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WELLHEAD PROTECTION DELINEATION REPORT
FOR
THE VILLAGE OF BEAR LAKE

DECEMBER 2002

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TABLE OF CONTENTS

ATTTACHMENTS

1.0 INTRODUCTION

In order to protect their public drinking water supply system from potential sources of contamination, the Village of Bear Lake is developing a wellhead protection program. Protection is provided by determining the area that contributes ground water to the Village's supply wells, identifying potential sources of contamination within that area, and developing methods to cooperatively manage the area and minimize the threat to their drinking water.

This report presents how data was collected, processed and interpreted in the delineation of the geographic area that provides ground water to the well field containing supply wells #2 and #3 within in a ten year travel time. The resulting final delineation area as approved by the Michigan Department of Environmental Quality will be used to establish the wellhead protection area for these supply wells.

The activities undertaken to delineate this wellhead protection area were originally presented in a work plan submitted to the Michigan Department of Environmental Quality (MDEQ) dated December 2000. The MDEQ subsequently approved of the work plan activities in a correspondence dated march 6, 2001.

1.1 Site Location

The Village of Bear Lake is located in Bear Lake Township (T23N, R15W) in Manistee County, Michigan. An Area Topographic map is included as Attachment 1.

1.2 Water System Data

The Village's water system relies on two wells to provide service to approximately 438 people. The supply wells are located in the SE ¼ SE ¼ SW ¼ of Section 5 of T23N, R15W, Bear Lake Township, Manistee County, Michigan. The well field location is illustrated in Attachment 1. Both supply wells are completed in unconsolidated glacial deposits consisting primarily of sand and gravel with interspersed clays and silts.

Well #2 was installed in 1966 to a depth of 127 feet, is screened between 102 and 127 feet below grade, and has a flow rate of approximately 220 gallons per minute (gpm). Well #3 was drilled in 1979 to a depth of 130 feet, is screened between 99-124 feet, and has a flow rate of approximately 320 gpm. A review of the driller's log for Well #3 indicates that sand and gravel were generally encountered from the ground surface to total depth. The District Health Department and the well drilling contractor were contacted regarding a copy of the well log for Well #2, however, no log was available. The diameter of Well #2 is 8-inches and Well #3 is 12-inches. Note that Well #1 was previously plugged and abandoned. Copies of well logs can be found in Attachment 2.

Water is regularly supplied to the Village's system from both wells. Normal water production involves the alternate use of each well when water is required to replenish the system's water tank.

The subject of this report is the delineation of the wellhead protection area for the well field containing wells #2 and #3.

2.0 SOURCES OF INFORMATION

2.1 Regional Ground Water Flow

Ground water elevations and flow directions were initially estimated using the water levels as reported on residential water well logs and surface elevations from USGS topographic maps. Ground water elevations were verified by field measurements at eight locations including seven water wells and on surface water location.

Interpretation of the regional ground water flow regime was then refined through the use of the measured static water levels in wells in the general vicinity of the anticipated wellhead protection area. Well locations and top of casing elevations were confirmed via GPS survey. The surface water elevation at Bear Lake was also measured and included in the interpretation of ground water flow.

Residential water wells were selected based on an interpretation of each log and determination of the geologic relevance of each log with respect to the production wells.

A summary table of wells utilized in the regional ground water flow assessment and corresponding well logs are found in Attachment 2.

2.2 Aquifer Characterization Data

An aquifer test was performed in September 2000. A copy of the "Aquifer Test Report" was submitted to the Michigan Department of Environmental Quality, Drinking Water and Radiological Protection Division, Wellhead Protection Unit. The delineation of the wellhead protection area presented in this report uses the aquifer parameters calculated from this aquifer test. The resulting aquifer parameters are summarized in Section 5 of this report.

