REPORT TO

EAST KING COUNTY
REGIONAL WATER ASSOCIATION
ON
DRILLING AND TESTING OF
MIDDLE FORK TEST WELL
AND RECOMMENDATIONS
FOR ADDITIONAL GROUNDWATER INVESTIGATIONS

SNOQUALMIE BASIN
GROUNDWATER ASSESSMENT PROJECT

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TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
	1.1 Background Information	1
	1.2 Scope of Work	1
	1.3 Report Organization	2
2.	INVESTIGATION RESULTS	3
	2.1 Geologic Conditions	3
	2.2 Pumping Test Analysis	3
	2.3 Water Quality	4
	2.4 Hydrogeologic Conditions in Middle Fork Aquifer	5
3.	RECOMMENDATIONS FOR ADDITIONAL WORK	7
	3.1 Phase I Studies	7
	3.2 Phase 2 Studies	8
	3.3 Phase 3 Studies	9
	3.4 Recommendations for Phase 2 Studies in the Middle Fork Sub-Basin	9
	3.4.1 Basin Monitoring	9
	3.4.2 Detailed Exploration	10
	3.4.3 Groundwater Model	11
	3.4.4 Public Involvement/Water Rights	11
4.	REFERENCES	12

LIST OF APPENDICES

Appendix A	Middle Fork Test Well No. 1 - Snoqualmie Basin Assessment, North Bend, Washington - Prepared by Hart Crowser
Appendix B	Water Quality Data
Appendix C	Washington Department of Ecology Temporary Permit

LIST OF FIGURES

1-1	Exploration Areas and Stream Gage Locations, Snoqualmie Basin
2-1	Location Map

1. INTRODUCTION

This report presents the results and conclusions of a test well drilled to evaluate the groundwater supply potential of the Middle Fork Snoqualmie Valley, east of North Bend, Washington. The work was performed by Golder Associates Inc. assisted by Hart Crowser on behalf of the East King County Regional Water Association (EKCRWA). The work is part of a multi-phase groundwater assessment project to identify, evaluate and develop a regional groundwater supply source capable of providing about 40 MGD.

1.1 Background Information

In 1993, Golder Associates completed a geophysical survey of two areas within the Upper Snoqualmie Basin, termed Areas 2 and 3 (Figure 1-1). Area 2 was identified as having the greatest potential for groundwater supply purposes. Test wells were recommended to determine the groundwater supply potential of the aquifers in both areas. Area 1 was recommended for geophysical investigations.

1.2 Scope of Work

The EKCRWA authorized Golder Associates to proceed with the drilling and testing of a 500 foot deep test well in Area 2 on January 6, 1994. The scope of work included:

- Identifying an appropriate location for the test well;
- Preparation of technical specifications and contract documents for the well drilling and pumping test;
- Selection of a well driller;
- Obtaining necessary permits from local and state agencies;
- Overseeing the drilling and testing of the well;
- Collecting water samples for analysis;
- Interpreting the pumping test data to determine the hydrogeological conditions and groundwater supply potential; and
- Providing recommendations for future work to confirm the groundwater supply potential.

1.3 Report Organization

This report is organized as follows:

Section 1	-	Introduction, including background information and scope of work;
Section 2	-	Results of the well drilling and testing;
Section 3	-	Recommendations for future activities;
Section 4	-	References;
Appendix A	-	Hart Crowser Report on Drilling and Testing;
Appendix B	-	Water Quality Analyses; and
Appendix C	-	Department of Ecology Preliminary Permit for Well Construction and Testing

2. INVESTIGATION RESULTS

The location of the test well is shown on Figure 2-1. The well is located about two miles east of North Bend at the intersection of S.E. 131st St and 461st Ave S.E. The well is located on an easement on property presently owned by Mr. R. Lamb.

The Hart Crowser report included in Appendix A describes the drilling and testing of the test well and the monitoring well. A well construction log is included in Appendix A. Following well completion, the well was pump tested for three days at a constant rate of 1,500 gpm to determine aquifer properties. Water samples were collected by the City of Seattle and by Hart Crowser personnel during the test. The results are presented in Appendix B.

The following is a brief summary of the results of the drilling and testing.

2.1 Geologic Conditions

The stratigraphy observed in the test well (Appendix A) is consistent with the regional geology of the basin. At the well site, the upper 109 feet consist of gravelly sand with cobbles and boulders. Between 109 and 207, feet dense silt-bound sand and gravel interpreted as glacial till are present. An aquifer consisting of coarse sand and gravel extends from a depth of 207 feet to at least 360 feet below ground surface. Casing could not be advanced past a depth of 360 feet, which is the predicted depth of the base of the aquifer and top of lacustrine sediments, based on the geophysical sounding. However, the presence of inter-bedded fine sands and a hydrogen sulfide odor between depths of 340 and 360 feet suggests that the aquifer was fully penetrated and that the casing was driven to the top (or very close to the top) of lacustrine sediments. The aquifer is screened between 246 and 340 feet below ground surface.

