1. Introduction

L.F. Morasch, C.T. Kincaid, and R.W. Bryce

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeast Washington State (Figure 1.1). The site occupies approximately 1,517 square kilometers (586 square miles) north of the city of Richland, Washington. About 6% of the land has been disturbed and is actively used. The Columbia River flows eastward through the northern part of the Hanford Site and then turns south, forming part of the eastern boundary. The Yakima River flows near a portion of the southern boundary of the Hanford Site before it joins the Columbia River south of the city of Richland.

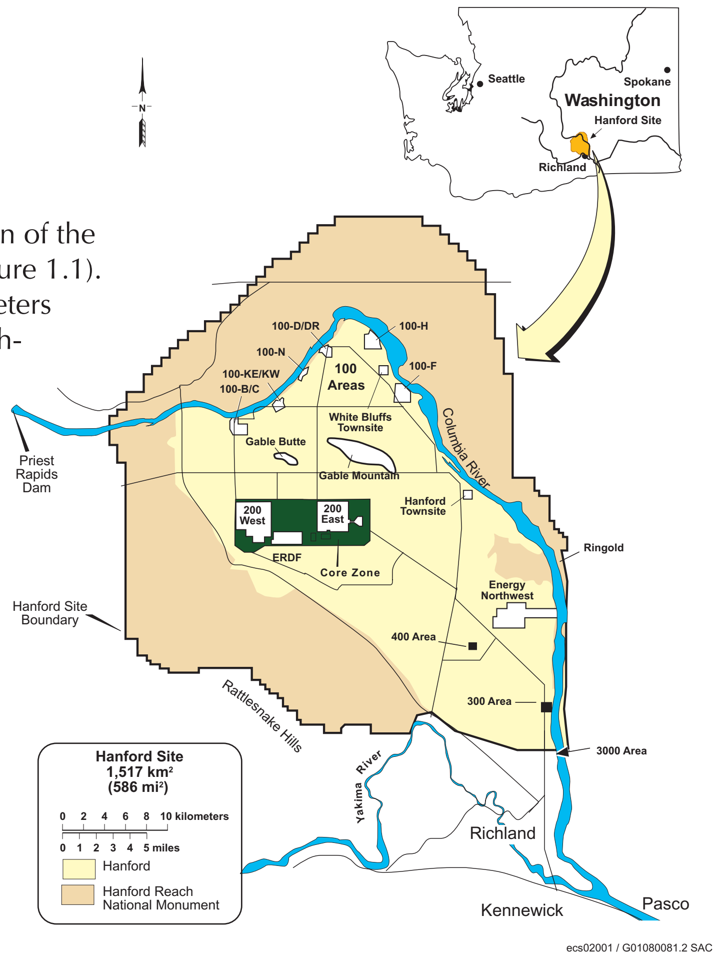

Figure 1.1. *Location of the Hanford Site.*

Hanford is a dry area, known for its sandy soil, basalt ridges, and shrub-steppe vegetation. A description of the Hanford Site can be found in the annual environmental report (Poston et al. 2001). Details about Hanford Site groundwater can be found in the annual monitoring report (Hartman et al. 2002). Unconfined and confined aquifers underlie the Hanford Site. In general, groundwater flows from the higher elevation of Rattlesnake Mountain and the Central Plateau toward the Columbia River. The groundwater is the most likely path of future contaminant transport off the site because current plans call for covers to be placed on waste sites isolating the waste from surface release processes.

The public's input has been a crucial element throughout the development of SAC.

From its creation in 1943 until the late 1980s, the Hanford Site was dedicated to the production of plutonium for national defense and management of the resulting waste. These activities produced about 2,600 waste sites on the Hanford Site. The severity of contamination at individual waste sites ranges from contaminated tumbleweeds to radioactive and chemical waste in underground tanks. The majority of the waste was disposed within the 100, 200, and 300 Areas. However, some waste was disposed of outside these operational areas at:

- Gable Mountain Pond.
- Waste disposal trenches and caissons adjacent to Energy Northwest property.
- 300 North burial ground.
- Environmental Restoration Disposal Facility.

