CAESA Canada - Alberta Environmentally Sustainable Agriculture Agreement

PROPOSED
COMMUNITY-FOCUSED
MANAGEMENT STRATEGY
for the

GRIMSHAW GRAVELS AQUIFER

TECHNICAL REPORT

Canada

Agriculture - Building a Healthy Environment

Alberta

PROPOSED
COMMUNITY-FOCUSED
MANAGEMENT STRATEGY
for the

GRIMSHAW GRAVELS AQUIFER

TECHNICAL REPORT

Prepared by: Earth Sciences Division - Regina, Sask..
Prairie Farm Rehabilitation Administration (PFRA)
Agriculture and Agri-Food Canada

September, 1996

Revised March, 1998

Accepted as final: April 9, 1998

ISBN 0-660-17898-2
CATALOGUE A98-3/3-1999

TABLE OF CONTENTS

REPORT FIGURES

APPENDICES

ACKNOWLEDGMENTS

This report was prepared for the Grimshaw Aquifer Management Advisory Committee. It was reviewed and edited by the Technical Advisory Committee.

Grimshaw Aquifer Management Advisory Committee Members:
MD of Peace #135
MD of Northern Lights #22
MD of Clear Hills #21
MD of Fairview #136
Town of Grimshaw
Village of Berwyn
Weberville Water Coop
East Grimshaw Water Coop
West Grimshaw Water Coop
Griffin Creek Water Coop
Golden Meadow Water Coop

Technical Advisory Committee Members:
Alberta Agriculture, Food & Rural Development , Fairview
Alberta Environmental Protection, Grande Prairie/Peace River/Edmonton
Peace Health Region, Peace River
Mackenzie Municipal Services Agency, Berwyn
Prairie Farm Rehabilitation Administration, Peace River/Regina

If you have any comments, questions or would like more information, please contact us:

Grimshaw Gravels Aquifer Management Advisory Committee
c/o Mackenzie Municipal Services Agency
Box 450, Berwyn, Alberta T0H 0E0 Phone: (780) 338-3862
OR
Municipal District of Peace #135
Box 34, Berwyn, AB. T0H 0E0 Phone: (780) 338-3845

1.0 INTRODUCTION

In the past few years, discussions on developing a community-focused management plan for the Grimshaw Gravels Aquifer have been initiated. This has led to the formation of the Grimshaw Aquifer Management Advisory Committee (GAMAC), which consists of local elected officials and water co-operative representatives. The goal of this Committee is to develop an aquifer management plan that stresses the wise use of groundwater and encourages practices that will protect the aquifer from contamination. This group has recognized that it will be less expensive to prevent any potential problems than have to deal with them in the future.

The approximate extent of the Grimshaw Gravels Aquifer is shown in Figure 1.

1.1 OBJECTIVE

The objective of this report is to provide GAMAC with the ability to make "informed" decisions on aquifer-related issues, and thereby, ensure sustainable aquifer development.

1.2 SCOPE OF REPORT

The report is organized in a progression of information steps, guiding the reader through the following topics:

- *general aquifer system:* includes a description of the local geology and a general discussion on how groundwater flow is distributed in the aquifer. The potential impacts of groundwater withdrawals and the sensitivity of the aquifer to overuse and contamination are also reviewed.

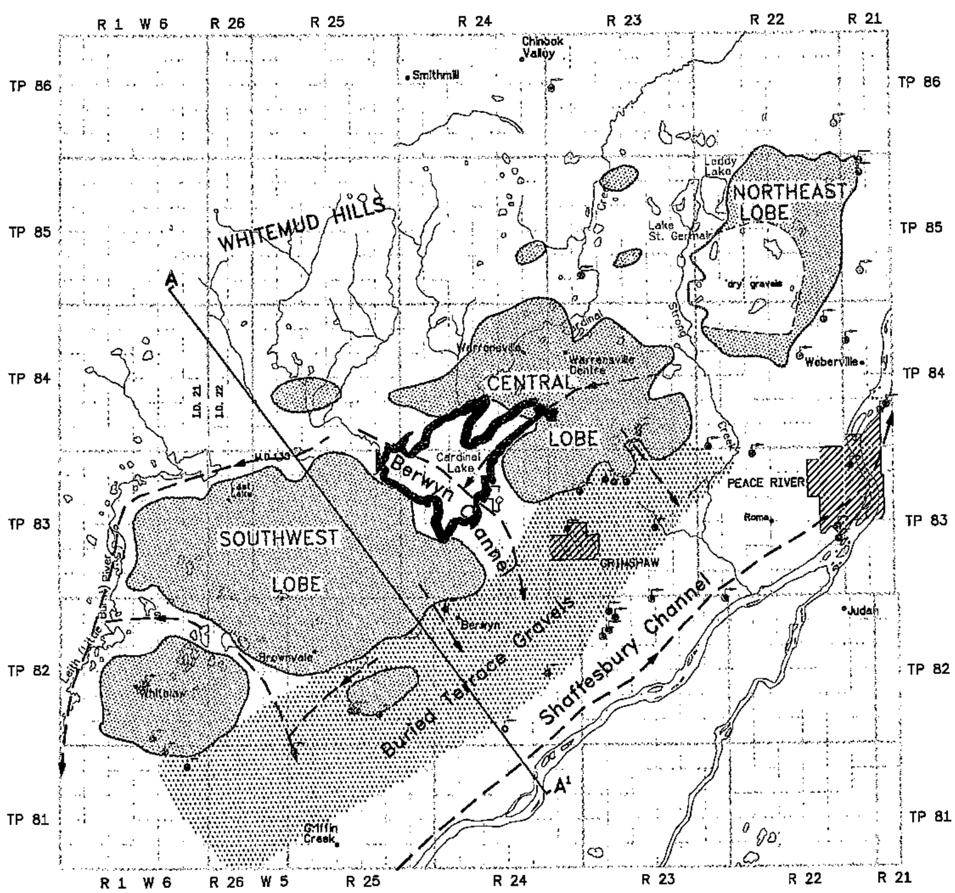


FIGURE 1 General Location Plan

- ***presentation of management issues:*** introduces three main aquifer management issues:

  a) Municipal/Irrigation Water Supply Sites

  b) Potential Point Sources of Contamination

  c) Potential Non-Point Sources of Contamination

Several ideas and management techniques are presented to enable decisions to be made on how to best manage development on the aquifer.

- ***recommended actions:*** presents several items for GAMAC to consider as they proceed with the implementation of a management plan.

- ***future considerations:*** provides a brief outline of several future activities that could improve the ability to manage the aquifer.

To assist the reader in understanding the concepts and managements techniques presented in this report, a definition of some of the technical terms, some illustrative maps and instructive tables are included in the Appendices.

2.0 THE GRIMSHAW GRAVELS AQUIFER SYSTEM

The Grimshaw Gravels Aquifer has an excellent water quality and is one of the most economical water supply sources in the Peace River region. To protect this aquifer, one must first understand how the aquifer relates to its surrounding environment. A typical geological cross section through the Grimshaw Gravels in the area is illustrated in Figure 2.

The Grimshaw Gravels were deposited by ancestral rivers as a continuous unit directly on underlying bedrock units of sandstone and shale. However, over geologic time, the continuity of the gravels was broken by local stream channel erosion, leaving three main gravel bodies: i) southwest lobe, ii) central lobe, iii) northeast lobe, and numerous smaller outlier deposits. Many of these later stream channels were infilled with drift deposits and are now present as "buried valleys" in the area. One such buried valley is the Berwyn Channel, which separates the southwest and central lobes. A smaller channel also dissects the western part of the southwest lobe (see Figure 1).

There are also several minor channels that have eroded the Grimshaw Gravels resulting in discontinuities in this deposit and further separating this gravel body into smaller components. It is believed that stream channel erosion caused the discontinuity between the central and northeastern lobes. However, there is a lack of geological data to confirm the nature of this discontinuity. The Shaftesbury Channel, which is a major buried valley in the area, has downcut below the present-day level of the Peace River valley, leaving the Grimshaw Gravels as a high-level terrace deposit. Between the Grimshaw Gravels and the Shaftesbury Channel, buried lower level terrace deposits are present. These sand and gravel deposits are not as extensive as the Grimshaw Gravels, but are significant in that they provide some aquifer potential. The Town of Berwyn obtains its water supply from a well completed in these lower level terrace deposits.

Each of the aquifer lobes has unique and distinguishing features and, for management purposes, can be considered as separate aquifer units. However, the individual lobes of the Grimshaw Gravels Aquifer, overlying surficial aquifers, underlying sandstone aquifers, and various buried valley and lower buried terrace deposits all form part of the Grimshaw Gravels Aquifer system. Surface water bodies such as Cardinal Lake, which are either located on or adjacent to the Grimshaw Gravels, and springs and wetland areas, are also considered to be part of the aquifer system.

