Appendix H—Better Brite Site Data

The hydrogeologic characterization of the Better Brite site is based on data collected and interpreted by the USGS and USEPA. A total of 16 investigative methods were used at borehole BN-483 (fig. 38) to develop the hydrogeologic framework for the Better Brite site. Detailed discussion of the investigation is presented in Batten and others (1999).

Previous investigations

Most of the previous geologic characterizations on the Galena-Platteville dolomite were completed as a result of other projects in the area. Hydrologic characterization of Brown County by Krohelski (1986) and Walker and others (1998) were used as the basis for describing the geologic and hydrologic frameworks. The site investigations were limited to the surficial deposits overlying the Galena-Platteville aquifer (Simon Hydro-Search, Inc., 1992).

Lithologic logs

Fractured dolomite was observed during lithologic logging of borehole BN-483 in the upper part of the bedrock deposits from about 566 to 576.5 FANGVD29 (depth of 24.5 to 35 ft) (table H1). Fractures were infilled with silt and clay material. Lithologic logging was not done below 566 FANGVD29, where core was available from this interval.

Core analysis

Continuous 3-in core was cut from the bottom of the casing at 566 FANGVD29 to the end of the borehole at 432 FANGVD29 (depth of 169 ft). A total of 126 ft of core was recovered from the 134-ft cored interval. Approximately 6 ft of core was not recovered from the fractured dolomite between 557 and 576 FANGVD29 (depth of 35-44 ft) and 2 ft of soft sandstone was not recovered from the interval between 432 and 436 FANGVD29 (depth of 165-169 ft).

A lithologic description and stratigraphic interpretation of the rock core from borehole BN-483 was completed by Michael Sargent and Zakaria Lasemi (Illinois State Geological Survey, written commun., 1994)(table H1). The ISGS found the units encountered in borehole BN-483 to be difficult to correlate with those collected from other locations in southern Wisconsin and Illinois. However, on the basis of their lithologic description, ISGS identifies the Galena Dolomite from about 545 to 576.5 FANGVD29 (depth of 24.5-55.8 ft), the Decorah Formation from about 488 to 545 FANGVD29 (depth of 55.8-112.8 ft), and the Platteville Formation from about 441 to 448 FANGVD29 (depth of 113-160 ft). Sandstone of the Glenwood Formation is present below the Platteville Formation to about 433 FANGVD29 (depth of about 169 ft). Choi (1998) completed a study correlating approximately 60 rock cores and outcrops in east-central and southern Wisconsin including the core from borehole BN-483. Choi interprets the Decorah Formation as being absent in borehole BN-483, with the Galena Dolomite unconformably overlying the Platteville Dolomite at about 488 FANGVD29 (depth of about 113 ft).

Among the samples from the Sinnipee Group, porosity values in samples collected from the core ranged from 1.8 percent near the base of the Galena Dolomite to 7.7 percent in a sample from the Platteville Formation. The mean porosity of two Decorah Formation samples is about 6.8 percent compared to a mean of 3.5 percent for seven Galena Dolomite and Platteville Formation samples. The low porosity of the Galena Dolomite and Platteville Formation likely is explained by the massive, crystalline nature of the dolomites in these units at this borehole.

There appears to be no appreciable difference in either the bulk or grain densities in samples of the Sinnipee Group. Grain density ranges from 2.67 to 2.87 g/cm^3, the higher of which are typical values for pure dolomite (Hurlbut and Klein, 1977, p 308).

Geophysical logs

Borehole Camera

A borehole-camera log was completed December 20, 1993, with a 2-in., black-and-white camera. A wash out of the dolomite below the surface casing from 556 to 565 FANGVD29 (depth of 36 to 45 ft) was identified. This interval also is where no core was recovered, indicating that the dolomite is weathered. Borehole-camera logging also identified the presence of layering within the Galena-Platteville dolomite.

