This study was a comparison of the prevalence of infectious gastrointestinal disease and the quality of construction of individual, surface source water systems in Lincoln County, Oregon.

Two measurement instruments were developed for this study. An objective instrument was developed to determine if the water systems observed in the study were adequately or inadequately constructed. A second objective instrument was developed to determine if individuals interviewed in the study were ill with an infectious gastrointestinal disease. The Delphi Method was used to validate the two instruments, and was based on a consensus of opinions by a panel of experts regarding this subject matter.

The sample population was identified through a systematic selection of dwellings using a Lincoln County Department of Engineers road map and a list of random numbers. Individuals were interviewed using the Surface Source Water System Gastrointestinal Disease Evaluation instrument to determine if they had an infectious gastrointestinal disease. The surface source water systems were evaluated using the Individual Surface Source Water System Evaluation Instrument to determine if they were adequately constructed.
Subsequently, the individuals were categorized as being ill or not ill. The water systems were all categorized as being adequately or inadequately constructed.

The chi square statistic was used to determine if there was a significant difference between the number of people with and without an infectious gastrointestinal disease using inadequately constructed individual, surface source water systems. Also, the chi square statistic was used to determine if there was a significant difference between the number of people with and without an infectious gastrointestinal disease using adequately constructed, individual, surface source water systems. The statistical analysis revealed that there were significantly more well people than ill people using both types of water systems at a significance level of 0.05.

Because of a lack of clear differentiation in the data, the common public health concept that quality of construction of individual surface source water systems as a factor in the spread of infectious gastrointestinal diseases cannot be supported or refuted. A major recommendation was to repeat the study by examining the water directly using laboratory techniques. This would positively establish the presence or absence of a disease causing organism in the water system.

A literature search by the author revealed that effective measurement instruments for evaluation of relationships of gastrointestinal diseases and well construction quality were not readily available. The instruments developed by the author may require further testing to yield more definitive data.
A Comparison of the Prevalence of Infectious Gastrointestinal Disease and the Quality of Individual, Surface Source Water Systems in Lincoln County, Oregon

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>I. INTRODUCTION.</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope.</td>
<td>1</td>
</tr>
<tr>
<td>Focus.</td>
<td>1</td>
</tr>
<tr>
<td>Demographic and Geographical Data.</td>
<td>2</td>
</tr>
<tr>
<td>Objectives.</td>
<td>4</td>
</tr>
<tr>
<td>Definitions.</td>
<td>6</td>
</tr>
<tr>
<td>Descriptions of Construction of Individual, Surface Source Water Systems Components.</td>
<td>7</td>
</tr>
<tr>
<td>Shallow Wells</td>
<td>9</td>
</tr>
<tr>
<td>Spring Boxes</td>
<td>12</td>
</tr>
<tr>
<td>Streams and Ponds</td>
<td>15</td>
</tr>
<tr>
<td>Infiltration Galleries.</td>
<td>16</td>
</tr>
<tr>
<td>Water Transmission Lines</td>
<td>16</td>
</tr>
<tr>
<td>Water Treatment Facilities</td>
<td>19</td>
</tr>
<tr>
<td>Filtration.</td>
<td>19</td>
</tr>
<tr>
<td>Disinfection with Chlorine.</td>
<td>20</td>
</tr>
<tr>
<td>Water Storage Tanks.</td>
<td>22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. LITERATURE REVIEW</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water As a Vehicle of Infectious Disease Transmission</td>
<td>25</td>
</tr>
<tr>
<td>Problems Associated with Individual Water Systems.</td>
<td>26</td>
</tr>
<tr>
<td>Groundwater as a Domestic Water Supply</td>
<td>28</td>
</tr>
<tr>
<td>Surface Water as a Domestic Water Supply</td>
<td>30</td>
</tr>
<tr>
<td>Infectious Gastrointestinal Waterborne Diseases Found in the Pacific Northwest</td>
<td>32</td>
</tr>
<tr>
<td>Giardia lamblia (Giardiasis).</td>
<td>32</td>
</tr>
<tr>
<td>Entamoeba histolytica (Amebiasis or Amebic Dysentery)</td>
<td>32</td>
</tr>
<tr>
<td>Salmonella typhi (Typhoid Fever).</td>
<td>35</td>
</tr>
<tr>
<td>Shigella sp. (Shigellosis or Bacillary Dysentery).</td>
<td>38</td>
</tr>
<tr>
<td>Viral Agents.</td>
<td>40</td>
</tr>
<tr>
<td>Hepatitis type A.</td>
<td>42</td>
</tr>
<tr>
<td>Viral Gastroenteritis</td>
<td>43</td>
</tr>
<tr>
<td>Enterotoxigenic Escherichia coli</td>
<td>47</td>
</tr>
<tr>
<td>Effectiveness of Chlorination.</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. METHOD AND DESIGN</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Format.</td>
<td>50</td>
</tr>
<tr>
<td>The Measurement Instruments.</td>
<td>50</td>
</tr>
<tr>
<td>Selection of Sample Sections</td>
<td>52</td>
</tr>
<tr>
<td>Selection of the Study Population.</td>
<td>54</td>
</tr>
<tr>
<td>Data Collection Procedure.</td>
<td>55</td>
</tr>
<tr>
<td>Water System Evaluation.</td>
<td>56</td>
</tr>
<tr>
<td>Hypothesis.</td>
<td>57</td>
</tr>
<tr>
<td>The Statistical Instrument</td>
<td>58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV. DATA ANALYSIS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data.</td>
<td>60</td>
</tr>
<tr>
<td>Data Computations.</td>
<td>64</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hydrologic cycle</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Typical shallow dug well construction</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Sanitary well casing seal</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>Typical spring box construction</td>
<td>14</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Comparison of disease and the quality of construction of individual surface source water systems in Lincoln County.</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>Summary of source information from water system evaluation instruments.</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>Summary of transmission line information from water system evaluation instruments (42 systems).</td>
<td>62</td>
</tr>
<tr>
<td>4</td>
<td>Summary of treatment (chlorine and filtration) facility information from water system evaluation instruments (42 systems).</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>Summary of storage facility information from water system evaluation instruments (42 systems).</td>
<td>62</td>
</tr>
<tr>
<td>6</td>
<td>Summary of disease evaluation instrument data; Period of incidence of disease: December, 1979 - August, 1980.</td>
<td>63</td>
</tr>
<tr>
<td>7</td>
<td>Chi-square computations of ill and not ill individuals using inadequately constructed water systems.</td>
<td>64</td>
</tr>
<tr>
<td>8</td>
<td>Chi-square computations of ill and not ill individuals using adequately constructed water systems.</td>
<td>65</td>
</tr>
</tbody>
</table>
A COMPARISON OF THE PREVALENCE OF INFECTIOUS GASTROINTESTINAL DISEASE AND THE QUALITY OF INDIVIDUAL, SURFACE SOURCE WATER SYSTEMS IN LINCOLN COUNTY, OREGON

INTRODUCTION

Scope

Between the years 1976 and 1980, 68 cases of infectious gastrointestinal disease were reported in Lincoln County, Oregon, by physicians and hospital laboratories. Public health officials in Lincoln County believe there may have been many more cases of unreported waterborne diseases during this same period (Oregon Public Health Association, 1980). Until recently, some infectious diseases were not required by law to be reported. Giardiasis, an infectious disease known to be transmitted by water, was not reportable in Oregon until November, 1981 (Oregon Administrative Rules, Chapter 333, Division 17, section 17-600).

Generally, public health professionals believe that water on the surface of the earth is highly susceptible to contamination by infectious agents. Studies by Whitsell et al., (1974) indicated that springs and shallow wells are exceptionally susceptible to contamination. Water systems in Lincoln County, both private and public, utilize surface water as a primary source of drinking water (Stater, 1980).

Lincoln County, which has over 68 inches per year average rainfall, is unable to adequately recharge underground aquifers. Hence, it is unable to produce an adequate amount of water from its deep
wells to supply county dwellers. A U.S. Geological Survey (1977) groundwater survey found the county to be underlain with types of soil that are low in permeability. The types of soil in Lincoln County form poor aquifers and hold very little water that is available to deep wells. These factors require residents to be highly dependent on surface water supplies.

Focus

Water is a critical element in a human's life. To perform the physiological functions that support life, a human must consume, on the average, 2,200 grams of water, or 3.1% of his weight in water per day (Miller, 1962).

Many contaminants exist in this water humans need. Among those contaminants are infectious agents that cause gastrointestinal disease. The water a human consumes must have as few of these infectious agents as possible if it is going to be of any value.

In the early 1970's the U.S. Congress became aware of this problem and passed Public Law 93-523, the Safe Drinking Water Act of 1974. Part of this legislation was designed to control the level of contaminants that were believed to be in the water served to customers of public water systems (United States Environmental Protection Agency, 1977).

During Oregon's 1977 legislative session, the state chose not to directly enforce the federal drinking water act. The intent of the public law was to require each state to accept responsibility for its public water systems under that law. The state legislative bodies decided Oregon could not afford to enforce the mandated federal
program; therefore, the federal government was forced to enforce the safe drinking act. Because of this, there was no functional safe drinking water program in Oregon after the state's 1977 legislative session (Oregon State Department of Justice, 1977). Oregon public health officials believe this is one of the reasons Oregon ranks sixth in the nation in the incidence of waterborne diseases (Oregon Public Health Association, 1980).

One of the components of the drinking water program in Oregon was to insure that public water systems met certain construction criteria. Public health officials often make the assumption that the chance of becoming ill from an infectious waterborne disease agent increases as the quality of the construction of a water system decreases. Therefore, when public health professionals survey and sample water systems, they expect to find high rates of waterborne infectious disease associated with poorly constructed surface water systems. The focus of this study will be to examine the assumption that the prevalence of infectious gastrointestinal disease in Lincoln County, Oregon, is associated with the quality of the construction of individual, surface source, domestic water systems.

Demographic and Topographic Data

Lincoln County is a rural area on the central Oregon coast with a permanent population of approximately 28,000. During the peak of the summer tourist season that population doubles for short periods of time. The population is concentrated in the western half of the county along the Pacific coast line with the largest population centers being Newport, 8,500; Lincoln City, 7,500; and Toledo, 5,400
Principal industries in Lincoln County are forest products, fisheries, and tourism.

The area has a temperate marine climate. Nearness to the Pacific Ocean and exposure to middle latitude westerly winds are the principal climatic controls. The normal annual precipitation in Newport is about 68 inches. However, as the altitude increases, so does the precipitation. Inland, along the crest of the coast range, the annual precipitation can be as much as 200 inches. The annual average temperature at the county seat, Newport, is 51°F. (Frank et al., 1977).