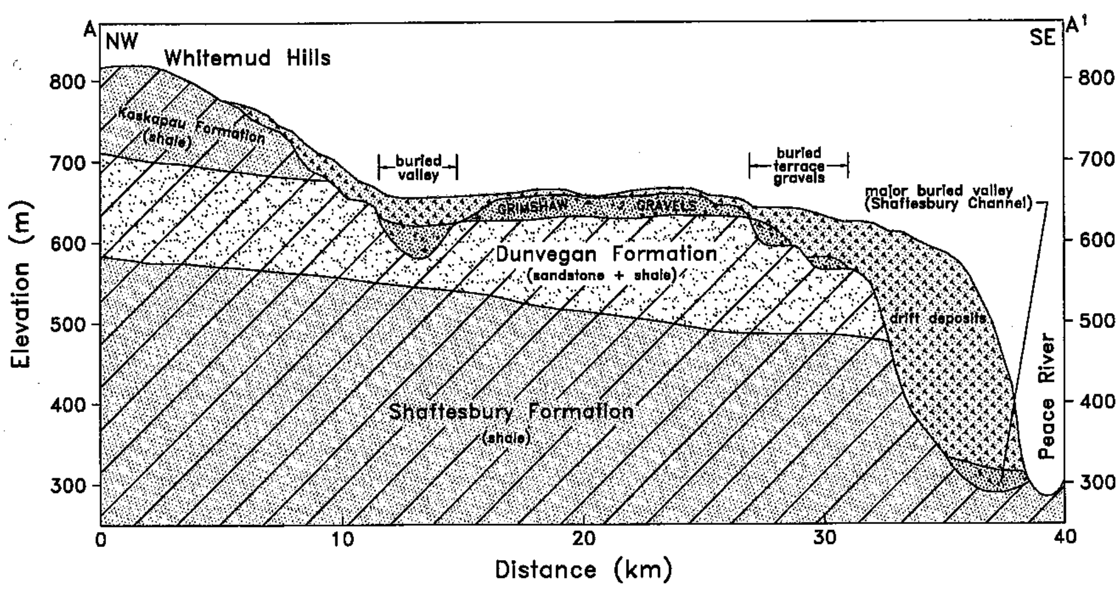


Figure 2 Typical Geological Cross Section (for cross section location see Figure 1)

Although there is a general understanding of the relationship between different parts of the system, insufficient information is currently available to permit anything better than an approximation of their interaction. Descriptive maps, illustrating the general features of the main aquifer lobes, are provided in Appendix B (Figures B2 - B4).

2.1 GROUNDWATER FLOW

How does water move through the system?

A conceptual diagram of groundwater flow through the Grimshaw Gravels Aquifer System is provided in Figure 3.

Rain or snowmelt which infiltrates through the ground into the Grimshaw Gravels is the main source of recharge to the aquifer. Local recharge into the aquifer also occurs from surface water bodies such as Cardinal Lake. As the water enters the ground, it moves downward through the Grimshaw Gravels and accumulates above the base of the aquifer to form the water table. Groundwater is continuously being redistributed and moves to the aquifer edges according to the slope of the water table. The general groundwater flow direction for the various aquifer lobes of the Grimshaw Gravels Aquifer is from northwest to southeast, as illustrated in Figure B5. When viewing this figure, it should be recognized that in many areas, the definition of groundwater flow directions is hampered by the absence of accurate test hole elevation data.

As shown in Figure 3, groundwater moves toward discharge points where it leaves the aquifer. Springs and wetland areas, along the edges of the aquifer, represent visible discharge points of groundwater at the surface. Subsurface discharge occurs into adjacent buried terrace deposits, buried valley deposits and underlying bedrock units. Groundwater that enters these deposits may later discharge as springs downslope of the aquifer. Groundwater also discharges into surface water bodies such as Cardinal Lake. At points where the water table is close to the surface during the growing season, a significant amount of groundwater may be consumed by plant transpiration. Therefore, all the recharge water that comes into the aquifer must be balanced by the sum of these various discharges from the system.

2.2 GROUNDWATER BUDGET

How is water distributed in the aquifer?

The amount of recharge water to the aquifer is estimated to be about 10% of the annual precipitation for the area. This recharge water is distributed to the various parts of the aquifer system. Any reduction in the annual recharge amount would first be noticed by a lower water level in wells installed in the aquifer or a reduced groundwater discharge to springs. Water well development is

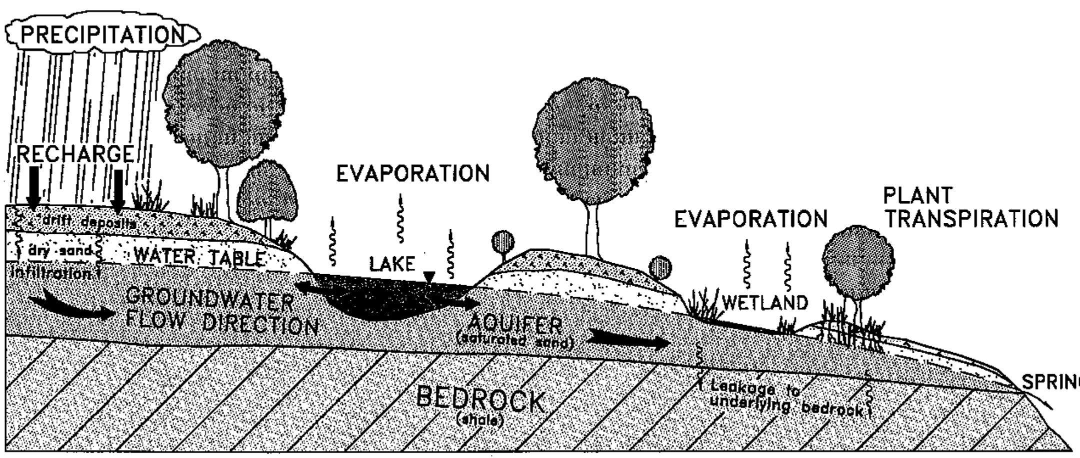


Figure 3 Conceptual Diagram of Groundwater Flow System

also an important component in the overall groundwater budget. On average, about 10% of the annual recharge amount (or about 1% of the total annual precipitation) is estimated to be withdrawn by wells. As might be expected, each aquifer lobe has a different level of groundwater development. The central lobe is estimated to use about 15% of its recharge amount, while the southwest and northeast lobes are estimated to use 6% and 4%, respectively. Although groundwater usage by wells appears relatively low, an increase in withdrawals by wells can decrease groundwater flow to other parts of the system. Pumping wells, for example, cause a lowering of the water table around the well, which gradually may expand to other parts of the aquifer system over time, as shown in Figure 4. In an effort to better understand groundwater use in the aquifer, a well owner's survey has been conducted, in cooperation with the local groups. About 75% of the well owners responded. The survey provided a general overview of the status and yield of the wells. This information will assist in defining the current groundwater use estimates. In the future, a more detailed survey may be required to refine these estimates.

To minimize impacts to springs and other wells in the aquifer, groundwater withdrawals by wells must take into consideration all other natural groundwater discharges. It is vital to be able to predict when, and to what degree, impacts from current or future groundwater withdrawals may effect other parts of the system. Especially since these impacts may be relatively slow in developing and not directly noticeable.

2.2.1 Aquifer Development

How do groundwater withdrawals impact the aquifer?

When water is removed by pumping wells, the natural movement of groundwater is altered. Pumping wells cause the groundwater around the well to be drawn into the well, changing the direction and velocity of groundwater flow. This underground area affected by pumping is called the cone of depression, and its extent will depend on the aquifer characteristics. For most domestic wells completed in the Grimshaw Gravels Aquifer, this cone of depression is expected to extend less than 100 metres from the well. Therefore, as long as other wells are located beyond this radius, well interference effects are expected to be minimal. At sites where large-scale groundwater developments are in place or proposed, a groundwater evaluation must be conducted by an experienced hydrogeologist. In this evaluation, the effects of long-term pumping can be estimated from a pump test, and recommendations can be provided on well spacing requirements.

In order to know how much aquifer development can be tolerated before impacts to other parts of the aquifer system are noticeable, a method must be developed to prevent potential groundwater overuse. One method is to approximate allocation amounts for wells based on the

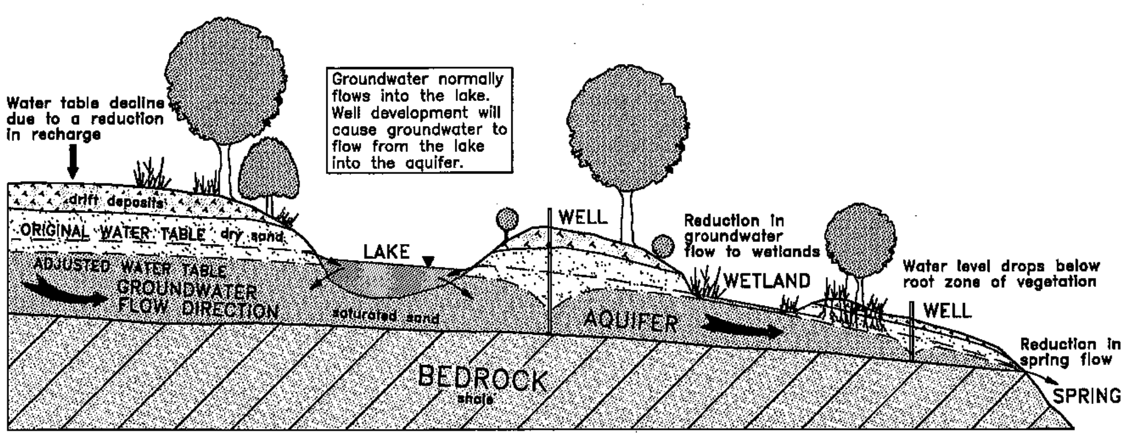


FIGURE 4 Potential Effects of Groundwater Use

available recharge for an area. For example, it is estimated that, on average, the aquifer receives 35 mm of recharge over its area. This means that the ***maximum*** amount of water available for withdrawal over one square mile (2.6 km^2) would be 2.8 L/s (37 igpm). However, this calculation does not take into account potential impacts of using this entire recharge amount for withdrawal by wells. The actual amount allocated for withdrawal must be held to amounts less than this, since the entire amount of recharge cannot be used for groundwater withdrawals by wells without producing impacts elsewhere in the system (e.g. at springs, wetlands, etc.).