3.0 DESCRIPTION OF AREA

3.1 Geology

Near surface unconsolidated soils were deposited in ground moraine environments[i]. Drift thickness in the area varies from 800 to 1000 feet[ii]. The majority of the soil deposited in this area and within the zone of interest consists of sand. There are also occurrences of gravel and a few occurrences of silts and clays. A review of well logs does not provide any evidence of an overlying confining layer. A cross section that illustrates the regional geology and ground water levels is included as Attachment 3. Well logs are found in Attachment 2.

Bedrock subcropping beneath the unconsolidated soils consists of Late Devonian deposits (Ellsworth shale)[iii]. As a result of the depth to bedrock and the depth of the subject aquifer, no additional consideration of bedrock conditions were warranted within the scope of this report.

Elevated concentrations of the hydrogen isotope tritium (^3H) in both wells suggest that the ground water supplying village wells has received surface water recharge within the past fifty years.

3.2 Hydrogeology

The Village's supply wells are completed in an unconfined sandy aquifer. Ground water in the subject aquifer recharges south of Bear Lake (surface water body) and then flows to Bear Lake. Water from the lake discharges to the east via Little Bear Creek which flows to the east-southeast. Regional ground water flow was found to generally follow major topographic features.

3.3 Surface Features

Surface features in the Bear Lake area include glacial moraine hills, which provide moderate topographic relief when juxtaposed with the lower lying outwash deposits. Surface water in the subject area includes Bear Lake and Little Bear Creek. There are also some unnamed ponds in the study area that were found to be perched and not directly related to the subject aquifer.

4.0 AQUIFER TESTS

4.1 Aquifer Test Methods

An aquifer test was performed at Well # 3 in September 2001. Well #3 was pumped at a rate of 320 gallons per minute for approximately 72 hours. Water level measurements were collected during the three consecutive phases of the test: 1) the pre-test period (18 hours); 2) the drawdown test (72 hours); and 3) the recovery period (24 hours). Water level readings were collected from two observation wells located 135 feet and 195 feet from Well # 3. The water levels were measured utilizing a pressure-reading transducer in each well connected to a two-channel Hermit data logger.

4.2 Data Analysis & Modeling

The aquifer test data was evaluated using two methods: Jacob's Straight-Line Method applied to Time Drawdown and Theis' Type-Curve Method. Recovery data was analyzed using Jacob's Straight-Line Method Applied to Recovery. These interpretations were utilized to estimate the transmissivity and storativity of the aquifer. The results of the aquifer test and analysis are presented in the Gosling Czubak "Aquifer Test Report", September 2001.

The modeling of the draw-down produced by the supply wells in determining the wellhead protection areas is discussed in Section 5.2 of this report.

5.0 MODEL CONCEPTUALIZATION

5.1 Assumptions

Modeling of the wellhead protection area is based on the following:

1) Regional ground water flow as characterized through the use of monitor well and residential well ground water elevations as well as surface water elevations.
2) The ground water draw-down cone of depression resulting from pumping of the supply well(s) is modeled assuming that the supply well(s) is pumping continuously at maximum flow rates.
3) The two data sets representing the regional ground water flow and the draw-down cone of depression are combined via superposition and the resulting surface represents the regional ground water flow under stressed (i.e., pumping) conditions.
4) The 10-year capture zone is estimated by tracking particle flow paths up-gradient to the subject supply well.

5.2 Methods

Several software packages were employed as tools to aid in the delineation of the wellhead protection area, including SURFER®, WinTran®, and the particle tracking software GWPATH®. The general methodology of Bair et al.[iv] was the basis for modeling efforts.

Regional Ground Water Flow

Ground water contours of regional static water conditions were generated both manually and by using Surfer® contouring and 3D surface mapping software. The program was used to import the static water level data set, consisting of x,y,z-coordinates (a relative x,y-position for each well and corresponding ground water elevation, z), which is non-uniform, and generates a uniform grid of elevations using Kriging. The (regional) Ground Water Contour Map was generated using this method.