Most of the western edge of the county is bordered by terraces which range from 50 to 200 feet above the sea level. The terraces are broken by headlands of resistant rock that has altitudes of 400 to 700 feet. Lincoln County is drained primarily by the Siletz, Alsea, and Yaquina Rivers (Frank et al., 1977).

Objectives

The Oregon State Health Division and the Lincoln County Health Department share the responsibility for maintaining records of disease outbreaks in Lincoln County. However, reliable data comparing the relationship of infectious gastrointestinal diseases with inadequately constructed surface source, domestic water systems has never been collected in Lincoln County.

The Oregon State Department of Water Resources has the legal responsibility for maintaining records of individual water systems when they are installed by a licensed well driller. Systems such as shallow wells and spring boxes are normally installed by the system's owner or a nonlicensed excavator with a backhoe. These systems are
not required to be recorded by the Oregon State Department of Water Resources. Therefore, there is very little information regarding the sanitary quality of individual water systems in Lincoln County.

Public health officials normally do not inspect or approve construction or use of individual water systems in Lincoln County. At the present time, Oregon does not provide for county or state health official examination of individual water systems. Water supply systems installed by nonlicensed well drillers are assumed to be questionable by the local health department (Stater, 1982).

The county officials only involvement with individual systems is to make recommendations regarding the construction of the systems. Recommendations are usually made upon request of the system's users.

Lincoln County Public Health Department records indicate that between 1976 and 1980, 68 cases of infectious gastrointestinal diseases were reported (Oregon Public Health Association, 1980). However, upon close examination, the records yield very little data regarding percentage of gastrointestinal cases that were associated with individual water systems.

Infectious gastrointestinal diseases commonly seen in Lincoln County include Giardiasis, Amebiasis, an undetermined assortment of viral diseases, and a toxic strain of Escherichia coli. These diseases have symptoms that range from severe, bloody diarrhea and vomiting to a mild headache.

Public health officials report that they suspect many of these cases are not clinically evident and are not therefore diagnosed and reported. It is possible these individuals are asymptomatic carriers of infectious gastrointestinal diseases. Asymptomatic carriers are
persons that can harbor and shed the disease and not be ill themselves (Burrows, 1968).

The objectives of this study will be the following:

1) Identify the prevalence of infectious gastrointestinal disease in a study population in Lincoln County.

2) Identify the number of people using inadequately constructed, surface source domestic water systems in a study population in Lincoln County.

3) Statistically demonstrate an association between objective one and objective two.

Definitions

Annular space: An annular space is that area in a drilled well that is between the casing and the undisturbed soil.

Aquifer or aquifing layer: "... an underground layer of permeable rock or soil that permits the passage of water"(U.S. Environmental Protection Agency, 1974).

Deep well: "... a well which penetrates through an impervious formation of extensive area, derives water from a confined aquifer beneath that impervious formation, and has a casing which extends to a depth of at least 18 feet below ground surface and is sealed at least 5 feet into the impervious formation"(Oregon Administrative Rules, 1982).

Disinfection: "Killing of infectious agents outside the body by chemical or physical means directly applied"(Salvato, 1972).

Infectious gastrointestinal diseases: An illness involving the stomach and intestines caused by pathogenic microorganisms.
Infiltration gallery: "... a system of perforated pipes laid along the banks or under the bed of a stream of lake installed for the purpose of collecting water from the formation beneath the stream or lake" (Oregon Administrative Rules, 1982).

Shallow well: "... a well which derives water from an unconfined aquifer above which there is no impervious formation" (Oregon Administrative Rules, 1982).

Spring: "... a naturally occurring discharge of water appearing at the ground surface as flowing water" (Oregon Administrative Rules, 1982).

Surface Source Water System: A water system that uses an infiltration gallery, shallow well, spring, pond, lake or stream as its source of water.

Description of Construction of Individual, Surface Source Water System Components

Water on this planet is continually in motion through a process called the hydrologic cycle (Figure 1). The movement is endless from the sea to the atmosphere, from the atmosphere to the land, and from the land back to the sea (New York State Department of Health, 1976). On the land, water is available for human consumption from surface sources or subterranean sources. This study is concerned primarily with surface source water systems and their relationship to infectious gastrointestinal disease.

Generally, untreated surface sources are undesirable for human consumption and should be used only when groundwater sources are not available or inadequate. Clear water is not always safe, and the old
Figure 1. Hydrologic cycle.
adage that running water purifies itself is not true (U.S. Environmental Protection Agency, 1974).

Public health officials consider surface source water systems a high risk and a poor alternative to properly constructed subsurface systems because of the high susceptibility to contamination by infectious agents.

Surface sources are generally identified to be shallow wells, springs, infiltration galleries, impoundments, streams, and ponds. Surface sources are particularly vulnerable to contamination from infectious agents if not properly constructed.

Surface source water systems generally have four basic components: raw water source, water transmission lines (pipes), treatment, and storage. Minimum public health construction criteria necessary for adequate water system protection are as follows:

1) Prevent or limit infectious agents from entering the water source.

2) Remove the infectious agent from the water before it is served.

A variety of construction models are available for use as a surface supply of domestic water. Brief descriptions of the most popular types of systems are discussed as follows:

Shallow wells: These types of wells mine water from very shallow aquifing layers. Wright (1977) considers a shallow well one with a pump at the top of the well within sucking distance of the aquifing layer. At sea level, this sucking distance is 15-28 feet, depending on the pump (Wright, 1977).

Shallow wells must be constructed with the same goal one would
use when constructing a deep drilled well. That is to prevent as much contaminated flood water as possible from entering the well.

Many times a shallow well is constructed by hand with a pick and shovel or a backhoe. In these cases, the well is rarely more than 16 feet deep.

As illustrated in Figure 2, the top of the casing of a shallow dug well should be fitted with a watertight seal to prevent contamination from flooding. There should be a steel reinforced concrete floor slab around the casing. It should be drained to daylight, assuming there is a well house. The area around the well should be graded to drain away surface water (Wright, 1977). The area around the well should be backfilled with tight clay or other appropriate material to protect the well from flooding. The entire vicinity of the well should be fenced against animals (Oregon Board of Health, 1962).

Shallow dug wells normally have a diameter of three feet. That is because they are usually lined with three foot in diameter concrete casing rings that are easily purchased. However, dug wells can be lined with bricks, stones, or concrete poured in place, depending on the availability of material.

If a shallow well is drilled, it should be constructed in accordance with the Oregon State Department of Water Resources standards. Again, these standard's goals are to prevent contaminated flood water from entering the well (U.S. Environmental Protection Agency, 1974).

A well is drilled either by the percussion method or the hydraulic rotary method (U. S. Environmental Protection Agency, 1974).
Figure 2. Typical shallow dug well construction.
The percussion method uses the technique of raising and dropping a heavy drill bit. This crushes and dislodges the soil and rock. The hydraulic rotary method uses the technique of driving a rotary drilling bit through the soil and rock.

Drilled wells normally do not need casing more than 12 inches in diameter. Therefore, they are easy to cap with a sanitary seal as illustrated in Figure 3. The annular space around the casing of a dug well and drilled well should be filled with a water tight material to protect the well from flooding. Also, as with a dug well, there should be a concrete slab around the casing. The well house should drain to daylight (Oregon State Department of Water Resources, 1975).

**Spring Boxes:** A spring box is similar to a dug well located on the side of a hill. It mines the water at a point just before it breaks free of the ground. The main difference between a dug well and a spring box is a spring box is built horizontally into the side of a hill. A well, of course, is vertical. Also, a spring box is custom-designed to fit the geological and topographical conditions (U.S. Environmental Protection Agency, 1974). A spring box collects water through buried perforated pipe (Figure 4).

Construction criteria for the spring box enclosure, that portion of the system that collects the water before it is piped to treatment, are the same as those used in construction of a shallow well. All care must be taken to exclude flooding water. However, if collecting tiles (the perforated pipe) are used, they need extra care. They should be laid in clean gravel to facilitate flow. This gravel should be covered with an impervious clay or concrete to exclude surface water (Oregon State Board of Health, 1962). Springs should be
Figure 3. Sanitary well casing seal.
Figure 4. Typical spring box construction.
protected from surface water runoff by having a diversion ditch dug several feet uphill from them and completely around them on the uphill side (Salvato, 1972).

**Streams and Ponds:** Generally streams and ponds are not satisfactory for domestic water system use unless the entire watershed can be completely closed to humans and animals. This condition is rare, according to the Oregon State Board of Health (1962). They should only be used when groundwater, shallow or deep, is unavailable (U.S. Environmental Protection Agency, 1974). Water from streams and ponds usually needs complete treatment including disinfection and filtration.

If an open stream is required for a domestic water system, care must be taken in locating the water intake upstream from sewer outlets and other sources of contamination. Also, consideration must be given to potential high silt loads of streams and ponds during high water runoff. Water should not be pumped to storage or treatment during these periods (Salvato, 1972).

Streams normally require a substantial amount of runoff water from large uncontrolled watersheds. Questionable bacterial quality of water from uncontrolled watersheds may impose high loads of bacteria and silt-laden water on a treatment facility not designed to handle such loads (Chanlet, 1973).

Ponds also receive runoff from watersheds that are difficult to control. The Environmental Protection Agency (1974) recommends that watersheds around ponds be adequately protected from contamination at all times. Several protective measures are suggested. The watersheds should meet the following criteria:
1) Grassed.
2) Free from barns and septic systems.
3) Protected from erosion.

Ponds have one advantage over streams (U.S. Environmental Protection Agency, 1974), in that they have the ability to store water for use during dry periods. Ponds being considered for use as a domestic water source should meet the following criteria:

1) Large enough to store one year's supply of water.
2) Fenced to exclude livestock.
3) Kept free of weeds, algae, and floating debris.

Infiltration Galleries: Infiltration galleries are normally constructed in watershed areas that are heavily forested and largely uninhabited by man. Even under these conditions, pathogenic bacteria and soil bacteria have been found in water being served by these systems (U.S. Environmental Protection Agency, 1974).

Typically, an infiltration gallery involves constructing a sand filter trench parallel to a stream bed. The trench, usually located about 10 feet from the stream, is 30 inches deep and 10 feet wide. Perforated pipe or open joint tile is laid in the bottom of the trench on a bed of gravel. This collection facility is covered with relatively impervious material. Shallow groundwater flows in, is collected, and is pumped to a storage facility (U.S. Environmental Protection Agency, 1974).