An alternate approach is to make a more conservative estimate by using precipitation data for a drought year. Using data from 1981, the estimated aquifer recharge would be about 21 mm. This equals about 1.7 L/s (22.5 igpm) of groundwater available from one square mile.

These approximate allocation amounts can serve as a general guide to indicate areas where groundwater withdrawals may becoming excessive. However, in some areas where there is a direct connection to a surface water body such as Cardinal Lake, or where there is no drift cover over the aquifer, the recharge potential would be higher allowing for possible increased well development.

2.2.2 Water Level Data

What role does water level monitoring play in the management of the aquifer system?

The Grimshaw Gravels Aquifer system is in a state of continual change, where the inflow and outflow of water may vary considerably over time. An analysis of water level trends can provide valuable insight on effects and potential impacts to the aquifer system. In conducting this analysis, the following factors must be considered:

- historical water levels
- natural drainage characteristics
- natural groundwater discharge (springs)
- natural groundwater recharge (precipitation)
- pumping from wells/overall demand
- climatic effects associated with recharge

The following is an example of how water level data can be used to assist in aquifer management. This example will illustrate how ongoing monitoring, along with aquifer model simulations, can be used to assess potential impacts on the aquifer.

a) **Monitoring:** Water level data for Alberta Environmental Protection observation wells 338 and 339, along with precipitation data for the area, are shown in Figures 5a and 5b. Both these observation wells were installed in 1965 and their location is shown in Figure B5. Observation well 339 is located on the southwest lobe, in an area where there are no major production wells nearby. Observation well 338 is located on the central lobe, in vicinity of the high-producing Town of Grimshaw well. This well was installed in 1981, in LSD 8-25-83-24 W5M, about 2 km west of observation well 338. In Figure 5c, average production rates from the Town of Grimshaw well have been superimposed on the water level data from observation well 338.

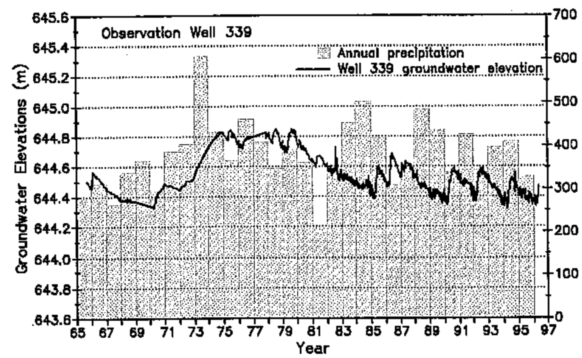


FIGURE 5a Water Level and Precipitation Data

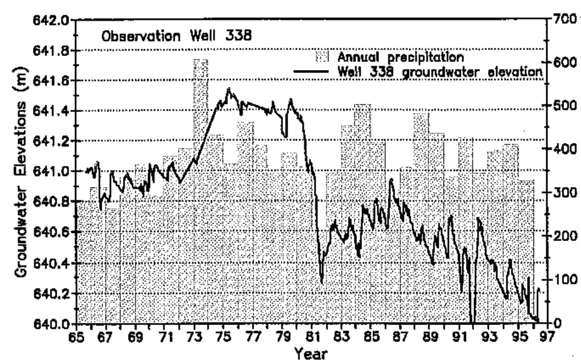


FIGURE 5b Water Level and Precipitation Data

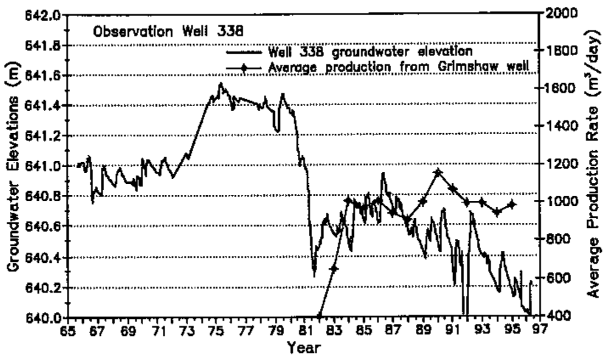


FIGURE 5c Water Level Data and Production Data from the Town of Grimshaw Well

The following observations can be made from this data:

- water levels in observation well 339 mirror climatic trends, although there appears to be a one or two year "lag time". This is also true for observation well 338, but only until the Town of Grimshaw well was installed in 1981.
- climatic effects, such as drought periods (e.g.1980 - 1982; 1986 - 1987) can cause water levels to decline at rates between 6 to 8 cm per year (Figure 5a). Wet years can cause water levels to rise 20 cm or more in one year.
- increased aquifer development appears to have caused a dramatic lowering of the water level in observation well 338. This occurs with minimal "lag time". There is also evidence of a gradual declining water level trend in the early 1990's.

Often the gradual nature of aquifer development presents a difficult management challenge since water level changes, due to increased development, may be "masked" or sometimes completely hidden by the climatic effects. Aquifer modelling studies can assist by using historical water level trends to simulate natural water level trends and to predict future water level trends, based on anticipated development.

b) Modelling: Using the data from observation well 338, Figure 6a shows model simulations with only climatic (precipitation) effects included. This figure illustrates the predicted water levels in the aquifer, at the location of observation well 338, had the Town of Grimshaw well not been operated.

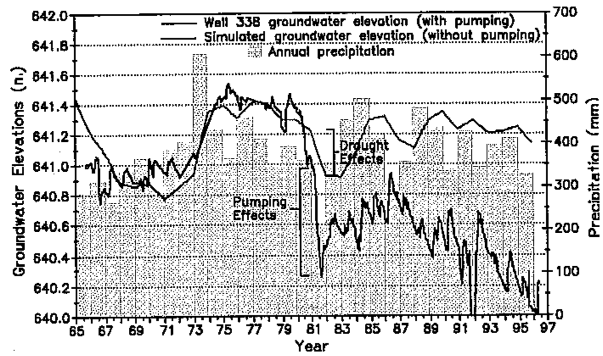


FIGURE 6a Simulated Water Level Data without Pumping

This simulation indicates that the aquifer would have continued to mirror the effects of climate, as it had in the past, and would have recovered from the effects of the 1981 drought. Therefore, the intensity and duration of the 1981 drought is insufficient to have solely caused the decline in water levels at observation well 338. This decline has also continued in-spite of average to above average precipitation. Clearly, increased aquifer development since 1981, including operation of the Town of Grimshaw well, has caused the downward water level trend in observation well 338.

Figure 6b shows the simulated water level data in observation well 338, if pumping data from the Town of Grimshaw well is included.

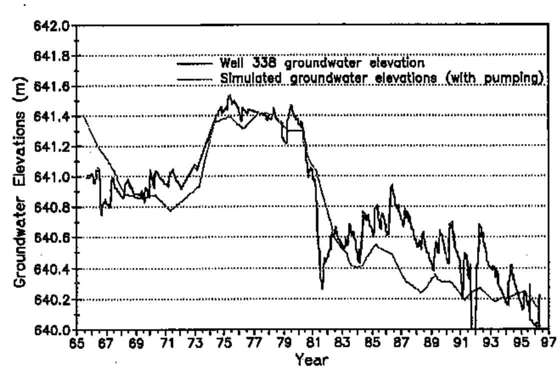


FIGURE 6b Simulated Water Level Data with Pumping

The simulated water level data closely reflects the offset and increase in water level decline at observation well 338. This simulation can be used to illustrate possible future water level trends in the aquifer at the location of observation well 338.

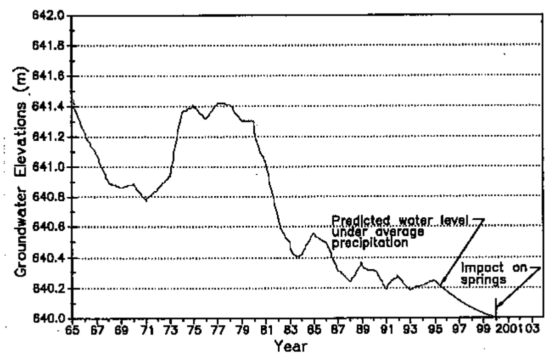


FIGURE 6c Predicted Water Level Trends

Figure 6c shows the simulated water level trendline extended into the future. This assumes continued pumping of the Town of Grimshaw well at the current rate and average precipitation conditions. Based on this scenario, the current level of development may have an impact on nearby springs by the year 2000. Monitoring of nearby springs would be required to confirm the modelled potential impacts of continued aquifer development in this area.

The above example illustrates the use of monitoring and modelling as management tools for the aquifer. The water level decline, observed in 1981 in observation well 338, is dramatic and would naturally draw the attention of groundwater managers to this situation. However, equally important to aquifer management is the combined effect of all the incremental demands placed on the aquifer. The need for ongoing aquifer monitoring and analysis of water level data is an essential part of aquifer management.