Now, decisions need to be made about how to most efficiently clean up and close the Hanford Site. However, the complexity of the site means that decisions cannot be made on data and intuition alone. A method to consider the collective impact of Hanford's many waste sources on the environment is needed so that decisions on the cleanup of an individual waste site can be made in the context of surrounding sites. Toward this end, the System Assessment Capability (SAC) was developed.

Over the years, assessments have been performed to address a broad range of questions. Until this initial assessment, however, the collective impact of radioactive and chemical waste that will remain at Hanford had not been brought together.

Historically, DOE has used various tools to assess the effects of waste management and cleanup activities on the environment. Assessments have been performed to address a broad range of questions. Some have focused on individual waste sites or waste types, for example the assessment performed to evaluate the future performance of the glass waste form proposed for isolating low activity waste currently in tanks (Mann et. al. 2001). Others have looked at contaminants from a variety of sources. The Hanford Environmental Dose Reconstruction Project estimated human health impacts from past releases to the atmosphere and river (Farris et al. 1994) during operation of Hanford facilities from 1944 until 1972. The Columbia River Comprehensive Impact Assessment (DOE/RL 1998a) examined ecological and human health effects that might result from the current distribution of contaminants in the environment in and near the Columbia River. The composite analysis (Kincaid et al. 1998) performed in 1997 considered the impact of selected radionuclides from approximately 200 waste sites in the 200 Areas.

The collective impact of all of the waste that will remain at Hanford, however, had not yet been brought together to provide an understanding of the cumulative effects of Hanford Site activities on the Central Plateau as well as in the river corridor. SAC was developed to fill this gap and has benefited from the lessons learned in previous assessments.

The task of developing SAC involved assembling software and gathering the data needed to assess the cumulative impact of Hanford's radioactive and chemical waste. Computer codes that were well tested at the Hanford Site were used when possible and new software was written when necessary to simulate the features and processes that affect the release of contaminants into the environment, transport of contaminants through the environment, and the impact those contaminants have on living systems, cultures, and the local economy. The components were organized so that they would simulate the transport and fate of contaminants from their presence in Hanford waste sites, through their release to the vadose zone, to their movement in the groundwater, and into the Columbia River (Figure 1.2). Components such as the groundwater model, the ecological impact component, and the human health component were originally developed and tested for previous Hanford assessments.

The SAC tool used computer codes that were well tested at the Hanford Site and new software when necessary.

The elements of the SAC computational tool include:

Inventory Module – develops an inventory of specific waste disposal and storage locations for the period 1944 to December 2050 based on disposal records, process knowledge, and the results of tank and field samples. December 2050 was used because it had been identified as the time of site closure when the assessment was initiated. Future runs will use the current closure date. This module also identifies the material scheduled for disposal in offsite repositories including high-level waste, transuranic waste, and spent fuel.

Release Module – simulates the annual release of contaminants to the vadose zone from the variety of waste types in the modeled waste sites.

