority. Consequently, the intent of the prioritization effort is to provide general guidelines for comprehensive D&D planning. Planning for an extensive and long-term enterprise such as D&D at Hanford requires flexibility and willingness to periodically update and revise plans based on improved information and evolving policies. In this sense, planning for D&D at Hanford will be an ongoing process.

TABLE 1. Preliminary Prioritization of 25 Surplus Hanford Facilities[a/]

Rank	Facility	Offsite Hazard	Onsite Hazard	Maint. Cost	Future Compatibility	Priority Index
1	Reactor	56	100	69	89	766
2	Reactor	56	100	69	85	761
3	Reactor	56	80	79	82	705
4	Reactor	56	80	79	82	705
5	TRU Contaminated Building	61	79	74	38	660
6	MFP/TRU Burial Ground	74	18	59	55	505
7	MFP/TRU Burial Ground	79	19	30	55	483
8	MFP/TRU Unplanned Release	81	25	1	35	442
9	MFP/TRU Crib	64	41	1	38	438
10	AP Burial Ground	60	18	48	55	437
11	MFP/TRU Burial Ground	48	22	38	94	436
12	AP Trench	68	21	17	55	431
13	MFP/TRU Burial Ground	82	20	23	7	439
14	MFP/TRU Burial Ground	71	22	7	55	429
15	MFP/TRU Burial Ground	71	22	5	55	426
16	MFP/TRU Unplanned Release	76	24	1	35	423
17	Retention Basin	53	42	13	42	418
18	AP Trench	68	21	10	49	412
19	MFP/TRU Trench	86	17	1	14	412
20	MFP/TRU Unplanned Release	81	14	1	35	409
21	MFP/TRU Burial Ground	56	31	31	31	409
22	Fuel Reprocessing Building	30	44	81	17	405
23	Retention Basin	60	31	13	35	403
24	MFP/TRU Crib	59	41	1	18	392[b/]
25	MFP/TRU Crib	59	41	1	18	390[b/]

a/ Facility classes not yet prioritized include most Fuel Reprocessing Facilities; Laboratories, most Transuranic Facilities; Uranium Facilities; and Waste Management Facilities.

b/ Priority index discrepancy resulting from rounding off criteria scores.

KEY: TRU - Transuranic
MFP - Mixed Fission Product
AP - Activation Product

D&D Mode Selection

A two-stage process is used to select preferred D&D modes for retired facilities. First, the set of feasible D&D modes must be identified for each class of facilities. This eliminates infeasible modes from consideration wherever possible, simplifying the derivation of costs, project durations, waste volume production and other information required to compile and assess D&D plans. Feasible D&D modes were identified by experts familiar with Hanford facilities and experienced in the management of radioactive materials. Feasible modes for each class of facility are shown in Table 2. Secondly, as plans for D&D at Hanford are developed, specific modes for individual facilities will be selected. It is planned to develop a selection methodology similar in concept and general structure to the prioritization methodology to assist in this selection process. Currently, D&D modes are selected based on subjective judgements.

D&D Activity Characterization

Characteristics of D&D activities required for development and assessment of D&D plans include:

- D&D Cost
- Project Duration
- Manpower Requirements
- Occupational Exposure
- Volumes of Transuranic, Fission/Activation Product and Uncontaminated Wastes

TABLE 2. Feasible D&D Modes for Hanford Facility Classes

Facility Class	Mode: Layaway	Prot. Stor.	Entomb.	Dismantle
CONTAMINATED LIQUID DISPOSAL SITES				
Transuranic Cribs & Ponds[a]	X	X	0	X
MFP/TRU Cribs & Ponds[a]	X	X	√[b] [c]	X
Mixed Fission Product Cribs & Ponds	X	X	X[c]	X
Activation Product Cribs[d]	X	X	X[c]	X
Uranium/Thorium Cribs & Ponds	X	X	0	X
CONTAMINATED SOLIDS DISPOSAL SITES				
Transuranic Sites[a]	X	X	0	X
MFP/TRU Sites[a]	X	X	√[b] [c]	X
Mixed Fission Product Sites	X	X	X[c]	X
Activation Product Sites[d]	X	X	X[c]	X
Above Ground Storage	X	0	0	X
Uranium/Thorium Sites	X	X	0	X
FUEL REPROCESSING FACILITIES	X	X	√[b]	X
FUEL STORAGE BASINS	X	X	0	X
REACTOR GAS & EXHAUST AIR FAC.	X	X	0	X
RETENTION BASIN SYSTEMS	X	X	0	X
REACTORS	X	X	0	X
TRANSURANIC FACILITIES	X	X	0	X
URANIUM FACILITIES	X	X	0	X
LABORATORIES	X	X	0	X
WASTE MANAGEMENT FACILITIES	X	X	0	X