2.3 GROUNDWATER CONTAMINATION CONCERNS

How vulnerable is the aquifer to contamination?

Just as recharge water infiltrates through the ground into the aquifer, potential contaminants from any activities occurring above the aquifer may also move down to the aquifer, as illustrated in Figure 7.

The only natural protection the Grimshaw Gravels Aquifer has is from overlying drift deposits. These deposits vary in character and thickness and may even be absent in some areas. At some locations, the drift cover has been removed by gravel pit excavations, exposing the top of the aquifer. Where present, and comprised predominantly of clay, these overlying drift deposits may inhibit or even prevent the downward movement of contaminants into the aquifer. Accordingly, knowledge of the presence, distribution and nature of the drift deposits can be used to identify areas where the aquifer may be

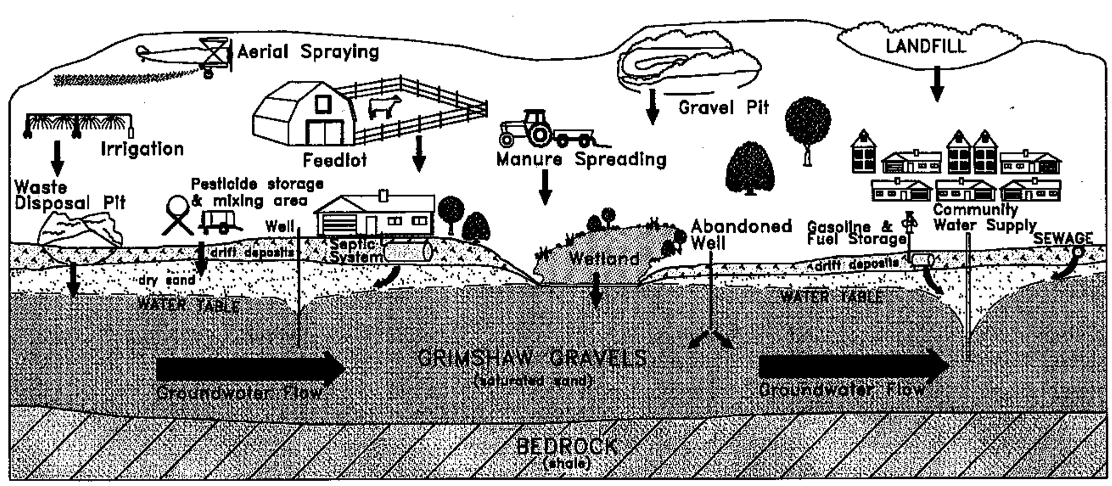


FIGURE 7 Potential Sources of Contamination

more vulnerable to contamination from surface sources. As a first step, the approximate thickness of the drift cover can be used to identify potentially sensitive areas, as shown in Figure B6. Areas with less than 4 metres of drift cover have been designated as potentially highly sensitive areas. Additional test drilling would be required to confirm the nature and thickness of the drift cover and, over the long term, a more comprehensive "aquifer vulnerability" map should be developed.

Potential contamination from surface sources is generally the main concern in protecting the water quality of the aquifer. However, the upward movement of poorer water quality from underlying bedrock units may also contribute to water quality degradation in certain parts of the aquifer. In areas where water levels from the underlying bedrock units are higher than those in the aquifer, there is the possibility of water entering the aquifer from below. As groundwater development increases in such an area, the upward movement of the poorer water from the bedrock may increase and cause a progressive deterioration in the overall quality of the aquifer. Although the current data does not show this to be a major problem, some monitoring may be required in areas with ongoing groundwater development.

2.3.1 Well Capture Zones

How do we protect our water supply sources?

Once a well has been installed, there is a need to protect the groundwater supply from surface contamination. In many communities, delineating well capture zones has proven to be an effective measure. The purpose in delineating this area is to assist in the initiation of protective management practices that can prevent any contaminants from reaching the well. One technique often used to delineate this area is to define the well capture zone, as illustrated in Figure 8.

A well capture zone is defined as the area that specifically contributes recharge water to a pumping well.

Potential contaminants within the capture zone can move along the same flowpaths as the recharge water to the well. The capture zone for any well can be estimated by using a simple calculation, as shown in Appendix D1.

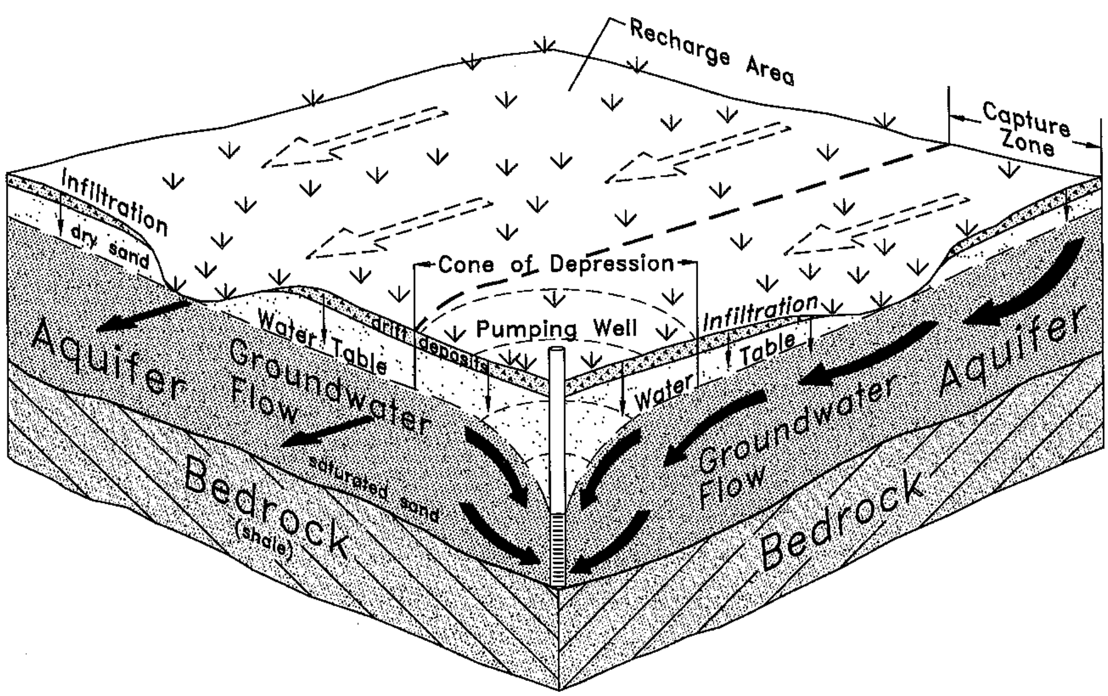


Figure 8 Well Capture Zone

This calculation uses basic aquifer data, along with the pumping rate of the well, to determine the width of the capture zone and the distance down gradient of the well where groundwater does not move to the well. In theory, the capture zone will extend up gradient of the well until an aquifer edge or groundwater divide is encountered. As this may not always be easily defined, there are several other ways the up gradient boundary can be estimated. One method is based on the drawdown criteria, defined by the areal extent of the cone of depression of the well. Another method is the time of travel criteria, which is based on the time it takes groundwater or a contaminant to flow to the well.

The method used in this report is based on recharge criteria. The capture zone is defined by the land area that provides the amount of annual recharge required to balance the quantity of water being discharged at the well. As described in Section 2.2.1, about 1.7 L/s (22.5 igpm) per square mile may be a reasonable annual recharge amount that could be used for withdrawal by wells. Therefore, if the withdrawal rate for a well is 3.4 L/s (45 igpm), then the areal extent of the capture zone would be about 2 square miles. If other wells are completed in this capture zone, the area must be increased. Again, this is just a guide and the actual pumping data and local aquifer conditions must be examined before deciding the best approach to use for defining the areal extent of the well capture zone.

For existing municipal wells, preliminary well capture zones have been delineated, as shown in Figure B13. More detailed field investigations are required to confirm the "final" well capture zone areas that could be used for each municipal well.

3.0 MANAGEMENT ISSUES

How do we best manage development on the aquifer?

There are a variety of issues related to management of the Grimshaw Gravels Aquifer, each with its own allocation and/or protection concerns. In dealing with concerns related to these various issues, a clear and practical technique must be developed. Three of the main issues to be considered in this report are:

- Municipal/Irrigation Water Supply Sites
- Potential Point-Sources of Contamination
- Potential Non-Point Sources of Contamination

A series of maps and tables have been developed to address issues with common management implications. These maps and tables are presented in Appendices B and C, respectively. The tables provide a brief description of the nature of the management decisions anticipated for a particular issue, and the maps provide some guidance in making these decisions.

3.1 MUNICIPAL/IRRIGATION WELLS

How do we select a suitable well site?

In siting a municipal well, there are allocation and protection concerns that must be addressed (Appendix C, Table 1). A method to allocate groundwater should be in place to ensure sufficient water is available to sustain the current population and allow for future growth. An understanding of how much water can be safely withdrawn without adversely affecting other groundwater usages is fundamental in making management decisions. Special tools, such as an aquifer model, which can provide a reasonable representation of various allocation scenarios, can be used. Water level and spring flow monitoring can also provide some guidance on the effects of current groundwater development, and to verify conditions and water level trends in sensitive areas.