Water Transmission Lines: Water transmission lines (pipelines) are that part of the system which transmits water from the source to a treatment facility and to the consumer. Public health officials believe there are at least two major issues to consider when
designing a water transmission system.

The first issue is to insure an adequate amount of water at the service connection. If the pipelines are inadequate in size and do not meet minimum design standards, even the best source and pumping system will not be able to supply enough water through the pipes. The second issue is to insure the distribution system meets minimum construction standards and can withstand the environment and not be damaged.

The latter issue is of the most concern to public health officials. They reason that if potable water can escape from the line, contaminated water can enter the line. This situation occurs when the water in the line is subjected to a negative pressure allowing contaminated water outside the line to flow in.

The Oregon State Health Division has adopted standards for installation of water transmission lines on public water systems. These same standards are strongly recommended for individual systems as well.

When building a water transmission system, it is important to note the pressure limits printed on the pipe. If the gravity feed system or the water pressure exceeds this limit, it may break the pipe (Oregon Administrative Rules, 1975).

Pipelines should be buried 30 inches and carefully bedded in the bottom of a trench. If a pipeline must be laid in hazardous water, all joints should be water tight (Oregon Administrative Rules, 1975).

Proximity of the water transmission line to a sewage transmission line must be considered to prevent, where possible, the chance of cross contamination. Water pipelines should be located at
least 10 feet away, horizontally, from a sewage line. When the two cross, they should be at a 90° angle. The sewer lines should be 18 inches under the water line. If the sewer line is under pressure, the water line should be encased in another length of pipe (Oregon Administrative Rules, 1975).

Cross connections in water transmission lines may be particularly prevalent in homes with individual systems. A cross connection is defined as "any physical connection--between two separate piping systems, one of which contains potable water and the other of questionable safety, where there may be a flow from one system to another" (U.S. Environmental Protection Agency, 1973). Normally private homes are not officially visited by health officials or others whose business it is to watch for cross connections.

A common example of cross connections is a hose attached to a faucet with the end of the hose submerged in non-potable water, such as a stock watering trough, or simply lying on the ground in a puddle. Through a series of relatively likely events, the water in the hose can run backward, sucking non-potable water past a closed faucet valve and into a potable water system. This happens commonly when there is a large demand on a main water line because the water is being used for fire fighting, or when there is a large break in the line.

Consumer literature describes five basic devices used to protect against cross connections (Watts Regulator Co., 1975). The first and most effective is an air gap. An air gap is a physical separation of the potable and non-potable water sources by an air space. The other four are mechanical devices that vary in expense and size. They are
designed to be used in a variety of plumbing situations where a cross connection exists. However, they all work on one principle. They allow potable water to flow in one direction past a flapper valve. They will not allow non-potable water to flow backward past that same valve (U.S. Environmental Protection Agency, 1973).

**Water Treatment Facilities:** Two of the most common components of an individual water supply treatment facility are filtration and disinfection with chlorine. They are particularly important on a surface source.

**Filtration:** The primary purpose of water filtration is to remove turbidity, suspended dirt, and organic material from the water. Studies by Le Chevallier et al., (1981) show that if the turbidity is low, chlorine disinfection is more efficient. This results in treated water that may have fewer infectious gastrointestinal disease-causing organisms.

Standards for turbidity in public water supply systems have been identified in the National Primary Drinking Water Regulations (U. S. Environmental Protection Agency, 1976). These regulations provide for a maximum allowable level for turbidity of one (1) unit, as measured by the Nephelometric Method.

The two types of filters most commonly found on small systems are pressure sand filters and cartridge filters. Pressure sand filters are completely enclosed. They are used normally on swimming pools and sometimes on industrial installations. Their main advantages for use on an individual water system are they are initially inexpensive to purchase and they are compact. They require only one pump to take the water from a source and force it through the filter.
There are, however, two disadvantages with pressure sand filters. First, it is difficult to introduce chemicals that aid in coagulating suspended material on the filter sand (New York State Department of Health, 1976).

A second problem is the inability of an operator to watch the filter operation or maintain the filter sand. For example, the dirt to be filtered sometimes coagulates into large pieces called mud balls. These have to be taken out by hand (New York State Department of Health, 1976).

Because of these problems, pressure sand filters are generally considered unsafe for drinking water systems. However, they do have limited value for use on individual domestic systems with a low level of contamination in their source (Salvato, 1976).

Cartridge filters are the preferred filter for use on individual domestic water systems today. They function similarly to an automobile oil filter. The media, usually fabric, is wound around a core. All filtering is strictly mechanical straining. Cartridge filters have also been shown to be effective in removing asbestos fiber, five microns long, from drinking water (Cook et al., 1978).

These systems have the advantage of being inexpensive to purchase and install. Also, they are easy to maintain. The old media cartridge is simply disposed of and a new one inserted into the unit. Usually cartridge filters are designed to fit on a single tap. Therefore, all the water being pumped to a home cannot be filtered.

Disinfection with chlorine: Federal, state, and local laws generally prohibit contaminating surface water with fecal material
that contains infectious gastrointestinal disease-causing organisms. Despite this, surface water systems are still commonly contaminated by inadequately treated domestic sewage, animal feed lots, and septic systems discharging onto the surface of the ground. Therefore, surface water must be continually disinfected because of its susceptibility to contamination by infectious agents. Chlorine (Cl\textsubscript{2}) is believed to be the most cost efficient disinfectant. The vast majority of both public and individual water systems use chlorine to destroy infectious agents in potable water (Chanlet, 1975).

When elemental chlorine combines with water free of ammonia, organic nitrogen, and other organics, the chlorine reacts as follows:

$$\text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{H}^+ + \text{Cl}^-$$

HOCl, hypochlorous acid, goes on to disassociate:

$$\text{HOCl} \rightleftharpoons \text{H}^+ + \text{OCl}^- \text{ (Hypochlorite ion)} \text{ (Chanlet, 1973).}$$

Hypochlorous acid and the hypochlorite ion are the forms of free chlorine that kill microorganisms in a water system (Chanlet, 1973). Chlorine is a very active oxidizing agent that reacts with many substances dissolved or suspended in the water. Once this happens, the chlorine is essentially used up and is no longer available to destroy bacteria. The chlorine reacts most readily with reducing compounds such as hydrogen sulfide, manganese, iron and nitrates. Remaining chlorine molecules are then attracted to organic material to form chloramines. Chloramines, chlororganic compounds, and chlorine combined with reducing compounds are weak disinfectants (New York State Department of Health, 1976). What is left is considered free chlorine available to disinfect the water in a water system.

Hypochlorination is the most common and safe technique to apply
chlorine to an individual water system. A hypochlorinator can use a bleach solution of 5.25% available chlorine. It is easy to apply and purchase. Tablet hypochlorinators are also available as solid pellets. The solid pellets of calcium hypochlorite are dissolved in a solution which is injected into the water system (U.S. Environmental Protection Agency, 1974).

To continuously disinfect a water supply, the chlorine must be applied mechanically. Hypochlorinators do this by pumping or injecting chlorine into the water. If they are maintained adequately, they will reliably remove bacteria from a water system with low turbidity (U.S. Environmental Protection Agency, 1974).

The chlorine must be in contact with the water to be disinfected for a certain period of time. The Oregon State Health Division rules for community and public water systems require that free chlorine at 0.2 parts per million be in contact with the water for 30 minutes before the water is served.

Water Storage Tanks: Water storage tanks are designed to hold filtered and chlorinated water until the consumer requires it. Public health officials believe there are at least two major concerns when designing and building storage tanks. The first is the tank's ability to exclude outside contamination. It does no good to carefully collect, filter, chlorinate, and transfer water if the storage tank is susceptible to contamination. To accomplish this, the Oregon State Health Division has developed elaborate construction requirements for storage tanks on public water systems. These requirements are used as guidelines by public health officials in evaluating individual domestic systems.
Construction requirements include access into the storage tank and facilities for cleaning. A hatch, a drain, and an access ladder are necessary for inspection and maintenance (Oregon Administrative Rules, 1975). Such provisions are necessary because occasionally silt can build up in a tank, small animals can sometimes gain entry into the tank and drown, and occasionally the tanks are plagued with algae growth.

Water storage tanks should have a steel reinforced, concrete foundation to prevent cracks in the tank due to settling of the soil. The American Water Works Association (1978) committee on concrete water holding structures has found that properly engineered concrete tanks can provide long-lasting water storage.

The second major concern in water tank design is the provision of 30 minutes of contact time for the chlorine. Public health officials commonly believe this to be the minimum time required to destroy infectious gastrointestinal organisms in water.

The two most common types of water storage tanks found on small systems are pressure tanks and ground level reservoirs. Most water storage tanks have some form of storable energy that is used to transmit the water to the user. A pressure tank stores energy in the form of air under pressure. The air pressure forces the water out of the tank to the point of use (Water Systems Council, 1977).

Public health officials recognize pressure tanks as one of the stronger points in a water system. If a tank can hold compressed air, it certainly must be tight enough to exclude disease causing microbial agents.

A disadvantage of pressure tanks is that normally their
capacities are small compared to the total daily consumption (U.S. Environmental Protection Agency, 1974). This can be significant when considering free chlorine contact time.

Ground level reservoirs are a common type of water storage tank on individual domestic water systems in Lincoln County. They can be constructed of many materials, including scrap steel, wood, fiberglass, and concrete. They provide water pressure by gravity flow from the reservoir. The reservoir must be constructed at a significantly higher altitude than the home it serves to provide that gravity flow.

The owners of the individual domestic water systems do not often have the expertise, money, or interest to construct a storage facility that will continually exclude disease causing organisms.
LITERATURE REVIEW

Water as a Vehicle of Infectious Disease Transmission

Henderson (1913) states, "Water is ingested in greater amounts than all other substances combined, and it is no less the chief excretion. There is hardly a physiological process in which water is not of fundamental importance. The continued absence of liquid intake by man eventually results in the end of the life process."

Humans consume, on the average, 2,200 grams or 3.1% of their body weight in water per day (Wolf, 1958). To be completely useful, this water should be free of disease causing organisms.

Many of the disease causing organisms in water use the medium simply as a habitat. Others require water to complete their life cycle or as a vehicle to infect the unsuspecting human. Some attack directly while others need a water living intermediate host to be able to infect their host (Miller, 1962).