a/ Transuranics exceeding release limit of 10 pCi/g.

b/ Entombment is a potentially viable mode if TRU's > 10 pCi.g min are removed first.

c/ Entombment of subsurface facilities may be limited by technical feasibility.

d/ Not including sites containing ^{14}C from reactor sources.

LEGEND:		
	Feasible Mode	X
	Conditionally Feasible Mode	√
	Infeasible Mode	0

These items must be derived for the full set of feasible D&D modes applicable to each facility to allow full planning flexibility. The existance of several feasible D&D modes for each of a large number of facilities mandate the use of mathematical models, where possible, to obtain the needed information. Individual estimates are used only for model calibration, and for very complex or one-of-a-kind facilities.

The general modeling approach identifies sets of similar facilities (facility classes) and selects a representative facility within the facility class for characterizing D&D activities. Conceptual engineering procedures are then prepared for D&D of the representative facility, using each of the feasible modes. Based on these conceptual procedures detailed estimates of the effects of each D&D mode are made. Models are then constructed to predict costs, project duration, waste volume generation and other activity characterization information, based on the characteristics of the facilities in the class. Physical and radiological characteristics for individual facilities are supplied directly off the computer-based information system. Unit costs and other model variables are derived from the detailed estimate for the representative facility. As a result, the completed model is capable of characterizing D&D activities for each facility in the class.

Scenario Development

Potential future scenarios for the Hanford Reservation are now being identified. Scenarios will be based on objectives cited in the Hanford Waste Management Environmental Impact Statement;[2] the Hanford Master Planning Guide,[7] and the Hanford Radioactive Waste Management Plans[8] plus input from Hanford operating contractors and ERDA Richland Operations and Headquarters Officials.

Three scenarios which have been selected for preliminary investigation include the unrestricted use scenario, the current trend scenario, and the minimum level of effort scenario.

Unrestricted Use Scenario: This scenario is based upon achieving unrestricted use of the entire Reservation, except for a central waste repository and sites presently occupied by active or standby facilities. This land use objective would be accomplished by dismantling all presently inactive facilities. Two constraints are being examined: (1) achieving the desired objective within 100 years (a 1980-2080 program) and (2) funding the program at $10,000,000 (constant value dollars) annually.

Current Trend Scenario: This scenario is based on a continuation of current trends in preparation for facility decommissioning. The general objectives would be to achieve unrestricted use for the river shoreline areas and conditional use for the 200 areas (except for a central waste repository and sites of currently active and standby facilities). A 20 year completion period (1980-2000) has been selected for this scenario.

Minimum Level of Effort Scenario: This scenario projects minimum expenditures for D&D in the near future. To achieve this objective, all currently inactive facilities would be placed into layaway. This would require restricted land use of the Reservation for the period encompassed by the program. The anticipated useful lifetime of layaway modifications is 20 years, consequently a 20 year project period (1980-2000) was selected for this scenario. Additional decommissioning action for facilities placed into layaway in year 1980 would be required by the year 2000.

As noted above these three scenarios are strictly preliminary attempts at defining potential goals for future use of the Hanford Reservation, and it is expected that many scenarios will be explored prior to arriving at a final future scenario for Hanford. A computer-based interactive planning system, described in the following section, was designed to rapidly develop plans to achieve alternative future scenarios and to provide an assessment of the effects of these plans.