3.1.1 Selection Criteria for a Well Site

When selecting a well site, the local aquifer conditions must be evaluated. If there is a risk of over-development, an experienced hydrogeologist should be consulted to evaluate the groundwater supply potential. Technical and Regulatory Assistance can be acquired through Regional Water Management Administration Branch of Alberta Environmental Protection in Peace River.

The following are a series of decision steps that must be taken:

Step 1: Determine water requirements, and then, consult the well yield map to determine expected yields (Figure B7). This map serves as a guide to determine if exploration is warranted, or if other areas should be considered.

Step 2: Establish water quality parameters and determine suitability. The water quality maps indicate the general quality parameters expected for an area (Figures B8-B11). Sampling of nearby wells can be carried out to confirm water quality parameters.

Step 3: *If the above two conditions appear favourable,* a groundwater evaluation for the site can be prepared to determine the expected yields and any potential impacts.

Step 4: After some testing at the site, a well capture zone should be established to define the area that contributes recharge water to the well.

Step 5: A well inventory should be conducted, with the proximity to other wells noted. Wherever possible, a well should be developed outside the capture zone of other wells, *if this is not possible then,*

Step 6: The well should be developed in an area where interference effects are expected to be tolerable. Simple analytical methods can be applied to well pumping test results to estimate the amount of interference and to predict the effect of long-term pumping on water levels. The assistance of an experienced hydrogeologist may be required.

Step 7: If wells share the same capture zone and interference effects are significant, another site may have to be considered, or the existing wells deepened. If the site is developed, then ongoing monitoring will be required to forewarn of declining water level trends.

Step 8: In areas where well capture zones overlap and groundwater development is well established, the water levels must be monitored. In the event that water table decline becomes intolerable, alternate water supplies must be considered.

3.1.2 Preventing Contamination of the Well Site

Protection of the water supply is a high priority and the following are some of the management considerations:

- all activities that represent sources of potential point and non-point contamination should be avoided within the capture zone of a well, *if this is not possible then,*

- an inventory of all potential contamination sources located within a well capture zone should be conducted so that they can be properly managed, in order to minimize any contamination threat.

- if there is a high risk of contamination, measures should be in place to reduce or eliminate the risk of contamination. An emergency preparedness plan must also be in place to deal with the possibility of locating an alternate water supply source or to deal with accidental spills.

In the case of siting an irrigation well or any other high-capacity well, the management considerations would be similar. However, the soil suitability must be determined when considering irrigation development, since the movement of pesticides and fertilizers through the soil may represent a contamination threat to the underlying aquifer.

3.2 POTENTIAL POINT SOURCES OF GROUNDWATER CONTAMINATION

Point source contamination is contamination which may occur to groundwater at specific locations, such as feedlots, waste disposal sites, chemical or fuel storage sites, sewage lagoons, septic fields, pipelines, drainage wells, borrow pits, or accidental spills. Since the Grimshaw Gravels Aquifer is predominantly an unconfined aquifer, it is vulnerable to contamination from these potential sources. The predominant types of potential point sources of contamination in the area are shown in Figure B12. The following are some of the management considerations when dealing with these sources (also described in Appendix C, Table 2a):

a) if possible, potential sources of contamination should not be located on the aquifer; *since this may not always be feasible,*

b) an attempt should be made to locate point sources of contamination on the aquifer down gradient of high groundwater use areas.

c) consideration should be given to the level of protection that is expected at a site that overlies the aquifer. The thickness and permeability of drift cover are the main criteria that should be considered. A minimum thickness of at least four metres is suggested. The drift cover map (Figure B6) provides a general indication where sensitive areas(<4m) of the aquifer may be located.

d) if existing or proposed sites overlie the aquifer, they should be sited outside well capture zones and must be managed to minimize any pollution threat.

e) if these sites are located within a well capture zone, a plan must be in place to deal with any monitoring or decommissioning requirements. This would include any special design requirements to deal with potential hazards.

f) a contingency plan should be in place if a move to an alternate site may be required.

In assessing the suitability of sites for potential point sources of contamination, the drift cover map serves only as a quick guide to determine if an area should be given further consideration. For a particular type of development, detailed site-specific investigations and evaluations are always recommended before proceeding with any development.

3.2.1 Individual Water Wells

Wells are unique in that they not only represent a means to extract groundwater, but also a potential source of contamination. Wells are direct access points to the aquifer and must be constructed, operated, reclaimed and/or managed in a manner that protects water quality (see Appendix C; Table 2b). The general nature of management decisions related to water wells are outlined as follows:

- ideally, wells should be located upslope of any potential contamination sources and outside the capture zone of other wells.

- wells should be constructed with an impermeable seal between the hole and well casing to prevent infiltration of contaminants and the well should be securely capped. Well pits are not recommended.

- wells should be constructed in a manner that will not allow cross communication between two different aquifers, such as a bedrock aquifer and an overlying gravel aquifer.

- all surface runoff should be directed away from the well to prevent ponding.

- if a well is abandoned, the casing should be removed and the hole plugged with bentonite or cement grout. Well reclamation procedures are provided by Alberta Environmental Protection.

3.2.2 Gravel Pits

Gravel pits are permanent excavations that not only represent a potential point source of contamination, but if properly managed, may also represent a potential source of artificial recharge to the aquifer. In any case, gravel pits must be located, constructed, operated and decommissioned in a manner that protects the water quality of the aquifer, as described in Appendix C (Table 2c). The key management considerations are as follows:

- locate pits in topographically high areas, with surface runoff diverted around the pit.

- if possible, pits should be situated down gradient or outside capture zones of wells.

- for active or non-active pits situated on the aquifer, plans must be in place to deal with any monitoring or decommissioning requirements.

- signs and controlled access to the pit should be in place, indicating that waste disposal is not permitted in gravel pits.

- a contingency plan should be in place in the event of accidental spills.

3.2.3 Test Holes and Excavations

Ongoing activities such as test hole drilling and excavations represent potential avenues of contamination (Appendix C, Table 2b). It is important that these activities not be overlooked. All exploratory test holes, seismic shot holes, and excavations within the area of the aquifer must always be properly reclaimed. When drilling or excavating, no contaminants should be introduced into the test hole or excavation. Excavations into the aquifer for the purpose of draining sloughs or any other surface effluent that may contain potential contaminants should also be avoided.

3.3 POTENTIAL NON-POINT SOURCES OF GROUNDWATER CONTAMINATION

Non-point source contamination is contamination that occurs from a source dispersed over a large area. This includes activities such as aerial and ground spraying of chemicals, and the application of agricultural chemicals to cropland or chemicals applied to maintain golf courses and lawns. All these activities must be sensitive to local hydrogeological conditions (see Appendix C; Table 3). Other activities such as irrigation also represent potential non-point sources of contamination. Excess irrigation water saturates the soil and causes water to flow downward to the aquifer at higher rates than normal. This water may carry residues from pesticides and fertilizers applied to the land. Animal wastes concentrated in areas represent potential sources of nitrate contamination, since precipitation can leach the nitrogen from the animal wastes downward into the aquifer.

As with any potential contamination source, the following are some management considerations:

- if possible, potential non-point sources of contamination should be situated down gradient of the Grimshaw Gravels Aquifer; *since this may not be feasible then,*

- all activities related to non-point sources of contamination should be located outside well capture zones and in areas where the drift cover is sufficient to reduce the downward movement of potential contaminants.

- in areas where potential non-point contamination sources are within a well capture zone or in areas of thin drift cover, the manner in which pesticides and fertilizers are applied must be carefully managed.

Often it is difficult to completely avoid some of the activities described above. However, in the interest of protecting local water supplies an education and awareness program should be implemented that stresses best management practices. Best management practices are simply methods, measures or practices designed to prevent or reduce the risk of contamination to underlying aquifers.

4.0 RECOMMENDED ACTIONS

How can this strategy be implemented?

Several ideas and techniques on how best to protect the Grimshaw Gravels Aquifer from overuse or contamination have been presented. These should be reviewed by GAMAC before an approach for an aquifer management plan is finalized. The group can then proceed with the implementation of a plan. As GAMAC develops their management plan, the following items should be considered:

- public participation and awareness program
- existing database
- delineation of well capture zones
- aquifer vulnerability mapping
- ongoing monitoring
- planning and review process
- aquifer management policies

4.1 PUBLIC PARTICIPATION AND AWARENESS PROGRAM

This activity is probably the most important. In order to achieve the goal of implementing a locally-driven aquifer management plan, the general public must be encouraged to take an active role. This plan will only be effective if the local community, which relies on the Grimshaw Gravels Aquifer as a water supply source, supports and understands the range of measures required to protect the aquifer.

The following are some of activities that can be considered:

a) a public awareness and education program, designed to be both informative and interactive.

b) a community open-house that relates general groundwater and management concepts to the public.

c) a groundwater festival that targets both children and adults.

d) educational/extension material on ground-water issues in the form of pamphlets and brochures.

e) develop checklist or guidebook on protection issues for individual use.

f) establish telephone "hot-line" for individuals to obtain more specific information.

g) road signs designating groundwater management areas.

h) interpretative roadside displays, describing local groundwater conditions

i) demonstration projects, such as proper well reclamation, well treatment procedures, etc.

These activities would not only assist the public in understanding the issues, but encourage them to consider implementing water conservation and pollution prevention practices.