The aquifer is interpreted to represent an advance glacial outwash deposit or ice-marginal stream deposit that was subsequently over-ridden by glacial ice depositing a till cap. The till is likely absent further up-valley (to the east) in the direction of the Middle Fork Embankment. The present Middle Fork Embankment may therefore be continuous with the earlier advance outwash deposits observed in the test well.

2.2 Pumping Test Analysis

The well was pumped at a rate of 1,500 gpm (2.2 MGD) for 72 hours. The water level in the well stabilized in accordance with Ecology guidelines set in the preliminary permit (Appendix C).

The transmissivity of the aquifer is estimated to be 21,400 ft^2/day (160,000 gpd/ft). The aquifer is confined, based on the water-level in the aquifer, but the storativity cannot be calculated without an observation well in the same aquifer. Based upon well efficiency calculations and well hydraulics, a prototype production well at the same location completed in the aquifer could yield up to 3,500 gpm (5 MGD).

The pumping test indicates minimal leakage through the till, but the test appears to be influenced by two boundaries:

- a barrier boundary, caused by the bedrock valley walls affects the data during the first 900 minutes of the test; and
- a recharge boundary affects the data from about 1,000 minutes until the end of the test. The recharge boundary could be the result of one or a combination of the following:

    1) Direct infiltration from the Middle Fork at some distance up-valley where the till has pinched out;

    2) Gravity drainage from an unconfined aquifer condition in the Middle Fork Embankment; or

    3) Leakage from underlying or overlying sediments.

The monitoring well in the upper aquifer responded to the pumping test with a drawdown of about 1.2 feet. There was no recovery in the monitoring well. This suggests that the monitoring well may be completed in an isolated water bearing zone and may not be representative of the upper unconfined aquifer as a whole. The static water-level elevation in the observation well is estimated at about 500 feet. The estimated river elevation adjacent to the site is 480 feet. A more detailed elevation survey and water-level monitoring is needed, but the water bearing zone in the observation well may be perched above the river.

2.3 Water Quality

Water quality data are included in Appendix B. The water meets all Safe Drinking Water Act requirements and recommendations, including organic chemicals and pesticides.

The water meets the target water quality goals set in CH_2M Hill's feasibility study (CH2M Hill, 1993) including a pH of greater than 8 and low levels of iron and manganese. The water is compatible with all delivery points for the existing supply.

Arsenic is measured at 6 ppb. The MCL for arsenic is presently 50 ppb. The MCL will likely be lowered in the future to 5 ppb or less. Arsenic is naturally present in the igneous rocks of the Cascades.
The water was positive for sulfide odor throughout the test. Sulfide concentrations are about 96 ug/L. Seattle Water Department's "Flavor Rating" indicated that after two hours contact time with

2.5 mg/L chlorine, the water was marginally acceptable to the three taste panelists, having a slight sulfurous taste/odor.

2.4 Hydrogeologic Conditions in Middle Fork Aquifer

Based upon our analysis of the pumping test, the following conclusions are drawn related to the hydrogeologic conditions in the Middle Fork Snoqualmie valley:

- The well is completed in the Middle Fork Aquifer is a confined aquifer at the test well location. The confined aquifer is overlain by an unconfined aquifer, in which an observation well is located. The confined aquifer may become unconfined to the east of the well site if the overlying till pinches out. The aquifer is recharged by infiltration over the Middle Fork Embankment and losses from the Middle Fork Snoqualmie River where the till layer is probably absent. West of the Middle Fork Embankment, the confining layer is probably regionally extensive, based on the 15-foot upward head difference between the confined aquifer and the unconfined aquifer.

- The presence of a till confining layer indicates that, at the test well site, the Middle Fork Aquifer is not in direct hydraulic communication with the Middle Fork Snoqualmie River. If the till pinches out to the east, the aquifer may be in direct hydraulic communication with the river. However, as identified in the earlier geophysical report (Golder Associates, 1994), the Middle Fork Snoqualmie River naturally appears to lose about 30 MGD to the aquifer in the area near the test well. If the river loses large quantities of water naturally to the aquifer in this reach, pumping may not cause an impact to streamflow on this section of the river. The focus of an impact assessment would therefore shift downstream to potential surface-water discharge points for the Middle Fork Aquifer. The aquifer is expected to be confined for a significant distance downstream based on observed head differences.

- An unconfined aquifer is present above the till in the upper 100 feet of sediment. The unconfined aquifer is recharged by infiltration and streamflow losses where the head in the river is above that of the aquifer.