Integrated Planning and Plan Assessment

Preparation of a single plan to achieve an identified future scenario at Hanford may require selecting a D&D mode for each of the 600 or more facilities from as many as 2400 alternatives (4 potential modes for each facility). These activities must then be scheduled over lengthy time periods (100 years for one case of the unrestricted use scenario).

To reduce this problem to manageable proportions and permit rapid assessment of many alternative D&D plans, an interactive computer-based planning system has been developed. Basic planning assumptions are user-specified. These include: (1) identification of facilities to be decommissioned, (2) estimates of inflation, (3) land use objectives, (4) time or budget constraints, and (5) D&D mode selection. The system then compiles a schedule of D&D activities for the identified facilities over the required time period. Facility ordering is based upon assigned priorities for D&D. Annual budget requirements are computed in both constant and inflated dollars. This process is illustrated in Appendix A for a hypothetical scenario for an example group of facilities.

At present, the system is capable of compiling schedule and budget information, as described above. However, when fully developed the system will be capable of producing a comprehensive assessment of major quantifiable effects of plan implementation. These will include annual costs of maintenance and surveillance, labor requirements, waste volumes, and estimates of occupational exposure. This information will facilitate evaluation of alternative future scenarios at Hanford and plans for achieving these scenarios.

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APPENDIX A

AN EXAMPLE OF THE HANFORD D&D INTERACTIVE PLANNING SYSTEM

AN EXAMPLE APPLICATION OF THE HANFORD D&D INTERACTIVE PLANNING SYSTEM

For purposes of this discussion we will assume that a future scenario has been established for the 100-F Production Reactor Complex requiring achievement of a conditional land use by the year 1990. The Hanford D&D Interactive Planning System (IPS) is used to develop and assess the impact of alternative D&D plans for achieving this scenario.

IPS resides on a Digital Equipment Corporation PDP 11/35. A Vector General video display scope with light pen attachment is provided for information display and interactive input, and a Gould 4800 electrostatic printer for hard-copy output. Overall system control is provided by a decision tree processor[a/] especially created for this system.

A planning session begins with the selection of a subsetting scheme for identifying the facilities on which a plan is to be developed. Three alternatives are available. These are displayed on the screen and the user is asked to pick one with the light pen:

- Geographic Area
- Facility Class
- Complex

For this example the 100-F area is of interest and the facilities in the area can be identified by geographical area. When "Geographical Area" is selected, a map of the Hanford Project is displayed on the

a/ A program that elicits from the user the necessary decisions at each node in a planning decision tree.

Vector General and the user is requested to identify on this map the areas of interest. Using the light pen, the user can outline areas on this map and enlarge them to identify specific contaminated facilities. An enlargement of the 100-F Area is shown in Figure A-1. When the desired planning unit has been delineated, as in Figure A-1, facilities within the unit are entered into the planning system by use of a light pen. After the planning unit has been identified, a report on each facility in the planning unit can be requested (Table A-1).

The next step is to select the desired land use objective for the planning unit. Three alternatives are available.

- Restricted Use
- Conditional Use
- Unrestricted Use

With the light pen we select the conditional land use objective to be consistent with our assumed scenario. Because this land use objective limits the feasible D&D modes for each facility class in the planning unit, a matrix of acceptable modes for D&D of each facility class in the planning unit is then displayed on the screen (Table A-2). The user selects the preferred mode with the light pen. When a preferred mode is selected, IPS changes the dash (-) to an "X".

The next step is to select the desired scheduling constraint. The two scheduling constraints are:

