VARIATIONS IN RESIDENT APPRAISALS OF GROUNDWATER QUALITY ON SASKATCHEWAN FARMS

A Thesis

submitted to the College of Graduate Studies and Research

in Partial Fulfilment of the Requirements

For the Degree of

Master of Science

in the

Department of Geography

by

Diane Janese Forsdick Martz

Saskatoon, Saskatchewan

UNIVERSITY OF SASKATCHEWAN

COLLEGE OF GRADUATE STUDIES AND RESEARCH

Saskatoon

CERTIFICATION OF THESIS WORK

We, the undersigned, certify that Diane Janese Forsdick Martz

(full name) B.A. (degrees)

candidate for the degree of Master of Science

has presented her thesis with the following title

Variations in Resident Appraisals of Groundwater Quality on Saskatchewan Farms

(as it appears on title page of thesis)

that the thesis is acceptable in form and content, and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on June 27, 1983

External Examiner ____________________

____

Internal Examiners ____________________

____

____

____

____

____

____

____

Date June 27, 1983

PERMISSION TO USE POSTGRADUATE THESIS

Title of Thesis VARIATIONS IN RESIDENT APPRAISALS OF GROUNDWATER QUALITY ON SASKATCHEWAN FARMS

Name of Author DIANE JANESE FORSDICK MARTZ

Department or College DEPARTMENT OF GEOGRAPHY

Degree MASTER OF SCIENCE

In presenting this thesis in partial fulfilment of the requirements for a postgraduate degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the professor or professors who supervised my thesis work, or in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my thesis.

Signature ______________________

Address ______________________

____

Date ______________________

ABSTRACT

Due to climatic and lithologic factors groundwater in Saskatchewan is often of poor quality. Common problems include high levels of iron, manganese, hardness, sulfates, nitrates, and total dissolved solids. These water quality problems may impose economic health and aesthetic costs on Saskatchewan farmers.

Groundwater quality data from Saskatchewan Research Council was combined with data gathered by mailed questionnaires to define four groups of farmers based on the water quality analyses and the farmers' assessment of his water quality.

Discriminant analysis was used to determine whether those variables found to be important in explaining variations in perception in previous research were useful in explaining variations in perception of groundwater quality as illustrated by these groups.

Respondents considered water quality to be less important than problems relating to production and economic issues. They have a high awareness of the presence of general water quality problems, however when asked to identify specific water quality problems, variations begin to arise in perception. The analysis indicates that the severity of the problem and the value of water to the farming operation are positively related to perception of poor quality groundwater. Age and experience with the resource are negatively associated with perception.

Table of Contents

List of Tables

List of Figures

ACKNOWLEDGEMENTS

I wish to thank my supervisor, Dr. M. B. Green for his help and encouragement in the preparation of this thesis. Thanks are also due Dr. J. E. Fitzgibbon and Dr. E. L. Jackson for assistance during the earlier stages of this thesis.

R. G. Arnold and Bill Smith of Saskatchewan Research Council were instrumental in providing the water quality analyses.

Financial assistance was provided through a University of Saskatchewan Teaching Fellowship, a Hantelmann Humanities Scholarship, and a University of Saskatchewan Graduate Scholarship.

Finally, I am grateful for the patience of Robert, Sarah, and Lawrence Martz.

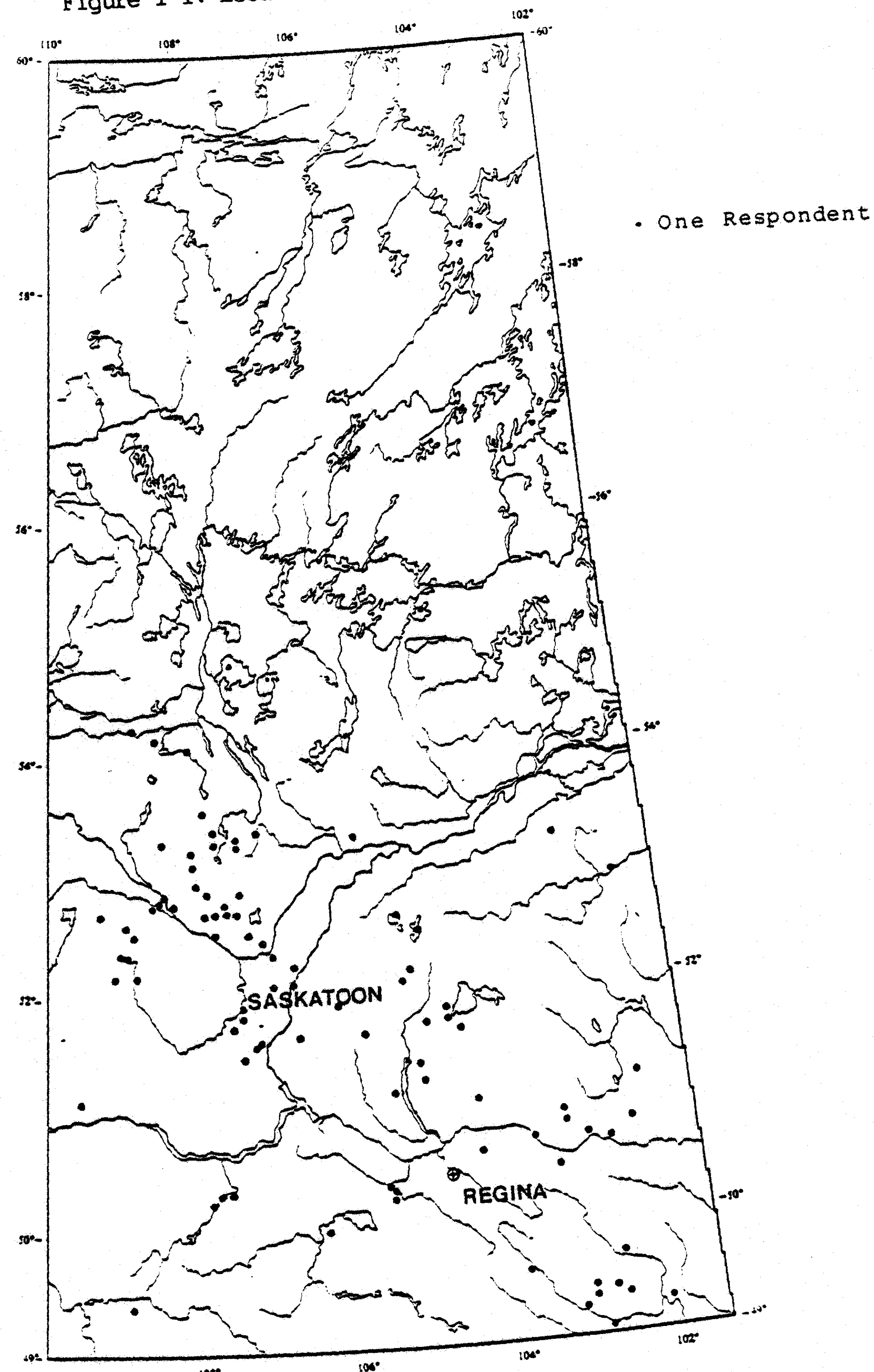
1. INTRODUCTION

The objective of this research is to determine whether farmers perceive they have a water quality problem when they are defined as having a problem by the Canadian Water Quality Standards. Also of interest is to what extent perceivers, those who accurately assess their water quality, and non-perceivers, those who do not feel they have a water quality problem can be described by factors found to be important in previous perception research. The area of study is defined by the farmers who responded to the survey. These respondents are all located in southern Saskatchewan, south of township 62, as shown in figure 1.1

Water quality is an important aspect of water use in Saskatchewan. As a result of both climatic and lithologic conditions, the natural quality of ground water is often poor. Common problems include high levels of total dissolved solids, iron, sulfates, manganese, nitrates, and hardness.

These problems impose health economic, and aesthetic costs on the user. Major economic costs can be attributed to reduced service life of appliances and water systems, water treatment costs, and higher energy costs. As a group, farmers may have higher economic costs than the average consumer as they must maintain large water systems and may have higher overall water use.

Figure 1-1. Location of Respondents to the Survey



1.1 Water Quality

According to the Thornthwaite (1946) classification, most of the settled portion of Saskatchewan can be classed as semi-arid, with potential evapotranspiration exceeding precipitation (Rutherford, 1967; Richards, 1981). Where the rate of evaporation exceeds precipitation as in Saskatchewan, water percolating down to the groundwater zone is often highly mineralized due to the concentration of minerals (Rutherford, 1967).

The major influence on groundwater quality are the leachable salts of precipitate and evaporite sediments. These are calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$) calcium sulfate ($CaSO_4$), sodium bicarbonate ($NaHCO_3$), sodium sulfate (Na_2SO_4), magnesium sulfate ($MgSO_4$), and sodium chloride ($NaCl$) (Rutherford, 1967). These minerals are derived from glacial deposits which include carbonates and gypsiferrous minerals from the parent bedrock and from granite and limestones to the northeast (Rutherford, 1967).

Aquifers yielding water of sufficient quality for domestic use are located in the glacial drift and in the underlying tertiary and cretaceous sediments of alternating marine and non-marine origin.

For the purposes of this research, poor quality water is defined as water having a mineral concentration greater than the maximum allowable limits under the Canadian Guidelines (McNeely, 1979). The Saskatchewan guidelines are based on the Canadian guidelines with higher allowable levels for sodium, sulfate, total dissolved solids, and hardness. as "some values had to be modified in line with the actual situation in Saskatchewan" (Environment Saskatchewan, 1977). The Canadian limits are shown in table 1.1 along with the proportions of respondents with water quality constituents over those limits.