The existing test well is capable of supplying at least 2 MGD. The capacity of this well is limited by the size of the pump that can be installed rather than by the aquifer conditions. A larger diameter well at the same location could theoretically yield about 5 MGD. Within a one to three mile distance from the site (in the valley), at least 10 to 20 MGD could be developed from three to five wells. The effect of these potential withdrawals on streamflow, if any, and the location of any effect on the hydrogeologic system or other wells cannot be predicted without further study of the hydrogeological conditions.

Additional groundwater supplies could be developed either downvalley within the Middle Fork Aquifer, or within the South Fork Valley, or in the vicinity of the Middle Fork Embankment. An additional 20 MGD, or more could be developed through induced infiltration in the unconfined portion

of the aquifer near the Middle Fork Embankment. Groundwater supply potential in the South Fork Valley and further west in the Middle Fork Valley (Area 1) is unknown but could be significant as indicated by the CH_2M Hill report. Additional hydrogeologic investigations are required to fully evaluate the groundwater supply potential of these areas.

3. RECOMMENDATIONS FOR ADDITIONAL WORK

The following is a brief summary of general activities required to fully evaluate and develop a regional groundwater supply source within the Upper Snoqualmie Basin.

We recommend that the project be organized according to sub-basin (i.e., North Fork, Middle Fork, South Fork, and Main Fork) and broadly defined tasks as follows:

PHASE 1

- Aquifer Viability

PHASE 2

- Basin Monitoring
- Detailed Exploration
- Groundwater Modelling
- Public Involvement/Water Rights

PHASE 3

- Engineering/Feasibility Studies
- Wellfield Design/Prototype

These tasks are arranged more-or-less chronologically for each sub-basin. Once a viable aquifer is established, basin monitoring and detailed exploration should follow. The exploration data should then be used to formulate a groundwater model, design a wellfield, and install a prototype production well. Each task is described in general detail below.

3.1 Phase I Studies

Aquifer Viability

This task entails the types of investigations performed so far in the Middle South Fork and North Fork basins. The principal objective is to obtain reconnaissance-level information based on existing information and geophysical data, and install a test well to determine whether a significant water-bearing aquifer is present. The Aquifer Viability task is completed for the Middle Fork sub-basin, while other sub-basins remain partially

investigated. Completion of the test well tasks in the South Fork and North Fork sub-basins is also recommended for a more complete initial investigation of the upper Snoqualmie Basin.

We recommend that the Main Fork of the Snoqualmie (Area 1) be re-evaluated based on our analyses to date. We believe that significant groundwater resources may be present in this area and additional data collection is warranted for a complete perspective of the groundwater supply potential for the Upper Snoqualmie Basin.

3.2 Phase 2 Studies

Basin Monitoring

We recommend initiating basin monitoring as early as possible to establish baseline conditions in water-levels, water quality, stream aquifer interaction, stream flow and precipitation. Having a sufficient database for the later stages of basin analysis will greatly improve the defensibility and accuracy of wellfield yield predictions and impacts. The database will substantially improve negotiation and resolution of water rights and basin management issues.

Detailed Exploration

More detailed exploration in the sub-basins would depend initially on whether a successful test well was installed. The types of explorations would vary for each sub-basin but might include:

- Additional geophysics, including seismic reflection or TDEM to more accurately stratigraphic relationships and aquifer extent; and
- Additional exploratory wells, focusing on aquifer delineation and testing.

Groundwater Modelling

Development of a groundwater model is necessary to integrate the hydrogeologic data into a single tool that can be used to design a wellfield and evaluate hydrologic impacts to the basin. The geometry of the basins appears to be favorable for a "piece-meal" construction of the model, focusing on one sub-basin at a time, and linking each basin to eventually construct a model of the entire Upper Snoqualmie Basin.

There are already sufficient data to construct a preliminary model of the Middle Fork Basin. This model could be used to guide exploration and wellfield feasibility, and to assess first order impacts and mitigation strategies. The complexity of the boundaries in the aquifers requires the use of a numerical model to interpret the groundwater flow regime.

Public Involvement/Water Rights

Communication and involvement of a variety of interests in this technically oriented project is necessary to ensure the success of the project. The RWA has so far been well prepared and open in its communications with Ecology, the public, and other interested parties. We recommend continued

and possibly intensified interactions with the Department of Ecology, Weyerhaeuser, Puget Power, Indian Tribes and other concerns with respect to the feasibility of the project. The Department of Ecology has identified the Snoqualmie/Cedar/Snohomish drainage for a Water Resource Inventory Area report, with a target completion date of March 1995. These assessments will be used to "facilitate batch water right decision making by Ecology". Further evaluations in this basin by the RWA could be timely from a water rights standpoint.