It is not a new concept that water can be the vehicle for certain diseases. Pictures illustrating water purification facilities have been found on Egyptian walls dating back to the 15th century, B.C. Hippocrates (460-354 B.C.) recommended that collected rainwater be boiled and filtered (National Academy of Science, 1977). In 1854 John Snow did his classical Broad Street cholera study in London where he conclusively established a relationship between contaminated water in the Broad Street well and the disease of cholera (Richardson, 1936).

The National Academy of Science's publication, Drinking Water and Health (1977), discusses many infectious diseases that are
transmitted by water. Some of the disease causing agents include enteric viruses, protozoan and helminthic parasites, and bacterial agents. Studies by Whitsell, Hutchinson, and Taylor (1974) show the most commonly transmitted water diseases are amebiasis, cholera, gastroenteritis, infectious hepatitis, salmonellosis, and typhoid fever.

Problems Associated with Individual Water Systems

Whitsell, et al. (1979) reports that 50 million people in the United States depend on individual water systems and 40% of these systems are contaminated. Among the studies to determine the relationship between individual contaminated water systems and infectious gastrointestinal disease is the study done by Weibel, Dixon, and Weidner (1964). Their study was a retrospective literature search where they reviewed literature involving waterborne disease outbreaks for the 15 year period between 1946 and 1960. They identified 228 outbreaks involving 25,984 cases. An outbreak in this study was defined as two or more cases being linked to the same causal event. The majority of their information came from the files of the National Office of Vital Statistics (NOVS) for that time period. They also obtained additional information by reviewing medical and engineering literature. Their conclusions were that semi-public and private (individual) water systems were involved in 70% of the outbreaks. More than 10% of the outbreaks in the individual systems were in systems that used untreated surface water as their source.

One problem with this type of research is incomplete data.
Weibel, et al., (1964) noted the reporting of the outbreaks was not complete. He thought this reflected the lack of effort of some local health departments in reporting the cases. Also, when one does a retrospective study, one can not be completely sure about the reliability of the reporter or the validity of the raw data.

The Whitsell, et al. (1979) study took a different approach to determine the relationship between infectious gastrointestinal diseases and contaminated individual water systems. The basic technique was to determine if there were coliform bacteria in the individual water systems surveyed. Coliform bacteria are defined as all aerobic and facultative anaerobic, gram negative, nonspore forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C (American Public Health Association, 1979).

Coliform bacteria are, presently, the only index of hygenic quality of water. The rational for using them as an index is indirect. They are present in feces in large numbers, as many as a billion per gram. Pathogenic organisms may also be present in the feces and leave the body in excreta. Consequently, if one finds coliform, there may also be pathogens present (Chanlett, 1973).

The Whitsell, et al. (1979) study was designed to look at individual water systems in four counties in Georgia with two of the objectives as follows:

1) To see how well the systems met the U.S. Public Health Service drinking water standards, and

2) To determine how construction affected the safety and adequacy of the systems.
A major effort was made to collect all the information possible about construction details. There is a basic assumption among sanitary engineers and public health workers that evaluating the system's construction is paramount in determining the consistent safety of a water system.

Whitsell, et al. (1979) found that 70% of the systems showed evidence of contamination and 79% of the dug and shallow wells showed evidence of contamination. Deficiencies in construction were so numerous that the data was uninterpretable.

Sandhu, Warren, and Nelson (1979) did a similar study in South Carolina to evaluate the amount of coliform bacteria in private rural water supplies. They wanted to specifically determine whether the system's bacterial quality met American Public Health Association (APHA) drinking water standards for bacterial contamination. They also wanted to determine the sources of pollution. Sandhu, et al. (1979) took 460 water samples from private water sources in three counties; 92.5% of the samples were contaminated. Their conclusion was that the contamination was associated with septic tanks.

Groundwater as a Domestic Water Supply

One-third of the United States lies over aquifers capable of yielding 100,000 gallons per day to a single well. This is the best kept secret of the water witch (U.S. Environmental Protection Agency, 1950). The supply of usable fresh water within the first mile of the surface is 20 times greater than the amount in all the rivers, lakes, and streams in the United States (U.S. Environmental Protection Agency, 1980).
McNabb (1977), in an Environmental Protection Agency report, demonstrates how critical the groundwater resources are. Twenty percent of the total national water demand is met with groundwater, and 50% of the total population and 95% of the rural population receive drinking water from groundwater. Still, as McNabb explains, over the years we have abused the groundwater resources by using the subsurface as a dumping ground for many dangerous wastes.

In the report on groundwater contamination by Geraghty and Miller (1978), they state: "One of the least recognized problems in the U.S. is the degradation of underground water which has developed as an outcome of man's activities on the land's surface." These researchers determine that onsite sewage disposal systems are the most serious cause of the groundwater contamination problem. They also say, "Septic tanks and cesspools rank highest in the total volume of wastewater being discharged directly into the groundwater and are the most frequently reported sources of groundwater contamination." They were referring to contamination by nitrates and fecally transmitted microorganisms. Septic systems discharge over 2 trillion gallons of wastewater annually to the subsurface. All of these are a potential source of groundwater pollution.

Schaub and Sorber (1977) examined the groundwater under a land wastewater disposal site by looking for fecally transmitted virus and coliform bacteria as indicators of groundwater contamination. The virus were found in a 60 foot (18.3 m) observation well and in the groundwater at horizontal distances of 600 feet (183.0 m). Fecal Streptococcus, a fecally transmitted bacteria, was also found
in the groundwater under the disposal site.

**Surface Water As A Domestic Water Supply**

It has always been assumed by public health workers that untreated water from surface source systems is more likely to transmit an infectious gastrointestinal disease than a drilled, deep well. Chanlet (1973), a public health worker, considers the following reasons why surface water is less desirable for a domestic water system than deep groundwater:

1) Surface water usually has to be treated before it can be used; a minimum being disinfection.

2) The physical, chemical, and bacteriological state of surface water can vary rapidly.

3) If the source is a major river, there may be wastes being discharged upstream.

4) Impoundments can develop anaerobic bacteria activity or excessive algae growth.

5) High quality sources are hard to find close to population centers.

To help determine what problems are associated with using surface water as a domestic water source, Dondero et al. (1977), examined the prevalence of salmonella species in surface water in central New York State. They found that out of 322 water samples tested, 39% were positive for salmonella species. Many of the positive samples were taken from a stream draining out of an operational feed lot. Other positive samples were taken from streams that were subject to storm runoff from an urban area. Samples positive for
salmonella were also found in rural areas that ostensibly were not subject to contamination as were the urban areas. The authors suspect the latter positive samples were due to the scattered homes in the area. The soil was known to be poorly suited to accept and treat septic tank effluent. Also, they thought some of the positive samples may have been due to both domestic and wild animals that were infected with salmonella organisms.

The authors did note that there was not a high incidence of salmonella in the area. Also, organisms isolated from the cultures of salmonella were not virulent to laboratory mice.

Surface water, such as a lake in a recreation area, has also been associated with a hepatitis A outbreak by Bryan et al., (1974). In 1969, 14 cases of hepatitis A developed in the members of a Boy Scout troop. The boys had been camping next to a grossly contaminated lake four weeks earlier. The fact that some of the campers had either swallowed water while swimming or had used the water for drinking was statistically associated with the cases of hepatitis A. The source of the hepatitis A virus particles in the lake was not clearly identified.

Another outbreak of hepatitis A was reported to be associated with surface water. In this case, the source of the viral particles was identified (Chapman, 1976). In 1974, 26 cases of hepatitis A were identified in children in Salishan, Washington. This was 13 times greater than what was expected for the population of the area. The outbreak was traced to a stream that was used as a play area for local children and, upon investigation, it was discovered that failing septic systems were draining into that stream.
Infectious Gastrointestinal Waterborne Diseases Found in the Pacific Northwest

**Giardia lamblia (Giardiasis).** The intestinal parasitic protozoan, *Giardia lamblia*, has become increasingly interesting to public health officials within the last 25 years. The main reason for this is the realization that the Giardia parasite is indeed a potential pathological agent. Giardiasis is currently the most common identified intestinal parasite in the United States and the United Kingdom (Meyer and Jarroll, 1980). As a matter of fact, it is endemic in the United States (Craun, 1978).

Symptoms of a Giardia infection can range from an asymptomatic cyst passage stage to severe gastrointestinal involvement. Common symptoms include diarrhea, abdominal cramps, fatigue, weight loss, flatulence, anorexia, and nausea (Benenson, 1975).

The disease has an incubation period of one to eight weeks. The mean duration of the illness is two to three months (Benenson, 1975). Laboratory confirmation is obtained by examining fecal material for cysts or trophozoites, or examining duodenal drainage for trophozoites (Benenson, 1975). The trophozoites which live in the duodenum and upper jejunum have sucking discs that enable them to resist ordinary peristalsis. Therefore, they are rarely found during fecal exams (Brown and Belding, 1968).

Humans are a major natural host of *G. lamblia*, but the parasite is three times more common in children than adults. The carrier rate in humans in the U.S. ranges between 1.5 and 20% (Benenson, 1975). Recently, animals have been implicated in the transmission of Giardia
(Frost et al., 1980). This study was done in Washington State where fecal material of commercially trapped muskrat, beaver, nutria, mink, raccoon, otter, bobcat, and lynx was examined. The study demonstrated that the beaver and the muskrat specimens were commonly infected with Giardia.

In 1975, an extensive survey of wild and free-ranging domestic animals and man was done in Colorado (Davis and Hibler, 1978). This survey was done to determine the prevalence of *Giardia lamblia*. Over a two year period, subjects of all species of animals examined (human, beaver, coyotes, cattle, cats, and dogs) were found to be infected with Giardia.

Davis and Hibler (1978) attempted to infect a variety of animals with Giardia taken from human fecal specimens. He was successful with laboratory rats, gerbils, guinea pigs, beaver, dogs, raccoons, and big horn and prong horn sheep. The most significant was the beaver. It was determined that the beaver may be an excellent sentry animal for Giardia contamination of water.

An outbreak of Giardia occurred in Rome, New York, in late 1924 and early 1925. A random household survey showed an overall attack rate of 10.6%. There was a significant association between having Giardiasis and using Rome's water (Shaw, 1977). There were homes in the water shed, which indicates the water could have been contaminated by human sewage.