Table 1-1: Canadian Maximum Allowable Limits

Constituent	Limit	Sample Range	Percent Over Limit
Total Dissolved Solids	500mg/l	445 - 8740	96.9%
Hardness	120mg/l	25 - 2150	93.0%
Chloride	250mg/l	1 - 2560	9.4%
Sodium	270mg/l	14 - 1060	43.8%
Nitrate	10mg/l	0 - 450	21.9%
Iron	0.3mg/l	0.8 - 39.1	87.5%
Manganese	0.05mg/l	0.1 - 8.23	91.4%
Alkalinity	30 - 500mg/l	0 - 1090	64.8%
Sulfates	500mg/l	0 - 3080	60.9%

Table 1.1 indicates the scope of water quality problems in Saskatchewan. Over 90% of the respondents have problems with manganese, hardness and total dissolved solids. Between 50% and 90% have levels of sulfates and iron above the maximum allowable limits as defined by the Canadian guidelines. This table

suggests that groundwater quality problems are widespread in Saskatchewan.

Appendix A displays the sources and effects of the common minerals in Saskatchewan water supplies.

1.2 Economic Costs

The use of poor quality water imposes economic, health, and aesthetic costs on the user. Even though a farmer does not consider that he has a problem, he will be subjected to economic costs arising from reduced service life of appliances and plumbing, and higher energy costs. The existence of these costs, which could be thought of as costs of misperception, illustrates the value of identifying those who are non-perceivers .

In areas with poor quality water, household plumbing and appliances are subject to corrosion and abrasion from the mineral constituents in water, thus reducing the service life of the item. The presence of hardness in water necessitates the use of larger amounts of soap and detergent for cleaning. High concentrations of calcium, magnesium, sulfates, iron, potassium, carbonate and bicarbonate increase the operating and energy costs of appliance usage by the formation of heat retarding and flow restricting scales on pipes and heating equipment.

Patterson and Banker (1968) found the service life of water piping, toilet flushing mechanisms, garbage grinders, and washing equipment significantly affected by minerals. They also found the total mineral concentration to be more significant than the individual constituents themselves. The following table shows the difference in average life of these items for 250 ppm total dissolved solids and 1700 ppm total dissolved solids.

Table 1-2: Average Life of Household Items Under Varying Water Quality

	Service Life in Years	
	250mg/l tds	1750mg/l tds
Water piping	35	20
Wastewater piping	45	25
Water heaters	13	6
Faucets	11	7
Toilet flushing mechanisms	10	3
Garbage grinders	8	5
Washing equipment	10	7

Tihansky (1974) studied the effects of total dissolved solids and hardness in order to arrive at an estimate of damage by mineral constituents in water. He found a reduced service life for utensils, appliances and plumbing, operation and maintenance costs, costs for soaps and detergents and costs of water treatment. Per capita damages for well water range from $1.04 in South Carolina to $36.09 in Colorado (in 1970 dollars). Damages for Saskatchewan may approach those for Colorado because of the high mineralization of groundwater in both locations.

These costs represent the minimum cost a farmer would face. Farmers using groundwater must install and maintain large water systems. In some operations higher water use will accelerate the depreciation of equipment. These figures include costs only for total dissolved solids and hardness, additional costs could be expected if high levels of iron, manganese, or iron bacteria were present.

1.3 Health Costs

Water with high levels of dissolved minerals can affect humans in a number of ways. Sulfates, magnesium, and potassium in large quantities can lead to gastrointestinal irritation and laxative effects especially for new users. A tolerance is developed over time and constant consumers are not usually bothered (McNeely, 1979; Lehr et al 1980).

Water containing high levels of sodium may aggrevate cardiac, renal, and circulatory problems. High levels of nitrates may be toxic to infants, causing methaemoglobinaemia, a reduction of the oxygen carrying capacity of the blood. High levels of flouride may result in dental flourosis, a pitting or dark brown discoloration of the teeth. and concentrations greater than 4 mg/l may affect bone structure (McNeely. 1979; Lehr et al, 1980).

Conversely high levels of hardness have been associated with lower death rates from heart disease. although the significance of this is still the subject of much discussion (Joyce, 1980; Brenniman. 1980).

1.4 Aesthetic Costs

An important but difficult to measure aspect of water quality are the aesthetic costs of poor quality water. Most of the dissolved minerals have a taste when present in large quantities, however a tolerance is developed over time and users may find other water tastes poor to them.

The staining of clothing and household items associated with iron and manganese, as well as the scale caused by hardness could be considered aesthetic costs, serving as a constant reminder of the problem and thus be an important motivation for action to reduce the problem.

The above discussion illustrates the water quality problems faced by Saskatchewan farmers. Due to climatic and lithologic conditions, the most common problems are high levels of total dissolved solids, iron, sulfates, manganese, and hardness. The presence of these minerals in a farm water supply may impose substantial costs on the farmer through deterioration of water supply systems and appliances and the provision of treatment to improve water quality. Additional health and aesthetic costs are also present, but due to measurement problems for both health and aesthetic costs and a lack of knowledge of the long term physiological effects of these minerals, these costs are difficult to quantify. Nevertheless, a definite problem exists which imposes large costs on the farmers of Saskatchewan.

2. PERCEPTION STUDIES

The perception approach to the study of water quality problems is valuable in that the behavior of farmers with respect to coping with these problems will be based on their perception of the problem and their perception of the options available for dealing with the problem. Lack of awareness of a problem or of a solution effectively prevents adoption of measures to minimize that problem. Even though a problem is not perceived, it may still pose a cost on the affected individual or group.

For the purpose of geographic research, perception or social perception is defined as " human awareness and understanding of the environment in a general sense" (Burton, Kates, and White, 1978). Awareness is one aspect of perception and is necessary for perception to occur. The study of perception grew out of the need to explain the actions of man in his environment, an explanation that was not achieved by looking soley at the physical nature of the environment (Kates, 1962). Perception studies arise from the theory that "environmental decisions and behavior are based on individual or group images of the real world (Saarinen, 1976).

The environment provides information that is perceived in different ways by different people. These perceptions or images in turn lead to decisions and behavior in the environment which then generates new information and the process continues.

The area of study within geography that has contributed most to perception research is natural hazard research. Natural hazard research has followed the philosophy of Harlan H. Barrows (1923) who defined geography as the "study of human ecology". From this basis, natural hazard research has sought to explain the relationships between the distribution and activities of man and those aspects of the physical environment that are harmful to him. These relationships are viewed from the perspective of man's adjustment to his environment in that "hazards can only be defined in terms of their impact on human society, therefore, they must be seen as the joint product of the events occuring in nature and the existing human adjustment to those events" (Russell, 1969). In this sense, a natural hazard exists wholly neither in the physical realm nor in the human realm. Based on this concept, hazard research has traditionally concerned itself with human behavior which is characterized by the adoption of hazard adjustments.

2.1 Early Natural Hazard Studies

Barrows' ecological approach was applied by Gilbert White in his monograph, Human Adjustment to Floods. White identified the range of adjustments to floods practised in the United States at that time. The predominant adjustments to the flood hazard were flood protection and Government relief. Action to cope with the flood hazard was essentially of a crisis response nature, rarely occuring until after a flood disaster (White, 1945).

Subsequent publications under the direction of White at the

University of Chicago focused on specific adjustments to flooding (Murphy,1958; Sheaffer, 1960), assessment of the extent and change of flood plain occupance, (White et al; Burton, 1962) and a collection of papers exploring specific aspects of the adjustment process (White et al, 1961).

2.2 Attitude and Perception Studies

The studies of flood plain occupance conducted by White and others (1958) and Burton (1962) marked a change in the focus of research from a "somewhat deterministic geography of the physical milieu of flood plains to an inquiry into man's choice in the complex social, economic, and physical world that surrounds him (Kates, 1962).

These studies showed that factors other than the physical aspect of flooding influenced people's decisions to live and work on the flood plain. Site conditions, urban growth, economic factors, and the relationship of the hazard to local resource use were found to be important in man's decision to use the flood plain (White et al, 1958; Burton, 1962).

Burton (1961) and Roder (1961) investigated the relationship between attitudes toward flooding, socioeconomic class, levels of flood hazard, and protection information. They found no direct relationship between knowledge of protective structures or socioeconomic class and residents' expectation of future floods. However , attitudes toward flooding were found to be related to past experience and flood plain residents were not very concerned with the flood hazard as it was only one of many problems affecting their lives (Burton, 1961; Roder, 1961).

White(1961) described choices in resource use as shown in figure 2.1.

Figure 2-1: Choices in Resource Use

```
Theoretical Range        Practical Range          Actual Range
of Adjustments           of Adjustments           of Adjustments

        T ........... ...... P .................  A
         1                    1                    1
        T  ................. P ... .............  A
         2                    2                    2
        T  ...... .......... P    Limiting Factors
         3                    3
        T  ....... ......... P      economic
         4                    4     technological
        T                           environmental
         5     social constraints   social
        T      status quo
         6     awareness
        T
         7
        .
        .
        .
        T
         n
```

Although in theory, a decision in resource management involves a choice among a large number of alternatives, "no manager has open to him in practise the full theoretical range of choice" (White, 1961). The model illustrates that some choices are blocked by social constraints, awareness, and the status quo, resulting in a practical range of choice that is usually much narrower than the theoretical range of choice. The practical range of choice is further reduced as the resource manager takes into consideration economic, technological, environmental, and social factors. The actual choice is thus equivalent to the decision made (White, 1961).

Jackson (1980) found this model useful to describe decisions and choices for coping with energy problems and rising energy costs.

These ideas were developed further by Kates (1962) and White (1964) in a pair of studies that carried on the examination of attitudes, knowledge, and experience begun in the Burton (1961) and Roder (1961) studies. Kates studied the perception of choice of adjustment, the perception of the flood hazard and the relationships between them.

He found that awareness of the hazard increased with frequency of flooding, and that a wide variety of perceptions of the flood hazard existed. This suggested that information and experience were not the only determinants of hazard perception, rather that information was interpreted by the observer and fitted into deterministic, indeterministic, or probabilistic views of flood events.