Supply Well Draw-Down

Draw-down produced by the supply wells was modeled using WinTran®, a 2-dimensional ground water flow model. WinTran is a steady-state, finite element modeling program based on equations derived by Otto D. L. Strack[v]. The program uses the principle of superposition to compute the head at a point in the aquifer system. Win-Flow assumes a homogeneous, isotropic aquifer of infinite extent.

Based on the geologic and hydrogeologic data reviewed for this study, the following aquifer parameters were used in generating draw-down models:

Hydraulic Conductivity:	216 ft/day
Porosity:	25%
Aquifer Thickness:	56 ft.
Pumping Rate for Well No. 3:	320 gpm

Steady-state draw-down was estimated for Well No. 3. The resulting ground water elevations were exported to a data file in x,y,z-coordinates for compatibility with Surfer generated regional ground water data. The modeled drawdown is illustrated in Attachment 6. The model inputs and outputs are found in Attachment 7.

Combining Data Sets

In order to estimate the regional ground water flow conditions during pumping, the draw-down data calculated by WinTran was superimposed on the grid of measured static water conditions. The results were then contoured to represent regional ground water flow under pumping conditions.

Particle Tracking

The capture zones for the supply wells were determined using GWPath, a ground water pathline and travel time analysis program. The pathlines are derived based on Darcy's law for incompressible fluids. GWPath was utilized to create "reverse paths" originating in the vicinity of the supply well tracking particles in reverse for a prescribed length of time. For the purpose of delineating the wellhead protection area, a 10-year (3650 day) time period was used to generate the pathlines. The 10-year capture zone for the supply well encompasses the area outlined by the pathlines.

5.2 Application to Study Area

Given the relative homogeneous soil conditions in the area of investigation, the historical data from hydro-geological investigations in the Bear Lake area, and the agreement of historical ground water flow results with results of this study, the presented modeling approach should provide an adequate representation of the aquifer supplying the subject well field.

6.0 RESULTS & INTERPRETATION

6.1 Calibrations to Known Data

The method used to model the wellhead protection area relies in part on measured static water levels collected from monitor wells, residential wells, and the surface water in and around the wellhead protection area. Only field confirmed data points were used to generate the regional ground water flow regime upon which the wellhead protection area model is based. Additional data points from estimated ground water elevations were used to corroborate the interpretation.

6.2 Ground Water Flow Directions and Gradients

The regional ground water flow direction and gradient in the Bear Lake area varies by location with respect to the surface water body of Bear Lake.

South and east of the lake, where the subject well field is located, the ground water flow direction is from southeast to northwest. The flow gradient is 0.002, as measured from reference well W-17 to Bear Lake (surface water). This result is consistent with the ground water flow direction and gradient as measure in the subject well field as illustrated in Attachment 5.

6.3 Level of (un)certainty

Areas of uncertainly include those areas where limited data is available to verify assumptions made in developing the ground water model. These areas include:

<u>Aquifer Thickness.</u> The aquifer thickness has not been confirmed in the area of the subject supply wells. No data was found in the vicinity that confirmed where a competent and continuous underlying confining layer might be found. The modeling of the wellhead protection area assumes that the aquifer thickness is limited at depth to the bottom of the well. This provides an aquifer thickness of 56 feet.

<u>Homogeneity.</u> The assumption of homogeneous soils typically provides a great deal of uncertainty in the development of a ground water model. However, well logs from the study area confirm the extent and the relative homogeneous nature of soil conditions.

7.0 CONCLUSIONS

7.1 Estimate of the Wellhead Protection Area

Wells #2 and #3 operate in sequence and do not run simultaneously. Therefore, for purposes of delineating the wellhead protection area for this well field, a single well pumping continuously at the flow rate of 320 gpm was used.

The "Wellhead Protection Study Area" for the resulting wellhead delineation based on the presented modeling methods is found in Attachment 8.