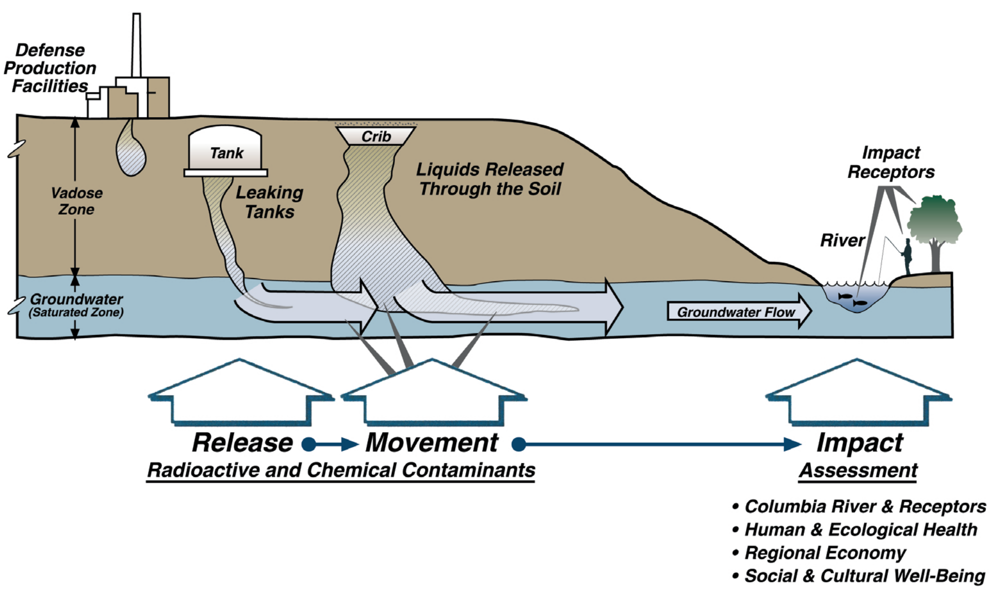

Figure 1.2. *Movement of contamination from waste sites to the Columbia River.*

The pathways included in SAC are the principal ones through which contaminants from past Hanford operations could reach the Columbia River and potentially affect humans and the environment.

This module also simulates future remediation actions that move waste to the Environmental Restoration Disposal Facility.

Vadose Zone Module – simulates the flow and transport of contaminants in the vadose zone, which is the unsaturated sediment between the land surface and the unconfined aquifer.

Groundwater Flow Module – simulates the flow and transport of contaminants in the unconfined aquifer that underlies Hanford using the three-dimensional sitewide groundwater model.

River Module – simulates river flow and contaminant/sediment transport in the Hanford Reach from Vernita Bridge downstream to McNary Dam. This module simulates background concentrations and background plus the Hanford Site contribution to enable an assessment of the Hanford Site incremental impact to the Columbia River and its ecosystem.

Riparian Zone Module – uses river and groundwater information to simulate the concentration of contaminants in seep or spring water and in the wet soil near the edge of the river.

Risk/Impact Module – performs risk/impact analysis in four topical areas: human health, ecological health, economic and cultural impact with the latter two being new impact metrics for Hanford assessments.

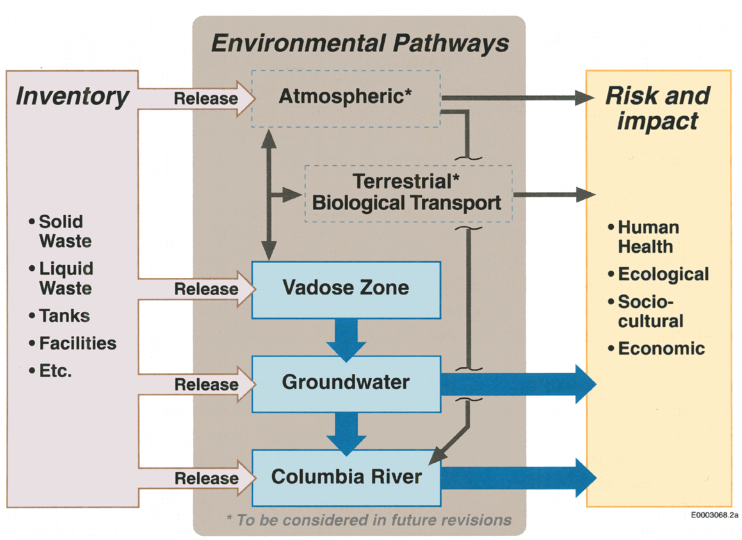

Figure 1.3. *Conceptual model of the System Assessment Capability.*

Each module was assembled so that it could be tested and evaluated independently of the other modules. The inventory, release, and environmental pathway were then linked to test the overall performance of the system.

The conceptual illustration of SAC (Figure 1.3) portrays a linear flow of information. In general, data flows in the initial assessment in the following manner: The Inventory Module provides input to the Release Module, which provides input to the

Vadose Zone, Groundwater, and River Modules. The Vadose Zone Module provides input to the Groundwater Module. Finally, both the Groundwater and River Modules provide input to the Risk/Impact Modules. This version of the SAC conceptual model does not allow feedback between modules.

Each module was assembled so it could be tested and evaluated independently prior to testing of the complete system.