A companion study by White (1964) sought to determine "the circumstances in which private and public managers choose among several possible adjustments to floods and the extent to which any concious choice is made". White continued the use of his model (figure 2.1, page 12)) to describe the decision processes of flood plain managers. Six factors were seen as useful to describe these decision processes. These were:

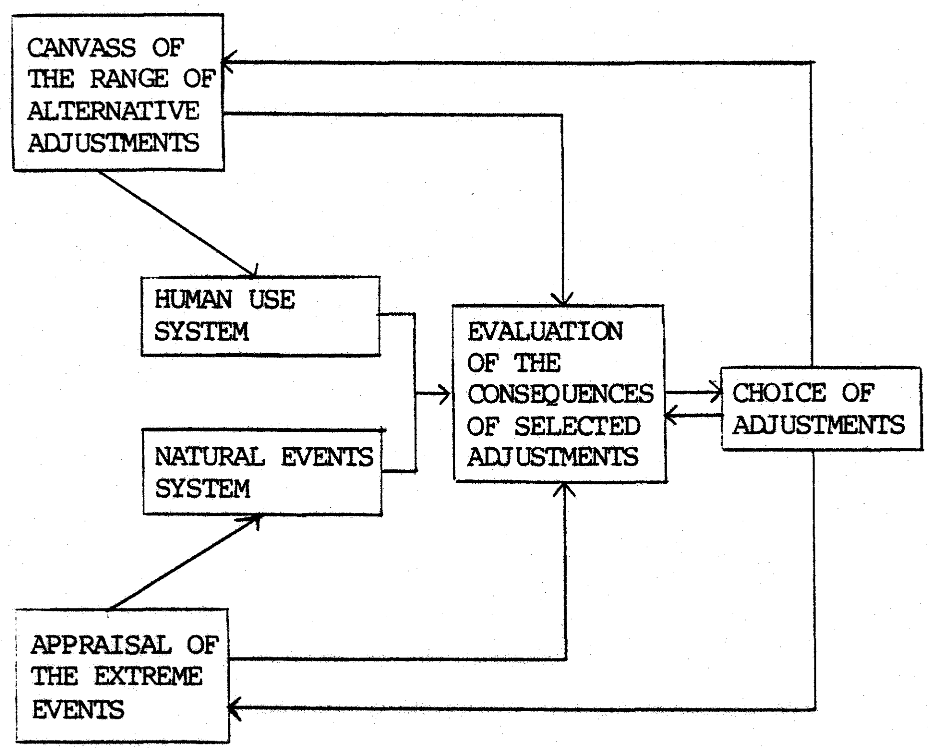
1. economic efficiency
2. the perception managers have of the theoretical range of choice open to them in making adjustments to the flood hazard.
3. The perception managers have of the flood hazard
4. the technology perceived by the managers
5. the managers recognition of the spatial linkages between action in the flood plain and resource use in other areas
6. The complex of social restraint that affects the other elements.

In 1968 the Natural Hazard Research Project was initiated by the University of Chicago, the University of Toronto, and Clark University. A series of papers resulted from this project, exploring such topics as adjustments to hazards, methodologies, responses to natural hazards in different cultural settings, and theoretical aspects of natural hazard research.

The findings of this research project were summarized by Kates (1970) as he described the process of human adjustment to natural hazards. That model was further refined and published by Burton, Kates, and White (1978).

The model shown in figure 2.2 states that both the human use system and the natural events system together produce a natural

Figure 2-2: Human Adjustment to Natural Hazards



hazard. When a hazard occurs, effects such as costs and losses and intangibles are realized and above some threshold, people begin to perceive a problem exists. If the costs are perceived to be severe enough, the hazard event will result in the adoption of adjustments. Whether or not a manager considers adjustments to a hazard depends on his event perception, personal experience, and personality traits. However a manager is not able to consider the full theoretical range of adjustments due to social constraints, level of awareness, and the status quo. He evaluates a known set of adjustments as to environmental fit, technological feasibility, economic gain, and social conformity. Other variables which influence the adjustment process are managerial attributes such as role responsibility and communication access (Kates, 1970). The resulting adjustment decision feeds back to affect both the human use and natural event systems.

A number of personality variables have been used to explain perception and adjustment to natural hazards. The thematic apperception test (Saarinen, 1966; Sims and Baumann, 1974), locus of control (Sims and Baumann, 1972; Simpson-Hausley, 1978; Schiff, 1977), and cognitive dissonance (Adams, 1974; Shippee et al, 1980) have all been utilized with contradictory results. Adverse hazard experience has been the most powerful variable in explaining perception of hazardous events and the propensity to adopt adjustments.

2.3 Studies of Agriculturalists' Perceptions

One of the early hazard studies by Burton (1962) found farmers were more knowledgeable about the flood hazard than their urban counterparts. Burton also comments that the farmer "responds to a variety of conditions among which the flood hazard is not often of primary significance... in appraising the resource potential of his farm, the operator places weight not only on external factors such as markets and transportation, but also on the whole resource complex over which he exercises control and not simply on the individual parts of it" (Burton, 1962).

Saarinen (1966) studied the perception of the drought hazard on the Great Plains. Perception of the drought hazard was found to vary with degree of aridity, amount of drought experience, personality variables and the type of farming operation. Farmers were generally optimistic with respect to drought frequency and tended to overestimate the number of drought free years. Boyer (1977) studied perception of the frost hazard among orchardists in British Columbia. A high level of awareness of the frost hazard was found. There was no apparent relationship between age, education, or experience and perception of the frost hazard. Respondents had a tendency to deny the severity of the problem and to look at the hazard in a cyclical and therefore knowable fashion. Ward (1974) also found the farmers made inaccurate appraisals of the frost hazard.

These studies all found a high level of hazard awareness by those involved in agricultural activities. However a study by Jackson (1977) into perception of environmental damage associated with irrigation showed a low level of awareness by both farmers and non farmers. The author concluded that the respondents either denied the damage in keeping with the view that irrigation was a beneficial practise, or that the benefits outweigh the costs enough that people accept the negative consequences.

2.4 Studies into the perception of Water Quality

Studies by Elizabeth David (1971) in Wisconsin and Mary Barker (1971) in Ontario found that most common means to determine pollution of water bodies was visual. In the study by David, 40% mentioned algae and green scum and 35% mentioned murky dark water. More than half of the respondents in the Barker (1971) study based their evaluation of water quality on appearance as did 90% in a study by Nicholson and Mace (1975) An interesting finding in the Barker study was that although people based their evaluation of water quality on physical appearance, the majority felt that pollution was caused by bacteria and chemicals which may not result in conditions that are readily apparent visually.

A study by Kooyoomjian and Cleseri (1974) of the perception of water quality at four lakes, two of which were oligotrophic and the other two eutrophic showed that a nutrient rich condition can be readily recognised by an untrained observer. Parkes (1973) also found a high and generally accurate awareness of change in water quality at recreation sites.

The use dependent aspect of water quality was supported by Kooyoomjian and Cleseri (1974). They found fisherman were most sensitive to water contact features such as temperature, clarity and bottom conditions, and that cottage owners and home owners were critical of shoreline problems, odours, colour, and taste. In addition, recreationists were least critical of overall quality while the cottage and home owners were the most critical. This factor may be a result of the prolonged contact the owners have with the lake, whereas the recreationists would have only intermittant contact.

Experience was found to be important by Hines and Willeke (1974) as those who had learned about water quality problems by personal contact thought water quality problems were more critical. Socioeconomic variables such as age and sex seem to have little consistant bearing on the perception of water quality and Hines and Willeke (1974) conclude that perceptual variables are more important than any demographic variables in peoples' assessment of water quality. In studies by Parkes (1973), and McEvoy, (1973) education showed a slight positive association with awareness of water quality problems.

Barker's (1971) study of Toronto Beach Users found that attitudes and values toward the environment were important. Those who considered man was dominant over nature were more critical of the action being taken to combat water pollution.

The effects of perceived water quality on behavior was found by Parkes (1973) and Coughlin (1972) to be significant. Both studies found a positive relationship between reduction in recreational water use and diminishing water quality. This was also found by Barker in the case of swimming, however some users continued to go to low quality sites because of convenience. This is possibly a result of restricted mobility caused by reduced leisure time and other socioeconomic variables. People were observed swimming even when signs were posted warning of the danger of doing so. There was a tendency among frequent users of the same beach to discount the pollution levels at the place they frequented and to express the view that the pollution was worse or more widespread elsewhere (Barker, 1971).

2.5 Perception of Air Quality

Studies into the perception of air quality have shown a positive relationship between observer appraisals and physical measures of air quality. Most people evaluate air quality on the basis of visual and olfactory clues, and people are generally unaware of gaseous pollutants unless concentrations are high enough to cause physical discomfort. Social status was also found to be positively related to awareness and concern with air quality. However, most respondents assign a low importance to air pollution problems (Barker, 1976).

2.6 Summary

On the basis of the research into perception of natural hazards and water and air quality, a number of factors have been shown to influence perception. These are experience, the severity of the hazard or problem, the need for the resource, age, education, and whether the problem can be easily sensed.

2.7 Purpose and Hypotheses

The purpose of this research is to determine the usefulness of variables found important in previous perception research to differentiate among groups of farmers with varying perceptions of their groundwater quality.

Four major hypotheses have been formulated:

1. The number of farmers who perceive they have water quality problems will be less than the number whose water is evaluated as being poor by the suggested guidelines.

2. Increased perception of water quality problems will be positively related to the severity of those problems as defined by the stated Canadian government guidelines.

3. Increased perception of water quality problems are a positive function of past experience.

4. Increased perception of water quality problems is a positive function of the value of water to the farming operation.

These hypotheses will be tested using the statistical technique, discriminant analysis, which provides a means of differentiating between these groups of farmers on the basis of a group of independent variables found to influence perception in earlier research.

3. METHODOLOGY

3.1 Data Sources

Two sources of data provide the basis for this Thesis. The Saskatchewan Research Council has accumulated a file of approximately 5000 water quality analyses since 1962. These samples are collected and analysed for the major chemical constituents according to specific guidelines (Meneley and Hagen, 1975). Following the analysis, copies are distributed to the owners of record, Water Rights Branch, and Family Farm Improvement Branch of the Provincial Government.

