Crude-oil spill research project near Bemidji, Minnesota—Bibliography, 1984-1994

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CONVERSION FACTORS, ABBREVIATIONS AND VERTICAL DATUM

Multiply	By	To obtain
liter (L)	0.2642	gallon
meter (m)	3.2808	foot
kilometer (km)	0.6215	mile

Land-surface datum: In this report "land-surface datum" refers to altitude, in meters, above the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abstract

The U.S. Geological Survey began a research project at the site of a crude oil spill near Bemidji, Minnesota in 1983. The project is part of the U.S. Geological Survey's Toxic Substances Hydrology Program. The objectives of research at the site are to obtain an understanding of the mobilization, transport, and fate of petroleum derivatives in the shallow subsurface and to use this understanding to develop predictive models of contaminant behavior. This report presents a bibliography of scientific papers on research at the site that have been published from 1984 to early 1994. Research results have been published in scientific journals, conference proceedings, U.S. Geological Survey Reports, and academic theses.

Introduction

Ground-water contamination by toxic organic, petroleum-based liquids is a widespread problem. These liquids may enter the subsurface as a consequence of spills on the land surface, leakage from underground storage and disposal containers, and other discharges. The volume of the subsurface contaminated may be larger than the original volume of the organic liquid source because of dissolution and transport by ground water, and vapor phase movement through the unsaturated zone. Most organic liquids are subject to some attenuation by chemical and biological transformations; some are degraded completely by microbial processes and others can persist in the environment indefinitely. A better understanding of the behavior of organic liquids in the subsurface is needed to design effective remedial action at contaminated sites.

On August 20, 1979 approximately 16 kilometers northwest of Bemidji, Minnesota, the land surface and shallow subsurface were contaminated when a crude-oil pipeline burst, spilling 1,700,000 L (liters) of crude oil onto a glacial outwash aquifer (fig. 1). After cleanup efforts were completed 400,000 L of crude oil remained. The site was selected for study by the Office of Hazardous Waste Hydrology of the U.S. Geological Survey in 1982. Research began at the site in 1983. Characteristics of the site that make it suitable for long-term, interdisciplinary study include the following: (1) the introduction of a source of uniform composition at a known place and time, (2) the absence of other sources of contaminants, (3) a simple hydrogeologic setting that is susceptible to ground-water contamination and is representative of many other toxic waste sites, (4) the presence of three fluid phases (oil, water, and air), (5) the low potential for harmful effects to humans owing to the remoteness of the area and the sparse population, (6) the absence of human-induced hydraulic stresses such as pumping wells and irrigation, and (7) the low toxicity of crude oil compared to other hazardous wastes.

Purpose and Scope

The purpose of this report is to provide a bibliography of the published reports, journal articles, abstracts, and unpublished academic theses that document the research conducted at the site. Research is conducted by a coordinated effort of researchers from the National Research Program (NRP), Districts of the Water Resources Division (WRD), and Geologic Division (GD) of the USGS, and several academic institutions. The scope of the project was to obtain a more detailed understanding of the mobilization, transport, and fate of petroleum in both the saturated and unsaturated zones, to better understand the physical, chemical, and biological processes that control contaminant behavior, and to use this understanding to estimate the future behavior of the contaminants. This understanding will benefit efforts to design remediation at other sites with similar problems.

Description of the Site

The oil spill occurred in the recharge area of a local flow system that discharges to a small lake 400 m (meters) downgradient from the pipeline. The land surface is formed by pitted and dissected glacial outwash that is 5 to 10 m thick and underlain by other stratified glacial deposits that differ considerably in texture and origin. At a depth of about 25 m, a regionally persistent and uniform till occurs. The water table ranges from near land surface to about 11 m below the land surface (Smith and Hult, 1993). Two hundred and forty-six wells and test holes have been installed at the Bemidji Research site. Crude oil, water, soil, and vapor samples have been collected and analyzed.

History of Investigations

Field work by the U.S. Geological Survey began in May, 1983, approximately four years after the spill occurred. Information about the spill was obtained from the Lakehead Pipeline Company and the Minnesota Pollution Control Agency. Data collected immediately after the spill (August through September, 1979) were

compiled and interpreted by Pfannkuch (1979) and summarized by Hult (1984b).

Some of the crude oil infiltrated the ground and percolated to the water table. Some petroleum compounds and degradation products have been dissolved by ground water and transported downgradient. Volatile constituents have diffused through the unsaturated zone. By 1992, liquid petroleum had moved as a separate fluid phase about 30 m in the direction of ground-water flow, constituents dissolved in the ground water had moved at least 200 m, and vapors in the unsaturated zone had moved horizontally about 100 m (Hult, 1991).