Atmospheric and terrestrial biological transport were not included in this computational tool. These two pathways were omitted because their contribution to contaminant migration in a post-closure setting when waste forms and disposals are stable is assumed to be relatively small. The inclusion of atmospheric and terrestrial biological transport pathways will be considered during the design of future revisions to SAC. These future revisions will occur during fiscal year 2003 and beyond.

The data used in the initial assessment come from a variety of sources, including environmental monitoring activities on the Hanford Site, Hanford historical records, a waste site information database, and other geohydrologic and physical property databases. The remediation actions included in the assessment are based on the collection of disposal and remedial actions identified in the Tri-Party Agreement that are planned to occur as the Hanford Site moves toward closure.

A series of workshops was held in the spring and summer of 1999 with regulators, stakeholders, and Tribal Nation representatives that resulted in the selection of seven radionuclides and three chemical hazards as the first set of contaminants whose transport and fate through the vadose zone, groundwater, and Columbia River would be modeled in this demonstration assessment. Within this set of selected contaminants (Table 1.1) are those that move at different rates through the subsurface environment.

One of the challenges associated with performing an assessment of this nature is understanding how well the results predict what might actually occur. The attributes of the site that affect transport of contaminants, the impact of contaminants on living systems, and the future conditions used in the assessment, as well as many other factors upon which the predictions depend, are not completely understood. The tools and data sets that were assembled for the initial assessment attempted to estimate the uncertainty in the results due to many of these factors. Where uncertainty is not incorporated into the calculations, it will be described along with the quantitative results. More complete information on the uncertainties in the calculations is included in Chapter 11.

An assessment of this nature provides information and insights about the migration and fate of contamination on the Hanford Site. In addition, this

Table 1.1. *Radionuclides and chemicals selected for the initial assessment.*

Radionuclide or Chemical	Why was it Selected?
Carbon tetrachloride	Carbon tetrachloride makes up the largest organic chemical plume underlying the 200 West Area.
Chromium	One of the most significant inorganic groundwater plumes is chromium in the 100 Areas. Chromium comes in two valence forms: III and VI. Chromium III tends to precipitate, is immobile, and is relatively nontoxic to humans and animals. Chromium VI is a carcinogen that is highly mobile in water.
Tritium, Technetium-99	Both are potentially significant dose/risk contributors – tritium for present day and technetium-99 in the future. Both are highly mobile and field data exist for history matching.
Iodine-129, Uranium-238	Both are significant potential dose/risk contributors, and both are generally observed to be moderately mobile in Hanford sediment.
Strontium-90, Cesium-137	Significant quantities of these two fission products were generated and remain at the Hanford Site. They are generally observed to be less mobile than iodine-129 or uranium in the Hanford Site sediment.
Plutonium-239/240	Plutonium-239/240 have long half-lives. Plutonium is a potential health risk if it is mobile, but past studies indicate it is not mobile in Hanford Site sediment.
Total uranium	Uranium was included as a human health risk (for example, it is toxic to the kidney).

The results of cumulative assessments performed with SAC will provide insight into where we need to improve our understanding of the impact of Hanford waste on the environment.

work provides the necessary information to design and build an improved assessment capability and to assist in the prioritization of characterization and science and technology activities. While the effort was limited in scope, the initial assessment identifies:

- The amount and location of contamination in waste sites (inventory).
- Where contaminants are anticipated to move in the future.
- What the impact to human and ecological health, cultures, and the local economy might be.

Cumulative assessments will improve as additional work is performed at Hanford. Scientists are performing field and laboratory experiments to improve parameter values used in assessments and are improving an inventory model of 200 Area operations based on process knowledge and transfer records. Other projects within the DOE Richland Operations Office and the Office of River Protection are collecting field data and performing facility-specific assessments that provide a basis for future cumulative assessments. In turn, the results of the cumulative assessments performed with SAC will provide insight into where to focus additional field characterization or basic science to improve our understanding and reduce our uncertainty in the impact of waste on the environment. This approach ensures that users, including regulators, Tribal Nations, and stakeholders have the opportunity to view results at intermediate stages in the development and influence the design of the evolving capability. And finally, the information and insights from the initial assessment are valuable for setting cleanup priorities.