From these records, a random sample of 600 water quality analyses were selected. Of the 600, 326 analyses were for farm wells. Questionnaires were sent to the owners of these wells, providing the second source of data. A copy of this questionnaire may be found in Appendix B.

The questionnaire design was based on the type generally used in natural hazard research (White, 1974) and formatted following suggestions from Dillman (1980). Many of the questions were similar to those in other studies of perception of natural hazards in order to allow comparisons with previous work in this area. In addition, the majority of questions were open ended to minimize leading the respondents .

The questionnaire consisted of 4 sections. The first section deals with general questions about farming in the area, and provides some measure of the importance of water quality problems with respect to other issues. The second section refers to water quality problems, then focuses more specifically on the individual problems and adjustments to those problems. The third section explores the respondents sources of information and experience with government assistance. The fourth section is intended to provide socioeconomic data about the respondents. An additional question regarding the respondents willingness to participate in research conducted by the Department of Agricultural Engineering was included to aid one of their research programs. The questionnaire included a number of questions designed to ensure the respondents were referring to the same well as the water quality data represented.

The questionnaire was pretested by a group including farmers, geographers, and engineers familiar with the area of water quality. This pretest resulted in some changes being made to the questionnaire. The revised questionnaires were mailed to the 326 farmers from the random sample of water quality analysis. The package included a cover letter to introduce the study and solicit the respondents assistance, the questionnaire, and a stamped self addressed envelope.

A reminder was sent to those who had not responded 5 weeks after the initial mailing, timed so that harvesting would be complete. This appeal brought in a substantial number of completed questionnaires.

Of the 326 questionnaires mailed, 29 did not reach their destination, 128 usable questionnaires were received, a 43% response rate. The sample size was further narrowed down to 88, by choosing those who could be matched with the water quality analysis with certainty and those who were using their water for drinking and household use.

The water quality analyses provided the physical measure against which the respondent's estimation of his water quality and his adoption of adjustments were analysed. This resulted in the formation of a number of distinct groups:

1. those who had no water quality problems
2. those who had a water quality problem, but did not indicate they did.
3. those who had a water quality problem and were aware of their problem.
4. those who had a water quality problem, were aware of the problem, and were taking steps to alleviate that problem

3.2 Statistical Analysis

The statistical technique used to test the hypotheses was discriminant analysis. On the basis of the questionnaire, four distinct groups could be defined. Discriminant analysis is useful in the study of the differences between groups on the basis of a number of variables. The discriminating variables used for this analysis were:

1. township
2. range

3. age

4. education

5. value of the farming operation

6. the number of years the family had farmed in that location

7. the number of years the respondent had been farming

8. the number of head of cattle

9. the number of acres in grain

10. the number of years since the well was constructed

11. the number of years since the well water was analysed

12. amount of alkalinity

13. amount of total dissolved solids

14. amount of sulfates

15. amount of iron

16. amount of hardness

17. amount of nitrates

The majority of assumptions necessary for discriminant analysis were met as the respondents were members of at least two mutually exclusive groups, there were at least two cases per group, the number of cases was more than three times the number of discriminating variables, and the covariance matrices for each group were tested and found to be equal (Klecka, 1980; Lachenbruch and Goldstein, 1979).

Three of the discriminating variables were measured at the ordinal level rather than the interval level. To cope with this, the discriminant analyses were run with dummy variables but these analyses did not offer much improvement in the measures of association, and introduced the problem of dealing with interaction effects which was not possible with the size of data set available. The one analysis in which the use of dummy variables gave a significant improvement had a sample size of only 50, precluding the introduction of interaction effects into the model.

The second problem was the lack of a normal distribution on some of the discriminating variables. The water quality constituents, total dissolved solids, alkalinity, nitrates, and iron were not normally distributed. When the variables were log transformed, the analysis was improved marginally in some cases, not at all in others. On the basis of Klecka,(1975) who states " that the technique is very robust and these assumptions need not be strongly adhered to", and considering the problems of interpretation introduced by log-transformation, the variables were not transformed.

Discriminant analysis has two purposes, explanation and classification. The first purpose, explanation is achieved through the computation of discriminant functions which are a linear combination of the discriminating variables, such that the group means are as different as possible. The form of the discriminant function is shown below.

$$D_i = d_{i1} Z_1 + d_{i2} Z_2 + \ldots + d_{ip} Z_p$$

where: D_i is the score on the discriminant function

d_{ip} is the discriminant coefficient of the p th variable used in the analysis.

Z_p is the standardized value of the p th discriminating variable used in the analysis.

Discriminant function coefficients are determined considering the group means, standard deviations, and the interrelationships (covariance and correlation) between variables. If the groups are distinct, the amount of dispersion within the groups will be less than the amount of dispersion of the total data set.

The values of the discriminant functions indicate the relative contribution of the independent variables to the group functions (Lehmann, 1979).

Measures of the usefulness of the discriminant functions in differentiating between groups are:

1. The canonical correlation which measures the strength of the relation between the groups and the discriminant function.

2. Wilks'lambda which is a multivariate measure of group differences over the discriminating variables. Lambda varies between 0 and 1 with values near 0 indicating high discrimination and values near 1, no discrimination.

3. The chi square test of significance computed with Wilks' lambda.

4. The percent of cases correctly classified by the discriminant function.

Once a group of variables that differentiate between the groups are determined, classification functions can be derived for each group. The classification coeficients are determined from the pooled within groups covariance matrix and the centroids for the discriminating variables and are used as follows:

$$C_i = C_{i1} V_1 + C_{i2} V_2 + \ldots + C_{ip} V_p + C_{i0}$$

where: C_i is the classification score for group i

C_{ip} is the classification coefficient for the p th discriminating variable for group i.

C_{i0} is a constant for group i

V_p is the raw score on the p th discriminating variable

Each case will be assigned as many scores as there are groups and will then be classified into the group for which that case has the highest score (Klecka, 1975).

The most useful discriminating variables were selected using a stepwise procedure that selects the variable that provides the greatest univariate discrimination then combines this variable with others to get the best possible combination for discriminating between the groups. The Wilks' criterion was used in this analysis. This method "maximizes the overall multivariate F ratio for the test of differences among group centroids and considers differences between all the centroids and the homogeneity within the groups" when determining the discriminant functions (Klecka, 1975).

Thus, on the basis of the water quality analyses and the questionnaire, three groups of farmers with water quality problems can be defined for four common minerals. These groups include those who do not perceive they have a water quality problem (non-perceivers), those who do perceive they have a water quality problem (perceivers), and those who both perceive a problem and take steps to reduce the problem (adjusters).

Discriminant analysis provides a means of differentiating between these groups on the basis of a number of variables found to be important in previous perception research. These include adverse hazard experience, the severity of the problem, the value of water to the farming operation, and socio-economic variables.

The stepwise discriminant analysis selects the optimal set of variables for describing these group differences and the statistical measures associated with the analysis provide an indication of the significance and the magnitude of these group differences.

4. PERCEPTION OF WATER QUALITY

To assess the relative importance of groundwater quality problems, the respondents were asked to list the principal advantages and disadvantages of farming in their location. The following tables show the percentages of farmers citing each advantage and disadvantage. To the majority of these farmers, water quality is much less important than factors directly related to production such as climate. land condition, and closeness to markets.

Table 4-1: Advantages of Farming in Their Area

Favorable land conditions	59
Close to urban areas and services	29
Favorable climatic conditions	24
Water availability	12
Close to markets	7
Good transportation access	7
Other	22
Everything	7
Nothing	6
No response	23

Table 4-2: Disadvantages of Farming in Their Area

Unfavorable climatic conditions	45
Unfavorable land conditions	38
Transportation	10
Weeds and Pests	6
Too far from cities	6
High Land Costs	5
Poor water quality	5
Poor water supply	5
None	11
No response	33

Table 4.3 indicates that the major problems facing farmers were

economic , and these far outshadowed other concerns.

Table 4-3: Major Problems Facing Farmers Today

Poor return on goods	92
High costs of production	109
High interest rates	44
Inflation	5
Government regulation	4
Poor water quality or supply	3
Weather	3
Other	8

The responses to these questions show that water quality problems are not the most important concerns farmers have. Problems relating to economic issues and thus directly to their livlihood take precedence. Like other problems of this type, for example air quality, water quality problems have low salience.

In general, the farmers have a very high awareness of the incidence of water quality problems. The majority, 71.9% indicated that farmers in their area had problems with the quality of their water. A further 10% indicated some farmers had problems while 17.2% thought there were no water quality problems in their area.

When asked if they had problems themselves, 71% indicated they did, 4% had problems sometimes, and 23% felt they had no water quality problems. This finding is consistent with hazard research as a number of studies of agriculturalists perceptions of flooding, (Burton, 1962) drought, (Saarinen, 1966), and frost, (Ward, 1976; Boyer, 1977) have found farmers have a generally high awareness of hazards or problems that may affect their lives or livlihoods.

However when the respondents were asked to be specific about the type of problem, variation arises in the awareness. The following table shows the percentage of farmers indicating problems with individual water constituents

Table 4-4: Perception of Individual Water Quality Constituents

	No Problem	Non-Perceivers	Perceivers	Adjusters
Iron	13(14.8%)	23(26.1%)	19(21.6%)	33(37.5%)
Iron Bacteria	13(14.8%)	41(46.6%)	09(10.2%)	25(28.4%)
Sulfates	38(43.2%)	39(44.3%)	09(10.2%)	02(02.3%)
Total Dissolved Solids	3(3.4%)	68(77.3%)	10(11.4%)	7(8.0%)

Iron was the most readily perceived problem with 69.4% of those with a defined problem aware of their problem. Iron is a highly visible problem and the high awareness is consistent with studies of water quality problems where respondents based their appraisals of quality on visual cues (David, 1971; Barker, 1971).

Sulfates and total dissolved solids are much less readily perceived. Of those with high levels of sulfates, 22% were aware of their problem. Although the presence of sulfates often causes gastrointestinal irritation, a tolerance is developed over time, and thus ceases to annoy the user.