3.3 Phase 3 Studies

Once additional exploration and basin monitoring data are collected and the feasibility of the project is considered favorable by interested parties, the project can focus on engineering and design issues. At this phase, the probability that a wellfield will be installed should be high. Some additional exploration and monitoring data may be needed, but the field data focus would be on prototype wells and large-scale pumping tests. The groundwater model developed for the basin would be used to evaluate impacts and wellfield layouts. Engineering studies aimed at system layout, design, treatment and distribution would be addressed at this stage.

3.4 Recommendations for Phase 2 Studies in the Middle Fork Sub-Basin

The Middle Fork Aquifer has been shown to have the potential for significant groundwater supply development and should be investigated further as a regional groundwater supply. Investigation can take place over time as funds are available. However, it should be recognized that evaluation and development of a 20 to 40 MGD groundwater supply will require a detailed investigation program to satisfy the needs of the Department of Ecology. According to the general tasks outlined above, we recommend the following activities be undertaken:

3.4.1 Basin Monitoring

The following monitoring program is recommended:

- Obtain continuous water-level monitoring of the test well and shallow observation well over the next year to determine the interaction of the unconfined and confined aquifer;

- Re-activate stream gage 1415 at Mt. Si Bridge to determine the potential streamflow losses on the Middle Fork. The USGS will reactivate the gage if it is in the public interest;
- Establish a precipitation gage on the Middle Fork Snoqualmie Embankment;
- Obtain monthly water-level measurements in wells in the area; and
- Obtain water-quality information from wells in the area.

3.4.2 Detailed Exploration

Additional exploration will be required in Area 2 to determine the overall aquifer conditions and quantities of groundwater available. We recommend a staged approach consisting of test wells and geophysical measurements as follows:

- Re-evaluation of the TDEM soundings to evaluate whether till may or may not be present at previous sounding locations. This will give a preliminary indication of the extent of the aquifer. Additional soundings should be performed based on the re-interpretation of the data.
- Seismic reflection test profiles axial and transverse to the valley. Reflection seismic may give a more detailed "picture" of the till confining layer and aquifer thickness, compared to the inferred stratigraphy from the TDEM.
- One 400-foot, 12/8-inch exploratory well should be drilled in the confined aquifer, located down-valley of the test well to determine the down-valley extent of the aquifer, its hydraulic gradient, and the possibility of developing the source closer to the I-90 corridor. A 24-hour pumping test should be performed to evaluate aquifer properties and water quality.
- One 400-foot 12/8-inch exploratory well should be drilled up-valley of the test well at the base of the Middle Fork Embankment. This well will be used to evaluate the potentially unconfined aquifer condition and water-levels near the recharge area. A 24-hour pumping test should be performed to evaluate aquifer properties and water quality. Water-levels should be monitored in conjunction with river stage measurements.

Once the above work is completed, hydrogeologic conditions should be re-evaluated and where necessary additional exploration undertaken. Preliminary groundwater modeling will assist in the identification of additional data needs. It is possible that several additional exploratory holes/test wells will be required in the Middle Fork basin to determine the overall groundwater supply potential.

3.4.3 Groundwater Model

Once additional exploration and basin monitoring data are obtained, a preliminary groundwater model should be developed between the Middle Fork Embankment and the confluence of the Middle and South Forks. A model is necessary to evaluate the complex boundary responses expected in the aquifer based on the test well. This model will allow us to evaluate in better detail the capacity of the aquifer, the impact of pumping on recharge sources, and the possibility of artificial recharge and streamflow enhancement.

3.4.4 Public Involvement/Water Rights

It is recommended that key agencies and parties, including the Department of Ecology, Puget Power, Weyerhaeuser, and Indian Tribes should be formally updated on the project and consulted regarding the feasibility of the project. In addition to meetings and presentations, oversight of Basin Assessment activities being performed by Ecology should be considered as part of this task.

If the results of the detailed exploration and modeling continue to indicate favorable conditions, a third phase of investigations would begin, focusing on engineering and design issues. Representative activities would include installation of a proto-type production well, a large scale pumping test, wellfield layout and design evaluations, initial model simulations of impacts to recharge and streamflow, and engineering studies to refine costs and design parameters.

4. REFERENCES

CH_2M Hill, 1993. Final Report, Snoqualmie and Issaquah Valley Aquifer Report. Prepared for East King County Regional Water Association.

Golder Associates Inc., 1995. Summary Report to East King County Regional Water Association on Snoqualmie Basin Groundwater Supply Evaluation Geophysical Survey.

FIGURES

APPENDIX A

MIDDLE FORK TEST WELL NO. 1 - SNOQUALMIE BASIN ASSESSMENT, NORTH BEND, WASHINGTON - PREPARED BY HART CROWSER

APPENDIX B

WATER QUALITY DATA

APPENDIX C

WASHINGTON DEPARTMENT OF ECOLOGY TEMPORARY PERMIT