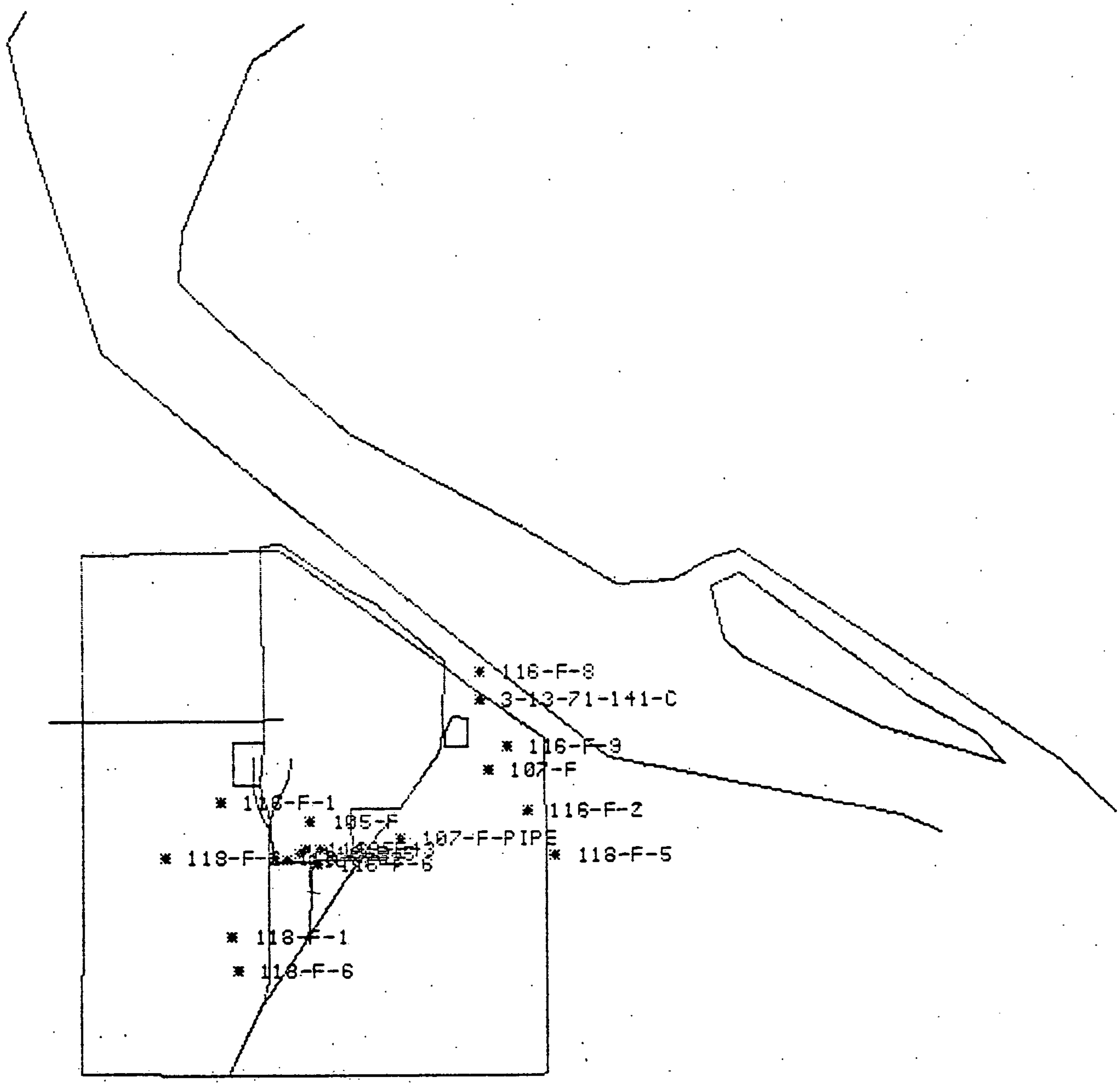


FIGURE A-1. 100-F Area and Associated Facilities Enlarged for Display on the Vector General Video Unit