4.2 EXISTING DATA BASE

One of the initial information-gathering steps was to gather data that would describe the aquifer characteristics and provide a better understanding of the Grimshaw Gravels Aquifer system. An aquifer data base was prepared by Cowan(1994), which contains most of the necessary aquifer-related information. Information obtained from the well owner's survey and the water table elevation (GPS) survey can also be added to the data base.

The existing data base was used to generate many of the maps presented in Appendix B. The goal is to design a data base that is management-focused and updateable at the local level. This will allow local users to make better decisions on the development of their aquifer. This data base will become an essential management tool, with the ability to illustrate, by way of maps, management-related issues in a clear and concise manner.

4.3 DELINEATION OF WELL CAPTURE ZONES

Although the entire aquifer area must be protected from overuse and contamination, special consideration must be given to areas surrounding pumping wells. Preliminary capture zones around the municipal-type wells located on the Grimshaw Gravels Aquifer are illustrated in Figure B13. To confirm these preliminary well capture zones, the individual well performance and local aquifer characteristics must be reviewed. Accurate water level elevations are also required. Any features such as local recharge areas can be incorporated into the well capture zone. By defining this area as precisely as possible, a protection program can be focused on the land area that provides the recharge water to the well.

4.4 AQUIFER VULNERABILITY MAPPING

The drift cover map indicates areas where the aquifer is likely more sensitive to contamination. The next step is to prepare a comprehensive "aquifer vulnerability" map, which considers the physical characteristics of the overlying drift cover (e.g. permeability, fracturing, etc.) in identifying vulnerable areas. When completed, this map will become an important management tool to assist in proper site selection for proposed developments. Some test drilling may be necessary to confirm "window" areas into the aquifer. Tests to evaluate the soil permeability may also be required at selected sites. Highly vulnerable areas must be inspected in the field to assess any potential risks to the aquifer.

4.5 ONGOING MONITORING

Additional observation wells may be required to confirm recharge estimates within each aquifer lobe. Ongoing monitoring of precipitation amounts, water levels and spring flows will be necessary to evaluate aquifer trends and assess the impacts of aquifer development. Water level monitoring can likely be carried out most cost effectively in existing wells, possibly supplemented by a few strategically located observation wells. As one suggestion, the group may use volunteers to measure the water levels in 10 to 30 wells located within each of the lobes, three or four times a year. Water levels should be measured in the morning before the pump has started operating for the day.

The collection of water samples from strategically located existing wells may also be necessary for ongoing monitoring of water quality. Water samples should be taken and tested for nitrates and chlorides about every 2 years, more frequently if elevated or rising levels are detected.

4.6 PLANNING AND REVIEW PROCESS

As part of the implementation of a management plan, a planning and review process should be established by the Grimshaw Aquifer Management Advisory Committee (GAMAC). The intent of this action would be to establish a protocol and a program for an ongoing assessment of both water quality and quantity in the aquifer. The objective of this process would be to review the effect of groundwater withdrawals and to introduce long-term planning measures that would effectively utilize and protect the groundwater resources.

4.7 AQUIFER MANAGEMENT POLICIES

At some point in the implementation of an aquifer management plan, public policies may have to be established to protect groundwater resources from overuse and contamination. In doing so, a broad-based representation from all perspectives within the local community is required. This is the only way to effectively implement a community-based groundwater allocation and protection policy on any of the issues raised in this report.

Provincial government agencies responsible for water management will always have a role in certain planning and policy issues (e.g. licensing of municipal and irrigation wells). However, the intent is for local groups, such as GAMAC to develop and direct management policies based on development issues for their aquifer. Of course, these policies should be consistent with provincial water management policies and take into account other related polices which may be in place. In developing policies and development strategies, groundwater must be recognized as a resource with both economic and ecological value.

5.0 FUTURE CONSIDERATIONS

What other activities can improve our ability to manage the aquifer?

Once a management approach is finalized and certain parts of the plan are implemented, there may be a need to gather some more information. As required, this information would be collected to deal with a specific management issue. The following are some future activities that could be considered.

5.1 IMPROVEMENT OF EXISTING DATA BASE

Information generated as a result of new, site-specific developments can be added to the data base. There are also several areas where additional or more accurate data is required to improve the information base. This can also be added, as required. Another example is the additional effort that must be made to understand the relationship between the various components of the Grimshaw Gravels Aquifer System (i.e. the gravels, Cardinal Lake, the underlying bedrock units, the buried valleys, etc). Some targeted test hole drilling and testing, and the installation of a few strategically placed observation wells would be required to obtain this data. Other pertinent information that would be a valuable addition to the data base is listed below.

5.1.1 Elevation Data

More precise surface and water table elevation data is required. Accurate water table elevation data would enable better estimates of groundwater flow directions to be made. Also, when any aquifer modelling is considered, it will be easier to calibrate the model with this improved data. Accurate surface elevation data is important to verify the geological cross sections that have been prepared as part of this report.

A GPS well survey was conducted on selected wells by PFRA personnel from the Peace River office. This survey should be expanded to include an additional 100 wells or more. This data would be collected in areas where no or minimal elevation data is currently available. To keep the cost of this survey to a minimum, it could be carried out in conjunction with any additional well surveys required in the future.

5.1.2 Well Owner's Survey

A well owner's survey has been completed. This survey should be reviewed, and the location and condition of any unused well should be determined. If a well is no longer in use, it should be reclaimed, or protected to ensure the well does not become an avenue for contaminants to enter the aquifer. In order to protect the water quality of the aquifer, the well owner should be instructed on proper well reclamation procedures and be provided with the names of contractors who can carry out this work.

Also, as specific issues arise a more detailed survey may be required to gather additional information.

5.1.3 Land Use Inventory

The purpose of a land use inventory is to determine if there are any land use activities that could potentially contaminate the groundwater supply. The assumption is that any activity that occurs on the land surface has the potential to contaminate the underlying aquifer. For example, the location of all gravel pits and highway borrow pits is important, since they may represent direct access points to the aquifer. The susceptibility of these sites to surface contaminants must also be assessed, to ensure that contaminants will not enter the aquifer. If these pits are no longer in use, the pit must be properly decommissioned to ensure that it does not become a potential source of contamination for the aquifer. (Refer to "Guide for Pits - Alberta Environmental Protection and Alberta Agriculture Food & Rural Development 1995")

An inventory of all potential contamination sites or activities located on the aquifer should be completed. The major sites have been noted on Figure B12. Other activities could include residential, agricultural, commercial or industrial activities which have the potential to contaminate the aquifer. These site areas can then be located and assessed for their risk potential (possibly using the Drift Cover Map - Figure B6 to set priorities for assessment). Areas where elevated concentrations of chloride and nitrate, or nitrate alone have been recorded in the past, should receive special scrutiny.

5.1.4 Test Drilling

Some targeted drilling may be required to determine the relationship between various aquifer units, such as the Grimshaw Gravels, bedrock aquifers, buried valley and buried terrace deposits. This could be done as the need arises and as funds permit. The results of all exploratory test holes and well installations in the area should be entered into the local data base.

5.2 APPLIED RESEARCH

Obtaining more detailed information on different aspects of the Grimshaw Gravels Aquifer system could become time-consuming and expensive. Therefore, every opportunity should be taken by GAMAC to obtain technical assistance by working together with industry, universities and governments. This could involve working on a special project with university graduate students to conduct more detailed water level or soil surveys. Another example is working with industry and government to evaluate practices that reduce the risk of aquifer contamination.

5.3 EMERGENCY PREPAREDNESS

An important part in aquifer protection is to be prepared for an emergency situation. This ensures that local communities have measures in place to deal with accidental spills or contamination of a water supply source. This should include an emergency response plan that can provide short-term water supply alternatives and, if necessary, long-term or permanent water supply alternatives.

If contaminants are released into the environment, a local team should be in place to implement emergency response procedures. These procedures must include the appropriate provincial and federal officials to contact, the appropriate equipment to have on hand and a well organized action plan. The appropriate provincial government agencies should be contacted to see what is already in place. These agencies can provide both information and guidance in developing a local emergency response plan.

Appendix A

Appendix A1

Bibliography

Earlier Study Reports

Cowan, A., 1994. Hydrogeologic Evaluation of the Grimshaw Gravels Aquifer; Grimshaw, Alberta. Interim Report. Prepared for Alberta Environmental Protection. Edmonton, Alberta.

Prairie Farm Rehabilitation Administration, 1995. *Interim Report for Grimshaw Gravels Test Drilling Program.* Earth Sciences Division. Regina, Saskatchewan.

Other References

Agricultural Law and Policy Institute, 1988. *Farming and Groundwater: An Introduction.* Issues Booklet No.1. Agricultural Law and Policy Institute, Inc. University of Minnesota. Minneapolis, Minnesota.

Alberta Agriculture, Food and Rural Development; Alberta Environmental Protection; Agriculture and Agri-Food Canada (PFRA), 1996. *Water Wells ... that last for generations.*

Driscoll, F.G., 1986. *Groundwater and Wells.* Second Edition. Johnson Division. St. Paul, Minnesota. ISBN 0-9616456-0-1

Omni-McCann Consultants Ltd., 1995. *Town of Grimshaw 1993/1994 Groundwater Monitoring Report.* Edmonton, Alberta.