Those aware of high levels of total dissolved solids include 20% of those with problems. In this instance, the lack of perception may result from unfamiliarity with the term total dissolved solids. An indication of this was that the majority of those who claimed to be adjusting to total dissolved solids were using water softeners, which do not reduce total dissolved solids.

To determine whether there where significant differences between non-perceivers, perceivers and adjusters, a discriminant analysis was performed. The discriminating variables used in the analysis were taken from previous research into the perception of natural hazards, air quality, and water quality . A number of factors have been reported by authors as influencing perception. Among these are:

1. The severity of the problem - measured by the levels of the water quality constituents, hardness, sulfates, iron, total dissolved solids, nitrates, and alkalinity.

2. Adverse hazard experience - measured by the age of the well. The older the well, the more experience the farmer may have had with the problems associated with that well.

3. The time elapsed since the last hazard event - measured by the number of years since the last water quality analysis, which should serve as a definite reminder of the water quality problems the farmer has.

4. Age

5. Education

6. The value of the farming operation.

7. The type of farming operation - measured by the numbers of cattle and acres of grain. Water quality

may be a more important factor in a cattle operation than in a grain farming operation.

4.1 Perception of General Water Quality

The first discriminant analysis used two groups differentiated by a yes or no response to the question ' Do you have problems with the quality of your water?'. The presence of a water quality problem was defined as having any of the water quality parameters above the recommended Canadian limits. Only three of the 88 respondents who made up the final sample did not have a water quality problem under this definition.

Table 4-5: Canonical Discriminant Functions for Water Quality Problems

Canonical Correlation	.51
Wilks' Lambda	.74
Significance	00

Standardized Canonical Discriminant Function Coefficients

Cat	Number of head of cattle	0.41
Yrsfar	Number of years farming	0.67
Welyrx	Number of years since well was constructed	0.54
Hard	Hardness of the water	-0.34

Canonical Discriminant Functions Evaluated at Group Means

Group	Function 1
1	-0.29
2	1.13

Percent of Cases Correctly Classified - 71.95%

As shown in Table 4.2, the discriminant analysis was significant at 0.00. The statistical measure, Wilks' lambda varies between 0 and 1, with a value of one indicating no difference between the groups. The value of Wilks' Lambda for the discriminant function is .74, indicating the analysis has significant although not excellent discriminating capability. The canonical correlation coefficients indicate the function is correlated with the variables in the analysis at .51. On the basis of the discriminanting variables, 71.95% of the cases can be classified into the correct groups.

The discriminant function coefficients indicate the relative importance of the discriminating variables in differentiating between groups of perceivers and non- perceivers. The variable with the largest coefficient and thus the most important is the number of years farming, with a coefficient of .67. This variable is highly correlated with age (.78). Consideration of the group means for this variable and the value of the coefficients suggest that the non-perceivers are those farmers with a higher number of years farming than the perceivers. The other variables important in differentiating between these groups are the number of years since the well was constructed, the number of head of cattle, and the level of hardness measured in the water quality analysis.

The group who do not consider they have a water quality problem are older farmers, with a larger number of years farming, and a well that is much older than those of the group who recognize their problem. This suggests that farmers who have been in contact with a particular water supply for a long period of time, become tolerant of the water quality and do not perceive it as a problem.

The perceivers have a higher mean level of hardness in their water supply, thus as the severity of the water quality problem increases, perception increases.

The group of farmers who do not perceive they have a water quality problem are typified by older farmers who have more farming experience, older wells, more head of cattle and a less severe water quality problem than the group of farmers who perceive a problem.

The remaining discriminant analyses consider three subgroups, non-perceivers, perceivers, and adjusters. The analyses were performed for four water quality problems; iron, iron bacteria, sulfates, and total dissolved solids.

Iron and iron bacteria problems are both defined by iron levels greater than 0.3 mg/l. At this level, iron is a problem and the potential for iron bacteria to exist is high. Both of these problems are visible and may be a source of constant annoyance to the user.

High levels of sulfates may cause gastrointestinal irritation in the new user, but a tolerance is developed over time , thus its stimulus would be at best intermittent. The threshold of perception would increase over time if the problem remained constant.

Total dissolved solids is a term which refers to the total of all dissolved minerals in the water supply, and as such has no specific stimuli as its effects are a function of the individual constituents in the water supply. In terms of this research the respondent may have been in contact with the term only once if he read the water quality analysis every respondent receives from Saskatchewan Research Council. Thus the term may not be recognised or may be misinterpreted as indicated by the majority of those adjusting to total dissolved solids using water softeners to do so, which is incorrect.

4.2 Perception of High Levels of Iron

High levels of iron were one of the most common problems, as well as the most readily detected by the respondents.

Table 4.6 shows the statistics, functions and discriminating variables for the iron problem. The discriminant analysis is significant at .01 and the Wilks' lambda of .51 offers good discrimination between the groups. The correct classification of 56.25% is low, but offers improved classification over both random assignment and assigning all respondents to the largest group.

The most important discriminating variables are two location variables, range and township. Those who have the least accurate

Table 4-6: Canonical Discriminant Functions for Iron Problem

Function 1

Canonical Correlation	.56
Wilks' lambda	.51
Significance	0.01

Standardized Canonical Discriminant Function Coefficients
Function 1

Age		0.23
Valu	Value of the farming operation	-0.08
Cond	Conductivity	0.00078
Nitrat	Level of Nitrates in water analysis	0.0056
Tnsp	Township	-0.64
Grain	Number of acres in grain production	-0.38
Welyrx	Number of years since well construction	0.43
Yearx	Number of years since water analysis	0.19
Range		1.07
Hard	Level of hardness in water analysis	-0.017

Canonical Discriminant Functions Evaluated at Group Means

Group	Function 1
1	-0.22
2	-0.66
3	1.03

Percent of Cases Correctly Classified - 56.25%

perception of their water quality live in the northwest portions of the study area whereas those with the most accurate perception tend to live in the south central areas. Range has a small negative correlation with the water quality variables , iron and nitrates. Thus those living in the northwest portion of the study area have less severe water quality problems than those in the southeast.

Those who do not perceive a problem exists are the older, farmers with older wells and a longer elapsed time since the well had been tested. These farmers may be acclimatized to the problem or may have forgotten the problem exists.

Those who were aware of their water quality problems had high levels of other water quality constituents notably nitrates, hardness, and total dissolved solids.

This group also tended to have a larger acreage in grain which was correlated with the value of the farming operation as those aware had a higher mean value of their farming operation.

The group of adjusters were not significantly different at the 0.05 level than those who were aware but not adjusting, however they did have higher levels of hardness and nitrates than the other two groups.

4.3 Perception of Iron Bacteria

As table 4.7 indicates, two significant discriminant functions were found for differentiating groups in this analysis. Function 1 explains 60.55% of variance and is correlated with the variables at .54. A Wilks' lambda of .55 indicates good discrimination between the groups. The second function explains 39.45% of variance, has a canonical correlation of .46, and has less discriminating power than function 1 with a Wilks' lambda of .79.

The variable offering the largest value to the discriminant functions is years farming. A higher number of years farming describes the group of respondents who are aware of the problem

Table 4-7: Canonical Discriminant Functions for Iron Bacteria Problem

	Function 1	Function 2
Percent of variance	60.55	39.45
Canonical Correlation	.54	.46
Wilks' lambda	.55	.78
Significance	0.00	0.04

Standardized Canonical Discriminant Function Coefficients

		Func 1	Func 2
Age		1.24	-0.87
Ir	Level of iron in water analysis	0.54	0.74
Nitrat	Level of nitrate in water analysis	-0.70	0.51
Tnsp	Township	0.32	- 0.43
Yrsfar	Number of years farming	-1.82	0.71
Range		0.08	0.86
Alka	Level of alkalinity in water analysis	0.49	- 0.13

Canonical Discriminant Functions Evaluated at Group Means

Group	Function 1	Function 2
1	0.38	0.67
2	-1.62	0.21
3	0.16	-0.44

Percent of Grouped Cases Correctly Classified - 64.79%

but do not make any adjustment. Age is highly correlated with years farming (.825) but is assigned an opposite sign on the function coefficient. The differentiation here exists between the adjusters and the other two groups. The group of adjusters are younger farmers, whereas the other groups have higher mean ages. However those with no perception have less farming experience than those who are aware of the problem.

The adjusters are differentiated from the other groups by higher levels of iron. The iron is a highly visible problem which contributes to this group being aware and adjusting to the problem. The adjusters and perceivers have higher levels of nitrates but lower levels of alkalinity than the non-perceivers.

As before, there is a negative correlation between the locational variables and the water quality variables, iron and nitrates. Thus, those with more severe groundwater quality problems live in the more southwesterly portion of the study area and their increased perception may be related to the severity of their problems.

4.4 Perception of High Levels of Total Dissolved Solids

As shown in table 4.8, the discriminant analysis for total dissolved solids has one significant function. This function explains 72.53% of the variance, is correlated with the variables at .57 and offers good discrimination among the groups with a Wilks' lambda of .57. The analysis correctly classifies 67.12% of the respondents, a substantial improvement over the 33.3% classification using random assignment.

The majority of those who have high levels of total dissolved solids do not perceive they have a problem. Those who are aware are those farmers with farming operations of higher value, whose families have resided on the farm for the least number of years. Both groups who are aware of a total dissolved solids problem tend to have higher concentrations of iron.

The group who are adjusting to high levels of total dissolved

Table 4-8: Canonical Discriminant Functions for Total Dissolved Solids Problem

Function 1

Canonical Correlation	.57
Wilks' lambda	.57
Significance	0.00

Standardized Canonical Discriminant Function Coefficients
Function 1

Age		-0.44
Valu	Value of the farming operation	0.73
Ir	Level of Iron in the water analysis	0.34
Famyrs	Number of years family has farmed in that location	-0.44
Yearx	Number of years since water analysis	0.41
Range		-0.51
Hard	Level of hardness in water analysis	-0.16

Canonical Discriminant Functions Evaluated at Group Means

Group	Function 1
1	-0.12
2	1.66
3	-0.29

Percent of Cases Correctly Classified - 67.12%

solids are not significantly different from the non-perceivers. This result is plausible as the majority of the adjusting group appear to interpreting hardness as total dissolved solids. This is also the youngest group, while the non-perceivers are the oldest. The lack of perception of total dissolved solids is related to a lack of knowledge or misperception of the terminology.