PRELIMINARY PLAN - CONDITIONAL LAND USE BY 1990 FOR 100-F AREA

PAGE 1

DATE 29-AUG-77

FACILITY DESIGNATOR	FACILITY NAME	COMPLEX	CLASS	STATUS
105-F	PROD REACTOR	F	RCTR	SURPLUS
116-F-1	V TRENCH	F	CRIBS5	SURPLUS
116-F-2	V TRENCH	F	CRIBS5	SURPLUS
116-F-3	V TRENCH	F	CRIBS5	SURPLUS
116-F-4	V CRIB	F	CRIBS5	SURPLUS
116-F-5	V CRIB	F	CRIBS5	SURPLUS
116-F-6	V TRENCH	F	CRIBS5	SURPLUS
3-13-71-141-C	V UNPL RELS	LL	CRIBS5	SURPLUS
107-F	RETENTION BASIN	F	RTNBS	SURPLUS
107-F-PIPE	EFFLUENT LINE	F	RTNBS	SURPLUS
116-F-8	OUTFALL STRUCT	F	RTNBS	SURPLUS
118-F-1	BURIAL GROUND	F	SWD5	SURPLUS
118-F-2	BURIAL GROUND	F	SWD5	SURPLUS
118-F-3	BURIAL GROUND	F	SWD5	SURPLUS
118-F-4	BURIAL PIT	F	SWD5	SURPLUS
118-F-5	BURIAL GROUND	F	SWD2	SURPLUS
118-F-6	BURIAL GROUND	F	SWD5	SURPLUS

TABLE A-1. Listing of All Facilities in the Planning Unit

ACCEPTABLE D&D MODES FOR
CONDITIONAL SURVEILLANCE

		LAYAWAY	PROT-STORAGE	ENTOMB	DISMANTLE	DECON
ACT PRODUCT CRIBS	(7)		X	–	–	
MFP/TRU SWD SITES	(1)		–		X	
ACT PRODUCT SWD SITES	(5)		X	–	–	
RETENTION BSN FACILITIES	(3)		–		X	
REACTORS	(1)		–		X	

(-) D&D Modes Consistent with Conditional Land Use

(X) D&D Modes Selected for this Example (Originally (-))

TABLE A-2. Matrix Display of Acceptable D&D Modes

- Time Constraint, and
- Budget Constraint.

By selecting a time constraint the user can specify the time period for D&D. IPS will then schedule each facility and feed back the required yearly budget to accomplish the plan. If a budget constraint is selected, the user can specify a maximum yearly expenditure for D&D in constant (non-inflated) dollars. IPS will then schedule each facility for D&D and feed back the time required to carry out the D&D plan.

In the example, it was desired to achieve a conditional land use for the 100-F Area by the year 1990. A time constraint is therefore specified. The 100-F D&D program would commence in 1980 and be complete by 1990.

To illustrate the effects of inflation on the D&D plan, the user is asked to provide an estimate of the average rate of inflation over the planning period. For this example we have assumed that inflation will be about 5% per year for the period 1980-1990. Sufficient information is now available to permit a plan for D&D of 100-F Area to be developed.

Three output reports are available from IPS. The first is a GANTT chart (Figure A-2) illustrating the schedule for the proposed D&D program. A second report, shown in Table A-3, is a detailed accounting of the D&D activities at each facility. This report indicates the selected D&D mode, constant and inflated costs, and the scheduled starting and ending dates for D&D of each facility. This report also shows that a budget of $2.6 million/year in constant value (1977) dollars will be required to carry out

PRELIMINARY PLAN - CONDITIONAL LAND USE BY 1990 FOR 100-F AREA

```
                                                       D&D SPAN IN YEARS
                                                       -----------------

                                       1    1    11
                                       9    9    99
   FACILITY          FACILITY          8    8    99
  DESIGNATOR           NAME            0    5    01
 ---------------   ---------------    ------------

 105-F             PROD REACTOR        XXXXXXXX
 107-F             RETENTION BASIN            XXX
 116-F-5           V CRIB                     X
 116-F-4           V CRIB                     X
 116-F-2           V TRENCH                   X
 116-F-1           V TRENCH                   X
 116-F-3           V TRENCH                   X
 116-F-5           V TRENCH                   X
 118-F-5           BURIAL GROUND              XXXX
 118-F-6           BURIAL GROUND              X
 3-13-71-141-C     V UNPL RELS                X
 118-F-1           BURIAL GROUND              X
 118-F-3           BURIAL GROUND              X
 118-F-2           BURIAL GROUND              XX
 107-F-PIPE        EFFLUENT LINE               X
 118-F-4           BURIAL PIT                  X
 116-F-8           OUTFALL STRUCT              X

                                      ------------
                                       1    1    11
                                       9    9    99
                                       8    8    99
                                       0    5    01
```