Ontario Ministry of Agriculture and Food, 1994. Best Management Practices: Water Management. ISBN 0-7778-2361-6

The Groundwater Foundation, 1994. *A Community Guide To Groundwater Guardian.* 1995 Program Year Edition. Lincoln, Nebraska.

Tokarsky, O., 1967. *Geology and Groundwater Resources of the Grimshaw - Cardinal Lake Area, Alberta.* Graduate Thesis, University of Alberta, Department of Geology. Edmonton, Alberta.

U.S. Environmental Protection Agency, 1993. *Wellhead Protection: A Guide for Small Communities.* Seminar Publication. Office of Research and Development, Office of Water. Washington, D.C. EPA/625/R-93/002

Appendix A2

Definition of Terms and Abbreviations

Analytical methods: the use of easily understood mathematical equations and calculations to define groundwater movement and contaminant transport.

Aquifer: a water-bearing unit that will yield water in a useable quantity to a well or spring.

Aquifer model: a computerized mathematical description of the aquifer system, used to understand its physical behaviour.

Aquifer system: a general term used to define all areas pertaining to the aquifer that contribute, remove or store groundwater.

Bedrock: a general term for consolidated material, such as sandstone and shale, that underlies soils or other unconsolidated material.

Capture zone: the entire area recharging or contributing water to a well or well field.

Cone of depression: the depression in the water table or potentiometric surface around a well caused by the withdrawal of water. It defines the area of influence of a well.

Confined aquifer: an aquifer completely saturated with water and bounded above and below by units, such as clay, which have a distinctly lower permeability than the aquifer itself. In a confined aquifer the groundwater is under pressure, and when a well is drilled into a confined aquifer, the water rises above the level of the aquifer.

Contaminant: an undesirable substance not normally present in the water or soil.

Contamination: the degradation of natural water quality as a result of man's activities. The degree of permissible contamination depends upon the intended end use, or uses, of the water.

Contingency plan: a plan that prepares for the unforeseen or an accidental occurrence.

Drift deposits: a general term for unconsolidated material transported by glaciers and deposited directly on land or in the sea.

Drawdown: the decline in groundwater level at a point caused by the withdrawal of water from an aquifer.

Flow lines: lines indicating the direction followed by groundwater toward points of discharge. Flow lines are perpendicular to water table contours.

Flow path: subsurface course a water molecule or solute would follow.

Groundwater: subsurface water contained in openings and pore spaces below the water table in an unconfined aquifer or located in a confined aquifer.

Groundwater divide: a ridge in the water table from which groundwater moves away in both directions.

Hydraulic gradient: the slope of the water table or potentiometric surface; that is, the change in water level per unit distance along the direction of maximum head decrease. Determined by measuring the water level in several wells.

Hydrogeologic: factors that deal with subsurface waters and related geologic aspects of surface waters.

Hydrologic cycle: the exchange of water between the Earth and the atmosphere through evaporation and precipitation.

Infiltration: the downward entry of water into soil or rock.

Interference: the condition occurring when the cone of depression of a well comes into contact or overlaps that of a neighbouring well. At a given location, the total well interference is the sum of the drawdowns due to each individual well.

IGPM: Imperial Gallons Per Minute

L/s: Litres Per Second

Leaching: removal of materials in solution from rock, soil, or waste; separation or dissolving out of soluble constituents from a porous medium by percolation of water.

Non-point source: a dispersed source that discharges contaminants into the environment.

Observation well: a non-pumping well used to observe the water table elevation or potentiometric surface.

Permeability: the measure of a material's ability to allow the passage of a fluid.

Potentiometric Surface: the potential level to which water will rise above the water level in an aquifer in a well than penetrates a confined aquifer, if the potential level is high than the land surface, the well will overflow.

Point source: a specific site from which contaminants are or may be discharged into the environment.

Porosity: the ratio of the total volume of voids available for fluid transmission to the total volume of a porous medium.

Potable water: suitable for human consumption as drinking water.

Recharge: the addition of water to the zone of saturation; also the amount of water added. Can be expressed as a rate (i.e. mm/yr) or a volume.

Recharge area: area in which water reaches the zone of saturation by surface infiltration.

Saturated zone: the portion of the subsurface environment where the void spaces are filled with water.

Spring: place where groundwater flows naturally from rock or soil onto the land surface or into a surface water body.

Time of travel (TOT): the time required for a contaminant to move in the saturated zone from a specific point to a well.

Transpiration: the process where water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface.

Unconfined aquifer: an aquifer where the water table is exposed to the atmosphere through openings in the overlying material.

Water table: level below which the ground is saturated with water.

APPENDIX B

Maps

APPENDIX C

Tables

TABLE 1
Municipal-Type or Irrigation Supply

Issue: *Allocation*

Groundwater withdrawals must be consistent with sustainable development of the aquifer. Areas that provide the primary recharge water to a well or well field have been defined as "well capture zones".

Nature of Management Decisions	Screening Tools	Contacts	Remarks
Initial Considerations: ❶ Well Yield: review reported well yields to select a site that can provide the required pump rate. ❷ Water Quality: review reported total dissolved solids, iron, nitrate and chloride levels. **Site Considerations:** *Most to Least Desirable:* ❶ Well developed outside the cone of depression of other wells. ❷ Well located within the cone of depression of an adjacent well/wellfield, but interference levels are low. ❸ Well located within the cone of depression of an adjacent well/ wellfield and the interference effects are significant. *(need to monitor wells/water levels to forewarn of undesirable declining water level trends.)* ❹ Contingency plans in place to move to alternate site.	**Well Yield Map** (Figure B7): illustrates point well yield data. **Water Quality Maps** (Figures B8 - B11): Total Dissolved Solids, Iron, Nitrate, and Chloride. **Water Table Elevation Contour Map** (Figure B5): general static water level contours. **Aquifer Model:** Input data into aquifer model to predict revised water table contours due to additional development. **Well Capture Zones Map** (Figure B13): establish capture zone of well and determine if other wells are within this area. (see Appendix D).	**Licensing:** Alberta Environment; Natural Resources Service, Water Management Division: **Evaluation Assistance:** Mackenzie Municipal Services Agency PFRA - Peace River: Alberta Environment, Environmental Service **Water Quality:** Local Health Authority: (Environmental Health Dept.)	• all withdrawals must be evaluated relative to aquifer capacity and active aquifer models must be in place to assist in making allocation decisions. • aquifer levels and licensed wells must be monitored regularly to compare to predicted trends. • guidelines available for obtaining a licence or permit. Natural Resources Service, Water Management Division approves licences and sets out terms and conditions for water use. • "Water Wells ...that last for generations" booklet provides guidance for both allocation and protection issues.

Issue: *Protection*

Wells must be located, designed and constructed to protect water.

Nature of Management Decisions	Screening Tools	Contacts	Remarks
Most to Least Desirable: ❶ Point and non-point contamination sources* should be avoided within capture zones of wells. ❷ Potential contamination sources managed in ways that minimize pollution threat if located within well capture zone. ❸ Engineered mitigation measures designed to reduce or eliminate contamination threat . ❹ Contingency plans in place to move to alternate site.	**Drift Cover Map** (Figure B6): level of protection dependent on the thickness and nature of drift cover. **Well Capture Zones Map** (Figure B13): determine if potential contamination source is within zone of influence of well. **Potential Point Sources of Contamination Map** (Figure B12)	Alberta Agriculture: PFRA - Peace River:	• all potential sources of contamination must be evaluated and managed in a manner compatible with the local hydrogeological conditions. • monitoring required as outlined in licence. • for irrigation development, the soil suitability must be determined.

* <u>Non-point sources of contamination include</u>: agricultural practices and other activities which occur within the capture zone of the well.
<u>Point source contamination includes</u>: underground storage tanks, feed lots, waste disposal sites septic tanks/fields, etc.

TABLE 2a
Point Sources of Contamination

Feedlots, Fuel/Pesticide/Fertilizer Storage Facilities, Landfills, Lagoons/Septic Fields, etc.

Issue: *Protection*

All point sources of contamination should be inventoried. As a general criteria, activities which represent point sources of contamination should be located at sites with a drift cover of greater than four metres in order to protect the aquifer from contamination.

Nature of Management Decisions	Screening Tools	Contacts
Most to Least Desirable: ❶ Ideally, all point sources of contamination should be situated down gradient of the Grimshaw Gravels Aquifer; where this is not possible then - ❷ sites which represent point sources of contamination should not be located within well capture zones; if not possible then - ❸ for all active/non-active sites of potential contamination located within a well capture zone, management plans must be in place to deal with any monitoring or decommissioning requirements. This includes any special design requirements to mitigate potential hazards; if necessary - ❹ a contingency plan should be in place to move to an alternate site.	**Water Table Elevation Contour Map** (Figure B5): flow directions on site. **Drift Cover Map** (Figure B6): level of protection dependent upon the amount of drift cover. **Well Capture Zones Map** (Figure B13): determine if site is within capture zone of nearby wells. **Potential Point Sources of Contamination** (Figure B12)	Alberta Agriculture, Food & Rural Development (AAFRD): PFRA - Peace River: Alberta Environment, Environmental Regulatory Services: Local Health Authority: (Environmental Health Dept.)

