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4. CONTAMINANT FATE AND TRANSPORT MODELING

4.1 OU 3-14 Conceptual Model

The conceptual model is a statement of understanding past and present site conditions, and it illustrates the physiochemical factors that control the movement of groundwater and associated contaminants in the subsurface. It is a representation against which observations can be compared. The conceptual model represents what is known about the physical setting and the subsurface hydrogeology, interaction of contaminants with the surrounding water and rock, and movement of contaminants from the source to a receptor. The conceptual model is the basis for the numerical model and for developing a list of data gaps resulting in DQOs, which are the basis for future data collection and use.

4.1.1 Physical Setting

INTEC is situated within the boundaries of the INEEL on the Snake River Plain. The elevation of INTEC is approximately 4,917 ft above mean sea level and receives an average of 8.7 in. of precipitation per year. Average snowfall per year is 27.6 in. that tends to accumulate over the winter months and is removed from areas such as roadways, sidewalks, and parking lots and placed in inactive areas until it melts in the spring. A detailed investigation of water infiltration rates was conducted at the Central Facilities Area Landfill by Miller, Hammel, and Hall (1990). Based on soil analysis, precipitation, and evaporation estimates, a range of infiltration rates from 1 to 1.6 in./yr was reported. The infiltration rate at INTEC may be lower in some areas due to impervious ground and drainage ditches and higher in others due to runoff infiltration areas that are fed by drainage from impervious surfaces.

By design, INTEC was constructed on relatively thick, gravely, medium-to-coarse alluvial deposits that allowed the burial of various utility lines, storage tanks, and other process-support infrastructure. The alluvium ranges in thickness from 25 to 60 ft and rests on top of basalt flows that form a topographic basin in the area directly south of the tank farm. The surficial alluvium is underlain by a series of basalt flows and continuous-to-discontinuous sedimentary interbeds. Water that infiltrates downward through the alluvium and underlying transmissive basalts encounters zones of low-permeability interbed material or low-permeability basalt flows, creating local areas of high-moisture content or saturation. If enough recharge water is present, perched water bodies form and exist as long as a source of recharge water is present.

Excavation of the alluvium to the surface of the basalt and backfilling associated with the construction of the subterranean tanks at INTEC likely resulted in areas of higher permeability. If a zone of low-permeable silt and clay was encountered during excavating, it was likely backfilled with the more permeable coarse alluvial material. This disturbed zone around the tank farm may have originally had an increased infiltration rate for liquids moving through the surficial sediments. However, a 20-mil-thick Dupont Polyolefin 3110 membrane was installed over the surface of the tank farm in 1975 and has likely decreased infiltration significantly. The membrane was sandwiched between two 3-in. sand layers, was covered with 3 in. of gravel, and is reportedly repaired each time a cut is made during construction work for maintenance, repairs, or operation. The membrane is approaching its 30-year functional design life, and infiltration rates may be increasing.

The topographic depression (discussed in Subsection 4.1.3.3) in the top of the basalt located south and southwest of the tank farm area could act as a basin, collecting water infiltrating through the alluvium and directing that water toward the depression, provided the basalt immediately beneath the surficial alluvium is relatively impermeable. If this basin feature is controlling the movement of groundwater in the subsurface, infiltration rates south of the tank farm area would increase and subsequently have significant effects on the distribution of water in the perched systems below.

4.1.2 Subsurface Geology of INTEC

The USGS and the DOE have drilled and sampled the INTEC subsurface extensively in an effort to understand and monitor the movement of groundwater and contaminants beneath INTEC. The geologic data acquired during well drilling at INTEC were used to interpret the INTEC subsurface.

To date, a total of 121 wells have been drilled at and around INTEC. Forty-seven of these wells were drilled to depths that penetrate into the SRPA (36 USGS monitoring wells, four production wells, and seven INTEC monitoring wells); 73 of the wells are completed in the vadose zone to monitor the various perched water bodies beneath INTEC; and numerous holes have been drilled at INTEC in the surficial sediments to the top of the basalt. Two of the existing deep aquifer wells and 11 of the shallow perched wells were cored during their installation. The well totals discussed above include the ICDF wells that were completed south of INTEC during October 2002. Five SRPA wells and six perched water wells with up to three completion intervals were installed to monitor groundwater around the ICDF.