FIGURE A-2. GANTT Chart of D&D Schedule

PRELIMINARY PLAN - CONDITIONAL LAND USE BY 1990 FOR 100-F AREA

LAND USE OBJECTIVE: CONDITIONAL
SCHEDULE CONSTRAINT: TIME
ANNUAL BUDGET ($1000): 2633.
INFLATION RATE: 0.0500

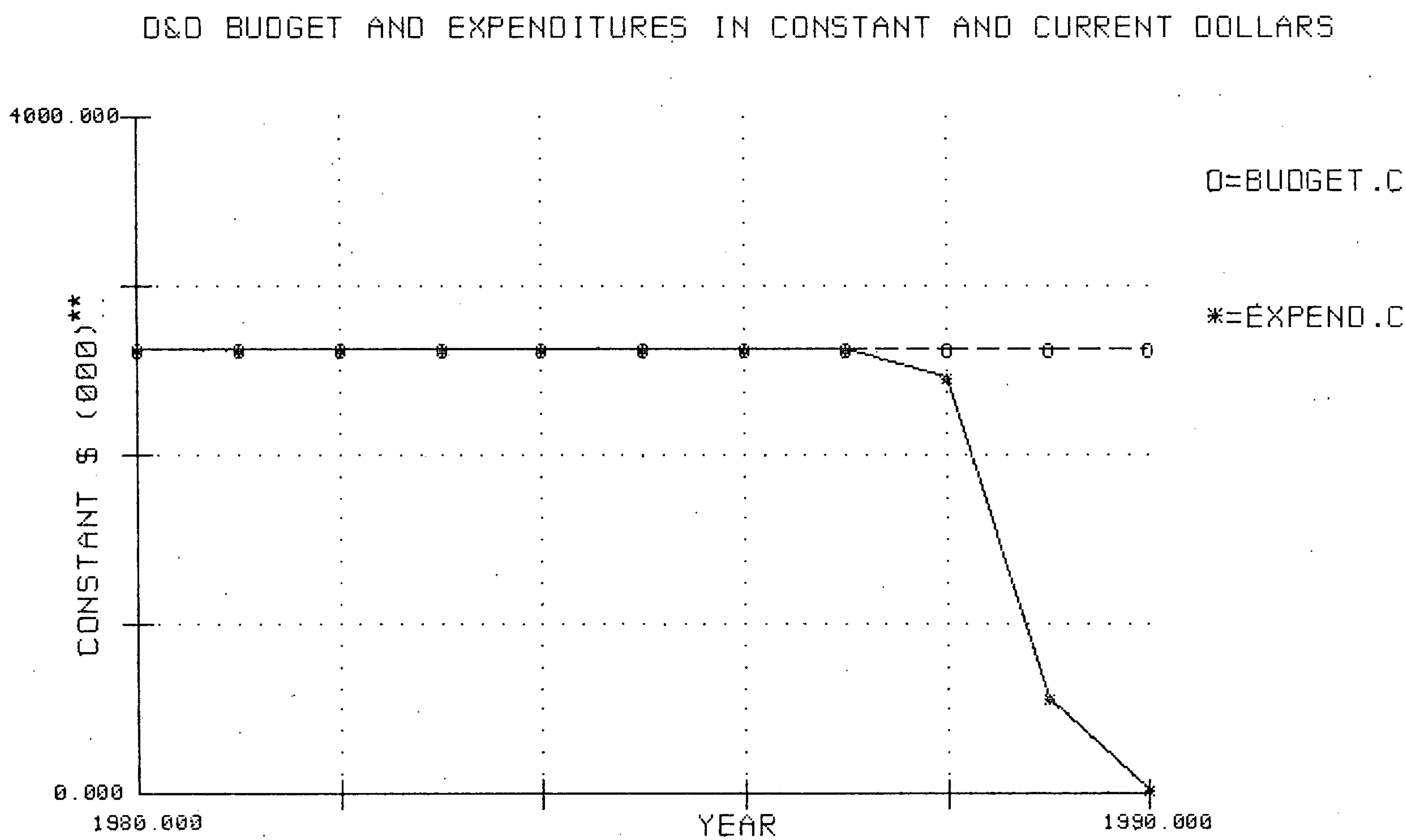
DATE: 29-AUG-77
TIME: 02:52:06

FACILITY NUMBER	FACILITY NAME	STATUS	CLASS	COMPLEX	D&D MODE	PRIORITY	COST CONSTANT $ X 1000	COST CURRENT $ X 1000	SCHEDULE START	SCHEDULE END
105-F	PROD REACTOR	SURPLUS	RCTR	F	DISMANTLE	7474.	18907.	22107.	1980	1987
107-F	RETENTION BASIN	SURPLUS	RTNBS	F	DISMANTLE	4408.	1580.	2333.	1987	1989
116-F-5	V CRIB	SURPLUS	CRIBSS	F	PROT STORAGE	3597.	7.	10.	1987	1987
116-F-4	V CRIB	SURPLUS	CRIBSS	F	PROT STORAGE	3597.	7.	10.	1987	1987
116-F-2	V TRENCH	SURPLUS	CRIBSS	F	PROT STORAGE	3574.	365.	514.	1987	1987
116-F-1	V TRENCH	SURPLUS	CRIBSS	F	PROT STORAGE	3556.	61.	86.	1987	1987
116-F-3	V TRENCH	SURPLUS	CRIBSS	F	PROT STORAGE	3304.	20.	28.	1987	1987