Caliper

The three-arm caliper log indicated an enlarged borehole from the bottom of the surface casing to approximately 557 FANGVD29 (depth of 44 ft). This result is consistent with the core and camera logs, which indicated removal of weathered and fractured dolomite

from this interval (fig. 39). The caliper log indicated competent bedrock through the rest of the borehole.

Natural Gamma

A sharp decrease in signal response on the natural-gamma log occurs below about 485 FANGVD29 (depth of about 116 ft). This transition is within 2 ft of the altitude of the contact between the Decorah Formation and Platteville Dolomite identified from the core analysis. The sharp decrease in signal response on the natural-gamma log represents the less argillaceous nature of the Platteville Dolomite compared to the Decorah Formation and the Galena Dolomite.

Single-Point Resistivity and Resistivity

A sharp increase in resistance values (SPR) and resistivity (normal resistivity) values occurs at 485 FANGVD29 (fig. 39). This increase is in response to the lower clay content in the dolomite of the Platteville Formation relative to the Galena Dolomite and the Decorah Formation.

Neutron

The neutron log indicates lower and less variable porosity in the Platteville Formation than in the overlying Decorah Formation and perhaps the Galena Dolomite (fig. 39). These patterns generally are consistent with the results of the porosity determined from the core analysis, which indicate increased porosity associated with the Decorah Formation, but may be inconsistent with the porosity data indicating similar values in the Galena Dolomite and the Platteville Formation. The lower part of the wash out from about 556 to 565 FANGVD29 corresponds to an interval of elevated log response and appears to be a response to the enlarged borehole at this interval.

Acoustic Televiewer

The major feature identified with the televiewer log is the wash out from the bottom of the casing to about 557 FANGVD29 (fig. 39). This interval corresponds to an area of weathered and fractured dolomite identified with the caliper and camera logs. The acoustic-televiewer log also shows some thin horizontal features from

Table H1. Lithologic description and stratigraphic interpretation by the Illinois State Geological Survey of core and drill cuttings from borehole BN-483 near the Better Brite Superfund Site, De Pere, Wis. (modified from Michael L. Sargent and Zakaria Lasemi, Illinois State Geological Survey, written commun., 1994)

Depth below land surface (feet)	Lithologic description of core and drill cuttings
0 - 24.4	Undifferentiated glacial deposits and soil, mostly red-brown sandy clay with trace of gravel.
24.5 - 41.5	Galena Dolomite; gray, very weathered, fractured (24.5-35 based on drill cuttings, 35-41.5 no return in core barrel)
41.6 - 55.8	Galena Dolomite; light olive gray to light brownish gray to pale yellow brown, occassional argillaceous shale or calcarenite interbeds, slightly fossiliferous becoming more fossiliferous in lower 7 feet, fossils include echinoderm and trilobite fragments and possibly bryozoans and brachiopods, predominant shale zone from 51.2 to 51.4 feet, quite fractured from 41.8 to 43.5 feet.
55.9 - 112.8	Decorah Formation; Interbedded dolomite and shale; section can be broken up into seven (possibly eight) cycles in which basal rock is pure dolomite that becomes progressively more argillaceous upward. Each cycle terminates at a hardground. Cycle thicknesses range from about 3 to 24 feet. Dolomites are mostly pinkish gray or very light brownish to medium dark gray and are finely crystalline. Some paper-thin shaley partings are present in the purer dolomite zones. A few small pin-head to about 0.5-inch size vugs are present throughout. Shale rocks are mostly dark grayish olive green. Entire formation is slightly fossiliferous but generally more fossiliferous in shaley zones. Bryozoans are most common recognizable fossil, but some zones contain abundant trilobite and brachiopod debris. Hardground surfaces are dark gray to dusky brown and are pyritic. Some of this dark colorization is probably phosphatization.
112.9 - 142.5	Platteville Formation (upper unit); very dense, fine-grained, mottled pinkish-gray to light gray; occassional paper-thin wavy dark shaley partings and olive-gray argillaceous streaks. Slightly cherty with several 0.5 to 1.5 inch thick chert beds and occassional scattered chert nodules; occasional small vugs throughout this zone; sublithographic calcarenitic beds (somewhat fossiliferous) from 116.8 to 118.9 feet. Upper unit includes rocks of the Quimbys Mill, Nachusa, and Grand Detour Formations in Illinois, but cannot be readily subdivided here using either Illinois or Wisconsin nomenclature.
142.6 - 159.8	Platteville Formation (lower unit); very fine-grained to lithographic; light brownish-gray matrix speckled with medium-gray to dark olive-gray, paper-thin wavy shale partings. This lower unit shows six sedimentation cycles ranging from about 2- to 5-feet thick; each cycle has a burrowed pure dolomite at it's base and becomes more argillaceous dolomite with wavy shale and argillaceous beds up to about 1-inch thick toward the top; very few pin-head to 0.5 inch vugs throughout this lower unit. The lower unit resembles only the Pecatonica Formation of Illinois and southern Wisconsin and cannot be subdivided. The contact with the underlying Glenwood Formation is sharp and at a hardground.
159.9 - 166.8	Ancell Group - Glenwood Formation; quartz sandstone; pale-brown, medium-grained, dolomite cemented; 0.1-inch thick hematite accumulation at 159.9 to 160 feet; pale-red to grayish-red sandstone at 160.0 to 161.8 feet.; mostly medium-dark gray to very light gray medium-grained sandstone from 161.8 to 166.8 feet; poorly cemented to friable below 162.6 feet.