The infectivity of the Rome water supply was confirmed by feeding dogs raw water from the system after *G. lamblia* cysts were found in the water. This was the first time that suspect water had infected laboratory animals.
A retrospective study was done by Wright et al., (1977) in Colorado in 1976. Medical records were reviewed and all those that had a positive stool for Giardia lamblia were identified. Then a state-wide survey of those individuals with matched controls was done. It was discovered that a higher proportion of cases than controls had camped out in the Colorado mountains (96% vs. 17%). The area around Aspen, Colorado, has been called the country's largest outdoor toilet. For some reason, the people enjoying this part of America's out-of-doors refuse to use the privies even when they are only a few feet away (Craun, 1978).

The first documented waterborne outbreak of Giardiasis involving a filtered water supply occurred in Camas, Washington, in 1976 (Craun, 1978). It affected 10% of the population. Although there were no human habitations on the watershed, several trapped animals were carrying Giardia cysts. Three of the infected animals were beavers that foraged close to the water intake for Camas.

Treatment for the water system included filtration and disinfection. No coagulation or sedimentation was used prior to filtration, but it was disclosed that there had been a failure of the water treatment equipment prior to the outbreak.

Another major outbreak in 1977 in Berlin, New Hampshire, that involved approximately 5% of the population (Juranek, 1975) was linked to a breakdown in the water system. Like the Camas water, the Berlin water was filtered and chlorinated before it was served. Also, as in Camas, the Berlin water system had a history of breaking down periodically.

Juranek (1975) states that the Rome, Camas, and Berlin
outbreaks of Giardiasis had some features in common:

1) They all resulted from surface water and not water from a drilled deep well.

2) Chlorine was used to disinfect the water.

3) Giardia was recovered from the water in all cases.

Data from waterborne outbreaks of Giardiasis in the U.S. indicates that disinfection alone is not adequate to treat surface water for Giardia cysts. For total protection, water treatment should include sedimentation, filtration, and chlorination. It is believed that particles the size of Giardia cysts can be removed by conventional sand filters if the water is pretreated before filtration (Craun, 1978).

Later studies by Jarroll et al., (1980) indicate some halogens at higher concentrations and warmer temperatures can destroy Giardia cysts. The halogens tested were halazone, chlorine, globaline, and iodine. The test concentrations of chlorine were higher than would be used in the normal water treatment process. At 3°C. in cloudy water, 6.36 parts per million of chlorine was effective.

*Entamoeba histolytica* (Amebiasis or Amebic Dysentery). An amoeba is a protozoan that is usually free living and found in soil, water, sewage, and organic material. They feed on bacteria, multiply by simple fusion, and form durable cysts (Lawande et al., 1979). The disease Amebiasis (amebic dysentery) is caused by the protozoan parasite *Entamoeba histolytica*.

*E. histolytica* was discovered in 1873 in the feces of a severely ill Russian; however, the definite association of the
parasite and dysentery was not established until 1887 by Kartolis (Brown and Belding, 1964).

The disease exists as a hardy infective cyst that is carried in a more fragile trophozite. The trophozites die quickly after leaving the body. The cyst form can survive for several months in cool water (Burrows, 1968).

Symptoms of amebiasis involve the gastrointestinal system. They include fever, chills, and bloody or mucoid diarrhea. Most of the time the disease is asymptomatic (Brown and Belding, 1964).

Amebiasis is a particularly insidious disease because it can set up a secondary infection in the liver. This condition can lead to necrotic abscesses that can cause generalized hepatitis. Lung abscesses occur in smaller numbers of people when the organism migrates from the liver through the diaphragm (Burrows, 1968).

The incubation period is variable from a few days to years with two to four weeks being a common incubation period. The patient is communicable as long as cysts are being passed. This condition can last for many years (Benenson, 1975).

Diagnosis of the disease is based on the evaluation of symptoms, examination of the stool for cysts and trophozoites, and examination of x-rays to determine if liver or lung abscesses are present. Most recently, serological techniques are being used to diagnose amebiasis (Sexton et al., 1974). Unless a laboratory technician has had specific training and is highly experienced, it is common to fail to see cysts-trophozoites in the direct examination of the stool (Krogstad et al., 1978).

It is difficult to determine the prevalence of the incidence of
E. histolytica infection in the U.S. because of the many geographical areas and socio-economic groups; however, Brooke (1964) estimates the average rate of infection to be from 5 to 33%, depending on the area and group being studied.

Certain generalizations can be made regarding the prevalence and distribution of E. histolytica. The prevalence is higher in rural areas, the southern states, and in lower socio-economic groups. The higher rates in the south are probably due to the generally warmer climatic conditions and diversity of socio-economic groups. However, the more notable outbreaks of amebiasis have been observed in northern states where poor sanitary conditions are found (Brooke, 1964). Amebiasis can be found anywhere fecal contamination of water and food is found.

In 1933 there was a major outbreak in Chicago. After a study was conducted, it became increasingly evident that amoebic dysentery could be transmitted in water (Hardy, 1935). The specifics of this outbreak involved a fire in the Chicago union stockyards, a potable water system, a nonpotable water system, and a direct connection of a contaminated and a noncontaminated water source. The increased pressure on the fire main pushed contaminated water directly into water lines serving noncontaminated water. As a result, about 100 thirsty firemen became infected with E. histolytica.

Another large outbreak took place in 1953 in South Bend, Indiana, and was studied by Brooke (1955). Thirty-one employees of a woodworking plant in South Bend became ill with amebiasis, and four of them died. This outbreak happened because of a connection between a sewage disposal line and a potable water transmission line.
The best protection against amebiasis is to prevent fecal contamination of the water source. However, sand filters will remove most of the cysts and diatomaceous earth filters will remove all of them. Chlorine, at the levels it is used in normal water treatment facilities, will not destroy the \textit{E. histolytica} cyst (Benenson, 1975). Although the specific chlorine level was not mentioned by LeMaisre et al., (1956) in their discussion of the South Bend outbreak, they did note the chlorine did not protect the consumers of the water from amebiasis.

\textit{Salmonella typhi} (Typhoid Fever). Typhoid fever is a systemic infectious disease. The more prevalent symptoms are continued fever, headache, malaise, anorexia, and constipation more commonly than diarrhea (Benenson, 1975). The disease is transmitted by the bacterial organism \textit{Salmonella typhi} and is similar to a coliform bacteria in its staining characteristics and its shape (Burrows, 1968).

The incubation period, depending on the dose, can range from one to three weeks and an individual remains communicable as long as the organism is found in the stool. Usually this is from the first week through convalescence. About 2% to 5% of the patients become permanent carriers (Benenson, 1975).

In the early 1900's and until recently the greatest health problem related to typhoid was managing carriers (Canadian Medical Association, 1978). Carriers of the typhoid organism are continually in danger of contaminating food or a water source if their fecal material is not properly disposed of.

One of the most interesting cases, involving a typhoid carrier,
involved Mary Mallon, nicknamed "Typhoid Mary" (Canadian Medical Association, 1978). Mary worked as a domestic in New York and, because of her intimate contact with families she worked for, she caused many cases of typhoid. She was known to have caused at least 60 cases. At that time, the only known cure was a cholecystectomy. Mary would have no part of it; therefore, she spent 23 years in the protective custody of a hospital.

Sunnaresan et al., (1974) discussed the relative value between immunization and sanitation as primary techniques to prevent typhoid. The conclusion was that sanitation is more cost effective. It has cumulative effects whereas vaccination does not. Also, it protects against other enteric diseases. Vaccination for typhoid in Oregon is not recommended (Communicable Disease Summary, 1981) for two reasons. The vaccine is not uniformly effective, and it can lead to a false sense of security, which in turn can lead to exposure to other infectious gastrointestinal diseases.

Laboratory confirmation of typhoid is normally done by microbiological examination of the fecal material (Benenson, 1975). There will also be a significant rise in the Vi Antigentiter (Burrows, 1968).

The first person to recognize typhoid fever as a communicable disease was William Budd in the mid 1800's (Moore, 1971). By using observation and epidemiologic techniques, he demonstrated that typhoid fever can be transmitted in drinking water that has been contaminated by the fecal material of individuals with the disease (Moore, 1971). He helped to stop at least one epidemic in a girl's school in 1863 by getting all body discharges and soiled linen
disinfected. He also convinced the women and nurses to wash their hands scrupulously.

It wasn't until 1880 that the microbiologist Berth Actual found the typhoid organism (Burrows, 1968). For a time, typhoid fever was the most prevalent infectious disease in the U.S. In 1900, over 35,000 people died from typhoid fever in this country alone (Burrows, 1968).

One of the last major outbreaks of typhoid fever in this country happened in 1973 (Saslaw et al., 1975). It occurred in the South Dade Labor Camp, Homestead, Florida, where there were 210 recorded cases but no deaths. The wells serving the water were determined to be unsafe for human consumption. This was concluded after coliform bacteria were found during a sanitary survey of the system.

A very large outbreak of typhoid occurred in Riverside, California, in 1965, where there were 16,000 cases with 20 people hospitalized and three deaths (Johns Hopkins University, 1971). In this case, the typhoid organism was found in the municipal water system. Water was obtained from deep wells, and the exact source of contamination was not determined. The outbreak was brought under control by recognition of the contamination and chlorination of the water system.

The typhoid organism has been demonstrated to be transmitted on contaminated food items such as frozen eggs and canned meat (Sharp, 1976). Such an outbreak took place in Scotland in the early 1960's.

Shigella Sp. (Shigellosis or Bacillary Dysentery). Shigellosis is caused by gram negative bacteria in the genus Shigella. This
genus is divided into four subgroups: A) *Shigella dysenteriae*; B) *Shigella flexneri*; C) *Shigella boydi*; and D) *Shigella sonnei*. Each of these groups is divided into 30 serotypes (Benenson, 1975).

Bacillary dysentery is a common disease in humans. It is usually associated with warm climates and crowding and is a continual problem during military operations. More soldiers died of diarrheal diseases during the Civil War than were killed with bullets (Burrows, 1968). Although contaminated water is a significant mode of transmission for the disease, it is not as important for shigellosis as it is for typhoid (Burrows, 1968).

The disease primarily involves the large intestine. It is characterized by diarrhea, fever, vomiting, and cramps. In severe cases, the stools contain blood, mucus, and pus (Burrows, 1968).

Laboratory diagnosis is usually done by examining the stool microbiologically. Specimens of stool are inoculated on to different types of media. The type of changes that takes place in the media will characterize the type of shigella (Benenson, 1975).

It is probable that many infections go unnoticed because of the mildness of these infections. Convalescent carriers can continue to discharge organisms for three to five weeks; however, it is believed that the carrier state for shigellosis does not last for a lifetime such as with the typhoid organisms (Burrows, 1968). As with most infectious diseases, shigellosis is most serious in those that are elderly, debilitated and suffering from malnutrition (Benenson, 1975).