116-F-6	V TRENCH	SURPLUS	CRIBSS	F	PROT STORAGE	3217.	14.	20.	1987	1987
118-F-5	BURIAL GROUND	SURPLUS	SWD2	F	DISMANTLE	2407.	270.	404.	1987	1990
118-F-6	BURIAL GROUND	SURPLUS	SWD5	F	PROT STORAGE	2407.	75.	106.	1987	1987
3-13-71-141-C	V UNPL RELS	SURPLUS	CRIBSS	LL	PROT STORAGE	2396.	18.	25.	1987	1987
118-F-1	BURIAL GROUND	SURPLUS	SWD5	F	PROT STORAGE	1586.	862.	1213.	1987	1987
118-F-3	BURIAL GROUND	SURPLUS	SWD5	F	PROT STORAGE	1417.	101.	142.	1987	1987
118-F-2	BURIAL GROUND	SURPLUS	SWD5	F	PROT STORAGE	1356.	394.	582.	1987	1988
107-F-PIPE	EFFLUENT LINE	SURPLUS	RTNBS	F	DISMANTLE	1278.	786.	1161.	1988	1988
118-F-4	BURIAL PIT	SURPLUS	SWD5	F	PROT STORAGE	858.	75.	111.	1988	1988
116-F-8	OUTFALL STRUCT	SURPLUS	RTNBS	F	DISMANTLE	799.	596.	881.	1988	1988
TOTALS						47233.	24138.	29731.		

TABLE A-3. D&D Activities at Each Facility this plan. The total cost of this effort will be $24.1 million in constant value (1977) dollars and $29.7 million assuming 5% annual inflation.