A detailed study of borehole data from the INTEC wells was completed during the preparation of the OU-3-13, Group 4 monitoring well and tracer study report (DOE-ID 2003a). The study included the evaluation of available basalt/interbed core; geochemical, paleomagnetic, and K-Ar age date; and petrographic data. Results of the study indicated that several distinct units exist beneath INTEC that can be used as marker units. The marker units included the following:

- Surficial alluvium—exists across the INTEC facility with the contact at the first basalt easily identified.
- Upper basalt flows—the number of basalt flows between 30 and 115 ft bgs ranges from one to four flow units. Up to four units exist beneath the northern portion of INTEC, and a single flow unit exists beneath the southern portion of INTEC. Paleomagnetic data for one of the flows at 100 to 115 ft bgs showed significantly higher inclinations than others in the group, which could potentially be used to better map the flow as new data become available.
- 110-ft interbed—generally encountered between 100 to 120 ft bgs and ranges from 3 to 25 ft thick. This interbed is an important marker unit due to its presence in nearly all of the wells that penetrate deep enough to encounter the unit. The thickest portions of the unit rest under the northeast corner of INTEC.
- High K_2O basalt flow—characterized by a high natural gamma count due to higher potassium content. The flow is found between 110 and 150 ft bgs and is absent from the east and southeast extremes of INTEC. When the flow is encountered, it lies stratigraphically below the 110-ft interbed.
- 140-ft interbed—typically encountered between 140 and 150 ft bgs. This interbed does not appear to be as continuous as the 110-ft interbed, which may be due in part to a lack of data.
- Middle massive basalt—one of the thickest, most massive basalt flows found in the vadose zone beneath INTEC. Typical thickness for this unit is around 100 ft. The base of the unit appears to be relatively flat-lying, while the upper surface has a south to southwest slope. This unit is encountered between 220 and 280 ft bgs.
- 380-ft interbed—a relatively continuous flat-lying layer that varies in thickness from 6 to 27 ft. Depth to the interbed ranges from 320 to 420 ft bgs. This interbed appears to be continuous and relatively thick beneath the INTEC tank farm and thins to the south.
- Low K_2O basalt flow—identified in wells USGS-121 and -123 and was found to have a low percentage by weight K_2O, based on geochemical sampling results. The basalt flow was found at

415 ft bgs in both wells. A similar reading from basalt was found at 384 ft bgs in well ICPP-COR-A-023.

4.1.3 Hydrogeological Setting

Water movement from the tank farm to the SRPA is impeded by less permeable geological features such as dense basalt and interbeds. A number of sources, both natural and artificial, provide water to the subsurface. This water can form perched water bodies and mobilize contaminants. At INTEC, perched water has historically formed two distinct, discontinuous zones—the northern perched water and southern perched water systems.

4.1.3.1 Sources of Perched Water. Perched water bodies exist at various depths within the 450-ft-thick vadose zone beneath INTEC. Several water sources may contribute to moisture movement and development of these perched water bodies. Human-made surface water features in the vicinity of INTEC consist of (1) two former percolation ponds that were used to dispose of water from the service waste system and (2) existing sewage treatment lagoons used to dispose of treated water. In addition, several landscaped areas at INTEC have typically been watered during the summer months, and a network of ditches is used to channel runoff from INTEC after precipitation events. Historically, a portion of precipitation runoff has been channeled to an old gravel pit (CPP-37-1) located in the northeastern portion of the INTEC, near well 37-4.

A major source of recharge has been the two former percolation ponds at INTEC (see lower center portion of Figure 4-1). An average of 1.16 million gal of wastewater was discharged to these percolation ponds each day. Discharges to these ponds ended in August 2002, when the water was diverted to a set of new percolations ponds located approximately 2 mi west of the INTEC facility. A second potential recharge source is the Big Lost River when it flows. The Big Lost River may flow all year or cease to flow entirely for several months or years, depending on the snowpack and precipitation that occurs in a particular year. Combined, these two sources were believed to supply about 90% of the recharge (DOE-ID 1997a, Appendix F). However, the contribution of recharge from the Big Lost River to perched water beneath INTEC is unclear and not well quantified. The sewage treatment lagoons (upper right, Figure 4-1), operational activities, and precipitation account for the remaining recharge. Average annual discharge to the sewage treatment lagoons is 13.9 million gal/yr. As a part of operational losses, steam condensate drains at various locations across INTEC contribute over 1.67 million gal per year to the subsurface. Although the volume of steam condensate is significantly less than the other sources, the drain locations may play an important part in recharging the northern shallow perched water zones. Other operational losses of water supply are variable and not well quantified. These are currently being identified.