Water was implicated in many cases of bacillary dysentery in a study done in Russia (Graun, 1978). Open bodies of water and canals were used for domestic purposes in the Dagestan area. The increased
contamination of the water and lack of proper treatment were cited as important factors responsible for the high incidence of dysentery in the area.

A later outbreak of shigellosis in this country took place in a junior high in Stockport, Iowa, where 208 people became symptomatic, with 117 rectal swabs positive for Sh. sonnei (Lindell and Quinn, 1973). In this outbreak, Sh. sonnei was found after 1600 ml. of water was drawn through a membrane filter.

During 1975 and 1976, there were three waterborne outbreaks of shigellosis reported in the U.S. (Center for Disease Control, 1977). Fifty-six of these cases were Sh. sonnei in Montana, 25 of the cases were Sh. flexneri in Alaska, and 2150 cases were Sh. sonnei in Puerto Rico.

Viral Agents

Viruses are the smallest of all infectious organisms. Physically, a virus is hardly more than a bundle of genetic material in a protein package. They are only 10-450 millimicrons in size (Chang, 1961). A virus is a strict obligate intercellular parasite that will grow only inside an appropriate host cell in a living state.

Until the 1970's, little attention was given to the possible hazards that viruses posed for potable water supplies. Domestic sewage contains viruses in hazardous concentrations. Waste water treatment plants discharged the majority of these viruses untreated into surface water (Cookson, 1974). Onsite sewage disposal systems are often associated with individual water systems. Sewage effluent from these systems possibly have an even higher concentration of
viruses. The sewage is discharged into the environment at a lower level of treatment (Cookson, 1974).

The importance of identifying pathogenic organisms in a water supply or water system is seldom disputed. The presence of pathogenic bacteria can be monitored fairly accurately by using coliform bacteria as an indicator of contamination. Unfortunately, the coliform index is not a reliable index for viruses (Cookson, 1974).

In many instances, coliform bacteria cannot be found in a sample of water where viruses can be found. There is no doubt that a positive fecal coliform index means that viruses are present. However, the absence of coliform bacteria does not necessarily mean that viruses are also absent (Cookson, 1974).

Vaughn (1975) states that viruses are removed from groundwater by an absorption process rather than a mechanical filtration process. Soils with a high clay and silt content are most effective with this process. Clean dry sand, such as in a rapid sand filter, is least effective. Conley (1981) also believes that efficient coagulation and filtration is the most effective way to remove viral particles from surface water.

Hepatitis - Type A. The hepatitis type A virus is classically associated with the fecal-oral route of transmission. Fecally contaminated water or food has to be ingested in order to infect an individual. This is in contrast to hepatitis type B. Transmission of type B is associated with being inoculated with human blood products (Benenson, 1975).

Hepatitis type A symptoms begin with nonspecific gastrointestinal
involvement, nausea, vomiting, anorexia, diarrhea, malaise, headache, weakness, and fever. However, there is a bright side. The patient may develop an aversion to nicotine (Barivowski and Green, 1976).

The illness varies from a mild occurrence lasting from one to two weeks to a severely disabling disease lasting several months. There appears to be a relationship between the severity of the disease and the age of the patient. Many times children are asymptomatic, the disease being recognized only by liver function tests (Benenson, 1975). Laboratory diagnosis is based on liver function tests that include tests for serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), and serum bilirubin. However, to determine between type A and type B, HBsAg (Australian antigen) must be tested for serologically. The test will be positive for type B (Barivowski and Green, 1976). Hepatitis type A has an incubation period of 15 to 60 days, with an average incubation period of 30 days. It is not generally known to be a zoonotic disease, but it does affect chimpanzees occasionally (Benenson, 1975).

The viral particle that causes hepatitis is approximately 27 nanometers around. It resembles an enterovirus or a parvovirus when observed in infective material (Fenner et al., 1971).

One of the more infamous hepatitis type A outbreaks involved the Holy Cross College football team (Morse et al., 1972). In this case, two groups of athletes, each using a single source of water, but at different times, were affected. This particular case is also a textbook study in the danger of cross connections. A cross connection is a direct, physical connection between a potable and a nonpotable
water source. Investigation linked the football teams to a group of children infected with hepatitis type A through an imperfect drinking water supply.

Chapman (1976) discussed an epidemiological study of an outbreak of hepatitis type A in grade school children in Salishan, Washington. The outbreak was linked to a small stream which the children used as a play area.

This particular stream was continually contaminated by a falling septic system. It had a fecal coliform count of 240 organisms per 100 ml of water tested.

Bryan et al., (1974) described a condition where the water implicated in a hepatitis type A outbreak was not necessarily used for drinking water. In a 15 day period, 14 Boy Scouts became ill with hepatitis type A. The troop had been camping on an island on a lake approximately four weeks earlier. An epidemiological association was made that linked the outbreak and the camping activity at the lake. The association could be made because of the clustering of onset dates and the appearance of cases only among troop members attending the campout. Upon interviewing the sick scouts, it was found that not all of them purposely used lake water for cooking and drinking. All of them did admit to swimming in the lake and possibly swallowing some of the water.

Viral gastroenteritis. No etiologic agent has been identified for a large portion of the waterborne outbreaks reported in the U.S. Causative agents were not found for 73% of the waterborne outbreaks in 1975 and 1976 (Craun, 1978). This phenomenon makes investigators
suspect viral agents since they are difficult to find in laboratory specimens. However, lab work was sometimes delayed which probably would have a significant effect on the possibility of identifying common bacterial agents. Also, the investigators seldom check for toxic strain of E. coli (Craun, 1978).

The Norwalk group of viruses and rotaviruses seems to be the major viral agents causing gastroenteritis (Kapikian et al., 1978). Kapikian et al., (1978) also states that the role of water is not clear. However, because the two groups of viral agents are transmitted by the fecal/oral route, it is highly likely that water is a significant vehicle for the viruses.

In 1976 there was an outbreak of gastroenteritis associated with a resort in Colorado (Morens et al., 1976). The drinking water was epidemiologically implicated. The camp's water supply was inadequately constructed and was being contaminated by a leaking septic tank, but routine tests did not reveal bacterial or parasitic pathogens. Virus-like particles were found in five stool filtrates and viral administration of these filtrates to two volunteers produced gastrointestinal illnesses similar to those observed in the resort visitors.

In 1973, poliovirus was found in well water in Monroe County, Michigan (Velde, 1973). Even though it is generally believed water is not significant in the transmission of polio, the findings by Velde are ominous (Benenson, 1975).

The groundwater feeding a well was being polluted by a classical combination of soil not suited for absorption and treatment of sewage from a septic tank and a poorly constructed well.
Enterotoxigenic Escherichia coli

Infections by enterotoxigenic *E. coli* (ETEE) have been under study since the early 1900's when veterinarians noticed problems with the organism in calves. In the 1920's and 1930's studies suggested problems with ETEE infections in infants. Later in the 1940's and 1950's the organism was demonstrated to be a globally important cause of outbreaks of intestinal disease in nurseries (Gangarosa, 1975).

ETEE is still an important cause of diarrhea disease in underdeveloped countries (Levine et al., 1980). The diarrhea disease is important to individuals from this country mainly when they travel to those under-developed areas.

In the most severe clinical cases of ETEE there is a cholera-like syndrome including severe diarrhea and vomiting. It is thought that travelers from developed countries are relatively non-immune, therefore they develop the disease with a frequency of 30-60% (Sack, 1978).

The incubation period is short, generally 24-48 hours. In a study done by Gorbach et al. (1975), the carrier state was developed in less than 5 days in 82% of a group of students infected while visiting Mexico.

The disease has a definite fecal/oral method of transmission. Studies done by Levine et al., (1980) indicate that the disease is not transmitted directly from person to person. Laboratory diagnosis depends on serological exams done on colonies of bacteria cultured from patient's stool (Tolloch, 1973).

Even though waterborne ETEE is not rampant in the Pacific
Northwest, there has been at least one dramatic major outbreak. In June and July, 1975, gastrointestinal illness occurred in more than 200 staff members and 2000 visitors to Crater Lake National Park, Oregon (Rosenberg et al., 1977). The outbreak was characterized by diarrhea, cramps, nausea, and vomiting and was significantly associated with the consumption of the park's water. The water system was contaminated with raw sewage.

Effectiveness of Chlorination

In 1908, chlorination of public water systems was becoming a common practice. Many state boards of health ordered the chlorination of public water systems to protect citizens from typhoid. By 1924, 3,000 cities that include 37 million people had their water protected by chlorination (U.S. Environmental Protection Agency, 1977).

A study was sponsored by the Environmental Protection Agency to determine the relationship between bacteriological quality and chlorine residual. The study showed the probability of finding coliform bacteria in a distribution system decreased as the free residual chlorine increased (U.S. Environmental Protection Agency, 1977).

Research by Le Chevallier et al., (1981) demonstrated that when the turbidity of a water sample increased, the disinfection efficiency of the chlorine decreased. The Environmental Protection Agency used the results of this study to justify the maximum contaminant levels for turbidity in the National Primary Drinking Water Regulations of the Safe Drinking Water Act.

Duffield (1975) found that chlorine residual acts as an indicator of problems within the transmission and storage system. Problems such
as broken lines, cross connections, and back siphonage can allow a great deal of contamination into a distribution system. When the free chlorine residual is challenged by this contamination, it will begin to dissipate.

Too much contamination can overwhelm the chlorine. It is believed that a coliform count of 50 organisms per 100 milliliters of water indicates pollution too great to be successfully chlorinated (Burrows, 1968).

Among the conclusions of the U.S. Environmental Protection Agency study (1980), are the following:

1) Free chlorine residual does provide protection against post-treatment contamination.
2) The free chlorine residual decreases noticeably when challenged with a contaminate. Therefore, it is an effective indicator when there is a problem in the distribution system.
3) Increased plate counts were associated with decreased chlorine residuals.
4) Maintenance of a free chlorine residual is the most effective measure for controlling an increased bacteria level in the distribution system.
Study Format

The format chosen for this study was a retrospective study. With retrospective studies, diseased and non diseased groups are selected and compared to a predetermined disease factor. The diseased group are considered to be a risk by the disease factor, the non-diseased group are not (Mausner and Bahn, 1974).

A prospective study however, begins with individuals free of the disease under consideration. The individuals are classified as being at risk or not by a predetermined disease factor (Mausner and Bahn, 1974).