about 459 to 551 FANGVD29. Review of the geophysical logs and inspection of the core indicates that these are thin (less than 1 in) partings of soft shale or clay that separate massive dolomite units above and below.

Hydrology

Ground-water flow at the Better Brite site was characterized by use of water-level measurements, geophysical logs, slug tests, and the location of contaminants.

Water-level measurements

Single water-level measurements were collected in test intervals isolated with a packer assembly and in two monitoring wells installed in borehole BH-483. Because borehole BN-483 is the only data point in the Galena-Platteville aquifer at the Better Brite site, vertical differences in water levels in this borehole are the only water-level data available for analysis.

Single Water-Level Measurements—Packers

Water levels were measured in test intervals isolated with a packer assembly in borehole BN-483 (table H2). Some of the test intervals were not fully saturated, indicating that equilibrium water levels had not been reached because of unsaturated conditions or the slow recovery rates resulting from the low permeability in the Galena-Platteville aquifer.

The static water level measured in the wash-out zone below the bottom of the casing (packed interval A) was about 585.3 FANGVD29. The static water level measured in the interval from about 441 FANGVD29 (depth of 160 ft) to the bottom of the borehole (packed interval H) was 452.0 FANGVD29 or possibly lower. The lower static water level in the St. Peter aquifer (indicated by packed interval H) relative to the Galena-Platteville aquifer is the result of municipal pumpage from the St. Peter aquifer (Krohelski, 1986). Comparison of static water levels in packed intervals A and H translates into a total drop in water levels of more than 130 ft across the Galena-Platteville aquifer at the Better Brite site, indicating that the aquifer has a low vertical hydraulic conductivity and may be partly unsaturated.

Single Water-Level Measurements—Monitoring Wells

Water levels were measured from monitoring wells installed in borehole BN-483 on October 17, 1994, by Simon Hydro-Search, the contractor to USEPA working on the site remediation. Because the elevation of the measuring point for the constructed monitoring wells is unknown, water levels are presented in feet below land surface (bls). The deep bedrock well had a depth to water of 119.65 ft bls and a measured water column of less than 0.5 ft, indicating that the deeper part of the Galena-Platteville may be unsaturated at the Better Brite site. The shallow bedrock well, screened approximately 81 ft bls, had a depth to water of 55.97 ft bls. The water table was about 9.70 ft bls in this area. All of these water levels indicate large downward vertical gradients. However, with only one round of water levels collected, the temporal/seasonal variations in water levels remain unknown.