4.1.3.2 Perched Water Systems. Perched water beneath INTEC is addressed under OU-3-13 Group 4; however, perched water is recognized as an integral part of the contaminant transport pathway from the tank farm soils to the SRPA and is, therefore, discussed in this subsection. Phase I of the monitoring system installation plan (DOE-ID 2000c) determined that two predominant perched water systems exist beneath INTEC, as is discussed in the monitoring well and tracer study report (DOE-ID 2003a). A diagram of the conceptualized perched water system is presented in Figure 3-39. Other perched systems may exist across the INTEC site as isolated bodies of water caused by a localized source of recharge, such as the intermittent shallow perched water observed near the CPP-603 basins. During past INTEC operations, two distinct perched water systems (northern and southern) were created, the northern perched system being the focus of this model (Figure 4-2). A north-south fence diagram of the subsurface of the INTEC is presented in Figure 4-3.

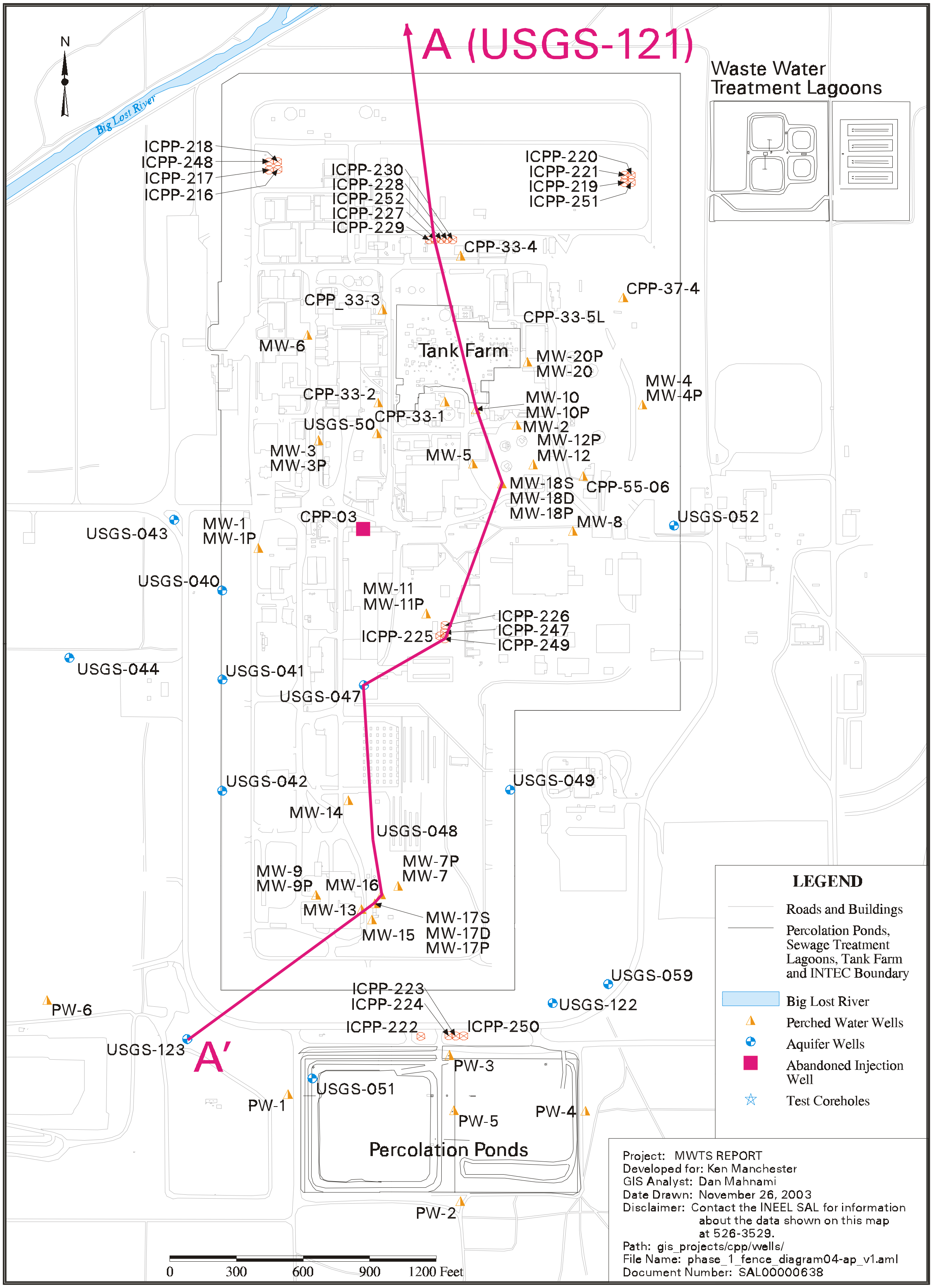

Figure 4-1. INTEC well location map.