Some advantages of a retrospective study over a prospective study include:

1. It is relatively inexpensive.
2. The number of subjects needed are smaller.
3. The results are quick (Mausner and Bahn, 1974).

The disadvantages of a retrospective study include:

1. Information supplied by the individual being studied may be biased.
2. The individual being studied may not have accurate recall (Mausner and Bahn, 1974).

The Measurement Instruments

Two instruments were developed for this study. The first instrument was developed to objectively score individual, surface source, domestic water systems for adequacy of construction. The second was
developed to objectively identify the extent individuals using the water systems were associated with infectious gastrointestinal disease. The decision was made to develop the two instruments after suitable instruments could not be identified from an extensive review of current literature.

Initially the instruments were developed by the author based on his professional knowledge of public health and environmental sanitation. The Delphi Method was the technique selected to validate the two new instruments.

The Delphi Method was developed in the early 1950's by the Rand Corporation. It was designed to obtain a reliable consensus from a group of experts once they had independently responded to a series of questionnaires (Linstone and Toroff, 1975). In this case, a consensus was established when all members agreed on the validity of the instrument.

The first instrument, developed to objectively score individual water systems, was independently reviewed by a panel of four engineers familiar with water system construction (Appendix C). Likewise, the second instrument was used to identify the extent individuals using individual water systems were associated with infectious gastrointestinal disease. It was independently reviewed by a panel of five health professionals familiar with gastrointestinal disease (Appendix C).

The first versions of the measurement instruments were distributed to members of the appropriate Delphi panel. Each member enumerated their comments regarding the validity of the instruments. After each member of the two panels responded to the instrument and judged its
validity of the instruments. After each member of the two panels responded to the instrument and judged its validity, their remarks were synthesized in a new instrument. Again, they were asked to review the new measurement instrument. This procedure was repeated until all members agreed on the validity of the instrument.

The panel of experts required three rounds to agree on the water system scoring instrument. The medical panel required two rounds to reach agreement on the instrument addressing the extent individuals using individual water systems were associated with infectious gastrointestinal disease.

A basic advantage of the Delphi technique over a group attempting to come to a consensus is a member cannot be "voted down" or "counted out". Because of the independence factor, no member has to defend his or her position against another threatening or dominating member (Cone, 1973). With the built-in lack of structure in the decision-making process, a panel member is free to make a decision regarding the instruments without being unduly biased by another panel member.

Selection of Sample Sections

Sections within Lincoln County were randomly selected for the study. The study population was then systematically selected out of the randomly selected section. The study population was interviewed to determine the incidence of infectious gastrointestinal disease associated with individual, surface source, domestic water systems.

The selection of sections used in the study were determined by using a list of random numbers (Sharp, 1979), and a county road map provided by the County Engineer's Office (Lincoln County Department of
Engineering, 1979). This map was chosen because it was current, it had visual clarity, and defined sections.

The first step in selecting the sections was to number them on the engineer's map. They were numbered left to right, row by row, beginning with the upper left hand corner. The sections were assigned numbers from 0001 to 1007.

The second step in selecting the sections was to enter the list of random numbers. Four adjacent columns of numbers on the list of random numbers were isolated; i.e., columns 1, 2, 3, 4. The numbers on the rows formed by these columns were used to form four digit numbers. Four hundred sections were selected and listed as they were identified on the columns of random numbers. The first 150 sections selected from the table of random numbers were used to select the study sections. The other 250 section numbers were held in reserve. Sections were excluded for the following reasons:

1) No road was indicated on the county engineer's map.
2) There were no dwellings in the section.
3) There was a community water system in the section.

This elimination process left 54 sections. These 54 sections were visited in the order they were selected during the random number identification process.

Examples of the section numbers selected from the list of random numbers are as follows:
Selection of the Study Population

Dwellings within each section were selected using the following systematic technique in order to assure consistency in the selection process. First, the most major road into a section was identified. A state maintained road had a higher priority than a county road. In the event of two state or two county roads, the paved road was chosen over an unpaved road. If two roads in a section were identical, the one with the most northerly entrance was chosen.

The section was entered from the north. If a northerly entry was not possible, in order of descending preference, a westerly, a southerly, or an easterly entrance was made.

After entering a section, the first two occupied dwellings on each side of the road were selected. Likewise, two more dwellings were selected on the other side as the road entered the section.

A dwelling was eliminated from the study for the following reasons:

1) The residents had not occupied the dwelling for six months.
2) There was no responsible adult at home.
3) There was an aggressive dog.
4) The residents were unwilling to cooperate.
5) There was no one at home.
6) The dwelling was served by a drilled well.

In the event any of the above situations existed, neighboring dwellings were visited until the occupants of two dwellings on each side of the road were interviewed.

Data Collection Procedure

To qualify for a participation in the study, the water system must have been a surface source and an individual system. Contact was established with the occupant of a home selected in the previously described selection process. The purpose of the visit was explained to a responsible adult and the dwelling occupant was given a copy of the informed consent sheet (Appendix D). The name of the individual was not noted on the survey forms. Only the section number was noted. Next, length of occupancy was determined. The current occupants must have been in residence for a minimum of six months. No data was collected on any individual less than one year of age.

The health history instrument developed by the Delphi panel was then filled in by asking each adult present to directly respond to the items on the "Individual Surface Source Water Infectious Gastrointestinal Disease Evaluation" instrument (Appendix B). If an adult responded for a child or another adult, that fact was noted on the instrument. An affirmative answer when questioned regarding a symptom on the disease instrument was noted by circling the points number next to that symptom. However, only the previous six months in the individual's health history was considered. Part of the disease evaluation was to determine if the individual had any chronic diseases. The question was asked two ways. First, the resident was asked
directly if he or she had any chronic or long term disease. Secondly, he or she was asked if any medication was taken routinely. If the answer was affirmative, the resident was eliminated from the study.

The resident was then interviewed regarding the items on the "Individual Surface Source Water System Evaluation" instrument (Appendix A). If the answer was affirmative when questioned regarding the items on the water evaluation instrument, it was noted by circling the points number next to that item.

**Water System Evaluation**

The process of evaluating the water system was begun by categorizing the surface source water system into the following categories:

1) A shallow dug well
2) An impoundment
3) An infiltration gallery
4) A spring
5) A stream

The water system was then evaluated using the appropriate section of the evaluation instrument.

While surveying shallow dug wells, it was determined if the well had a sealed lid to exclude surface water. It was noted if the casing was properly grouted to 10 feet to exclude surface water.

On-site sewage disposal systems were located and it was determined how far they were from all parts of the water system. One hundred feet of separation was required between the septic system and the water system.

While surveying impoundments, infiltration galleries, springs and
streams, septic systems and general construction upstream were noted. It was also noted if the watershed area was fenced to exclude animals.

The water transmission line was then examined to determine if it was buried or if any portion of the line was submerged in water other than the source. Pressure on the system was checked at a tap with a pressure gauge at a screw faucet to determine if the required 20 pounds of pressure on the system was being maintained.

The treatment facility was evaluated based on the following criteria: Chlorination, chlorine contact time, and filtration. Any size pressure tank or chlorine contact facility was considered adequate.

Storage facilities were inspected to determine if construction met the minimum criteria for exclusion of contamination.

Each item on the evaluation instruments was assigned a weighted number value by the Delphi committees. Upon completion of an interview using the disease evaluation instrument or upon completion of a survey using the water system evaluation instrument, the scores on each instrument were tallied. A score of 54 or better on the water system evaluation instrument was needed for a water system to be classified as adequately constructed. A score of less than 54 would classify the system as inadequately constructed.

A score of 14 or better on the disease evaluation instrument was needed for an individual to be classified as having an infectious gastrointestinal disease. A score of less than 14 would classify the individual as not having an infectious gastrointestinal disease.

Hypothesis

The questions to be considered in this study are included in the
following null hypothesis statements.

**H₀₁**: There is no significant difference between the number of people with an infectious gastrointestinal disease and those without an infectious gastrointestinal disease who consume water from inadequately constructed surface domestic water systems.

**H₀₂**: There is no significant difference between the number of people with an infectious gastrointestinal disease and those without an infectious gastrointestinal disease who consume water from adequately constructed surface source domestic water systems.

**The Statistical Instrument**

The statistical measure used in this study was the chi square statistic as described by Courtney and Sedgwick (1974). It was used to determine if there were significant differences between those people in the study with and without an infectious gastrointestinal disease.

The water systems that were included in the study were both the inadequately and adequately constructed ones. The chi square statistic is used to measure data that are in discrete units. Discrete units are units which can only be expressed in whole units and be assigned to categories. For example, in this study, water system #1 was found to be adequately constructed. Therefore, one unit would be assigned to the "adequately constructed" category.

Two one way tables of frequencies were used to test for significant differences between the number of people with an infectious gastrointestinal disease and the number of people without an infectious gastrointestinal disease who consume water from inadequately and
adequately constructed surface source domestic water systems. The level of significance for the tests were set at 0.05.
The water system evaluation instruments were scored to be "adequately" or "inadequately" constructed and the disease evaluation instruments scored as to be "ill" or "well". The following data was yielded.

Table 1. Comparison of disease and the quality of construction of individual surface source water systems in Lincoln County.

<table>
<thead>
<tr>
<th>Quality of system construction</th>
<th>Ill with an infectious gastrointestinal disease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>YES</td>
</tr>
<tr>
<td>Adequate</td>
<td>7</td>
</tr>
<tr>
<td>Inadequate</td>
<td>14</td>
</tr>
</tbody>
</table>

The items scored in the water system evaluation tools are summarized in Tables 2 through 5. A summary of the disease evaluation instrument data may be found in Table 6.
Table 2. Summary of source information from water system evaluation instruments.

<table>
<thead>
<tr>
<th>Shallow wells</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate distance from septic system</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Protected from surface runoff</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Scaled lids</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Grouted casing</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Total number of shallow wells</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

Impoundments, Infiltration Galleries,

**Springs**

| Adequate distance from septic system               | 26  | 1  |
| Building upstream                                  | 5   | 22 |
| Watershed fenced                                   | 1   | 26 |
| Total number of impoundments, infiltration galleries and springs |     | 27 |
| Total number of systems evaluated:                |     | 42 |
Table 3. Summary of transmission line information from water system evaluation instruments (42 systems).

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 PSI pressure</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>Line submerged</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Line properly buried</td>
<td>25</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 4. Summary of treatment (chlorine and filtration) facility information from water system evaluation instruments (42 systems).