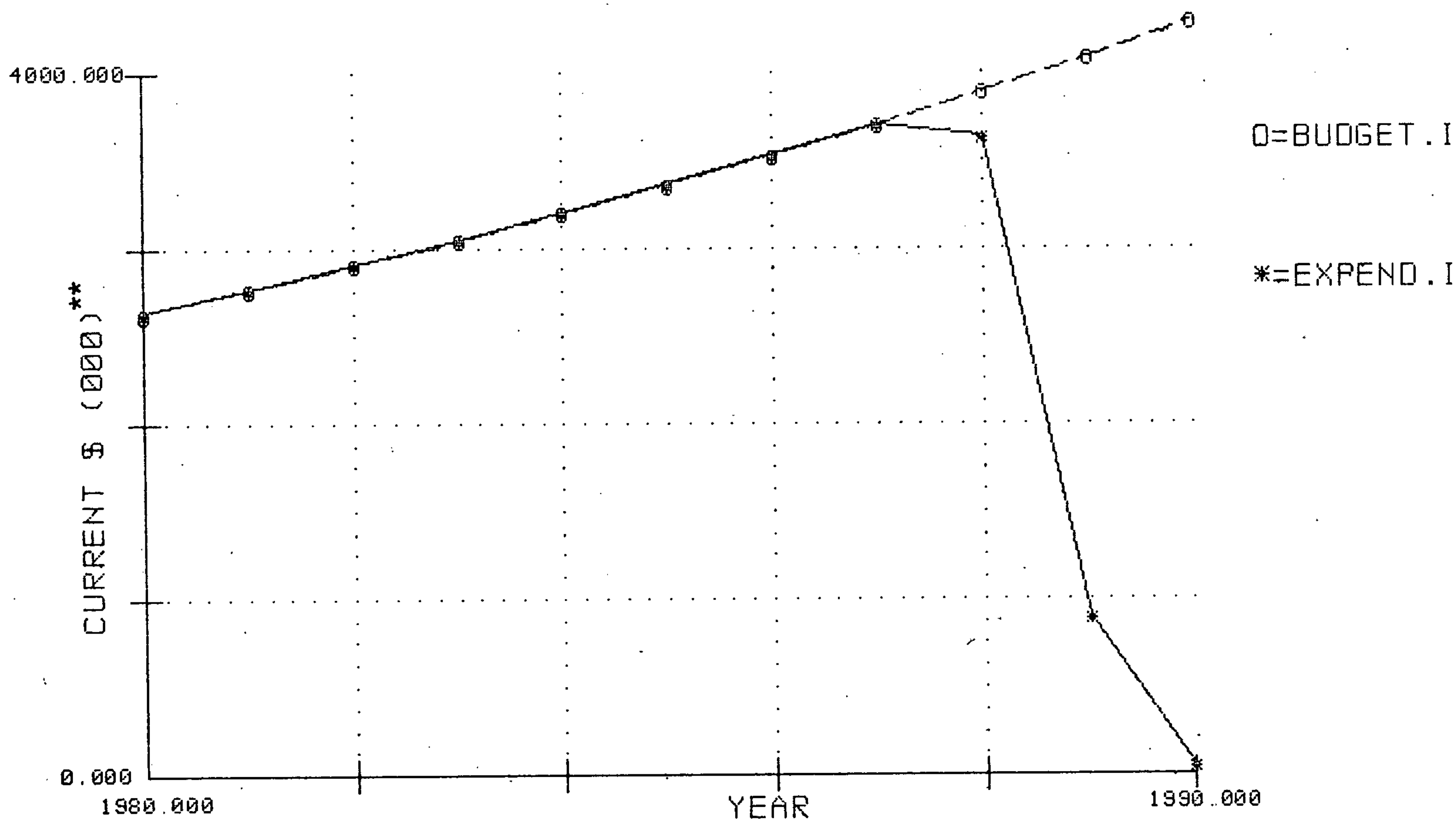
The third output report is shown in Figures A-3A and A-3B. Here, annual expenditures are plotted in both constant and current (inflated) dollars. It is important to note the effects of inflation on the yearly budget requirements. The constant dollar budget is approximately $2.6 million/year while the inflated budget ranges from $2.6 million/year in 1980 to approximately $3.7 million/year in 1987. Expenditures in subsequent years decrease as disposition of the remaining facilities is completed. Since Congressional budget allocations are in current dollars, it is important that D&D planners anticipate possible cost escalations over the long time period needed for D&D.

At present, the system is capable of compiling schedule and budget information, as described above. However, when fully developed the system will be capable of producing a comprehensive assessment of major quantifiable effects of plan implementation. These will include annual costs of maintenance and surveillance, labor requirements, waste volumes, and estimates of occupational exposure. This information will facilitate evaluation of alternative future scenarios at Hanford and plans for achieving these scenarios.



** Thousands of Dollars

FIGURE A-3A. D&D Budget and Expenditures in Constant (1977) Dollars



** Thousands of Dollars

FIGURE A-3B. D&D Budget and Expenditures in Inflated Dollars