Spatial differences in the physical properties and composition of the oil have developed owing to alteration of the originally uniform source. The oil is selectively losing soluble and volatile compounds through dissolution and vaporization. Annual oil-mass loss rates of the crude oil source at different locations range from 0 to 1.25 percent and total accumulated losses from the original oil mass are as much as 11 percent (Landon and Hult, 1991). Most of the petroleum derivatives moving as solutes and vapors are being degraded by biologically mediated processes to carbon dioxide, water, and methane (Baedecker and Cozzarelli, 1991). The aquifer is being altered through dissolution and redeposition of silicate materials (Bennett, 1989).

The U.S. Geological Survey Toxic Substances Hydrology Program has held five technical meetings since 1984 with plenary sessions at which the status of research at the site was summarized. Results of the project have been published in proceedings of these technical meetings (Hult, 1984a; Franks, 1987; Ragone, 1988; Mallard and Ragone, 1989; Mallard and Aronson, 1991; Morganwalp and Aronson, in press), in proceedings of other conferences, and in scientific journals. Smith and Hult (1993) present location and altitude data for selected features at the research site, water and oil level records from selected observation wells, and geologic information from 45 test holes collected from 1983 through 1991.

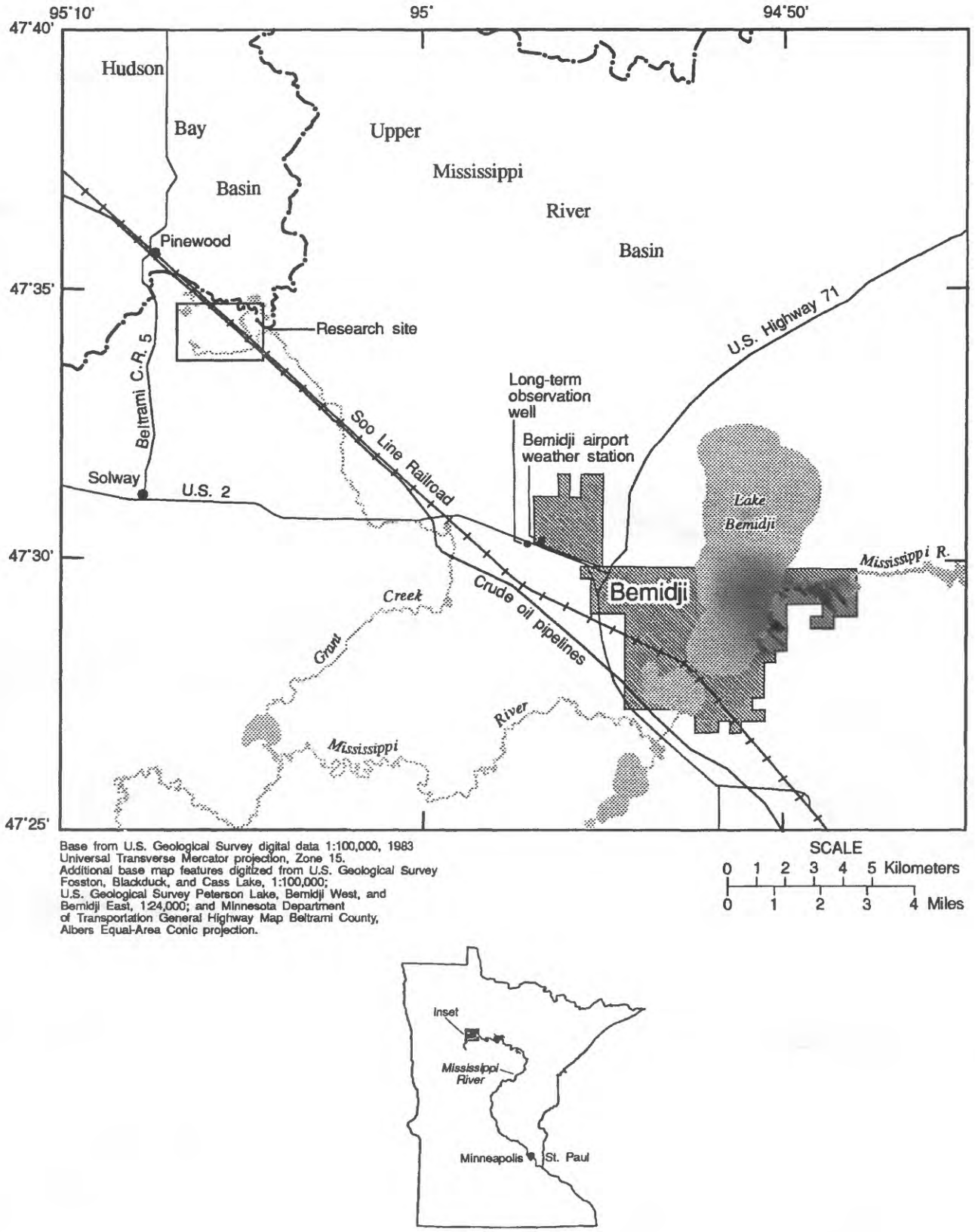

Figure 1. -- Location of research site near Bemidji, Minnesota

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