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free chlorine residual</td>
<td>1</td>
<td>41</td>
</tr>
<tr>
<td>Chlorine contact time available</td>
<td>1</td>
<td>41</td>
</tr>
<tr>
<td>Filtration</td>
<td>0</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 5. Summary of storage facility information from water system evaluation instruments (42 systems).

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructed to exclude contamination</td>
<td>39</td>
<td>9</td>
</tr>
<tr>
<td>Leaking</td>
<td>6</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symptom</th>
<th>M</th>
<th>F</th>
<th>N</th>
<th>F</th>
<th>M</th>
<th>F</th>
<th>M</th>
<th>F</th>
<th>M</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diarrhea</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Bloody Diarrhea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Vomiting</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Nausea</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Abdominal Cramps</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Fever</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>7. Chills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>8. Headache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9. Diagnosed with an infectious gastrointestinal disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Diagnosed with Hepatitis A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Any two of items 1-5 with bloating or excessive gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Any two items 1-5 with fever</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total persons interviewed: 16 10 6 14 15 20 13 5 3 2 3 12 10 4

Total persons with symptoms: 8 4 0 4 4 9 4 0 0 0 1 3 0 0

Total persons without symptoms: 8 6 6 10 11 11 9 5 3 2 2 9 10 4

TOTAL: 133

37

96
Data Computations

The following computations were based on data collected from residents of systematically selected dwellings in Lincoln County, Oregon. The 133 individuals interviewed represent approximately 1% of the population using individual surface source water systems in Lincoln County.

**Hypothesis Number 1:** Using the chi square statistic to determine if there was a significant difference between the number of ill and not ill people using inadequately constructed surface source water systems, the following results were demonstrated.

Table 7. Chi square computations of ill and not ill individuals using inadequately constructed water systems.

<table>
<thead>
<tr>
<th></th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not ill individuals</td>
<td>73</td>
<td>43.5</td>
</tr>
<tr>
<td>Ill individuals</td>
<td>14</td>
<td>43.5</td>
</tr>
<tr>
<td>Total</td>
<td>97</td>
<td>87</td>
</tr>
</tbody>
</table>

\[
X^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}
\]

\[
X^2 \text{ computed} = 20.0
\]

\[
X^2 \text{ tabulated} = 3.84
\]

A significant difference was observed in the data regarding Hypothesis Number 1 when the level of significance was set at 0.05. The null hypothesis was rejected.

**Hypothesis Number 2:** Using the chi square statistic to determine if there was a significant difference between the number of ill and not ill people using adequately constructed surface source water systems,
the following results were demonstrated.

Table 8. Chi square computations of ill and not ill individuals using adequately constructed water systems.

<table>
<thead>
<tr>
<th></th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not ill individuals</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>Ill individuals</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>46</td>
</tr>
</tbody>
</table>

\[ X^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}} \]

\[ X^2 \text{ computed} = 22.26 \]

\[ X^2 \text{ tabulated} = 3.84 \]

A significant difference was observed in the data regarding Hypothesis Number 2 when the level of significance was set at 0.05. The null hypothesis was rejected.
CONCLUSIONS

Discussion of Conclusions

The chi square statistic was used to demonstrate a significant difference in the number of ill and not ill people in the study using both adequately and inadequately constructed surface source water systems. Based on this data, the following conclusions can be considered:

1. The common public health concept that infectious gastrointestinal diseases are necessarily associated with inadequately constructed, individual surface source water systems cannot be supported or refuted with the data in this study.

2. It was felt by the author that the "Individual Surface Source Water System Evaluation Instrument" used in this study was a valid and effective instrument.

3. The disease evaluation tool, "Individual Surface Source Water System Gastrointestinal Disease Evaluation Instrument" was considered to have some possible weaknesses.

Weaknesses of the Study

The more obvious weaknesses of the study include the following:

1. Some of the individuals interviewed to determine if they had an infectious gastrointestinal disease may have had a subclinical infection. A subclinical infection is an infection that does not manifest symptoms. A subclinical infection obviously would not have been reflected on the disease evaluation tool.
2. The study procedure required individuals being interviewed to recall their personal health history for the previous six months. This possibly may have been too long a time period for an individual to recall specific health history.

3. In some cases one adult was asked to respond for children or other absent adults in the household regarding the disease evaluation tool. This could have caused a problem in the accuracy of the response.

Recommendations

Based on the conclusions and weaknesses of this study, the following recommendations can be made.

1. Recognizing the possibility of subclinical infections with an infectious gastrointestinal agent, the study could be repeated by determining if the individuals had an infectious gastrointestinal disease by using laboratory techniques. A positive laboratory result is a much more positive indication of a disease than evaluating symptoms. Stool specimens or rectal swabs could be screened for parasites, pathogenic bacteria, or pathogenic viruses.

2. The study could be repeated using a prospective technique rather than a retrospective technique. Individuals with no known infectious gastrointestinal disease could be followed over a period of time as both adequate and inadequate water systems are used. This may eliminate the problem of inaccuracy of an individual's recall of their personal health history.

3. Also to help reduce the problem of inaccurate recall, the study could be shortened to only gather the health history one month
previous to the interview.

4. Disease history should be gathered for only the individual being interviewed. This would help reduce the possibility of recall bias such as inaccurate responses regarding another person's health history.

5. The water could be examined directly for infectious agents. This would reveal positive evidence that the infectious agents are present and individuals using that water are at risk.
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Stater, Gail, Senior Sanitarian, Lincoln County Health Department, Direct Communication (1982).


APPENDICES
APPENDIX A

INDIVIDUAL SURFACE SOURCE WATER SYSTEM EVALUATION INSTRUMENT

Home Number________________________Individual numbers on home________________________

Location Number________________________Date________________________

I. Water Source

A) Shallow or dug well

Shallow or dug well:

1) Not within 100 feet of septic system drainfield
   and

   not within 100 feet "downstream of animal enclosure" 25

2) Protected from surface runoff with ditched or

   area around well is graded away from the well 5

3) Sealed lid to exclude surface contamination 5

4) Grouting around easing is adequate to exclude surface contamination 5

   40

B) Impoundment, infiltration galleries, springs and streams

1) No building activity upstream 10

2) No septic system within 100 feet of stream on up-
   stream side of collection facility 20

3) Watershed fenced to exclude animals 10

   40

II. Distribution System

A) Transmission lines at least 20 PSI pressure 4.5

B) Transmission line not submerged 4.0

C) Transmission line properly buried 4.0

   12.5
III. Treatment Process

A) Free chlorine residual available 11.7
B) Chlorine contact time available (30 min) 11.7
C) Filtration on line and functioning 11.6

IV. Storage Facilities

A) Construction to exclude contamination 6.5
B) Not leaking 6.0

TOTAL 12.5
APPENDIX B

INDIVIDUAL SURFACE SOURCE WATER SYSTEM GASTROINTESTINAL DISEASE EVALUATION INSTRUMENT

Individual number_________________ Home number_________________

Date_________________ Age: 1-10____ 11-20____ 21-30____ 31-40____

41-50____ 51-60____ 61-70____ 71 & over____

Sex: Male____ Female____ Existing chronic disease: Yes____ No____

Taking medication routinely: Yes____ No____

<table>
<thead>
<tr>
<th>Points</th>
<th>1) Diarrhea</th>
<th>2) Bloody diarrhea</th>
<th>3) Vomiting</th>
<th>4) Nausea</th>
<th>5) Abdominal cramps</th>
<th>6) Fever</th>
<th>7) Chills</th>
<th>8) Headache</th>
<th>9) Diagnosed with an infectious gastrointestinal disease</th>
<th>10) Diagnosed with a case of infectious hepatitis (Type A)</th>
<th>11) Any two of items 1-5 combined with bloating or excessive gas</th>
<th>12) Any two of items 1-5 combined with fever</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>14</td>
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</tbody>
</table>

TOTAL
APPENDIX C

DELPHI TECHNIQUE PANEL MEMBERS

A. Tool for scoring water systems
1) Richard Cuenea, Ph.D., P.E.
   Agricultural Engineering, Oregon State University

2) Arthur Corey, Ph.D., P.E.
   Agricultural Engineering, Oregon State University

3) J. A. Jensen, Sanitary Engineering, P.E.
   Oregon State Health Division

4) Martin E. Northcraft, P. E.
   Civil Engineering, Oregon State University

B. Tool for scoring individual gastrointestinal health histories
1) Cherry Currin, R.N., B.S., Supervisor of Communicable
   Disease Control, Benton County Health Department, Corvallis, OR

2) Norty Kalishman, M.D., Medical Officer, Benton County Health
   Department, Corvallis, Oregon

3) Mervin Moldowin, Ph.D., R.P.N.
   Pharmacy, Oregon State University

4) Jan Wallinder, R.N., M.S., Supervisor of Adult and Family
   Services, Lincoln County Health Department, Newport, Oregon

5) Paul Williams, D.V.M., Dr. P.H., Public Health Veterinarian,
   Office of Disease Monitoring and Control, Oregon State
   Health Division
Study Population Information Sheet

General Information About the Gastrointestinal Disease and Water System Study

I am doing a study to find out if there is any relationship between infectious gastrointestinal illnesses ("bugs" in the digestive system) and different types of home water systems. Your family has been selected randomly to take part in the study. The study is being done to fulfill my requirements for a master's degree at Oregon State University. It is not being paid for by a governmental agency.

To do the study I need to ask for two types of information. First, I need health history information. Second, I need information about your home water system. I need to determine its type of construction.

The information I gather will be useful in helping others that are building home water systems. It will help them build safer, healthier water systems.

All information will be kept confidential. All those people that choose to take part in the study will be kept anonymous.

If you have any questions, please call me.

Sincerely,

Hal Nauman
265-9049
Newport, Oregon
Decision Tree - Water System

Select Section Randomly

Road Indicated by County Map
  if yes   if no
       delete

Check for Community Water System in Section
  if yes   if no
       delete

Determine if Homes are in Section
  if yes   if no
       delete

Surface Source
  if yes   if no
       delete

Domestic Usage
  if yes   if no
       delete

Individual
  if yes   if no
       delete

Appropriate Individual Using Water
  if yes   if no
       delete

Survey
APPENDIX F

Decision Tree - Individuals

Using the Water 6 Months or More
  if yes
  if not
  delete

12 Months Old
  if yes
  if not
  delete

History of Chronic Diseases
  if yes
  if not
  delete

Ask If Taking Medication Routinely
  if yes
  if not
  delete

Interview