Remarks			
Feedlots:	Landfill/Waste Disposal Sites:	Fuel/Pesticide/Fertilizer Storage Facilities:	Lagoons/Septic Fields:
• guidelines that recommend a code of practice are available from Alberta Agriculture.	• regulations are in place for the design and operation of a landfill. Groundwater monitoring is a requirement. Guidelines are available for industrial and municipal landfills. • covered by the Environmental Protection and Enhancement Act. • Public Health Act has regulations on waste management.	• guidelines available for storage facilities using tanks and containers for hazardous material. • under the Environmental Protection and Enhancement Act, reporting of accidental spills is required. In the event of a spill Alberta Environment will respond (PERT). • Alberta Environment provides licences and permits for agricultural chemicals and under certain conditions can require groundwater quality monitoring. • voluntary program to register commercial storage tanks in Alberta: Management of Underground Storage Tanks (MUST).	• recommended guidelines for design, approval and operation of Sewage Lagoons and liners for municipal Waste-water stabilization ponds. • guidelines for private sewage disposal systems . However, private septic fields do not require a licence under Alberta Environment & Enhancement Act (EPEA). • regulations under the EPEA for septic tanks used for municipal developments. • Alberta Labour provides permits for onsite sewage disposal

TABLE 2b
Point Sources of Contamination

Water Wells: active, inactive, drainage/disposal well

Issue: *Protection*

Water wells are direct access points to the aquifer and must be located, constructed and reclaimed in a manner that protects water quality.

Nature of Management Decisions	Screening Tools	Contacts	Remarks
❶ Wells should be located upslope from any potential contamination sources and outside the capture zone of other wells. ❷ Wells should be constructed to avoid ponding, and surface water should be directed away from the well. ❸ Wells must be securely capped and a seal must be in place between the hole and well casing to prevent infiltration of surface contaminants. ❹ Wells that are inactive should be properly reclaimed. (Alberta Environment provides Well Reclamation procedures)	**Water Table Elevation Contour Map** (Figure B5): flow directions on site. **Drift Cover Map** (Figure B6): level of protection dependent upon thickness of drift cover. **Well Capture Zones Map** (Figure B13): determine if area is within capture zone of nearby wells. **Potential Point Sources of Contamination** (Figure B12)	Alberta Agriculture, Food & Rural Development (AAFRD): PFRA - Peace River: Alberta Environment: Local Health Authority: (Environmental Health Dept.)	• Alberta Environmental Protection & Enhancement Act (EPEA) provides regulations on water well drilling and construction. • Public Health Act provides general sanitation regulations. • waste disposal and drainage wells must be licensed; guidelines provided in terms and conditions of licence. • guidelines available on best management practices for wells from Agriculture Canada.

Test Hole Exploration/Excavations

Issue: *Protection*

All test drilling and excavation activities must be conducted and abandoned in a manner that protects water quality, since these activities may represent direct access points to the aquifer.

Nature of Management Decisions	Screening Tools	Contacts	Remarks
❶ during the drilling or excavation process, special care must be taken to prevent potential contaminants from being introduced into the aquifer. ❷ Once the work has been completed, all exploratory test holes, seismic shot holes and excavations into the aquifer must be properly reclaimed.	**Water Table Elevation Contour Map** (Figure B5): flow directions on site. **Drift Cover Map** (Figure B6): level of protection dependent upon thickness of drift cover. **Well Capture Zones Map** (Figure B13): determine if area is within capture zone of nearby wells. **Potential Point Sources of Contamination** (Figure B12)	Alberta Agriculture, Food & Rural Development (AAFRD): PFRA - Peace River: Alberta Environment: Local Health Authority: (Environmental Health Dept.)	• Alberta Environment has guidelines for reclamation procedures.

TABLE 2c
Point Sources of Contamination

Gravel Pits

Issue: *Protection*

Gravel pits must be located, designed, constructed and decommissioned in a manner that protects the water quality of the Grimshaw Gravels Aquifer.

Site Considerations	Screening Tools	Contacts	Remarks
❶ Gravel pits should be located in topographically high areas, with controlled surface runoff around the site. ❷ Situated outside well capture zones and down gradient from wells in the area. ❸ Waste disposal, of any type, not permitted in gravel pits. ❹ For active/non-active pits on the Grimshaw Aquifer, management plans must be in place to deal with any monitoring or decommissioning requirements.	**Drift Cover Map** (Figure B6): level of protection dependent on the amount of drift cover. **Water Table Elevation Contour Map** (Figure B5): shows general water tale elevations, contours and groundwater flow directions. **Potential Point Sources of Contamination** (Figure B12): determine if contamination sources are in vicinity of gravel pit.	Alberta Agriculture, Food & Rural Development PFRA - Peace River: Alberta Environment, Environmental Services:	• surface operations regulated under the Environmental Protection and Enhancement Act. • Alberta Sand and Gravel Washing Operations (Waste Water Effluent Guidelines). • Alberta Environment has Gravel Pit Development regulations.

TABLE 3
Non-Point Sources of Contamination

Pesticide/Fertilizer Applications, etc.

Issue: *Protection*

All non-point sources of contamination on the Grimshaw Gravels Aquifer should be identified. Activities such as aerial spraying, ground spraying and/or soil incorporation of pesticides and fertilizers must be sensitive to local aquifer conditions. As a general criteria, activities which represent potential non-point sources of contamination should be conducted in areas with a minimum drift cover of four metres, in order to protect the aquifer from contamination.

Nature of Management Decisions	Screening Tools	Contacts	Remarks
Most to Least Desirable: ❶ Ideally all non-point sources of contamination should be situated down gradient of the Grimshaw Gravels Aquifer; where this is not possible then - ❷ non-point sources of contamination should not be located within well capture zones and in areas where the drift cover is greater than four metres, in order to reduce the effect of downward leaching; if not possible then, ❸ for all non-point source contamination activities which must be conducted within a well capture zone or areas of thin drift cover, the amount and manner in which pesticides/fertilizers are applied should be carefully managed by specific management plans.	**Water Table Elevation Contour Map** (Figure B5): flow directions on site. **Drift Cover Map** (Figure B6): level of protection dependent upon the amount of drift cover. **Well Capture Zones Map** (Figure B13): determine if site is within capture zone of nearby wells. **Potential Point Sources of Contamination Map** (Figure B12)	Alberta Agriculture, Food & Rural Development (AAFRD): PFRA - Peace River: Alberta Environment, Environmental Services: Local Health Authority: (Environmental Health Dept.)	• regulations are in place for pesticide sales, use and handling under the Environmental Protection and Enhancement Act. • guidelines and standards are available for the safe and effective application of pesticide chemicals from Alberta Environment. • pesticide monitoring is not required unless directed by Alberta Environment. Groundwater pesticide analysis sites are shown in Figure B12.

APPENDIX D

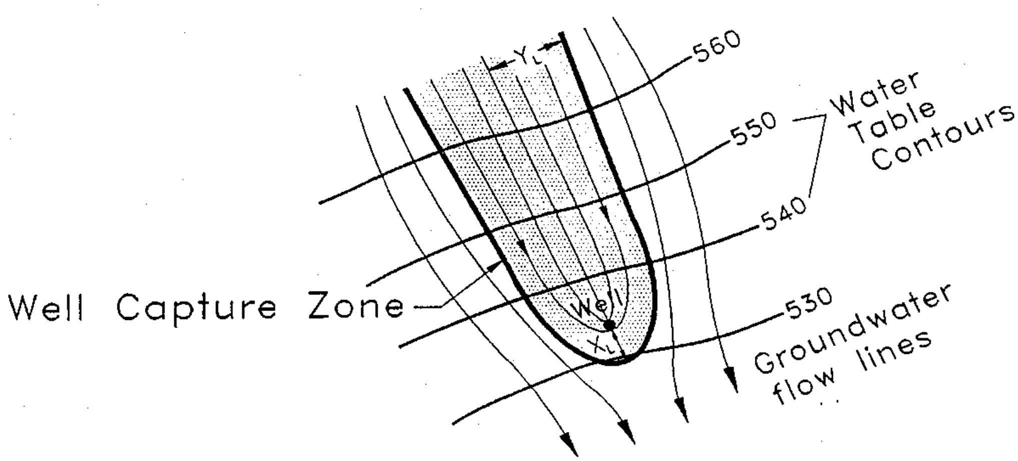
Appendix D1
Delineation of Well Capture Zone
(obtained from USEPA; Wellhead Protection: A Guide for Small Communities. 1993)

The well capture zone for a well can be calculated using the uniform-flow equation below, and estimating the hydraulic gradient from the water table elevation contour map (Figure B5).

Uniform-Flow Equation:

$$-\frac{Y}{X} = \tan\left(\frac{2\pi kbi}{Q}Y\right) \qquad X_L = -\frac{Q}{2\pi kbi} \qquad Y_L = \pm\frac{Q}{2kbi}$$

Distance Down Gradient — Width of Capture Zone From Well



where: Q = well pumping rate
k = aquifer permeability
b = aquifer saturated thickness
i = hydraulic gradient
$\pi = 3.1416$

For the Grimshaw Gravels Aquifer:

Assuming: average aquifer permeability(k) = 150 m/day
average hydraulic gradient(i) = 0.0005

then:

$$X_L = -\frac{Q}{0.47b} \qquad Y_L = \frac{Q}{0.15b}$$

X_L = distance in metres
Y_L = distance in metres
Q = well pumping rate in m^3/day
b = aquifer saturated thickness in metres