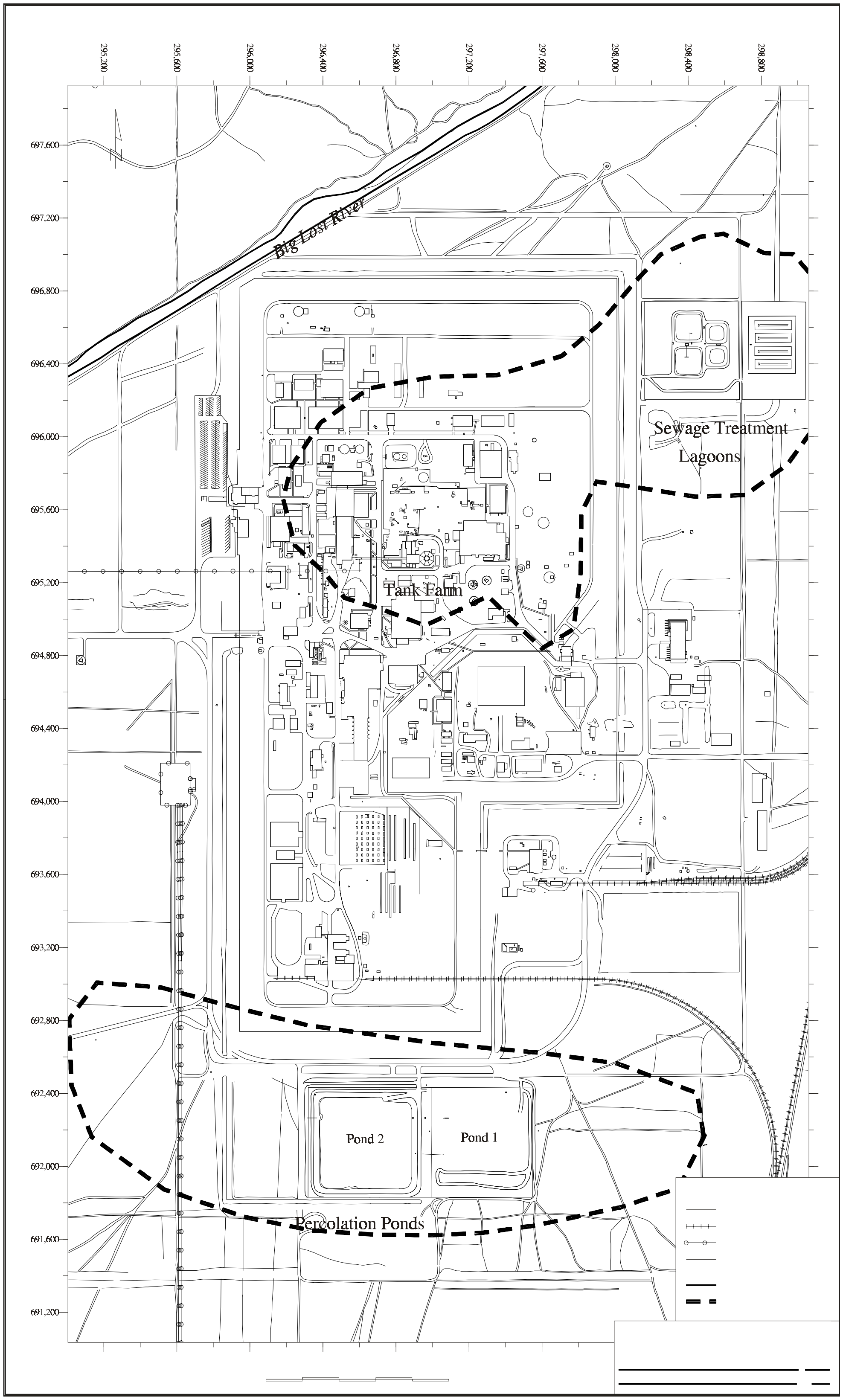

Figure 4-2. Approximate past extent of shallow perched water identified in the WAG 3 RI/FS.

Figure 4-3. North-south fence diagram of INTEC (DOE-ID 2003a).

4.1.3.3 Southern Perched Water System. The southern perched water system was created when disposal of service wastewater began at the former percolation ponds in 1984. With a continuous source of water, the southern perched water system began to form. Water infiltrating downward through the base of the disposal ponds and coarse surficial alluvium subsequently formed perched water on the deeper sedimentary interbeds and impermeable portions of basalt flows in its movement toward the SRPA. Service wastewater was diverted from the percolation ponds in August 2002, and the southern perched water system has mostly drained out. A detailed discussion of the southern perched water system is presented in the monitoring well and tracer test report (DOE 2003a). No further discussion of this perched water system is presented in this conceptual model.

4.1.3.4 Northern Perched Water System. The northern perched water system underlies the tank farm and may affect contaminant transport from the tank farm soils to the SRPA. However, the significance of this perched water system as a pathway to the SRPA is uncertain. The 1997 extent of the northern perched water system is shown in Figure 4-2. The northern perched water system is more complex than the southern perched water system in that recharge sources are not as apparent. The most significant source of recharge comes from the sewage treatment lagoons. Geochemical data suggest numerous waters may combine to create the northern perched water system. Recharge from the Big Lost River is not well understood at this time, but analysis of data on monitoring well water levels verses river flow has not definitively established a link between the northern perched water system and river recharge. Additional monitoring has been implemented to better understand this surface water/perched water connection.