The location variable, range is again significant in this analysis and is negatively correlated with the water quality indicators.

4.5 Perception of High Levels of Sulfates

Table 4-9: Canonical Discriminant Functions for Sulfate Problem

Function 1

Canonical Correlation	.72
Wilks' Lambda	.38
Significance	.00

Standardized Canonical Discriminant Function Coefficients

Ir	Level of Iron in water analysis	-0.90
So	Level of Sulfates in water analysis	-0.32
Tnsp	Township	0.44
Famyrs	Number of years the family has been farming in that location	-0.76
Cat	Number of head of cattle	0.52
Yrsfar	Number of years farming	0.65
Alka	Level of Alkalinity in water analysis	0.50

Canonical Discriminant Functions Evaluated at Group Means

Group	Function 1
1	-3.13
2	-1.29
3	0.49

Percent of Grouped Cases Correctly Classified - 84.78%

The discriminant analysis of those who perceived, did not perceive and were adjusting to sulfates was the most successful analysis. The first and only significant function explains 80.18% of the variance. The canonical correlation of the function with the variables was .72 and a Wilks' lambda of .39 indicates a large separation of groups.

The groups, perceivers and adjusters were not significantly different in this analysis, a result of there being only two adjusters in this group. Although these adjusters were aware of the problem, they are misperceiving their adjustments.

The most important variable in this analysis was iron with the perceivers having much higher levels of iron than the non-perceivers. Perceivers also have higher levels of sulfates but lower levels of alkalinity than the non-perceivers. The non-perceivers have farmed longer, and their families have farmed in their present location for a longer period of time than those who perceive a sulfate problem.

Those who have the largest mean number of cattle are the group with the more accurate perception. Levels of sulfates greater than 100 mg/l may have an effect on cattle causing loss of weight and decreased food and water consumption (National Academy of Sciences, 1974).

The two individuals who are adjusting to the sulfate problem have considerably higher mean levels of sulfates than the mean levels of the other two groups.

The remaining discriminating variable, township, indicates the group of perceivers are located in more southerly areas than non-perceivers. again negative correlations with water quality indicators may explain this.

4.6 Summary

A number of consistent relationships appear in the five discriminant analyses. In all five, age or years farming, two variables that are highly correlated are positively associated with the group of non-perceivers. The number of years the family has farmed in that location is also associated with the group who do not perceive they have a water quality problem. The finding that the older, more experienced farmers do not perceive these problems suggests that continued use of poor quality water may result in an habituation effect. Older farmers may also have lower expectations than those who are younger, more mobile, and who may have been in more frequent contact with better quality water.

The severity of the hazard or problem, as measured by the levels of minerals in the water supply is positively associated with perception. Those groups who recognize they have a water quality problem tended to have higher concentrations of all the constituents except alkalinity. Alkalinity is negatively correlated with iron, sulfates, and hardness and this may account for its contradictory presence.

At least one of the location variables, township and range appear in all the analyses of the individual water quality problems. The groups who accurately perceive their water quality live in the more southeasterly portion of the study area. These variables appear to be linked to the severity of the problem as the within group correlations indicate a negative relationship between range and township and the water quality measures, iron, nitrates and alkalinity.

Those farmers living in the southeast portion of the study area have higher levels of nitrates, iron and alkalinity than the less perceptive farmers living in the northwest portion of the study area. The higher levels of nitrates may be linked with the increased numbers of cattle in the southeast, as the source of nitrates in a water supply is often agricultural waste. High levels of iron and alkalinity may be associated with the surficial geology in this area being of marine origin rather than the non-marine deposits of the northwest. In addition, this portion of the study area is closer to sources of calcium carbonate which may be reflected in the glacial till (Rutherford, 1967).

Another group of variables having small within group correlations with the location variables are the age of the well, age, and the number of years the family has farmed in that location. These variables are associated with the less perceptive farmers in the analyses, and it was suggested that through time these farmers have become accustomed to their particular situation.

Thus spatial variations in perception are reflecting spatial variations in both the severity of the problem and the longevity of the farming operation.

A number of other variables were important in specific analyses. In the analysis of perception of high levels of sulfates, the number of cattle was positively associated with perception. High levels of sulfates can be detrimental to cattle and this may influence the farmer with large numbers of cattle to be more aware of sulfates in the water supply.

The age of the well was important in the analysis of iron problems. This variable was intended to measure the farmers' experience with the well but contrary to previous research which indicates increased perception with increased adverse hazard experience, this variable was negatively associated with perception. Again this may indicate the acclimatization of the user through time.

The value of the farming operation was associated with the more perceptive groups of farmers in the analysis of iron and total dissolved solids. The number of acres in grain also appears with value in the analysis of iron problems and is correlated with value. These variables may reflect higher expectations of quality of life. and increased mobility, leading to contact with better quality water, both of which may be associated with higher income.

5. SUMMARY AND CONCLUSIONS

5.1 Summary

Groundwater in Saskatchewan is often of poor quality. High levels of iron, manganese, sulfates, total dissolved solids, and hardness impose economic, health, and aesthetic costs on groundwater users.

Water quality problems are not onsidered to be the most important problems confronting farmers. Economic issues and problems relating more directly to production are more pressing. However, farmers show a high awareness of water quality problems with the majority (77.8%) recognising they have water quality problems when their water contains dissolved mineral concentrations higher than the Canadian Limits.

When the farmers were asked to be more specific as to the nature of their water quality problem, their assessments were less accurate. Iron and iron bacteria were the most readily identified, because they are highly visible, and thus a constant reminder or stimulus to the perceiver. As the frequency of stimulation decreases, the awareness of the constituent also decreases. Sulfates are less readily perceived. Although high levels of sulfates may cause gastrointestinal irritation, a tolerance is established over time and the user would not be reminded of the high levels unless these were to increase or someone with less tolerance was to use the water. High levels of total dissolved solids are the least perceived. Here the stimulus would be even less common, as for many of the respondents, the only contact they may have had with the term would have been when the water was tested.

These findings are consistent with water and air quality research where findings have indicated people evaluate air and water quality on the basis of their senses (Barker, 1976; David, 1971) even though they are aware many of the constituents are not visible.

The discriminant analyses have shown that significant differences exist between the groups of perceivers and non-perceivers. The variables on which these groups can be differentiated have been found to be important in previous perception research with one notable exception.

The most consistent relationships are:

1. As age or the highly correlated variable number of years farming (Yrsfar) increases, the perception of the problem decreases. Through time, these respondents have become accustomed to the high levels of minerals in their water supplies. Another possible explanation is that younger farmers may have higher expectations, having had more contact with better quality water as a result of more mobility.

2. As the severity of the problem increased, measured by the increase in levels of the minerals, iron, sulfates, total dissolved solids, nitrates, and hardness, perception increases. This illustrates the concept of thresholds referred to in the Burton, Kates, and White (1980) model in which a threshold had to be crossed before the hazard was perceived, and again before adjustment would take place. In all cases, perceivers had higher levels of mineralization and in those analyses where adjusters could be considered significantly different than perceivers, their levels of mineralization were higher than both

perceivers and non-perceivers.

3. Another consistent relationship over all the analyses was location as measured by township and range. The variation in perception described by these variables is possibly related to the negative correlation of the location variables to water quality. As well, location is positively correlated with variables such as age, age of the well, and the length of time the family had farmed in that location which suggests that increased experience with the water source leads to acclimatization with the problem. Thus, perception is varying in response to water quality and experience with the water source, which in turn vary over space.

4. Those respondents who had less accurate perception of their water quality were those who had not recently had their water analysed. This finding is also consistent with hazard research as perception was found to lessen as time passed after the hazard event.

5. One of the major factors found to explain variations in perception has been experience. In this analysis, experience does not appear to be positively associated with perception. Experience, measured by the number of years since the well was constructed, is negatively associated with perception, possibly due to the insidious nature of poor quality water, which results in a problem that is constantly present rather than a rare event such as an earthquake or flood , that creates a memorable impression when it occurs.

Of the four hypotheses proposed for this research, only one can be rejected on the basis of these findings.

The first hypothesis stated that the number of farmers who perceive they have water quality problems will be less than the number whose water is evaluated as being poor by the suggested guidelines. The data presented in Table 4.4, page 32 indicates that this hypothesis should not be rejected. Not only do the farmers not have perfect perception of their water quality , but that perception varies from problem to problem depending on the ease with which it is sensed.

The second hypothesis states that increased awareness of water quality problems will be positively related to the severity of those problems as defined by the stated Canadian government guidelines.

Increased perception was significantly associated with higher levels of the water quality variables in all of the analyses. The only variable that was not increasing with increased perception was alkalinity, which was negatively correlated with some of the more easily sensed variables such as iron and hardness.

The third hypotheses states that increased awareness of water quality problems is a positive function of past experience. This hypothesis must be rejected, as the opposite relationship appears to be true. Those farmers with the oldest wells, and thus with the longest experience with that particular water quality belong to the least perceptive group. Other measures that could be thought of as experience such as age, years farming, and the number of years the family had farmed in the location were also associated with the least perceptive group. Thus as time passes, the farmer becomes more acclimatized to the quality of water available to him.

The fourth hypothesis states that increased awareness of water quality is a positive function of the value of water to the farming operation. This appears to be so, as farmers with a higher average number of cattle are more aware of the presence of sulfates in their water supply. As high levels of sulfates are detrimental to cattle and thus to the farming operations, this hypothesis should not be rejected.

5.2 Value and Implications of This Research

Although farmers have a generally high awareness of their water quality problems, when they are asked to indicate specifically what their problems are, their perception becomes more variable. Even though a problem is not perceived, it may still impose costs on the user. Information regarding these costs and the methods of treatment available to the consumer would be beneficial to farmers.