Table H2. Measured static water levels (hydraulic heads) in borehole BN-483 near the Better Brite Superfund Site, De Pere, Wis.

Packed interval	Packed interval (feet below land surface)	Stratigraphic unit	Date of test (month-day-year)	Static water level(feet above National Geodetic Vertical Datum of 1929)
A	[1]35-52	Galena Dolomite	11-18-93	585.28
B	50-70	Galena Dolomite and Decorah Formation	11-17-93	583.56
C	66-86	Decorah Formation	11-23-93	583.68
D	72-92	Decorah Formation	11-18-93	[2] 587.03
E	86-106	Decorah Formation	11-23-93	586.67
F	112-132	Platteville Formation	11-19-93	[2] 586.56
G	131-151	Platteville Formation	11-22-93	[2] 501.19
H	[3]160-169	Glenwood Formation	11-17-93	[2] 452.02

[1] Packed interval is less than 20 feet, extending from the bottom of the casing to 52 feet.

[2] Water level had not reached equilibrium and reported level probably is higher than the actual level.

[3] Packed interval is less than 20 feet, extending from 160 feet to total depth of the test well.

Geophysical logs

Fluid temperature, resistivity, and SP logs were run in borehole BN-483.

Fluid temperature

Temperature measurements (fig. 39) show a slight increase consistent with ground water entering the borehole from the wash out between the bottom of the casing and about 555 FANGVD29 (depth of 46 ft). The temperature log also shows changes that are consistent with flow into the St. Peter aquifer below about 451 FANGVD29 (depth of 150 ft) (Fred Paillet, U.S. Geological Survey, written commun., 1999).

Fluid resistivity

Fluid-resistivity measurements (fig. 39) also indicate that ground water is entering the borehole from the wash out between the bottom of the casing and about 555 FANGVD29 (depth of 46 ft). The fluid-resistivity log indicated no change over the remainder of the borehole.

Spontaneous potential

The slight decrease in SP readings at about 485 FANGVD29 is indicative of the major lithologic and stratigraphic change at this depth (fig. 39). The log appears to be responding to the lithologic change at this altitude, rather than to a permeable feature. The change in SP within the cased interval of the borehole at about 565-570 FANGVD29 may be related to the effects of flow from the underlying wash out.

Aquifer tests

Slug tests were completed at this site to estimate the Kh of the aquifer.

Slug tests

Slug tests were attempted at eight test intervals isolated with a packer assembly within borehole BN-483 (table H3). The test intervals generally were 20 ft in length. Four of the eight intervals were slug tested successfully, the remaining four intervals could not be slug tested because water levels did not reach hydrostatic equilibrium within 2-12 hours. The values determined for the three intervals of the unweathered dolomite range from about 0.0005 to 0.0034 ft/d. These low values are

Table H3. Horizontal hydraulic conductivity of selected depth intervals in borehole BN-483 near the Better Brite Site, De Pere, Wis., estimated from displacement/recovery (slug) tests

[--, no data]

Test interval (feet below land surface)	Horizontal hydraulic conductivity (feet per day)	Comments
35-52 [1]	2.0×10^{-1}	Fractured and weathered dolomite from 35 to 44 feet. Hydraulic conductivity of this zone probably considerably higher than 0.2 feet per day.
50-70	--	No measurable response to slug injection. Water level recovered only 0.19 ft over a period of about 14 hours after pumping this borehole interval dry.
66-86	5.0×10^{-4}	Low-quality data in first 20 seconds of slug test.
72-92	--	No slug test. Water level recovered about 3 feet over a period of about 14 hours after pumping this borehole interval dry.
86-106	3.4×10^{-3}	Low-quality data in first 30 seconds of slug test.
112-132	--	No slug test. Water level showed no measurable recovery for about 40 minutes after pumping this borehole interval dry.
131-151	1.9×10^{-3}	Low-quality data in first 30 seconds of slug test. Actual hydraulic conductivity value may be lower because static water level in tested interval still was dropping prior to the slug test.
160-169 [2]	--	No slug test. Water level showed no measurable recovery over a period of 4 hours after pumping this borehole interval dry.