Water traveling through the surficial alluvium from each of the sources may perch on the alluvium/bedrock contact and begin to spread laterally if enough water is available. Based on limited monitoring of this potential perching mechanism, perched water does not appear to accumulate in significant quantities. However, when the Big Lost River flows, this shallow potential perching horizon may play a significant part in moving the rapidly infiltrating water laterally from the Big Lost River channel to the northern perched water area. The alluvium/basalt contact slopes to the southeast from the Big Lost River channel toward a depression in the central part of INTEC (Figure 4-4).

Water making its way past the alluvium/basalt contact continues down vertically with minor lateral spreading until this water encounters the 110-ft interbed, where vertical travel is impeded. The northern shallow perched water system then moves laterally and downward to create discontinuous perched zones associated with the 110- and 140-ft interbeds and neighboring basalt flows (Figures 4-5 through 4-7). Radiological contamination in the perched water is typically higher above the 110-ft interbed and lower in the perched zone associated with the 140-ft interbed. A significant fraction of perched water on the east side of the tank farm is believed to be originating from precipitation infiltration and/or from leaking process pipes, based on high nitrate levels, ratios of common cations and anions, and radiological contamination. The shallow perched water on the west side of the tank farm has lower nitrate concentrations, suggesting dilution of the perched water from a source having lower nitrate concentrations. One such source may be the lawn irrigation that takes place seasonally near MW-6 (Figure 4-1). Shallow perched water in the vicinity of the sewage treatment lagoons generally has higher chloride concentrations than the shallow perched water found in the tank farm area. Nitrate concentrations are elevated but not as elevated as some of the shallow perched water near the tank farm.

The extent of the northern shallow perched water remains limited mainly to areas around the tank farm and sewage treatment lagoons. The shallow perched water in this area is discontinuous and may be intermittent, depending on the regularity and output of the different recharge sources. Shallow perched water is not observed in the TF-SP well completed from 145 to 150 ft bgs northwest of well 33-4, which