The classification capability of discriminant analysis would be useful to identify those groups who would most benefit from increased education and information regarding water quality and the means of improving that quality.

From a research point of view, those studies which attempt to measure specific water quality problems by simply asking the respondents which problems are present may be underestimating the incidence of that problem, especially if it is not easily sensed by the respondent.

6. REFERENCES

Arbuthnot, J "The Roles of Attitudinal and Personality Variables in the Prediction of Environmental Behavior and Knowledge", Environment and Behavior, Volume 9, Number 2, 1977.

Barker, M. L. "Beach Pollution on the Toronto Region" in Sewell, W.R.D. and Ian Burton (eds.) Perceptions and Attitudes in Resource Management, Information Canada, Ottawa. 1971.

_________. "Planning for Environmental Indices: Observer Appraisals of Air Quality" in Craik, Kenneth H. and Ervin H.Zube (eds.), Perceiving Environmental Quality: Research and Applications. Plenum Press, New York, 1976.

Barrows, Harlan H. "Geography as Human Ecology". Annals of the Association of American Geographers, Volume XIII, Number 1, 1923.

Beamish, J.E. "Rural Water Supplies" in Rural Water Supplies A Symposium, Water Studies Institute, Report Number 3, 1967.

Boyer, Jeanette C. Human Response to Frost Hazard in the Orchard Industry, Okanagan Valley, British Columbia Department of Geography Publication Series No. 7, University of Waterloo, 1977.

Brenniman, William H. and A. Kojala. "Home Water Softeners, Water Softness and Possible Health Implications", Journal of Environmental Health, Volume 43, Number 2, 1980.

Burton Ian. "Invasion and Escape on the Little Calmut" in Gilbert F. White (ed.) Papers on Flood Problems, Department of Geography Research Paper No. 70, University of Chicago Press, Chicago, 1961.

_________ Types of Agricultural Occupance of Flood Plains in the United States, Department of Geography Research Paper No. 75, University of Chicago Press, Chicago, 1962.

_________ and Robert Kates. "The Perception of Natural Hazards in Resource Management". Natural Resources Journal, Volume 3, 1964.

__________, Robert Kates, and Gilbert F. White. The Environment As Hazard, Oxford University Press, New York 1978.

Coughlin, Robert E. "The Perception and Valuation of Water Quality", in Craik, Kenneth and Ervin Zube (eds.), Perceiving Environmental Quality: Research and Applications, Plenum Press, New York, 1976.

David, Elizabeth L. "Public Perception of Water Quality" Water Resources Research, Volume 7, Number 3, 1971.

Dillman, Don A. Mail and Telephone Surveys: the Total Design Method, Wiley, New York, 1978.

Environment Saskatchewan, Pollution Control Branch. Water Quality Objectives, 1977.

Everett, Lorne G. Groundwater Monitoring General Electric Company, 1980.

Golant, Stephen and Ian Burton. "A Semantic Differential Experiment in the Interpretation and Grouping of Natural Hazards" in Moore, Gary T. and Reginald G. Golledge (eds.) Environmental Knowing, Theories, Research, and Methods, Dowden, Hutchinson and Ross Inc., Stroudsberg, Pennsylvania, 1976.

Hem, John D. Study and Interpretation of the Chemical Characteristics of Natural Water, Geological Survey Water-Supply Paper 1473, United States Government Printing Office, Washington, 1970.

Hines, William W. and Gene E. Willeke. "Perceptions of Water Quality in a Metropolitan Area", Water Resources Bulletin, Volume 10, Number 4, 1974.

Jackson, E.L. "Perceptions of Energy Problems", The Canadian Geographer, Volume XXIV, Number 2, 1980.

Jackson, R.H. "Perception of Environmental Damage Associated With Irrigation", Journal of Environmental Management Volume 5, 1977.

Joyce, Micheal. "Does Drinking Water Hardness Affect Cardiovascular Disease?", Journal of Environmental Health, Volume 43, Number 2, 1980.

Kates, Robert W. Hazard and Choice Perception in Flood Plain Management, Department of Geography Research Paper No. 78, University of Chicago Press, Chicago 1962.

________. "Natural Hazard in Human Ecological Perspective", HYpotheses and Models" Economic Geography, Volume 47, July, 1971.

Klecka, William R. "Discriminant Analysis" in Nie, Norman H. et al. (eds.) Statistical Package for the Social Sciences, McGraw-Hill Inc., 1975.

________. Discriminant Analysis, Sage Publications, Beverly Hills, 1980.

Kooyoomjian, K. Jack and Nicholas L. Clesceri. "Perceptions of Water Quality by Select Respondent Groupings in Inland Water Based Recreational Environments", Water Resources Bulletin, Volume 10, Number 4, 1974.

Lachenbruch, P.A. and M. Goldstein. "Discriminant Analysis", Biometrics, Volume 35, March 1979.

Lehmann, Donald R. Market Research and Analysis, Richard D. Irwin Inc., Honeywood, Illinois, 1979.

Lehr, Jay H. et.al. Domestic Water Treatment, McGraw-Hill Book Company,1980.

McEvoy, James et al. Environmental Quality and Water Development, W. H. Freeman, San Francisco, 1973.

McNeely, R.N., V.P. Neimanis, and L. Dwyer. Water Quality Source Book. A Guide to Water Quality Parameters, Environment Canada, Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, 1979.

Meneley, W. A. and J. E. Hagen. Instructions for Collection of Water Samples and Completion of Water Quality Coding Forms, Saskatchewan Research Council, Geology Division Circular 7, 1975.

Murphy, Francis C. Regulating Flood Plain Development, Department of Geography Research Paper No. 56, University of Chicago Press, Chicago, 1958.

National Academy of Sciences. Subcommittee on Nutrient and Toxic Elements in Water, Nutrients and Toxic Substances in Water for Livestock and Poultry Washington, D.C., 1974.

Nicholson, J.A. and A.C. Mace. "Water Quality Perception by Users: Can it Supplement Objective Water Quality Measures?" Water Resources Bulletin, Volume 11, Number 6, 1975.

Parkes, J.G.M. Public Perceptions of Water Quality and Their Effects on Water Based Recreation, Social Science Series Number 8, Inland Waters Directorate, Water Planning and Management Branch, Ottawa, 1973.

Patterson, W.L. and R.F. Banker. "Effects of Highly Mineralized Water on Household Plumbing and Appliances", Journal of the American Water Works Association, Volume 68, 1968.

Richards, J. H. Saskatchewan: A Geographical Appraisal, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, 1981.

Roder, Wolf. "Atitudes and Knowledge on the Topeka Floodplain" White, Gilbert F. (ed), Papers on Flood Problems, Department of Geography Research Paper No. 70, University of Chicago Press Chicago, 1961.

Russell, Clifford S. Losses From Natural Hazards, Natural Hazard Research Working Papaer No. 10, University of Toronto, Department of Geography Toronto, 1969.

Rutherford A.A. Water Survey of Saskatchewan Groundwaters Chemistry Division, Saskatchewan Research Council, 1967.

Saarinen, Thomas F. Perception of the Drought Hazard on the Great Plains, Department of Geography Research Paper No. 106, University of Chicago Press, Chicago, 1966.

__________. Environmental Planning Perception and Behavior, Houghton Mifflin Co., Boston, 1976.

Schiff, Myra R. "Hazard Adjustment, Locus of Control and Sensation Seeking, Some Null Findings", Environment and Behavior, Volume 9, Number 2, 1977.

Sheaffer, John R. Flood Proofing: An Element in a Flood Reduction Program, Department of Geography Research Paper No. 65], University of Chicago Research Press, Chicago, 1960.

Shippee, Glenn Jeffrey Burroughs, and Stuart Wakefield. "Dissonance Theory Revisited, Perception of Environmental Hazards in Residential Areas", Environment and Behavior Volume 12, Number 1, 1980.

Simpson-Housley, Paul et al. "The Flood Hazard at Lumsden, Saskatchewan", Prairie Forum, Volume 3, Number 2, 1978.

Sims, John H. and Duane Baumann. "The Tornado Threat: Coping Styles of the North and South", Science, Volume 176. 1972.

__________ and Thomas F. Saarinen. "Coping with Environmental Threat", in Sims, J.H. and Duane D. Baumann (eds.) Human Behavior and the Environment Maaroufa Press, Inc., Chicago, 1974.

Swan, James A. "Psychological Response to the Environment" in Goldman, C.R. et al (eds.), Environmental Quality and Water Development, W.H. Freeman and Co., San Francisco 1973.

Tihansky, Dennis P. "Economic Damages From Residential Use of Mineralized Water Supply", Water Resources Research, Volume 10, Number 2, 1974.

Ward, Robert M. "Decisions by Florida Citrus Growers and Adjustments to Freeze Hazards" in White, Gilbert F. (ed.), Natural Hazards: Local, National, and Global, Oxford University Press, Toronto, 1974.

White, Gilbert F. Human Adjustment to Flood, University Department of Geography Research Paper No. 29, University of Chicago Press, Chicago, 1945.

__________ et al. Changes in the Urban Occupance of Flood Plains in the United States, University of Chicago Press, Chicago, 1958.

__________. "The Choice of Use in Resource Management". Natural Resource Journal, Volume 1, 1961.

________. Choice of Adjustment to Floods, Department of Geography Research Paper No. 93, University of Chicago Press, Chicago, 1964.

________(ed.) Natural Hazards: Local. National, Global, Oxford University Press, New York, 1974.

Whiting, J.M. A Study of the 1967-8 DREE/PFRA Dugout (Farm Water Supply) Development Program, A Joint S.R.C.-F.F.I.B. Project, 1976.