[1] Packed interval is less than 20 feet, extending from the bottom of the casing to 52 feet.

[2] Packed interval is less than 20 feet, extending from 160 feet to total depth of the test well.

more indicative of a confining unit than and aquifer (Freeze and Cherry, 1979, p. 29). The Kh of the four intervals that could not be tested are believed to be less than 0.0005 ft/d. The presence of shaley zones and partings in the core indicates that the vertical hydraulic conductivity of the unweathered dolomite probably is less than the Kh.

The estimated Kh of the test interval that includes the weathered dolomite just below the bottom of the casing is about 0.2 ft/d (table H3). Because less than half of the 20-ft test interval is the weathered section, its conductivity probably is appreciably greater than the 0.2 ft/d estimated for the entire interval.

Location of contaminants

Water samples were collected only from the uppermost test interval isolated with a packer assembly at 549-566 FANGVD29 (depth of 35-52 ft). The low permeability of the unweathered dolomite in the remaining test intervals prevented the collection of water-quality samples because the test intervals were pumped dry during purging and did not recover within 2-12 hours. No inorganic constituents of environmental concern were detected in the sample. Toluene was the only VOC detected, and was found in estimated concentrations of 1 and 2 µg/L in duplicate samples (Batten and others, 1997). However, toluene at low concentrations may be present because of field or laboratory contamination, and this detection may not be representative of in-situ water quality.

Water-quality samples from the monitoring wells completed in borehole BN-483 were taken by Simon Hydro-Search, Inc. in October 1994. The deep bedrock well could not be sampled because an insufficient volume of water was available, even after the well was allowed to recover for 1 week. Samples from the shallow bedrock well had higher concentrations of chromium, lead, manganese and zinc relative to the concentrations in the samples obtained by use of the packer assembly. However, this difference could be related to sampling method (bailers were used that could artificially increase turbidity) indicated by the color and clarity of the water, as well as the elevated concentrations of aluminum and potassium. No VOC's were detected in these samples (Simon Hydro-Search, Inc., 1995).

REFERENCES CITED

Batten, W.G., Brown, T.A., Mills, P.C., and Sabin, T.J., 1997, Rock-stratigraphic nomenclature, lithology, and subcrop area of the Galena-Platteville bedrock unit in Illinois and Wisconsin: U.S. Geological Survey Water-Resources Investigations Report 97-4054-B, 1 plate.

Batten, W.G., Yeskis, D.J., Dunning, C.P., 1999, Hydrogeologic properties of the Ordovician Sinnipee Group at test well BN-483, Better Brite Superfund Site, DePere, Wisconsin: U.S. Geological Survey Water-Resources Investigations Report 99-4199, 19 p.

Choi, Y.S., 1998, Sequence stratigraphy and sedimentology of the middle to upper Ordovician Ancell and Sinnipee Groups, Wisconsin: Unpublished PhD. Thesis, University of Wisconsin Madison, 284 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Prentice Hall, Englewood Cliffs, N.J., 604 p.

Hurlbut, C. S. Jr., and Klein, C., 1977, Manual of mineralogy (after James D. Dana): New York, John Wiley and Sons, 532 p.

Krohelski, J.T., 1986, Hydrology and ground-water use and quality, Brown County, Wisconsin: Wisconsin Geologic and Natural History Survey Information Circular 57, 42 p.

Simon Hydro-Search, Inc., 1992, Remedial investigation/Feasibility study, Better Brite sites, DePere, Wisconsin: Report to the Wisconsin Department of Natural Resources, Madison, Wis., variously paginated.

Walker, J.F., Saad, D.A., and Krohelski, J.T., 1998, Optimization of ground-water withdrawal in the lower Fox River communities, Wisconsin: U.S. Geological Survey Water-Resources Investigations Report 97-4218, 24 p.