I. Appendix A - Sources and Effects of Common Minerals

Iron	Sources - Iron is a very common mineral in the earth's crust. Sources include igneous rocks, and most sedimentary rocks. -iron may also be corroded off the metal in pipes and pumps. Effects - at concentrations as low as 0.1mg/l, iron oxidizes to form a reddish precipitate that stains clothing, porcelain and enamel, plumbing fixtures and cooking utensils. - causes scaling which encrusts pipes - imparts an objectionable taste to food and drink.
Iron Bacteria	Sources - the bacteria Crenothrix and Gallionella use iron as a source of energy. Effects -at iron concentrations of greater than 0.1mg/l, these bacteria may cause rusty water or slime to build up in the water system, making water inpalatable and clogging pipes
Sulfates	Sources - the oxidation of reduced sulfur compounds - most sedimentary rocks, notably shales, gypsum, and anhydrite. Effects - concentrations greater than 200mg/l may taste objectionable -greater than 500mg/l may result in gastrointestinal irritation and catharsis - in combination with calcium, sulfates form a heat retarding scale
Hardness	Sources- sum of calcium and magnesium in the water, and may be contributed to by iron, and manganese - sedimentary rocks such as limestone, dolomite, gypsum, magnesite, -igneous rocks such as the ferromagnesium minerals, pyroxines, and ampiboles.

Effects- formation of residues on washed items, inefficient cleaning, formation of flow reducing, heat retarding scale on pipes and water heaters.

Manganese	Sources- similar and often found in association with iron. -metamorphic and sedimentary rocks, and ferromagnesiam metals such as biotite mica, amd ampibole hornblende. Effects- concentrations greater than 0.2mg/l may be distasteful to drink and leave brown or black stains on fabric or porcelain -may precipitate on food during cooking -concentrations greater than 0.1mg/l may nurture the growth of bacteria similar to iron bacteria.
Nitrates	Sources-oxidation of nitrogen compounds -percolation of surface water containing human, animal or other agricultural waste into aquifers and wells. -greater than 4mg/l may reflect unsanitary conditions. Effects - concentrations greater than 45mg/l may cause methaimoglobinaemia in infants. - high levels may also affect infant cattle.
Total dissolved solids	Sources - All the dissolved minerals in the water, including carbonates, bicarbonates chlorides sulfates, and nitrates, of calcium, magnesium, sodium, and potassium, with traces of iron and manganese. Effects - depend on the amounts of the individual minerals in the water - in general, concentrations greater than 500mg/l may have an objectionable taste, and above 2000 mg/l may have a cathartic effect. (Hem, 1970, McNeely, 1979, Everett, 1980, Lehr et. al., 1980)

II. Appendix B - Questionnaire and Cover Letter

UNIVERSITY OF SASKATCHEWAN

ARTMENT OF GEOGRAPHY

SASKATOON, CANADA
S7N OWO

August 15,1982

Water suitable for consumption by people and livestock is essential. However, many farms in Saskatchewan have problems obtaining a sufficient amount of water. Many farms also experience water quality problems such as high levels of dissolved solids, iron, nitrates, and others.

Your farm is one of a small number in which people are being asked to report their water quality and water supply problems as well as their opinions as to the usefulness of government programs to aid in reducing these problems. Your farm was chosen from a random sample of the farms in Saskatchewan. In order that the results will represent the farmers of Saskatchewan, it is important that every questionnaire be completed and returned.

You are assured of complete confidentiality. The identification number on the questionnaire is only to account for those that have been returned. When your questionnaire is returned, your name will be crossed off the mailing list. Your name will never be placed on the questionnaire or used in the research results.

The results of this research will be made available to officials and representatives of the provincial government. If you wish to receive a summary of the results, write your name and address on the back of the return envelope. To ensure confidentiality, please do not put this information on the questionnaire itself.

If you have any questions about this research, please write to me at the Department of Geography, University of Saskatchewan, Saskatoon, Saskatchewan, S7N OWO.

Thank you for your time and assistance.

Yours truly,

Diane J. F. Martz

JFM:dy

UNIVERSITY OF SASKATCHEWAN

ARTMENT OF GEOGRAPHY

SASKATOON, CANADA
S7N OWO

September 22, 1982

Dear Sir or Madame:

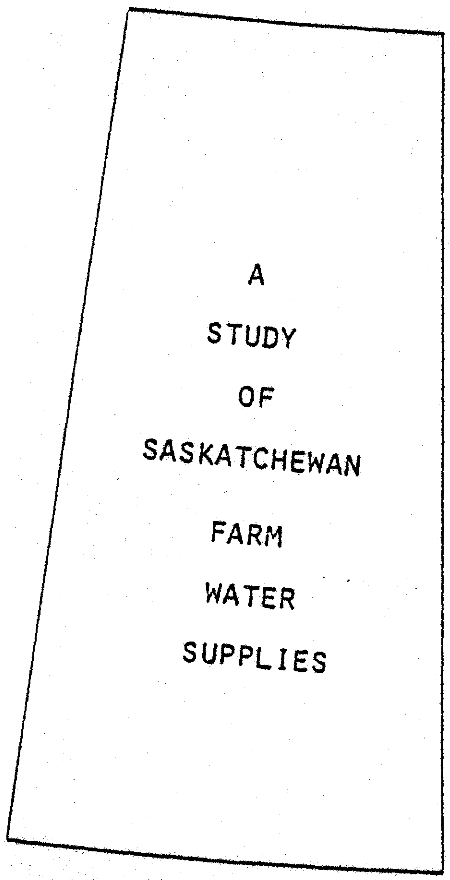
A few weeks ago, you were sent a questionnaire for a farm water supply study. The results of this questionnaire will be used as part of my Master's Thesis.

If you could fill out the questionnaire and send it to me, when you have time, it would be very much appreciated. If you have already mailed back the questionnaire, or intend to mail it back, thank you very much.

Your assistance is very important to this research.

Yours truly,

Diane J. F. Martz



A STUDY OF SASKATCHEWAN FARM WATER SUPPLIES

CONDUCTED BY: DIANE J. F. MARTZ
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF SASKATCHEWAN

In this first section, I would like to ask some general questions about farming in this area.

1. How long has your family farmed in this location? __________ yrs.

2. What type of farming operation do you have?

grain	__________	acres
cattle	__________	head
poultry	__________	(size of flock)
sheep	__________	head
hogs	__________	head
other (please specify)	__________	

3. What are the principal advantages of farming in this location?

____
____
____
____
____
____
____

4. What are the principal disadvantages of farming in this location?

____
____
____
____
____
____
____

5. What do you think are the major problems facing farmers today?

____
____
____
____
____
____
____

This next section is devoted to finding out what kinds of water problems are faced by farmers in your area.

6. Do farmers in this area have problems obtaining a sufficient supply of water?

   Yes ______ No _____

7. Do farmers in this area have problems with the quality of their water?

   Yes _____ No _____

8. What is the source of your water supply?

   For household drinking water ______________________________

   For other household uses ______________________________

   For stock watering ______________________________

   For irrigation ______________________________

9. If your water supply is a well, what is the Municipal Land Location of the well?

   Quarter_____ Section _____ Township _____ Range _____

10. How deep is the well? __________ feet

11. How was the well constructed?

    drilled _____ jetted _____ bored _____ dug _____ other _____

12. Do you have problems with the quality of your water?

    Yes _____ No _____

13. If yes, check the kind of problem(s) you have or have had.

    dissolved solids ____________

    taste ____________

    smell ____________

    iron bacteria ____________

    nitrates ____________

    iron ____________

    sulphates ____________

    algae ____________

    other (please specify) ______________________________

14. What steps have you taken to reduce the effect of these problems?

    dissolved solids ______________________________

    taste ______________________________

    smell ______________________________

    iron bacteria ______________________________

    nitrates ______________________________

    iron ______________________________

    sulphates ______________________________

    algae ______________________________

    other (please specify) ______________________________

15. Have these measures been successful?

Yes _____ No _____

16. How long have you been taking these steps to improve the quality of your water supply?

_________years

17. How much do you estimate these measures have cost you?

___________dollars

___________time (days per year)

18. Have you changed the source of your water supply in the past?

Yes ________ No _____

19. If yes, how many times have you changed? ___________

20. What were the previous sources of water?

____

____

____

21. What was the reason for changing?

____

____

____

____

____

22. Do you think you will have water quality problems in the future?

Yes _____ No _____

23. If yes, what kind of problems do you anticipate?

____

____

____

____

____

24. Will you do anything different than you have done in the past to improve your water quality?

Yes _____ No _____

25. If yes, what will you do differently?

____

____

____

____

____

____

26. Do you think you will have water supply problems in the future?

Yes _____ No _____

27. Will you do anything different than you have done in the past to improve your water supply?

Yes _____ No _____

28. If yes, what will you do differently?

29. If you want advice on an important farm water problem, who do you talk to?

30. What government agencies will assist you to find and maintain a satisfactory source of water?

31. What government programs have been helpful to you in finding and maintaining a satisfactory source of water?

32. What other assistance do you think could be provided?

Finally, I would like to ask a few questions about you for statistical reasons.

33. What age group are you in?

_____ younger than 24

_____ 25-34

_____ 35-50

_____ 50-65

_____ over 65

34. How many years have you been farming? __________ years

35. What was the highest level of education you attained?

_____ elementary school

_____ high school

_____ technical/vocational school

_____ university

36. What do you estimate the dollar value of your farming operation to be? (include land, buildings, machinery, livestock, and production).

_____ less than $100,000

_____ $100,000 - $500,000

_____ $500,000 - $1,000,000

_____ $1,000,000 - $2,000,000

_____ greater than $2,000,000

One method of improving the quality and maintaining the quantity of groundwater supplies is to inject treated surface water into suitable underground water bearing formations through existing wells (artificial recharge).

If you have a well supplying your water and the water quality is poor or the water supply is inadequate, would you be interested in participating in a research program being conducted by the Department of Agricultural Engineering, University of Saskatchewan to develop techniques for injecting and storing treated surface water in underground water bearing formations?

Yes _____ No _____

If yes, write your name and address in the space below and it will be forwarded to the Department of Agricultural Engineering.

____

____

____

____

____

____

Thank you very much for your time and consideration. If you have any other comments you would like to make, please do so in the following space.